The Lexicon of Restorative Agrisolar Design

A shared design language for agrisolar photovoltaic landscapes

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Restorative Agrisolar Design

Working draft, circulated for comment. Some citations are not yet verified and are marked where they appear, and the evidence base says what is established, what is inferred, and what nobody has measured.

Solar and farming want the same flat, open, well-drained ground. An array can carry pollinator habitat or gravel, slow runoff or redirect it, shade stock, retire irrigation demand, or help sustain a farm. Those are design decisions.

Agrisolar names solar that occupies agricultural land, sits among it, or results in continued or new production, whether or not anything still grows beneath the panels. **Agrivoltaics** is the narrower case of crops or livestock inside the footprint itself. Direct crop production under or between panels is under two percent of built practice, and it takes a large share of the research attention (Stid et al. 2022; Macknick et al. 2022). A working vocabulary has to describe the other ninety-eight percent as precisely as it describes the exception. Where the boundary is drawn decides what counts. Most accounting stops at the fence line, the top of the modules, and a meter into the soil. This document draws it around the farm operation and the community hosting it, so a lease that keeps a farm solvent, the water leaving the field, and the habitat next door are all inside the frame.

Restorative agrisolar design holds that ecological, hydrological, and community function belong among a project's objectives. This document gives that claim a vocabulary that can be tested on real ground.

A shared language

A solar grazier, township planner, hydrologist, and developer can describe the same eighty acres in incompatible terms. This lexicon is for the people deciding what an array does to an operation and a place.

Those decisions are being made now, and mostly in an information-poor setting: townships write ordinances without comparable data, developers and neighbors argue past each other, and several states have moved permitting authority away from the communities that host the projects (Susskind et al. 2022; Bessette et al. 2024). Shared terms will not resolve those arguments. They let people find out what they are actually arguing about.

Nothing here is finished, and that is the point. Agrisolar has no profession yet: no accreditation, no standard of care, no agreed name for most of what it does. This document does not declare one closed. It offers a language precise enough that one could form around it, which is why the terminology, the evidence base, and the sources are chapters rather than appendices — they are where a reader can trace a term, dispute a claim, and improve the work, and Joining in says how.

The build-out is not a forecast. Around 15,000 ground-mounted arrays already cover some 3,000 km² of the United States; roughly half of that ground was cropland beforehand and another third agricultural grassland (Stid et al. 2022; Sturchio et al. 2025). A net-zero grid by 2050 could put solar on 60,000–90,000 km², roughly 1% of the contiguous United States (Larson et al. 2021). Most of what comes next will be farmland too.

How the language works

The document answers five questions in order, and a reader who only wants one of them can start there.

Table 1: The five questions, and the chapter that takes each one up. The formal vocabulary below is what the answers are written in; the questions are what it is for.

	The question	Where it is answered
1	What can this project actually change?	Design Levers — six decisions, and nothing else
2	Who wants what from it, and who is going to lose?	Design Pressures — nine forces, with advocates
3	How much ground does it take?	The Scale Transect — a barn roof to ten thousand acres
4	What happens to the farming on that ground?	The Farming Axis — carried on, cut back, ended, or begun
5	What gets better, and who receives it?	Restoration Modes and Restorative Functions

Almost every decision in a solar project belongs to one of six groups, and this document calls them the design levers: scale, siting, structure, management, ownership, and contracts. They are the spine of everything else here. The pressures push on them, and what comes out the far end is the three readings this document puts on a project: its scale, its position on the farming axis, and the restoration mode that carried the work — and, from those, the functions the ground ends up performing.

Three of the nine pressures push toward restoration, three push away, and the direction of the last three is settled by the site, the buyer, or the county (Figure 2.1). Each one pushes harder

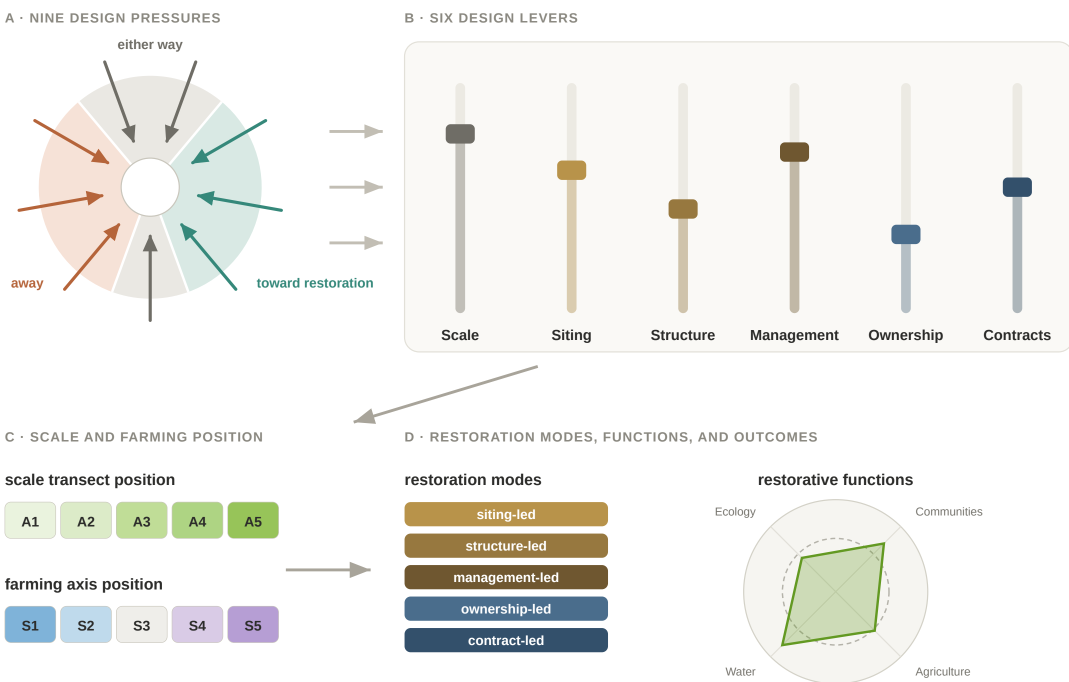

Figure 1: How the pieces fit. **Top row:** the nine design pressures, grouped by the direction each pushes, and the six levers they argue over, five of them colored by the restoration mode that lever carries. **Bottom row:** what a setting produces: positions on the scale transect and the farming axis, the restoration modes committed to, and a footprint across the four outcome domains.

in some regions than in others, which is why a California project and an Iowa project set the same six levers differently. A setting of the levers that recurs on real ground is an archetype: an array sized to the milking parlor, or one standing on ground whose irrigation was retired.

Two things here carry enough structure to need a chapter of their own, and only one of them is a lever. **Scale** becomes the scale transect, five calibration points from the farmstead to the complex, because interconnection, decision-making, and ground management all move together along it. Scale itself produces no restoration mode, which is why it carries no color of its own; what it decides is how much room the other five levers have to work in. The other is not a lever but an outcome: **siting, structure, and management** jointly produce a position on the farming axis, which records what happened to agricultural production: where a farm still works the ground, the position turns on whether the use is the one it carried before or a lesser one, which is settled by what was built and what is grown; where farming has stopped, it turns on what the ground was beforehand, which is settled by where the array went. Ground that carried no farming before the array and carries some under it takes a position of its own, past the sharing end.

The aim is argued; the dimensions are left to the site. This document takes a position on what agrisolar is *for*, and refuses to fix a clearance height or a row spacing, because the same lever settings that restore ground in one region deplete it in another. Regionality is where that gets explicit.

Chapter contents

Table 2: The document end to end. The chapters build on each other, and each one also stands alone.

Chapter	What it holds
Design Levers	the six decisions a project can actually make, three physical and two institutional, with scale setting the frame for all of them
Design Pressures	the nine forces arguing over how those decisions get made, where they collide, and how their weights shift by region
The Scale Transect	A1 to A5, farmstead to complex, and how much of every other lever survives at each size
The Farming Axis	S0 to S5, what happened to agricultural production on the ground the array took, and which positions each scale allows

Chapter	What it holds
Restoration Modes and Potential	which lever is made to carry the restorative work, how much each can still do at each size, why the community scale stands out, and the two different kinds of work called restoration
Restorative Functions	the four functions a design can be aimed at, the eight outcomes they carry, and which route each benefit travels to whoever receives it
Archetypal Forms	recurring settings of the levers that already exist on real ground, six worked through and seven sketched, from barnyard shelter to solar prairie strips
Terminology	every defined term, grouped by subject, with an A–Z index alongside
Evidence Base and Research Needs	how well each claim is evidenced, stated once rather than hedged everywhere, and the measurements that would settle what is still inferred
Sources	every claim traced, split into what has been verified and what still needs tracing

Joining in

Corrections, counterexamples, and proposed terms are welcome as issues or pull requests on GitHub. Especially useful: an archetype that recurs in your region and is missing here, a term that lands badly with the people who have to use it, or a citation you can trace further than we have.

1 Design Levers

A solar project is a long list of decisions, and almost all of them fall into six groups. How much ground to take. Which ground. What gets built on it. What grows there and how the place is run. Who holds the asset. What the parties signed. These are the **design levers**, and they are the only things anyone can actually change.

Everything else in this document sits downstream of them. The design pressures are the forces arguing over how the levers get set, and the restorative functions are what the settings produce. **Two chapters follow this one, and they are not the same kind of thing.** Scale gets one because a single lever carries that much structure: five calibration points from the farmstead to the complex. The farming axis gets one because it is not a lever at all. It is what siting, structure, and management jointly produce, five positions recording what happened to the farming on the ground the array took, and it is what most public argument about solar on farmland turns on. The four levers without a chapter are worked through here.

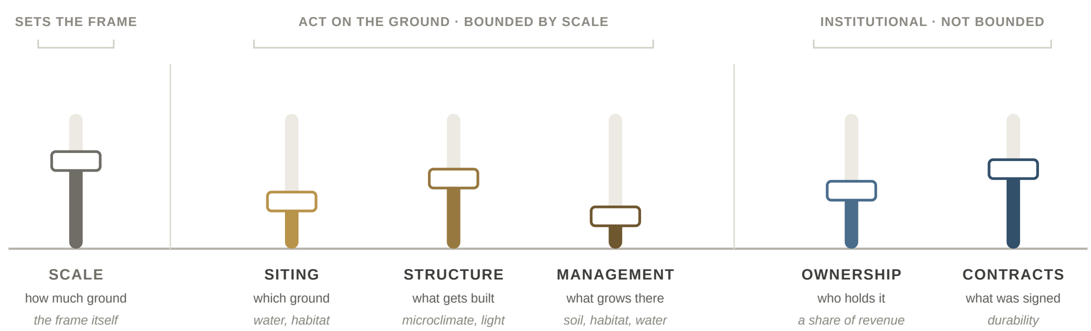

Figure 1.1: **The six design levers.** Six sliders on a rail, with what each decides and can deliver underneath: scale alone behind a rule, then siting, structure, and management, then ownership and contracts. The handles sit at different heights because a lever is something set rather than a fixed label; where each one happens to sit here is arbitrary and describes no project.

1.1 The levers

Table 1.1: The six design levers, and the decisions inside each. Scale sets the frame. The three below it act physically and are limited by how much ground there is; the two institutional levers are not.

Lever	What it decides	What it can deliver
Scale	how much ground the project takes · the capacity it is filed at, and the zone that follows · interconnection posture, from behind-the-meter to transmission · whether to build once or phase several arrays	the transect position, and how much of every other lever is left
Siting	which ground the array takes, and where on the parcel · whether it stands upslope or downslope of the problem it might fix · how near it is to the fields it might serve · whether a landscape carries a few large arrays or many small ones	water quality, habitat context, service to nearby fields
Structure	mounting type and clearance · row spacing and ground coverage · pore space · module technology · grading and site works · the built half of the edge: setback, berm, wall, fence line	microclimate, room to farm, light to the ground layer
Management	the ground layer and how it is established · the mowing and grazing calendar · stocking density · tracking and curtailment · construction sequencing and traffic lanes · the planted half of the edge: hedgerow, buffer, screening	soil and carbon, habitat, most of the water balance

Lever	What it decides	What it can deliver
Ownership	who holds the asset: owner-operator, landowner, developer, utility, cooperative, or shared · co-ownership or an equity stake in place of a rent	a share of generation revenue for the people on the ground
Contracts	lease terms and duration · offtake structure · interconnection posture · the community-benefit instruments · easements · the decommissioning bond	the community function, and durability for everything above

Two things that look like levers are not. What a project is *aiming at* is a goal rather than a decision about the project, which makes it the restorative goals pressure; what the ordinance requires is not chosen by anybody building, which makes it policy and permission. Both belong in §2, and a list that mixes a goal and a constraint in with actual choices is sorting three different kinds of thing under one heading.

> **Scale limits every other lever**
>
> Scale comes first because every other lever is bounded by it, and it earns a chapter of its own (§3). It does no restorative work of its own, since no field is repaired and no flock is fed by a project being 40 acres rather than 400. It is a decision for some parties and a constraint for others: a farmer with one parcel and a distribution line at the road has very little say in it, and a developer assembling acreage near a substation has a great deal. Both are choosing, and only one of them knows it.
> How much each of the other five can still deliver once scale has settled is the subject of §5.

1.2 The physical levers: siting, structure, and management

Siting is the choice of ground and the most powerful of the six where a designer still has it, though it settles a position on the farming axis only jointly, with structure and management (§4). It is also the first of the six to disappear as scale grows. Placement decides whether a water-quality claim is even available, because the two routes want opposite ground: avoided loading needs the impaired field itself, and interception needs ground between that field and the water (Schulte et al. 2017). It decides whether a pollinator planting reaches anyone, since a forager works a radius of roughly 1.5 km and about 3,500 km^2 of US farmland sits inside that distance of existing and planned facilities (Walston et al. 2018). And it is cheaper than the argument against it usually assumes: siting New York's entire 2050 build around biodiversity came to 0.17% above the least-cost case (Gallaher et al. 2026).

Structure is the hardware and its geometry. It owns microclimate outright, because shade, the drop in vapor-pressure deficit, and the shelter of nighttime minima are products of geometry rather than of anything growing, and those land in the water, ecology, and agricultural functions rather than in one of their own (§6). Row spacing is not quite a structural decision on its own, since crops differ in how much shade they will trade for relief, so the spacing and the ground layer are one decision taken by two parties (Weselek et al. 2019). Structure also decides how much earth gets moved, which is the least visible choice in the set and one of the most consequential: a racking choice made on cost sets the soil-carbon ledger for thirty years before any seed mix is chosen (§6.3).

Management is what grows underneath and how the place is run, from the first day of construction to the last year of the lease. It carries soil and carbon, most of habitat, and most of the water balance, and it starts earlier than people expect, because construction sequencing and traffic-lane discipline decide how much of the starting soil survives to be managed at all. It is also the only lever that can still be changed after the project is built, which cuts both ways: a planting that was right in year one can be undone in year four by a contractor doing exactly what the maintenance schedule says (Blaydes et al. 2022).

The edge is split between structure and management on purpose. A berm, a wall, and a fence line are built; a hedgerow is planted and kept. The halves fail differently, because the berm stands in year twenty whether or not anyone tended it and the hedgerow does not, so a project that promises screening and delivers it entirely in plantings has promised something with a maintenance bill attached.

Scale limits these three against each other rather than uniformly. As a project grows, siting narrows and management widens, and they trade places at A3 (§5.2).

1.3 The institutional levers: ownership and contracts

Ownership is who holds the asset, and it settles both who has standing to decide the rest and who captures what the array earns. An owner-operator, a cooperative, and a utility do not want the same things, and the differences show up in the ground layer rather than only in the accounts. Barnyard shelter solar is the clean case at the small end: it is restorative because the person who owns the array is the person who owns the animals under it, and no agreement was needed to align them.

Ownership is also the lever the transect moves furthest, and it moves in one direction. At the farmstead the array belongs to the operator. Through the commercial and community zones it belongs to the landowner, or to a community-solar structure with many small holders. At A4 and A5 it belongs to developer capital and then to a utility or an independent power producer, and the person on the ground holds a lease instead.

The generation revenue moves with it, and that is the largest thing an agrisolar project creates. A lease pays for the use of ground and is not a share of what the array sells, so a landowner earning three to four times what the crop returned per acre (Sturchio et al. 2025) is still being paid for land rather than for electricity. **Restorativity has an ownership question inside it, and the size of the lease payment does not answer it.**

That is what makes co-ownership, a community-solar subscription, and an equity stake in place of a rent restorative instruments rather than goodwill: each keeps some part of the generation revenue with the people who host the thing. Ownership produces no restorative function of its own, and instead decides who captures the ones the other levers produce, which is why the community and economic function is most at risk on absentee projects and most fully realized under local or shared ownership.

Contracts are what the parties actually signed. This lever carries the community and economic function almost by itself, and it is also what makes the other five last. The clearest published case runs through the institutional side alone: solar lease income can make a conservation practice affordable that federal biofuel policy had made unaffordable (Sturchio et al. 2025). No ground was chosen and no hardware was changed. The restoration happened in a contract, which is the lever most often left on the table.

Durability is the reason, and it follows from the levers being fixed at very different moments. Scale and siting are settled once. Structure is fixed on the day the project is built. Ownership turns over in decades and contracts in years, while management is continuous and can be changed next season. Brand (1994), after Frank Duffy, reads a building as several layers of differing longevity rather than as one object, and holds that a design works when the fast layers can move without tearing the slow ones; Habraken (2002) adds that each layer has a decision-maker of its own. Management is the fast layer here and therefore the fragile one. It survives only as long as somebody is paying for it and somebody else is checking, and both of those are contract questions: a seed mix is a management decision, and whether it survives to year twenty is a lease question.

Designed landscapes fail this way as a matter of course. The Landscape Architecture Foundation reports that parts of many projects fail within a year or two of installation because maintenance staff had no voice during design and the designer's scope ended at the final walk-through (Douglas and Deming 2015). A project can be sited perfectly, built correctly, and planted well, and still be gravel in fifteen years, because the levers that would have held it there were treated as paperwork rather than as design.

Which of the six is made to carry the restorative work is the project's restoration mode, and it is enough of a decision to have a chapter of its own (§5).

2 Design Pressures

The developer, neighbor, farmer, buyer, and county do not want the same thing from a solar project. The developer needs a simple rectangle it can build at the price it bid. The farmer needs clearance for a tractor and a lease that runs as long as the array. The neighbor wants a screen along the road, the buyer wants the credits its scorecard counts, and the county wants the tax revenue and its own setbacks observed. Every project settles those claims, and mostly settles them without anyone saying so: the seed mix goes to turf, or the permit stalls. These are the **pressures**: nine forces, each with a direction and an advocate. Naming them makes the disagreement arguable, and says who is carrying what the design could not settle.

2.1 The pressures

Nine forces act on every site. Three push toward restoration, three push away, and the direction of the remaining three is settled by the site, the buyer, or the county. Restorative goals is the one this lexicon exists to advance, and it is still a force among forces rather than a score to hold a project against. The third column is the one worth arguing about, because it is where a project's restorative claim is won or lost. Two pressures can point the same way and still collide, which is what makes the reversibility argument in §2.2 the hard one.

Table 2.1: The nine pressures and the direction each one pushes. Read the third column as a direction rather than a verdict on anyone advocating it, since every one of the nine has someone arguing for it in good faith.

Pressure	What it asks for	Push on restoration
Restorative goals	Wider rows, mixed ground cover, a plan covering all thirty years, and choices made for the sake of what grows underneath (Hernandez et al. 2019)	**Toward.** The one this document argues for. It still loses to the other eight most of the time

Pressure	What it asks for	Push on restoration
Community acceptance and benefit	Two things, and a design needs both. *Process*: engagement early enough that the answer can still change the design. *Receipts*: what the project pays back — tax revenue, agreements, subscriptions, local hiring, part-ownership	**Toward,** mostly. A township that gets a real say usually asks for more than a check. It can also ask for mown grass and a taller fence. And paying people without asking them first buys resentment, not consent (Crawford et al. 2022; Ryder et al. 2023)
End-of-life responsibility	Removable foundations, less digging, funded decommissioning, ground that can go back to what it was	**Toward.** Every trench and every graded acre is soil somebody has to rebuild later. The cheapest decommissioning is the one designed on day one, and the bond is what keeps the cost off the county
Agricultural production	Clearance for a tractor, room to turn at the end of a row, something worth growing underneath, and a contract the farmer can work within for the project's whole life	**Both.** It is why there are sheep under the panels. It is also why there is no prairie under them: ground that has to grow something salable cannot also be left alone
Grid and market demands	Whatever the buyer and the grid require: the power contract, the renewable-energy credits, the tax benefits, an interconnection the queue will actually deliver	**Both.** When a buyer's scorecard rewards pollinator habitat, habitat gets planted on a thousand sites at once. When that scorecard was written for a different climate, the wrong seed mix is in the contract for twenty years
Policy and permission	Whatever the rules require before the project can happen at all: the permitting path, prime-farmland and setback rules, state programs, and the subsidies that decide what pays	**Both.** In California, groundwater law pays a grower to retire irrigated ground. In Iowa, the ethanol mandate pays a grower to keep planting it. Same pressure, opposite instruction, and the state line decides

Pressure	What it asks for	Push on restoration
Operations and maintenance	Cover that is simple to mow, or gravel that does not grow at all, for twenty-five to forty years	**Away, then toward.** Somebody mows that ground for the next thirty years. Gravel never needs mowing, which is how gravel wins. Natives cost more for three years and less every year after, so which way this pushes depends on how far ahead the owner is looking
Energy yield	Panels packed close, tilted and turned to follow the sun, mounted low, covering the whole field	**Away.** This is why the standard array looks the way it does: low, tight, edge to edge. Not always opposed, though. Plants under the panels hold the dust down and keep the modules cool, and cool modules make more power (Merheb et al. 2025)
Cost and financing	Standard racking, low mounting, no special site preparation, simple rectangles instead of awkward shapes · a project big enough, and an offtaker sound enough, to raise the money against	**Away,** twice over. Anything unusual costs more and somebody will ask why it is worth it. And the paperwork does not scale down, so the middle of the transect pays a premium per watt for reasons that have nothing to do with how it was built. Sometimes the answer is cheap: siting New York's entire 2050 build around biodiversity came to 0.17% more than the cheapest version (Gallaher et al. 2026)

A site nobody will finance does not get built, and none of the nine can simply be argued away.

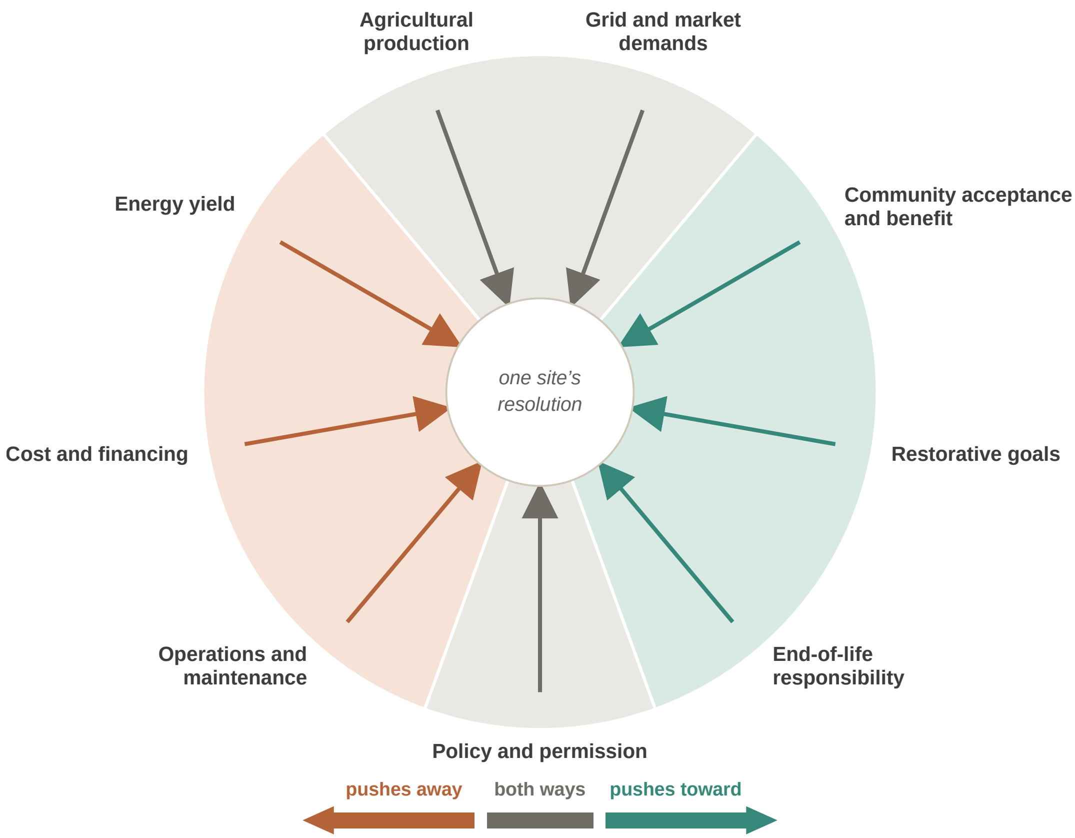

Figure 2.1: Nine pressures bearing on one site at once, arranged by the direction each pushes. The two colored groups never meet, because the three whose direction is decided by the site, the buyer, or the county sit in the gray wedges between them.

2.2 Where the pressures collide

What a given design leaves unresolved is its **design tension**. No setting of the levers reduces it to nothing, because the nine cannot all be satisfied at once and a project has to be built anyway. What varies is how much is left, and which parties are carrying it: a design can be quiet because the pressures genuinely accommodated each other, or quiet because one party gave up and went home. The settings that leave the least tension are the ones that get built repeatedly, which is where the archetypal forms come from.

Agricultural production vs. restorative goals. Should the ground under the panels grow food, or habitat? This is the American Farmland Trust / ecovoltaics argument. Requiring crops rules out pollinator plantings; choosing habitat gives up the farmland-protection case. Both sides are defending something real, which is why treating it as a misuse of words settles nothing.

Operations and maintenance vs. everything. Gravel and herbicide are easy; diverse perennial cover is not. The maintenance bill decides many restorative designs.

Grid and market demands vs. restorative goals. Buyers and scorecards can spread good ground-layer practice, but a rule written at a distance can also lock in a poor local fit for the term of a contract (Electric Power Research Institute 2021).

Energy yield vs. restorative goals. Clearance, spacing, and crop shade tolerance interact. Vegetation can also cool modules, reduce dust, and lower panel-washing demand, so the two pressures occasionally align (Merheb et al. 2025).

Cost and financing vs. operations and maintenance. Often mistaken for a single pressure. They split on what to plant, how high to mount, and how to get equipment in: cheap to build is frequently expensive to keep.

End-of-life responsibility vs. restorative goals. The hard one, because both pressures push toward restoration and still collide. Established habitat and rebuilt soil take years to create and resist clean removal: a project designed to disappear cleanly and a project designed to heal the ground are not always the same project.

Community acceptance and benefit vs. cost and financing. Community benefit costs money but cannot substitute for fair process. Its cost should be calculated, not assumed: a biodiversity-conscious New York portfolio was only 0.17% above the least-cost case, although farmland preservation made other tradeoffs (Gallaher et al. 2026).

2.3 The same pressures, weighted by place

The nine act on every site and carry different weight in every region. Shade that relieves a water-stressed crop in Arizona can cut maize yield in Ohio, and retirement above a depleted aquifer has no equivalent in a rain-fed county. The vocabulary travels; the weights do not. That is why this lexicon argues an aim and leaves the dimensions to the site.

2.3.1 Six factors that shift the weights

Table 2.2: The six regional factors and what each one changes. The vocabulary travels between regions; the weights do not.

Factor	What it changes
Resource: sun and cloud	Cloudier regions carry a higher diffuse share, which reaches under and between panels more readily than direct beam and gives a ground layer a more forgiving floor. Strong beam raises the value of tracking and the opportunity cost of clearance and wide rows
Grid operator	The grid market often fixes how big a project will be before the land does. Queue delays and curtailment cut the value of the marginal megawatt and soften the push toward dense geometry. Where no community-solar program exists, projects skip the middle sizes entirely and lose the range where the most design choices stay open
Aridity	Reverses the value of shade. Water-limited, high-radiation settings can trade light for relief; humid and temperate ones lose yield without a compensating saving, with the turn near 30 °C ambient across 367 paired observations (Merheb et al. 2025). Hydrologic work shifts from demand relief to interception
Latitude	Sets sun angle, tilt, row spacing, and therefore ground coverage. Wider northern rows give the ground layer more light and use more land; tighter southern arrays do the reverse. The resulting pore space is why vertical bifacial primary agriculture (S1) is not equally viable nationwide

Factor	What it changes
Cropping system	Decides whether keeping a crop under the panels is plausible at all. Leafy and root horticulture and many forage grasses tolerate moderate shade; C4 grains and many fruiting crops do not, so a maize and soybean region leans on grazing and on leases rather than on cropping through
Irrigation	Makes impaired-land siting possible where a district exceeds its aquifer budget, because retiring demand saves water and solar makes the retirement pay. Rain-fed regions have no consumptive use to retire, and their water work is interception instead

2.3.2 A worked calibration: the United States

The table below is one calibration, offered as a worked example rather than a finding. Regions are drawn loosely on the USDA resource regions and named for recognizability, and the last column is what the factors, taken together, tend to push a region toward.

Table 2.3: One regional calibration of the United States, offered as a worked example rather than a finding. Read each row as a starting hypothesis: a region doing something its profile says it should not is the most useful contribution this chapter can receive.

Region	Resource & light	Water	Cropping	Market	Tends toward
Desert Southwest	Highest GHI, low diffuse, strong beam	Arid; groundwater-limited	Irrigated specialty, rangeland	CAISO / WECC, large-scale	Shade as a benefit; cropping continues under the panels where irrigated horticulture persists, and irrigation is retired where water is the binding constraint
Central Valley & irrigated West	High GHI	Arid, and governed under SGMA	High-value specialty, heavily irrigated	CAISO, strong offtake	Retiring irrigated ground at scale; retired-irrigation solar
High Plains	High GHI, high latitude spread	Ogallala overdraft; declining wells	Grain, cotton, beef	SPP / ERCOT, curtailment risk	Retiring irrigated ground where the aquifer binds; grazing on the large arrays

Region	Resource & light	Water	Cropping	Market	Tends toward
Corn Belt	Moderate GHI, moderate diffuse	Rain-fed; runoff and nutrient export	C4 grain, soybean	MISO / PJM, deep queues	Leases and grazing; hydrologic function as interception, via prairie strips and pollinator ground layers
Great Lakes & Northeast	Lowest GHI, highest diffuse fraction	Humid; drainage, not scarcity	Dairy, forage, vegetables	Community-solar programs, so mid-sized projects are real	Crops and stock kept on the ground at small and community scale; vegetable agrivoltaics, barnyard shelter
Southeast	Moderate-to-high GHI, humid and cloudy	Humid; rainfall intensity	Row crop, pasture, poultry	Largely non-ISO, utility-led	Grazing at scale, and leases with managed ground layers

Read each row as a starting hypothesis, not an assignment. Counterexamples are worth reporting.

2.3.3 What follows

The pressures are constant but their weights are not. Designs should differ when resource, grid, crop, or water conditions differ. The characteristic failure is importing a resolution from another region, often through an offtake-conformity rule that travels farther than the evidence behind it.

What the array replaces is itself a regional fact, and it changes what a sparing argument even means. Nationally, cropland is the dominant thing US solar has displaced. In New York it is not: of utility-scale solar built to date, 48% displaced pasture and hay, 38% cultivated crops, and 11% forest (Gallaher et al. 2026). That puts forest conversion and grassland bird habitat at the center of a conversation that in Iowa would be about row crops and nutrient export. A position on the axis travels between regions; what sits on the other side of the decision does not.

This is why the document prescribes an aim rather than dimensions. Regional calibrations are especially useful contributions: the zone bands are indicative for the US Midwest, and a region with different bands, missing zones, or a different binding constraint extends the lexicon.

3 The Scale Transect

Somebody chose five megawatts rather than eighty. It was decided early, on grounds of interconnection and capital, probably before anyone walked the ground, and it set the limits of every choice the design had left: how much ground there was to choose among, what hardware was affordable, who would manage the vegetation, and who would end up owning the asset. That decision is **scale**, the first of the six design levers — how much ground the project takes, and the one most often mistaken for a fact about a site rather than something a person settled.

Scale earns a chapter because its consequences travel together. Interconnection posture, the decision unit, the permitting path, ground-layer management, and siting latitude all shift as projects get bigger, and they shift closely enough that naming a position on the gradient tells you many things at once. That gradient is the **scale transect**, and A0 through A5 are named points along it rather than a separate kind of thing.

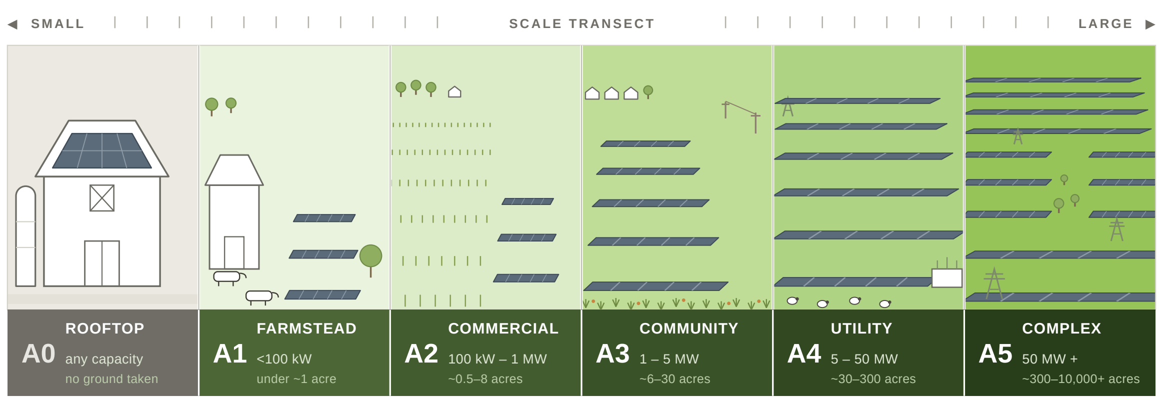

Figure 3.1: **Scale Transect Zones.** A0 through A5, one panel each, from a barn roof to rows running to the horizon. Each panel is at its own scale: what grows across the set is the array's share of the frame and what else is still in view.

3.1 Five zones on one gradient

A 30-kilowatt barn array and a 300-megawatt complex are both solar on farmland, but their decision-makers, finance, grid connection, ground management, and possible land functions differ. **Scale** is therefore a transect: a gradient of attributes that change together, rather than a set of capacity bins. Capacity is a useful hint, not the definition. The zones below are calibration points on that gradient in the sense the rural-to-urban transect uses them, which is to say named places to stand rather than boxes with walls. Pressures shift continuously along it, a 4 MW project and a 6 MW project differ by less than their labels suggest, and a project near a boundary should be read as being near a boundary. What moves together is:

- **How it connects to the grid**: behind the meter → distribution → transmission
- **Who decides**: one landowner → several parties at a table → a utility with a place in the interconnection queue
- **What it takes to permit**: allowed by right → site plan review → full environmental review
- **Who manages the ground**: existing farm labor → purpose-built for the site → an outside contractor
- **Where the money comes from**: the owner's pocket → tax equity and a power contract → project finance
- **Who has to be talked to**: the neighbors → the township → a regional process
- **Siting latitude**: opportunistic → strategic → decided by what land could be assembled near a substation

Physical effects change with geometry and scale as well. Soil cooling and moisture retention are more consistent than air-temperature effects, which vary by site (Zhang et al. 2025).

Table 3.1: The five zones, and the attributes that move together along them.

Zone	Indicative capacity	Indicative footprint	Interconnection	Decision unit	Ground-layer management
A1 — Farmstead	<100 kW	under ~1 acre	Behind-the-meter, net metered	Single owner-operator	Existing farm labor and equipment
A2 — Commercial	100 kW–1 MW	~0.5–8 acres	Behind-meter to distribution	Landowner, possibly one lease counterparty	Existing equipment, modest adaptation
A3 — Community	1–5 MW	~6–30 acres	Distribution; community solar, mid-market PPA	Multi-party: landowner, developer, offtaker, tax equity	Purpose-built: dedicated mowing, contract grazing, seeded establishment

Zone	Indicative capacity	Indicative footprint	Interconnection	Decision unit	Ground-layer management
A4 — Utility	5–50 MW	~30–300 acres	Distribution to sub-transmission; queue position matters	Developer-led, institutional capital	Contract enterprise: commercial graziers, habitat contracts
A5 — Complex	50 MW+	~300 acres to 10,000+	Transmission; merchant or utility PPA	Utility/IPP, multi-jurisdiction	Contract enterprise at ranch scale; multi-site rotation logistics

Capacity is how a project is filed; acreage is how landholders and communities experience it. Trackers and agrivoltaic clearance use more land per megawatt than dense arrays, so **acreage is the better guide when the two disagree** (Gallaher et al. 2026; Sturchio et al. 2025).

The conversion behind the acreage column, and its shelf life. The footprints above assume 5.5 acres per MW-AC for fixed tilt and 6.3 for single-axis tracking, which is what Berkeley Lab measures for operating systems under 20 MW; counting setbacks, access, and interconnection the total site runs nearer 6 to 8. Wide-row agrivoltaic layouts roughly double it. These are 2020s numbers and they have been falling for a decade as modules improve, so treat the acres as a conversion to redo rather than a constant, and expect a later edition of this table to show smaller footprints for the same megawatts. The fall is bounded, though. A commercial silicon module converts a little over a fifth of the light reaching it against a single-junction thermodynamic ceiling near a third, so there is roughly a third of improvement left in that architecture before physics closes it. Tandem cells can pass that ceiling, which makes the floor soft rather than fixed, but not open-ended. Land intensity will improve and then stop improving.

Building-mounted arrays are **A0 — Rooftop**: no ground to choose, manage, share, or spare, which puts them at the origin of the gradient rather than on it. A5 has no ceiling; its common condition is placement fixed by land assembly and restoration carried by management (§5.2).

A4 spans a wide range and probably contains a break of its own, near 20 to 25 MW. That is not a land threshold but a jurisdictional one: it is roughly where several states move siting authority from local boards to a state office, New York's being the clearest case. Below it a township still decides, and a design argument can be made to people who live there. Above it the venue changes and so does the audience. The lexicon has not split A4 on that line yet, because unlike the 5 MW boundary it rests on one attribute rather than several converging ones, but a reader working between 20 and 25 MW should expect the project to behave like the zone above rather than the zone below.

The bands in the table fit the US Midwest and should be redrawn elsewhere. Not every zone exists in every region.

A worked example: grazing across the transect. Sheep grazing keeps the same name from the farmstead to the complex, and stops being the same job about twice along the way. Following one practice across the zones shows what the transect is actually measuring, because nothing about the animal changes and almost everything about the arrangement does.

The choice of animal is made before the scale question arises. Sheep fit standard racking, goats climb it and chew wiring, and cattle and horses need more clearance than a standard array leaves them (Merheb et al. 2025), so in practice it is sheep or it is mowing.

Table 3.2: Solar grazing across the transect.

Zone	Who grazes	Typical figures	The design problem
A1–A2	the farm's own flock	~3 ewes/acre in New York and Michigan experience (Hartman 2026); 4–20 sheep/acre in rotational trials at Cornell	matching stocking to the forage and the weather in front of you, rather than to a published rate
A3	a contracted grazier	~$300–500/acre/yr for vegetation management	building a site that works for someone who does not live on it and visits on a schedule
A4–A5	a logistics enterprise	mowing medians across 54 utility-scale sites: $113/acre/yr at sheep-grazed sites, $121 at native-vegetation, $203 at turfgrass; herbicide $293 on gravel (McCall et al. 2023)	water, gates, hauling, and rotating a flock between parcels that do not touch each other

Two terms come apart here and are worth keeping apart. **Stocking density** is how many animals are on the ground at one moment, and **carrying capacity** is what the forage will feed across a season. Growth, utilization, and weather all move one without moving the other, which is why the A1–A2 figures above are a range rather than a rate.

Establishment is the cost that catches people out. Measured per activity, native and pollinator-friendly covers run *below* turfgrass, and yet total vegetation O&M came out slightly *higher*, because the first three to five years take more separate passes across the site (McCall et al. 2023). Restorative ground cover is expensive to establish and competitive once established, so anyone arguing for it on cost savings alone should expect to meet an operator holding the establishment invoices.

So "solar grazing" on its own names three different practices, and which one a person means is usually settled by the size of the project they last worked on.

3.2 Scale modulates the other five levers

Of the six design levers, scale is the only one that does no restorative work of its own. Choosing five megawatts over eighty plants nothing and obliges nobody. What it does is decide which of the other five a designer still has a hand on by the time the layout is drawn. **Scale is the master lever because it is spent before the others are picked up**, and little later in a project wins back what it closed.

Siting latitude shows the mechanism plainly, because the decision is physical and somebody has to point at a piece of ground. What changes with scale is whose arm does the pointing.

Table 3.3: Who chooses the ground, by zone.

Zone	What decides where it goes	Who actually chooses
A1	The yard, the herd, and the existing service drop	The operator, with almost no ground to choose among
A2	Spare corners, awkward field ends, ground already sitting idle	The operator
A3	Consistently low-yielding ground, where the water runs, buffer geometry	Developer and landowner, deliberately, together
A4–A5	Contiguous acreage near a substation and a place in the queue, nudged at the edges by prime-farmland rules, likely opposition, and which communities benefit	The land market and the grid, filtered through policy veto points

Read the two columns against each other. At the farmstead the operator holds the whole decision and has almost nothing to decide, since one spot in the yard may be the only spot. At A3 a developer and a landowner walk the field together and can put the array on the wet depression or the corner that never yields. By A4 the middle column has filled with things nobody at the table controls, and the right column stops naming a person. The developer still signs the lease. The ground was chosen by whatever acreage could be assembled near a live queue position, and everything else in that row only trims the list.

The other levers travel the same way, less visibly. Racking at A1 is whatever a local installer can source for one particular yard, and at A5 it is a catalog item bought by the megawatt, so the structural decision passes from a person standing in the yard to a procurement schedule. Ownership moves furthest: at the farmstead the party deciding and the party living with the decision are one person, and by A5 they are an investor, a landowner, and a township. Every lever survives the trip. None stays in the same hands.

What those levers can still deliver once scale has decided who holds them is a separate question, and §5 takes it up. The point here is that the capacity number on a term sheet has already answered part of it: a project filed at 80 MW gave away its choice of ground before the first site visit, and one filed at 3 MW kept that choice and will pay a premium per watt for it.

4 The Farming Axis

From the road, one array looks much like another: same modules, same rows, same fence. The differences are underneath it and beside it, in whether a farm is still taking anything off that ground and in what the ground was doing before the array arrived. The farming axis answers one question: **what happened to agricultural production on this ground?** Every ground-mounted project occupies one of five positions, S1 through S5, running from **land sharing**, where production continues on the ground the array occupies, to **land sparing**, where ground comes out of production so other ground can be left alone. A sixth position, **S0**, sits past the sharing end for the case the other five cannot read: ground that carried no farming before the array and carries some under it. The axis is largely independent of scale: scale says what was available; position says what happened.

The two halves of the axis are settled by different levers, which is why the names run on two stems. Where production has stopped, the position is a straight reading of which ground the array took — ordinary, idle, or impaired — and that is a siting decision, so those three are named for the ground. Where production continues, siting has almost nothing to do with it. A flood-prone corner that was rough pasture and still carries the farm's sheep is S1, and the same corner left to naturalize under the panels is S4, on identical ground. What separates them is what is grown and who takes it, so the sharing positions are named for the farming that survives rather than for where anyone put the array.

Most public argument about solar on farmland is an argument about this axis, conducted without it (Moore et al. 2022). About half of the ~3,000 km² (740,000 acres) of US ground-mounted solar was built on former cropland and about a third on agricultural grassland (Kruitwagen et al. 2021; Fujita et al. 2023), and globally croplands are the prior cover for roughly 59% of PV sites (Merheb et al. 2025). Naming the position first clarifies what a project can claim, what it must still argue for, and which objections apply. The framing borrows the neutrality of conservation ecology's land-sharing and land-sparing debate (Green et al. 2005; Phalan et al. 2011); it does not rank positions by definition. The closest existing scheme sorts solar landscapes by design ambition, as mixed-production, nature-based, or landscape-inclusive (Oudes et al. 2022); this axis cuts across all three, because it asks only what happened to production.

4.1 The positions

The two agricultural positions are read against what the ground did before, not against what the array needs. **S1** is the use carried on essentially unchanged with the array added to it,

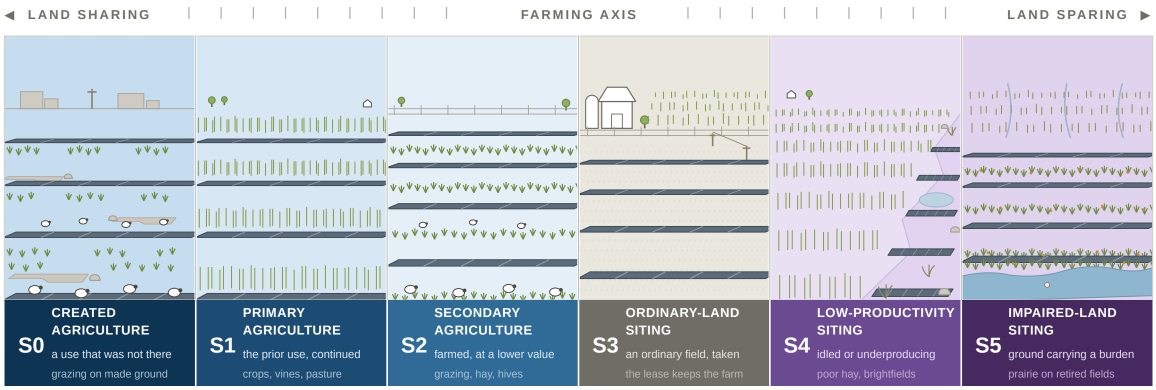

Figure 4.1: **Farming Axis Positions.** What happened to the farming on the ground the array took, drawn six ways at a single scale. The tint runs blue at the sharing end through neutral at S3 to purple at the sparing end.

which is agrivoltaics in the strict sense: a vineyard still a vineyard, a pasture still a pasture, a row crop still cropped between the rows. **S2** is agriculture continued at a lower value than the ground carried before, which in practice is usually solar grazing on former cropland, and also covers a sown layer worked for forage, hay, or hives. The same flock therefore reads differently on different ground: sheep on land that was already pasture are S1, and sheep on land that was growing maize are S2, because one use continued and the other stepped down.

Ordinary-land siting is the center of the axis and where most projects sit; direct crop production under panels remains a small share of US installations (Stid et al. 2022; Macknick et al. 2022). **S3 is where restoration is socioeconomic before it is biophysical**: the lease sustains the farm enterprise although production stops in the footprint. Where rent reaches a non-farming owner and the operation ends, the site is **bare conversion**, the non-restorative baseline. The distinction must be made for the landowner and tenant separately (§6.4) (Stid et al. 2025).

S4 and S5 both take ground out of production, and differ in where the benefit goes: S4 spares land not taken, S5 acts on the ground taken and its downstream effects. That difference is why only one of them can be checked where it stands. **S5's benefit lands on the ground the array is standing on; S4's lands on ground the array never reached.** Both names nonetheless record what was sited on, which is what a visitor can check, and leave the sparing claim to the definition. The burden that qualifies a site for S5 has to be a measurable one: chronically low yields, high runoff, nutrient or pesticide export, or irrigation draw beyond the aquifer's budget. Ground positioned where such a burden can be intercepted qualifies on the same reasoning. Prairie plantings on drainage-impaired crop ground illustrate the distinction (Schulte et al. 2017).

One case sits outside all five, and it runs the other way. The five positions are a ledger of displacement: each records a use kept, a use stepped down, or a use lost, and each is read against what the ground carried before the array. Ground that was built on, paved, filled, or otherwise carrying no agricultural use has nothing to displace, so an array that puts a flock on it is neither holding a use nor stepping one down. It is making one. That is **S0 — created agriculture**, and it sits past the sharing end, because production on the ground the array occupies is what the sharing end means and S0 carries more of it than the ground held before. A capped landfill grazed under panels, a decommissioned industrial parcel carrying sheep, previously developed urban and peri-urban ground put back to stock: all read S0. Its name runs on the sharing stem, for the farming rather than for the ground, since what defines the position is the use that started. The position is uncommon, and naming it makes no claim about quality. A use that began is not automatically a use worth having, and the position records the direction rather than the value.

Table 4.1: The six positions, and what changes across them. Read left to right, the first two columns settle the position and the last two say what follows from it.

Position	The ground beforehand	Production afterward	Typical ground layer	Where the benefit lands
S0 — Created agriculture	Developed, built, or otherwise carrying no agricultural use	Begins where there was none	Usually grazed; whatever a farm can take something off	On the same ground, and on whoever farms it
S1 — Primary agriculture	The use it already carried	Continues essentially unchanged	The crop, the vines, or the pasture itself	On the same ground
S2 — Secondary agriculture	Usually cropland; any ground whose use is stepped down rather than continued	Continues, at a lower value than before	Grazed, cut for forage or hay, or worked for hives	On the same ground, and on the farm working it
S3 — Ordinary-land siting	Ordinary productive ground	Stops inside the footprint	Whatever is maintained; often mown	On the farm enterprise, through the lease
S4 — Low-productivity siting	Already idle, marginal, or chronically low-yielding	Had already stopped before the array arrived	Often left to naturalize	On productive land elsewhere that went unbuilt
S5 — Impaired-land siting	Carrying a measurable off-site burden	Stops, and the burden stops with it	Perennial cover chosen against the burden	On the ground taken, and downstream of it

Corn-ethanol land: the large American S5 case. It reverses the usual objection. About 12 million hectares of US cropland, an area the size of New York State, already grows energy rather than food. One hectare of utility-scale array matches the energy of roughly 31 hectares of corn grown for ethanol, so converting 3.2% of that acreage would replace all of its energy and take utility-scale solar from 3.9% to 13% of US supply. Retiring the nutrient-exporting fraction under perennial vegetation would remove an estimated 54.8 million kg of nitrogen and 26.3 million kg of phosphorus from annual application (Sturchio et al. 2025).

The substitution is imperfect, because electrons and a fuel additive serve different end uses. But the land arithmetic is not close: this is not food land lost to energy, it is energy land used about thirty times better.

A position records the ground fact, not project quality. Pollinator habitat, prairie, and native grassland are restorative functions, not positions: the same planting can occur at S1 through S5, since a grazed array on former pasture can carry a pollinator understory as readily as a retired field can. What decides the position is whether a farm takes something off it. A sown meadow carrying hives is agriculture, because honey and colonies leave the ground and are sold, which puts it at S2 on the same footing as a flock; the identical meadow without hives is a ground layer doing ecological work on land that stopped farming, which is S3 or below.

Placing a site. The positions are exclusive, and two questions in order settle which one applies. Both are asked of the ground, not of the lease.

1. **Is a farm still taking something off this ground?** Name the farm and name what it takes. If the use is essentially the one the ground carried before, the site is **S1**. If a farm still works it but at a lower value than before, the site is **S2**. If the ground carried no agricultural use at all before the array, the site is **S0**, because there was no use to keep and none to step down from. Two things do not count. Rent is not production: it comes out of the contract rather than out of the ground, and a site whose only output is a lease payment is S3. Vegetation that is only mown is not production either, because nothing leaves and no farm takes anything.
2. **If nothing is taken, what was the ground before the array?** Ordinary productive land gives **S3**, ground already idle, marginal, or chronically low-yielding gives **S4**, and ground carrying a measurable off-site burden gives **S5**.

A flood-prone corner that was already rough pasture and still carries the farm's sheep is S1, because the use it had is the use it kept. The same corner cropped before the array and grazed after it is S2, because a farm still works it at a lower value than before. Left to naturalize under the panels, with nothing taken off it, it is S4. S3 asks one further question: does the farm enterprise survive the conversion? If not, it is bare conversion.

Sparing remains a landscape claim. S4 benefits only if the land left untaken was the genuine alternative and the array did not move onto something else worth keeping. Siting New York's 2050 build to preserve farmland spares roughly 80% of the farmland a least-cost build would take and opens more than 41,000 hectares of forest doing it, while the least-cost run itself concentrates on pasture and hay, nearly half of which overlaps grassland bird habitat (Gallaher et al. 2026). The array goes somewhere, and a position read at the site alone will not say where. S4 includes unlike sites, from remnants to brownfields, whose contamination and permitting constraints still belong in the site description. Building-mounted arrays are A0 and hold no position.

Read down the five and they are all answers to one kind of question: what was given up, and by whom. None of them says what the ground goes on to do afterward, which is a second kind of restorative work and is taken up in §5.4.

4.2 Scale and position interact to determine feasibility

Scale narrows the positions available through siting latitude, and it narrows them at one end only. Farming carries on under panels at every size: at A1 it is the operator's own yard, and at A5 it is a contracted flock on ground that was already pasture, which is why the sharing edge of the *feasible wedge* runs flat across the whole transect. What is scarce at the small end is sparing: S4 and S5 are available there and spare almost nothing, because the acres involved are too few to stand for anything. The wedge therefore opens downward from A1 to A3 and stays open. The one combination that genuinely thins toward the large end is **S4**: contiguous land assembly near a substation cannot collect scattered remnants, so ground that qualifies gets harder to find as projects grow. S5 does not thin with it, because impairment can be regional and an aquifer district assembles as readily as any other block of ground.

Grazing and ordinary-land siting form the spine. Grazing is what holds the sharing edge open at the large end, and it does so on the strength of the prior use rather than on any geometry: a flock on ground that was already pasture is S1, and the same flock on former cropland is S2. What stays genuinely exceptional is *cropping* at utility scale, where the tall clearances and wide rows are hard to justify against cost, with vertical bifacial arrays the documented case (Vaverková et al. 2026); greenhouse photovoltaics at small scale and pre-disturbed land for S4 remain the other two. Permanent crops are a second candidate exception on the sharing wing, since a vineyard or orchard already carries its rows at height and its crop can absorb a clearance that maize cannot, so a fifty-acre block under a canopy is a primary-agriculture project of some seventeen megawatts. The exception is geometric rather than economic: the structure premium still runs 1.8 to 2.7 times a conventional ground mount, and a trellis holds vines, not trackers. Native grassland remains a restorative function, not a position (Walston et al. 2025; Krasner et al. 2025).

S1 reached by *cropping* is climate- and crop-conditional, in a way S1 reached by carrying on a pasture is not: it is most plausible for shade-tolerant crops in hot, water-limited settings and mixed to negative for staple grains in temperate or humid settings (Barron-Gafford et al. 2019; Weselek et al. 2019; Merheb et al. 2025).

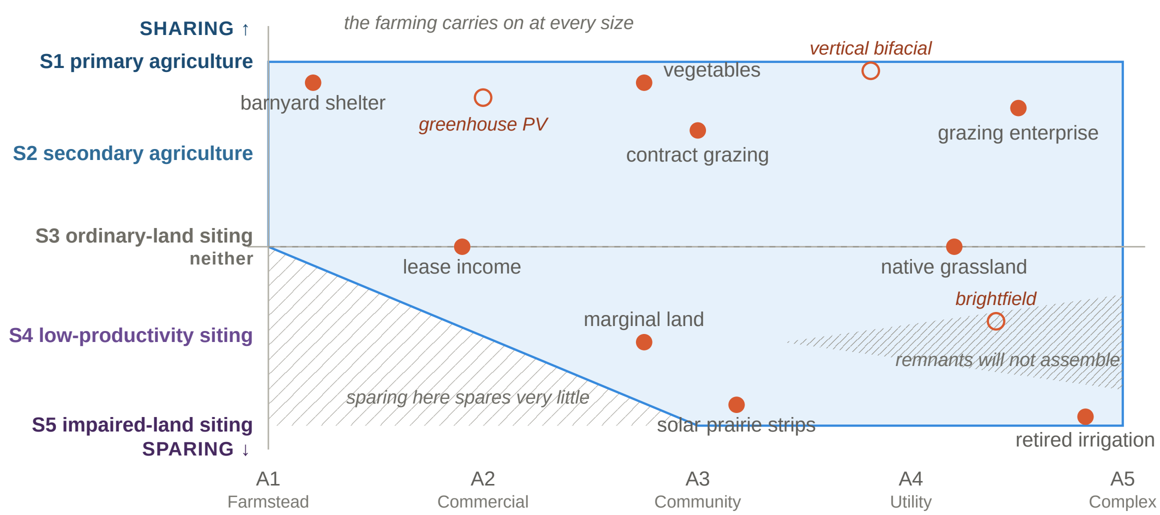

Figure 4.2: Which combinations of scale and position actually get built. The blue shape is where projects are common; solid points are practices in the field, hollow points the exceptions. The sharing edge runs flat because a farm can carry on under panels at any size; the hatching marks sparing that is too small to matter at A1, and remnants that will not assemble at A5.

American Farmland Trust's production-based dual-use definition requires S1 or S2. Critics include ecovoltaics, whose ecological ground layers sit as functions at S3 and below (Hernandez et al. 2019). This document describes that dispute rather than settling it.

5 Restoration Modes and Potential

A developer promises native grass under the panels and a flock to keep it down. Whether that promise is worth anything depends on which decision is carrying it. The grass could be there because the array went on the part of the field where the water already runs, because the rows were spaced wide enough to let light reach the ground, because a grazier was hired to seed it and bring the animals, because the farmer owns the array and the ewes both, or because the lease requires it for thirty years. The grass is the same in all five. What differs is who has to keep doing something, and what anyone could look at in year twenty to find out whether it held.

A project does not turn out restorative. Somebody decides which of those levers will carry that work and commits the design to it, early enough that the decision survives the last round of cost cutting. That choice is the project's **restoration mode**, and it is the third thing this document puts on a project. Scale says what was available. The farming axis says what happened to production. The mode says which lever actually did the restoring, and of the three it is the one a designer chooses outright.

One thing to clear first, because this audience carries a different meaning already. In a solar lease or a siting filing, *site restoration* is a decommissioning obligation: what the developer owes the ground when the lease ends. A restoration mode is not that. It is a choice made at design, about which lever will carry restorative work through the operating life, and it is settled decades before anyone reads the decommissioning clause.

Every one of the six design levers is in play somewhere on the transect, and none holds the same range throughout. Some run out entirely at one end. The pattern is not a general loss of freedom as projects grow. Three levers act on the ground and trade against each other along the transect, two are institutional and run in opposite directions, and scale is the axis the other five are read against rather than a curve of its own.

5.1 The five modes

Five of the six design levers can be made to carry the work.

- **Siting-led** — put the array where the ground itself does the work. Solar prairie strips are the case: the planting goes where the runoff already goes.

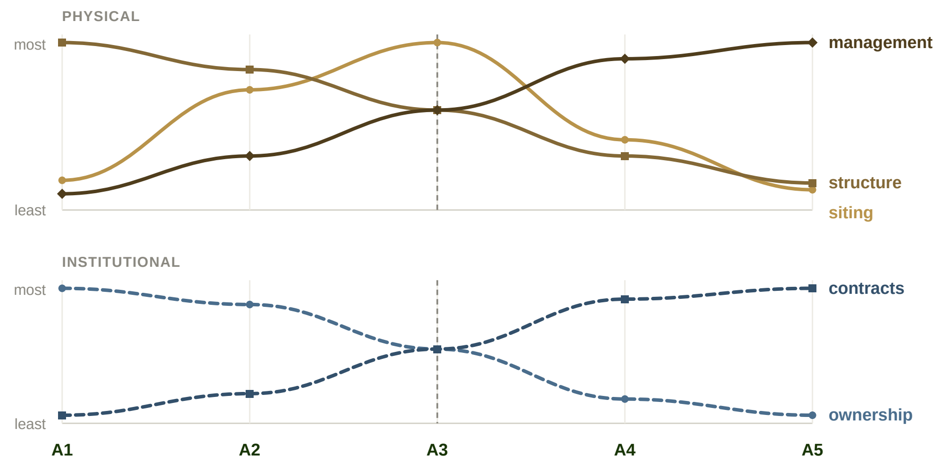

Figure 5.1: **Restoration potential.** How much restorative work each lever can still do at each size. The three physical levers run in the upper panel and the two institutional levers below, with scale as the axis rather than a curve of its own. Where a curve runs to zero, that lever has nothing left to offer at that end of the transect

- **Structure-led** — build the geometry to do it: clearance, row spacing, how much light the modules let through. Barnyard shelter is the case.
- **Management-led** — take placement as given and put the ground cover, the grazing regime, and the operational calendar to work. Regenerative solar grazing is the case.
- **Ownership-led** — structure the holding so that no agreement is required, because the interests were never opposed. Barnyard shelter is the case again, and for a second reason: the person who owns the array owns the animals standing under it.
- **Contract-led** — write it into the lease, the ordinance, or the benefit agreement rather than into anything on the site. The community and economic function runs on this one. Retired-irrigation solar is the case: siting the array retires the field, but only the water right, retired on paper, retires the pumping.

A mode is also what decides how a restorative claim can be checked. A siting-led claim is verified against a map, a structure-led claim against a drawing, a management-led claim against a maintenance schedule somebody has to keep for thirty years, a contract-led claim against a document that can be read, and an ownership-led claim against the deed and the operating agreement, which is the easiest of the five to check.

The last two share a panel of their own in Figure 5.1, and they are best read together. **Ownership-led and contract-led are the same problem at two scales.** An owner-operator needs nothing written down, because the party deciding and the party living with the decision are one person. A utility in another state needs everything written down, because they are not, and by A4 and A5 the owner is developer capital or a utility and the generation revenue has moved with them.

So the alignment ownership supplies for free at the farmstead has to be manufactured, clause by clause, as ownership moves up the transect. At A1 there is hardly a contract to write, for want of a counterparty. Through A3 the instruments arrive, as a PILOT, a subscription, a community-benefit agreement. By A5 the lease term, the maintenance obligation, and the benefit agreement are the only reach left. **Contract-led restoration is what you need when ownership-led restoration is no longer available.**

5.2 Scale controls restoration potential from each mode

The sixth lever sits outside that list, and the reason is worth stating plainly. **Scale is not itself a restoration mode. It governs all the others.** Choosing to build five megawatts rather than eighty is not a way of doing restorative work; it is what decides which of the five stay open to the design. How much range a lever still keeps at a given size is what decides whether it can carry the work at all.

That may not hold. If spillover turns out to scale with perimeter rather than with area, then several mid-sized arrays do ecological work one large array of the same capacity does not (§5.3), and choosing to build small and many *is* restorative work. Scale would earn a mode after all.

The lever the transect treats most sharply is **siting latitude**, the freedom to choose where the array goes. What is still open to a design, and what has already been settled for it, both change as projects get bigger.

Table 5.1: Siting latitude along the transect. What a design can still choose about where the array goes, and what has already decided it.

Zone	Restorative siting options	Key constraints
A1	The yard and the paddock the stock already use	The property line, and the existing service drop
A2	Spare corners, awkward field ends, ground already sitting idle	The operator's own holding, and nothing beyond it
A3	Consistently low-yielding ground, where the water runs, buffer geometry	Parcel size, and what the distribution line will take
A4–A5	Little beyond the edges: setbacks, buffer planting, and what grows under the array	Contiguous acreage near a substation, a place in the queue, prime-farmland rules, and likely opposition

Through A2 and A3 that latitude is the strongest instrument a design has, so the work there is **siting-led**: the planting goes where the runoff already goes, and the array goes on the part of the field that never performed. At A1 there is almost nothing to choose among, and by A4 and A5 the ground has been chosen by other forces entirely.

Structure runs the opposite way and peaks where siting is weakest, which is what makes the farmstead **structure-led**. At A1 an array is built to fit a particular yard, at a clearance the herd needs, out of whatever the local installer can source, because nothing about it has to be repeatable. Through the commercial and community zones the geometry answers to a crop. By A4 and A5 racking is a commodity bought by the megawatt, and the structural decision that still matters most is how much earth the system obliges anyone to move.

Management arrives last of the three. It barely exists at A1, where the work is done by hand alongside the rest of the farm, and it carries everything at A4 and A5, where seeding and grazing are contracted enterprises with a line of their own in the budget. That is what leaves the large end **management-led**: at utility scale restorative practice is mainly ground cover and grazing, and through the commercial and community zones it is mainly placement (Macknick et al. 2022; Randle-Boggis et al. 2020).

Both hand-offs fall in the same zone. Structure gives way to management among the physical levers, ownership gives way to contracts among the institutional ones, and siting latitude is at its widest over the top of both, the least well established of the three curves, which leaves **A3 the only zone where every restorative instrument is live at once**, a stronger claim than A3 merely having the widest siting latitude (§5.3). Below that zone a project restores by choosing its ground, by how it is built, and by who holds it. Above it, by how the place is run and by what the parties signed.

Read quickly, those curves say that restoration is a small-project business. **Restoration does not fall away with scale. It changes tool.** A developer handed that reading will scale back the ambition, when what needed changing was the lever. A 200 MW project cannot choose the ground it sits on in any meaningful sense, and it can still decide what grows there for thirty years, who holds the asset, and what the lease obliges anyone to do.

Those forces can be named. Across US utility-scale projects, siting tracks proximity to roads, transmission lines, and substations, together with higher population density, non-forested cover, and flatter terrain (Wu et al. 2026). None of those is a property of the ground that restoration cares about. A parcel is selected because a substation is close and the slope is mild, and whether it was leaching nitrate or carrying a wet depression enters the decision late or not at all. That is the mechanism behind the phrase *assembly-driven*, and it is why siting-led restoration works in the middle of the transect and runs out at the large end.

The economics point the same way. Greenfield land, prime agricultural ground above all, is the cheapest class to build on, while contaminated land carries a premium of 14 to 33% (Owusu-Obeng et al. 2025). The ground a restorative argument most wants taken is the ground a cost model most wants avoided, and the gap widens with project size, because a developer assembling several hundred contiguous acres has fewer candidate parcels and less appetite for a premium on any of them. Brightfields exist, and what stops them scaling is that premium together with how little such ground there is, not any limit on a given site.

5.3 The Community Scale (A3) Stands Out

Both hand-offs falling in one zone is the design argument for A3, and Figure 5.1 is where it is drawn. There is a second argument for the zone, and it is the one that decides whether restorative agrisolar matters beyond the field it is standing in.

> **A3 is where local restoration can add up to a global number**
>
> Restorative work happens at the scale of a wet corner, a contour band, a flock. Those are effects measured in acres, and they accrue to a watershed, a flyway, a county. None of them lands in a single national account the way a megawatt does. Energy is the opposite. A megawatt is fungible, and the climate arithmetic only cares about the total. The community scale is the one place those two facts meet, because a project small enough for a developer and a landowner to walk the ground together is also a project that can be built thousands of times over. Every one of those builds restores its own ground locally, and the fleet adds to a number that shows up in a national energy account.
>
> Nothing else on the transect does both. A farmstead array restores its own yard and will never total to anything nationally; a complex reaches the number and has already given up the choice of ground. The middle is the only zone where the restorative and the energetic case are the same case, and that is why this document keeps returning to it.

A parcel of forty or eighty acres is big enough that management arrives: someone is hired to seed it, a grazier turns up with a flock, and maintenance has a line of its own in the budget. It is also still small enough to place deliberately. A typical Midwestern crop field runs forty to eighty acres, so an A3 array fits inside one or two of them, which means it also fits inside one owner's decision.

The zone tops out near 5 MW on an assumption, and the assumption is worth saying out loud: a restorative community-scale array takes **at most about a third of its parcel**, which on a forty to eighty acre field comes to roughly 2 to 4 MW. Policy lands on the same boundary independently, since Massachusetts, Minnesota, New York, and Maryland all cap at 5 MW and Berkeley Lab splits its national datasets there. **That one-third assumption is load-bearing and has not been tested** (§9.4). It governs only the positions where production stops, S3 through S5, because under primary agriculture coverage is not removal: an array spanning a vineyard covers the whole parcel and takes none of it.

The zone takes its name from what the trade already calls this band, **community-scale solar**, and the phrase carries at least four senses worth separating. Solar sized to a community's load rather than to a wholesale market. Solar sited where communities already are, on the distribution grid. Solar whose benefits are structured to reach a community, through subscription, tax base, or local ownership. And solar that builds resilience, since a distributed fleet fails differently than one large plant. The restorative case for it is a fifth sense, and it is the one this document makes.

The capacity at stake is not a rounding error. NREL puts community solar technical potential at 967 GW-AC even under conservative siting assumptions, about sixty percent of the 1,600 GW-AC that DOE's Solar Futures Study puts at 2050 need (Ardani et al. 2021), and the middle is not wasteful of the land it uses: plants between 1 and 20 MW took 5.9 acres per megawatt against 7.2 above 20 MW. Much of the band never reaches the headline national numbers at all, because conventional utility-scale potential studies apply a contiguity filter equivalent to omitting sites of 1.2 MW-AC or smaller.

What binds at A3 is money rather than land. The nearest published band sits just above the zone: projects between 5 and 20 MW came in at $2.19 per watt-AC in 2024 against $1.38 above 250 MW, a penalty of about thirty-seven percent, and the fixed-cost logic implies the penalty is larger still below 5 MW, where nobody reports it. The reason is that the paperwork does not scale down: a 2 MW project needs much the same letter of intent, EPC agreement, and power purchase agreement as a 200 MW one, and its offtaker is likelier to lack a credit rating. The zone with the most design freedom has the least access to capital, which is why A3 is under-built against what it could do. That is a finance problem, not a verdict on the zone.

Where the restoration lands is a matter of geometry, and the pollinator evidence comes from arrays in this band. Two Minnesota sites at the top of this band produced bee visitation to soybean fifteen meters outside the fence at roughly two and a half times the rate inside the crop, with the effect bounded at half a kilometre to a kilometre and a half (Walston et al. 2018, 2024). A benefit delivered at that range scales with perimeter and proximity rather than with area, which is a mechanical argument for many mid-sized arrays over a few large ones, and the ecological literature has posed that question without answering it (Tölgyesi et al. 2023).

5.4 Reducing harm and promoting benefit

Restoration covers two jobs that have less to do with each other than the word suggests.

Stopping a harm ends something the ground was doing to somewhere else. Retire a field that was sending nitrate down its tile line and the nitrate stops; take a wet corner out of the rotation and the tillage stops with it. What gets claimed is a year that never happened, the one where the corn went in again, and the claim is capped by however much damage was already running. Ground that was not leaching cannot stop leaching.

Starting a benefit puts something on the ground that was not there before: native grass where there was bare fallow, roots deep enough to hold a hard rain where the crop was corn, shade the flock never had. Anyone can drive out in July and see whether it took, and the ceiling is whatever the site can grow. Permitting has sorted work in this order for decades, avoiding and minimizing harm first and repairing what is left afterward, and restorative design puts doing less harm a rung below putting something back (Reed 2007).

Every position on the farming axis answers a question about harm: whether a farm is still taking something off the ground, and whether it is the use that was there before (S1) or a lesser one (S2), whether the farm business survived losing the field (S3), whether the ground taken was already idle (S4), whether it was carrying a burden worth ending (S5). **None of the five positions says anything about what the ground goes on to do.** A project can sit at S5, the strongest answer that axis has, and still run gravel and a herbicide schedule under the panels for thirty years, while an ordinary S3 conversion delivers every one of the four restorative functions. Describing a project takes both readings. The one position outside that pattern is S0, which records a use that began rather than a use displaced, and so belongs on this side of the split rather than the other.

The two jobs often want different ground, which water shows plainly (§6.1). To stop the nitrogen at its source the array goes on the field that was leaking, because the cropping stops with it. To catch what is already moving it goes on the flow path below, which may sit on somebody else's farm. Same objective, opposite pieces of ground.

6 Restorative Functions and Outcomes

Two solar farms in the same county, the same size, the same panels, the same crop ground underneath. Under one, gravel and a herbicide schedule; under the other, a planting rooted deep enough to hold a summer storm where it falls.

Nothing about the land separates them. Where a project sits (§3) and what happened to the farming on it (§4) set the outer limits of what is possible there, but what the ground ends up doing is settled by how the design resolved its competing pressures (§2), and above all by whether anyone was still pushing for restoration when the cheaper option was on the table.

Restorative is therefore not something a piece of ground is. It is something a design produces, and on most sites it can be produced or withheld. **Restorative functions** name the four things a design can be aimed at.

- **Water** (§6.1) — what soaks in, what runs off, and what the runoff carries with it
- **Ecology** (§6.2) — what can live there, and what can move through
- **Agriculture and soils** (§6.3) — what farming gets from it, and what the ground underneath is made of
- **Community and economy** (§6.4) — what the people hosting it actually get

Read the table by route rather than by distance. Carbon is the exception the drawing cannot hold, leaving by air to everywhere and no one in particular, and land sparing is missing for a different reason: nothing travels at all, because its benefit is ground that stayed as it was (§6.5).

Microclimate is not on the list, and used to be. The shade is real and among the best-evidenced things an array does: daytime soil and canopy temperatures fall, nighttime minima rise, and vapor-pressure deficit drops (Sturchio and Knapp 2023; Pinos et al. 2026; Barron-Gafford et al. 2019). But it is a mechanism rather than an outcome, and its results are already counted elsewhere. Retained soil moisture is the water function. Thermal refuge for what lives under the panels is ecology. Relief for a shade-tolerant crop, shelter for stock, and shade for the people working there are agriculture. Naming it separately counted the same shade twice, which is why the vocabulary keeps microclimate modification as a term for the mechanism and drops it as a function.

A function is not a position on the farming axis. A project holds one position, which records what happened to agricultural production on its ground. It can deliver several functions at once, and the same function turns up at many positions: pollinator habitat is reachable

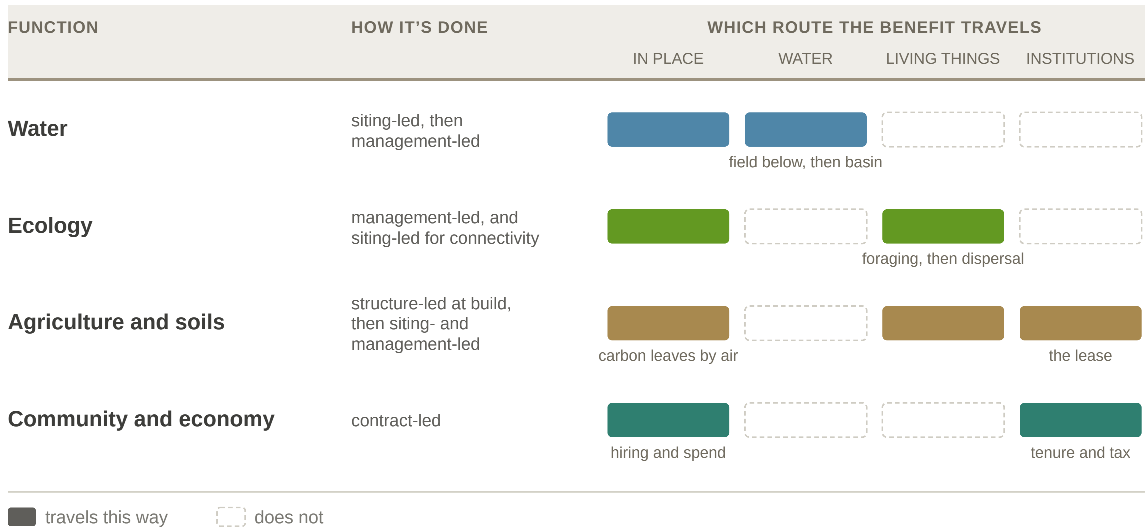

Figure 6.1: Four functions, which lever carries each one, and which route its benefit travels

under grazing (S1–S2, depending on what the ground carried before), on ordinary converted ground (S3), and on spared or retired ground (S4–S5) alike. Position narrows the set only where the ground is tilled every year, which rules out the functions that need an undisturbed ground layer — and that is a fact about cropping rather than about a position, since S1 also covers pastures and orchards that are never ploughed. The three registers stay distinct: a pressure is a force pushing on the design, a lever is something the design does about it, and a function is the result the two produce. Treat the four as a palette rather than a scorecard, since no project delivers all of them and some work against each other.

Two accounts, both needed. The farming axis is largely a ledger of harm reduced, since every position it records answers a question about displacement. These functions are where benefit gets promoted. The water function runs both ways at once and shows what the difference costs, because **avoided loading** needs the ground that was leaching while **interception** needs the ground below it, so one objective sends a designer to opposite parts of the same farm. The two are checked differently, too: a benefit can be gone to and looked at, while an avoided harm has to be argued against what would otherwise have happened. Neither ranks above the other, and on ground that was doing real damage, ending it is the larger result.

A note on "co-benefits." The field usually calls these co-benefits, and that grammar demotes what it names, since a *co*-benefit is something arriving alongside the real objective (Mayrhofer and Gupta 2016). The functions below are named as objectives instead.

6.1 Water

An array changes what happens to rain before it leaves, and what the water carries when it goes.

Quantity is the site's water balance. Panels intercept rainfall and concentrate it along drip lines while sheltering the ground beneath, shade cuts evaporation and transpiration so soil moisture is generally retained, and cover and grading decide how much infiltrates. At scale the more consequential effect is on the *budget* rather than the balance: where solar displaces irrigated cropland it retires that field's consumptive use and eases an aquifer across a whole management area (Stid et al. 2022, 2025), which holds only where groundwater governance keeps the saving from being pumped somewhere else (Zwickle et al. 2021).

Quality has two routes that want opposite ground. **Avoided loading** stops the source, by putting the array on ground that was leaching so the fertilizer and pesticide programs stop with the cropping; on corn-ethanol acreage with documented nutrient export, retiring it under unfertilized perennial cover would take an estimated 54.8 million kg of nitrogen and 26.3 million kg of phosphorus out of annual application (Sturchio et al. 2025). **Interception** treats what is already moving, by setting perennial vegetation where runoff passes so it catches sediment, nutrients, and the pesticide fraction bound to that sediment, which is the documented function of prairie strips in corn–soybean cropland (Schulte et al. 2017). Avoided loading needs the impaired field itself and competes with farming it; interception needs ground below that field and works whether or not the field ever changes. Which one is available is settled by placement, not management, so water is the function siting latitude buys the most of.

A creek below a twenty-acre array runs on water from several thousand acres, and twenty acres of changed cover does not show up in it. The same twenty acres draining one hollow does. That ratio is what the STRIPS work measured: a tenth of a field, planted where the water leaves it, held back more than 90% of the soil that used to go with it (Schulte et al. 2017). So what a watershed notices is not the size of the array but how much of the ground draining past it the array sits on, and a small project can matter more than a large one built somewhere the water is already diluted.

Size changes the shape of the flow as well. A few rows shed along their drip lines and the water leaves the way it always did, spread along the whole field edge. Put two thousand acres inside one fence and the same water arrives at a handful of culverts, in less time and in a smaller place. Ramsey Renewable Station absorbed the 100-year storm on sand at 3.4 megawatts. The same seed mix on tight soil, draining a bigger block to fewer outlets, is a harder storm to hold.

Water travels, so its benefits do. Moisture is held **in place**; slowed runoff and held-back sediment reach the field, the road, and the ditch immediately below before they reach anything further, which is the nearest and most checkable form this function takes; and retired consumptive use is felt across a basin. Direction decides all of it. Ground upslope of a problem can fix it and identical ground downslope cannot.

6.2 Ecology

Two halves: what can live on the ground, and what can reach it.

Habitat is built from the ground layer up. Floral plantings supply nectar and pollen, and the vegetation's vertical and horizontal structure supplies nesting substrate, cover, and the heterogeneity that lets many species partition one site. Panel shade shifts the timing, delaying bloom and increasing late-season floral abundance (Graham et al. 2021), and the shelter underneath is thermal refuge in a heat wave. The seed mix sets the ceiling, but *timing* decides what is realized: mowing or grazing during nesting or bloom undoes the resource it was meant to provide, which makes the operational calendar a design lever in its own right (Blaydes et al. 2022).

Connectivity is the other half, and it is designed or destroyed at four scales at once. Inside the array, continuity is broken by things nobody files under habitat design: access roads, gravel aprons, mown strips, and a perimeter fence whose mesh decides which animals pass. At the edge, what matters is whether the planting meets something already connected, since a site joining a fencerow or a riparian strip is part of a network while the same seed mix inside a fence in the middle of row crop is an island. Across a landscape, many small arrays can work as stepping stones where they fall within dispersal distance, while a few large ones give more interior and less edge, and which is better is a question about the species rather than a general rule. At regional range, a fleet under compatible mixes and calendars is a network on paper, and whether it is one in fact is unmeasured (§9).

The corridor experiments are what make this more than an analogy: connected patches exchange more individuals and accumulate more species over time than isolated patches of equal area, with butterflies as the model organism because their movement can be watched directly (Haddad and colleagues, Savannah River Site corridor experiments — *trace before citing*). Two lessons carry over. Connectivity is a property of the arrangement rather than of any one patch, so it cannot be claimed from a seed mix. And the scale that matters is set by the disperser, so a bee working a 1.5 km foraging radius, a butterfly crossing open ground, and a grassland bird holding a territory are three different design problems, and a connectivity claim means little until it names the taxon.

Both halves travel along living things. About 3,500 km² of US farmland sits within 1.5 km of existing and planned utility-scale facilities, roughly a pollinator's foraging distance (Walston et al. 2018), and pollinators from solar sites have been recorded in neighboring soybean (Walston et al. 2024). Further out along the same route it reads as a bird population rather than a parcel (Walston et al. 2025).

6.3 Agriculture and soils

Two things the same ground does at once, and the same decisions govern both: what the farm gets out of the array, and what the soil under it is made of.

Not the farming axis under another name. The axis records whether farming continues on the ground the array occupies. This asks what the array does *for* farming, and the two answers come apart: a project with production stopped inside its own fence can still be the reason the field next door gets pollinated, and the reason the host farm is still in business.

Position in the landscape counts for more here than for any other function, because a planting reaches only the fields inside a forager's range, and bloom sequence matters more than bloom, since a service to a crop depends on flowering when that crop needs it.

Where perennial, low-disturbance cover replaces a tilled row-crop baseline, roots stay in the ground year-round, traffic and tillage fall away, and soil organic carbon and aggregate stability build back. That is ordinary perennialization, running under and between the panels.

Construction cuts the other way and can cut deep. Grading removes the shallow horizon holding most of the carbon, trenching and traffic compact what is left, and compacted ground restricts the roots that would rebuild it, so a site can begin its thirty years in debt rather than at zero. How large that debt is depends on how much earth anyone had to move, which makes a racking choice a soil decision taken years before anybody picks a seed mix: a mounting system that tolerates slope leaves the ground roughly as it found it, and one that needs a level plane means mass grading. Establishment method, grazing regime, and stocking density then carry the accumulation, which is slow and cumulative and therefore hostage to a sustained operating regime.

The two halves are delivered differently. Soil stays where it is, so that half arrives **in place** and is the most fully captured of anything here by whoever holds the ground. The service to farming travels: pollination and pest regulation go out along living things to the fields inside a forager's range, and the lease that keeps the operation running arrives along institutions. Carbon is the exception and the limiting case, leaving by air to benefit everywhere and no one in particular, so it needs a market or a policy behind it before it is worth anything to the person holding the land.

6.4 Community and economy

The one function that is not about the land. The others ask what the ground can provide; this asks what the people hosting the project get. It is the result the community-acceptance pressure and the community-benefit lever aim at, not another name for them, and it holds three things: durable local income and tax base, whether people can live alongside the thing and had a real say in it, and whether burdens and benefits land on the same people.

A project returns value in several currencies at once: lease and royalty income, PILOT and tax revenue, wages through build and O&M, subscription savings, and, where ownership is structured for it, an equity stake rather than only a rent. The sums are not small. Landowners leasing cropland to solar earn three to four times what most crops return per acre (Sturchio et al. 2025), and where production continues alongside the array the reported gains run higher still (Merheb et al. 2025). The consequence runs past the balance sheet: federal biofuel policy has made conservation payments the less profitable option across much of the same acreage, so solar income can make a conservation practice affordable that was not affordable before (Sturchio et al. 2025). Livability and equity, though, turn less on the size of the payment than on the procedure. That is where benefit and acceptance come apart, and where a check without a fair process reads as a bribe.

Name the recipients separately. "The community" is not one party, and a benefit to one can be a loss to another.

- **Landowner** — lease and royalty income; the party a land payment reaches first, and often the only one it reaches.
- **Tenant farmer** — frequently the party who *loses*. Nearly 40% of Central Valley agricultural land is rented, and the leading analysis of agrisolar economics there assumes returns reach landowning farmers, naming that as one of its own limitations (Stid et al. 2025). This is the sharpest misalignment in the set, and the one a lease-income argument most often hides.
- **Neighboring residents** — bear viewshed, construction traffic, and glare, usually without a payment.
- **Local government** — PILOT and tax base, against service and road costs.
- **Tribal nations and communities of place** — treaty rights, cultural landscapes, and consultation standing that do not reduce to a payment.
- **Workers, subscribers, and ratepayers** — wages that may or may not be local, and savings that may accrue in another county entirely.

A project can score well on one of these and badly on the rest. Naming them is what keeps "community benefit" from collapsing into "somebody was paid."

This function travels almost entirely along institutions, by tenure, contract, and jurisdiction, which is why the list above does more work than any radius would. Part of it is genuinely local, since construction spend lands in the nearest town that can supply it, but the money that matters most moves along channels drawn for reasons that have nothing to do with distance.

6.5 Where benefits are delivered

A function is produced in one place and used in another. Ecosystem-service research treats that gap as its central spatial problem, since the area providing a service and the area benefiting from it have to be mapped separately (Syrbe and Walz 2012), and solar research has drawn the same line: Hernandez et al. (2019) sort a facility's outcomes into **sympatric**, overlapping the site, and **disjunct**, spatially separated from it, giving each a **serviceshed**.

What this document adds is that the useful question is **not how far a benefit goes but which route it takes**. Nearly every function here reaches from the panel to the region along some path, so distance bands sort them badly. Routes sort them well, because the route is what decides who can verify a claim and who receives it.

In place. Provider and beneficiary are the same ground: soil carbon, soil moisture, forage and shelter under the panels. The easiest delivery to measure and the easiest to over-claim from, since it says nothing about anywhere else.

Along a connection. Everything that leaves the site leaves by a network, and three carry almost all of it. **Water** takes runoff, sediment, nutrient, and recharge downslope, to the field immediately below and on to the ditch, the creek, and the aquifer. **Living things** carry pollination, pest regulation, and dispersal, at foraging range first and dispersal range beyond it. **Institutions** carry lease, tax, subscription, and easement along tenure, contract, and jurisdiction. The first two have a geography and the third does not, but all three behave the same way in the one respect that matters: the benefit goes where the network goes, not where a radius would put it. A creek can carry sediment past a neighbor who gains nothing, and a lease can carry money to a county that never sees the array.

By preservation. Land sparing delivers nothing that moves at all. Its benefit is ground elsewhere that stayed as it was, which makes this the one mode that is counterfactual rather than observed. It is still local, since a developer assembling acreage near a substation chooses among parcels within a fairly narrow radius, so the ground a project spares is realistically in the same county. That is what gives the claim somewhere to be checked, against the local land market and the sites genuinely in play.

One case runs backwards. Demonstration sites, field days, and school visits deliver value by bringing people *to* the array rather than sending anything out from it, which is much of what Jack's Solar Garden produces. It is among the easiest things to design for and the most often left to chance.

What naming the route settles. Three questions otherwise easily run together.

1. **Who can verify it.** In-place claims are measured on site. Connected claims need a gauge, a survey, or a document somewhere else, and preservation claims need the local land market and a credible account of what would otherwise have been built.
2. **Who captures it.** A landowner captures in-place benefit and can be paid for it. Benefits travelling water or living things accrue to people holding no contract with the project, so they need a policy, a market, or a watershed authority behind them to amount to more than goodwill.
3. **Which objection it answers.** A neighbor objecting to the view is describing something delivered at the fence line, and a developer answering with a carbon figure is describing

something delivered everywhere and to no one. Both can be true, and neither is a reply to the other.

6.6 Evaluating outcomes

The four functions each carry two outcomes, and together the eight are what a project can be judged on. Naming them separately matters because they move independently: an array can hold water on the site and still compact the soil under it, or pay a landowner well and give the neighbors nothing.

Table 6.1: The eight outcomes, two to a function.

Function	Outcomes
Water	quantity, meaning what soaks in and what leaves · quality, meaning what the water carries with it
Ecology	diversity, meaning what can live there · connectivity, meaning what can move through
Agriculture and soils	food production, meaning what the ground still grows · soil quality, meaning what it is made of
Community and economy	financial security, meaning durable local income · livability, meaning whether people can live alongside it and had a real say

Each outcome runs on the same scale, from causing harm at one end to promoting benefit at the other, with a point in between where the project leaves that outcome no worse than it found it. Figure 6.2 plots all eight at once. **The middle ring is a zero point rather than a pass mark.** It marks where the sign changes, and nothing here says how far past it a project ought to travel, which is a question the lexicon has deliberately not answered.

The polygon drawn there is a worked example and not a measurement. It belongs to a project that gives up food production for soil quality and ecological diversity, which is the trade a retired or heavily planted site makes. Reading a project this way does two things a single verdict cannot. It shows the trade, because a project that gains on one axis and loses on another has a shape rather than a score. And it shows who is owed an explanation, because an outcome sitting inside the ring is a commitment the design did not keep.

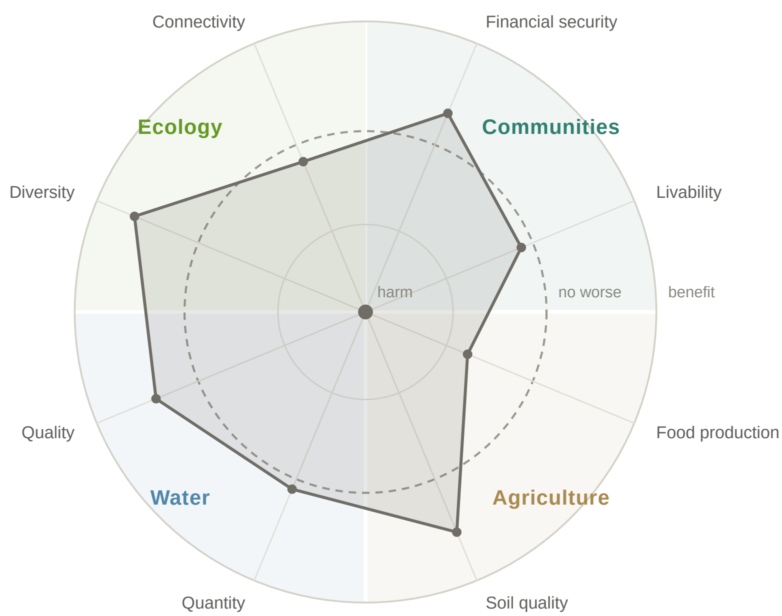

Figure 6.2: The eight outcomes plotted together, four quadrants, one per function. Each spoke runs from causing harm at the center, through the dashed ring where the outcome is left no worse than it was found, out to promoting benefit at the rim, so a larger shape is a better project.

7 Archetypal Forms

Certain designs keep turning up. A farmer's flock under panels, a prairie strip in a wet draw, a retired irrigated field: the same few arrangements appear on ground that has nothing else in common. They recur because the pressures bearing on a project are never evenly matched. Cost and financing and energy yield push hardest nearly everywhere, and where nothing pushes back the result is the same array anywhere in the country. Where something does push back, and keeps pushing through permitting and value engineering and the last round of cost cutting, the design settles into a shape that answers it. An **archetype** is one of those settled shapes. Nobody sets out to build one. The shape is what the pressures leave behind once they have finished arguing, and it is named after the fact, by people counting how often it turns up.

Scale and farming axis position decide which pressures can win. A farmer who owns the herd, the array, and the labor can let agricultural production beat generation, because the array is sized to the parlor and nobody is asking it to clear a hurdle rate. At five hundred acres that argument has no one to make it, and restoration has to come from how the ground is run instead. This is also why an archetype can disappear: when the policy or the market that let a pressure win is withdrawn, the shape stops being built. Archetypes classify how the pressures were resolved, while hardware taxonomies classify what was built, and the two can be read together.

Where the site sits changes which resolutions come cheap, because a region weights the pressures differently. In the irrigated West, retiring fields above an overdrawn aquifer answers a shortage that groundwater law now meters and enforces, which makes it the readiest restorative shape in the region, and the same aridity makes shade worth enough to pay for the extra steel a crop canopy carries. Solar prairie strips answer the runoff from rain-fed Iowa cropland, so where the rain is thin and the water arrives by pump, that form all but drops out.

Six featured archetypes carry a documented case each, ordered from farmstead to complex, and seven others are sketched more briefly. The figure below sets them out in another order, left to right by the lever the restorative work fell to, from ownership through structure, management, and siting to contracts, which is the nearest thing that ordering has to a sequence.

7.1 Archetypes across scale and position

Every archetype below carries a compact code under its name: its zone on the scale transect, its position on the farming axis, and its restoration mode, meaning whether the restorative

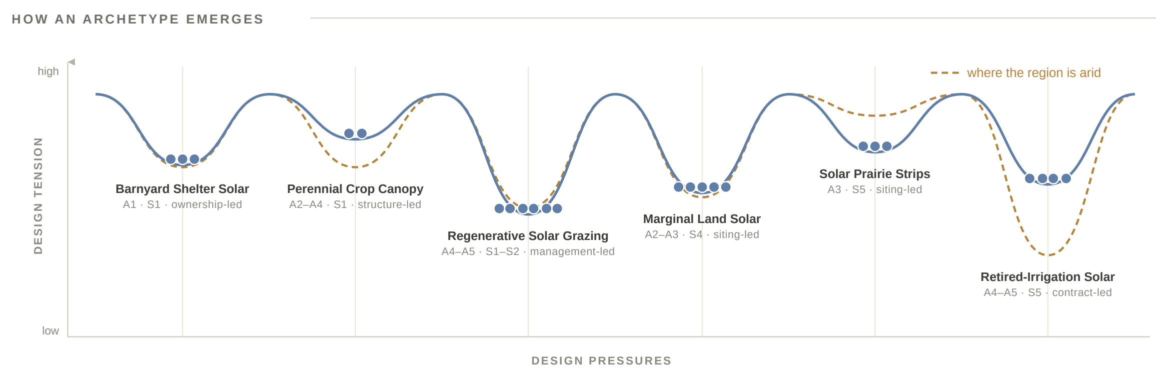

Figure 7.1: **How an archetype emerges.** Position along the bottom is one way the nine design pressures can come out; height is the conflict left standing. The low spots that keep collecting projects are archetypes, six of them named here with their codes. The dashed profile is an arid region.

work is carried by the choice of ground, by the array's geometry, by how the site is run, by who holds the asset, or by what the contracts say. So `A1 scale · S1 farming · ownership-led restoration` reads as a farmstead array on ground the farm's own animals keep using, restored by who holds it. The two tables sort the same forms by each coordinate in turn, with **featured archetypes in bold** and the others in plain text. Arrays mounted on buildings take no ground at all and sit at A0, off both tables.

Table 7.1: Which forms recur at each zone. Bold entries are the six developed in full below; the rest are sketched.

Zone	Forms that recur here
A1 — Farmstead	**Barnyard Shelter Solar**
A2 — Commercial	**Perennial Crop Canopy** · Vegetable Agrivoltaics · **Marginal Land Solar** · Solar Fencerows · Pivot-Corner Recharge
A3 — Community	**Perennial Crop Canopy** · **Solar Prairie Strips** · Vegetable Agrivoltaics · **Marginal Land Solar** · Pollinator Meadow Solar · Solar Fencerows · Pivot-Corner Recharge · Farm-Load Microgrid · Brightfield

Zone	Forms that recur here
A4 — Utility	**Perennial Crop Canopy** · **Regenerative Solar Grazing** · **Retired-Irrigation Solar** · Restored-Grassland Solar · Solar Fencerows · Farm-Load Microgrid · Brightfield
A5 — Complex	**Regenerative Solar Grazing** · **Retired-Irrigation Solar** · Restored-Grassland Solar · Brightfield

The crowding at A3 is the feasible wedge in practical form: it is big enough that management matters and small enough to site strategically (§5.3), so more forms are open there than anywhere else on the transect. A listed form has been built at that scale; climate, soil, water, market, and neighbors still decide whether it fits a particular site.

Table 7.2: The same forms arranged by what happened to agricultural production, rather than by size. A form appearing at more than one position is one whose ground layer can be run more than one way, or one whose position turns on what the ground carried before it.

Position	Forms that sit here
S0 — Created agriculture	Brightfield where the ground layer is grazed
S1 — Primary agriculture	**Perennial Crop Canopy** · Vegetable Agrivoltaics · Solar Fencerows · **Barnyard Shelter Solar** · **Regenerative Solar Grazing** on ground that was already pasture · **Marginal Land Solar** where stock stays on
S2 — Secondary agriculture	**Regenerative Solar Grazing** on former cropland · Pollinator Meadow Solar where hives are kept
S3 — Ordinary-land siting	Pollinator Meadow Solar · Restored-Grassland Solar · Farm-Load Microgrid
S4 — Low-productivity siting	**Marginal Land Solar** · Pivot-Corner Recharge · Brightfield · Farm-Load Microgrid
S5 — Impaired-land siting	**Solar Prairie Strips** · **Retired-Irrigation Solar**

The sharing wing is wider than it looks, and it is wide for two different reasons. Holding a *crop* under panels takes geometry that costs money, which is why only three forms manage it. Keeping a *pasture* takes nothing but the decision to put the array where the stock already were, which is why grazing reaches the largest zones without leaving the sharing wing at all. The sparing wing is where siting does the work. Grazing is the one form that reaches utility scale without giving up a productive ground layer, which is most of why it is the commonest restorative practice on large arrays.

7.2 Six featured archetypes

Each archetype is drawn in section, and each at its own scale, so a farmstead array fills the frame while a regional one runs off both edges. The bar in the lower corner gives the distance, and the panel is the same three-meter table throughout, which is what makes the frames comparable once the bar is read. What changes between them is real: the ground, the clearance, the cover, how deep the roots go, and how much land is in view. Sun falls from the upper left in every frame, so the bands on the ground are where the shade actually lands, offset from the panel that casts it. The outcomes footprint beside each drawing places the form across Communities, Agriculture, Water, and Ecology. A dominant pressure carries its domain out toward the rim; a yielded pressure pulls it in toward the center; domains the form does not engage sit near the ring. These are judgments about forms, not measurements, and not audits of the named projects.

The figures given for each form are indicative, drawn from the worked case and from forms in circulation, not requirements. Each featured archetype carries one real project. Several rest on developer pages, NGO case studies, and extension write-ups rather than peer-reviewed evidence; capacities and areas are as-reported and are traced in Sources. They illustrate the *form*. They are not verified performance data, and none of them has been independently audited against the restorative functions it is cited for.

7.2.1 Barnyard Shelter Solar

A1 scale · **S1** farming · *ownership-led* restoration

Barnyard shelter solar raises roughly 10 to 100 kilowatts of panel over the yard or paddock the farm's own animals already use, on under about an acre. Nothing new has to be established underneath, since the ground layer is the worn yard the stock already stands on. The clearance is set by the animals themselves, high enough that they can walk in and shelter under the array, and the wiring runs behind the meter against the parlor, the cold store, and the well pump. The same farmer holds the animals, the array, and the labor, so nothing has to be written down to align them, and that is what makes the form ownership-led.

What the form gives up is generation at scale, since the array is sized to the farm rather than the grid; agricultural production and operations and maintenance are the pressures that set

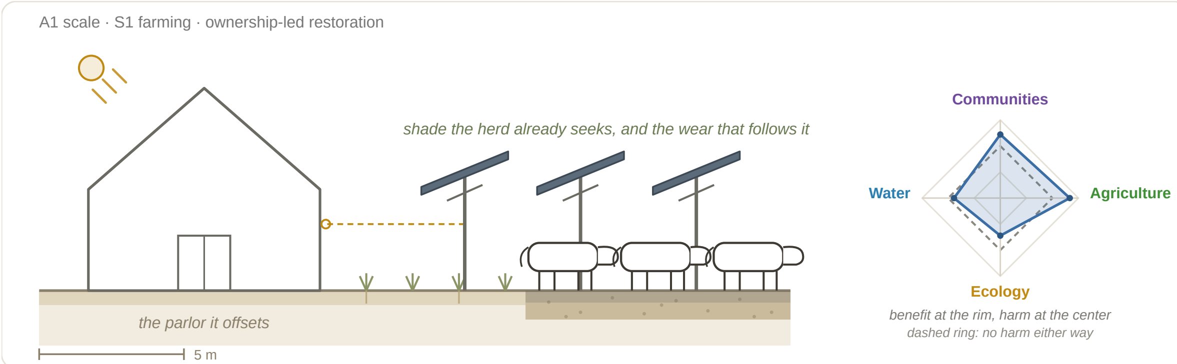

Figure 7.2: Barnyard shelter solar in section. The array is sized to the parlor rather than to the grid, which pushes Agriculture out toward the rim and leaves Ecology short of the ring. The drawing carries what the profile cannot: shade gathers the herd, and the ground beneath it compacts.

its shape. Shade gathers the herd into one place, so muck and wear concentrate where the animals crowd in, and the ground beneath the panels compacts in a way the open paddock does not. That wear is the farmer's to repair, and it belongs in the same accounting as the power bill the array offsets.

The worked case sits on a University of Minnesota dairy, the West Central Research and Outreach Center at Morris, Minnesota, where a 30-kilowatt array was raised over the pasture in 2018 to shade thirty to forty grazing cows and power the milking equipment. The shaded herd ran about a degree cooler and panted less while the same panels carried the parlor's load, a working demonstration that shelter and generation can sit together on one small farm.

7.2.2 Perennial Crop Canopy

A2–A4 scale · **S1** farming · *structure-led* restoration

Perennial crop canopy carries panels over a planting that is not lifted between harvests: wine and table grapes, tree fruit, trellised canes, and wild blueberry barrens. Projects run from a few hundred kilowatts to several megawatts across roughly 1 to 50 acres, feeding a packhouse and cold store behind the meter or a distribution line beyond it. The geometry follows the crop's own height, from a nearly conventional array over low-growing fruit to a canopy carried four or five meters up on one panel row per crop row, and either way the array is set out on a row spacing the farm already drives.

What makes the form structure-led is that the crop's life and the array's are the same length. Vines and tree fruit run 25 to 40 years and a wild blueberry stand longer still, so the planting under the panels will be the same planting when the modules come up for replacement. That is a permanence an annual rotation cannot offer: the trellis is already standing, the root system

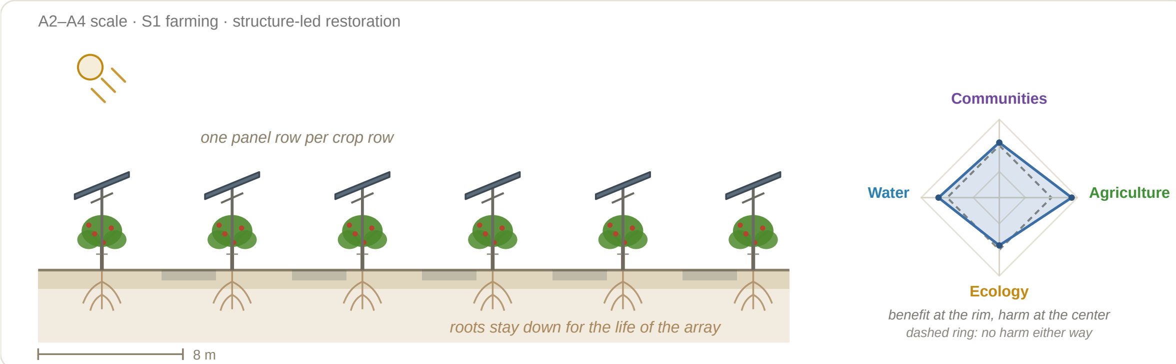

Figure 7.3: Perennial crop canopy in section. One panel row rides above each crop row rather than between them, and the planting keeps its trellis and its roots for the whole life of the array. Agriculture reaches nearest the rim, and Ecology sits just inside the ring, because what carries on underneath is intensive horticulture.

is already down, and nothing has to be worked around a plow. Build cost runs 1.8 to 2.7 times a conventional ground mount, so cost and financing is the pressure the form yields to, and what it defends is agricultural production on ground good enough that nobody would have sited an array there for any other reason.

The same permanence sets the form's sharpest risk, and it is not shade. A perennial stand cannot be re-established on the array's schedule, so what the machines do to the ground while the piles go in is carried by the crop for years afterward. On the benefit side, fruit-surface cooling is measured, with apple sunburn falling from 13% to 2% at half the radiation (Scalisi et al. 2026), and shade holds acidity by preserving turgor (Caravia et al. 2016). The shelter case is weaker: an array is not a roof, so rain exclusion shown under continuous covers does not carry (Yu et al. 2022), excluding rain shifts the disease spectrum rather than shrinking it, and after two hail seasons the Austrian trial found the array deflecting stones into the next row.

Maine has the built case at **Maces Pond** in Rockport, where 4.2 megawatts stand on about ten acres of wild blueberry, built in 2021 by BlueWave and owned by Navisun, with five of those acres given over to a University of Maine study running three construction treatments side by side. The early finding is about construction rather than about shade: the blueberries recovered best where the crews went in with the most care. *This is the low-growing end of the form, where the geometry barely departs from a conventional array. The tall canopy over vines and tree fruit is the other end, and Colorado has working examples of it over chardonnay and over peaches.*

7.2.3 Marginal Land Solar

A2–A3 scale · **S4**, or **S1** where stock stays on · *siting-led* restoration

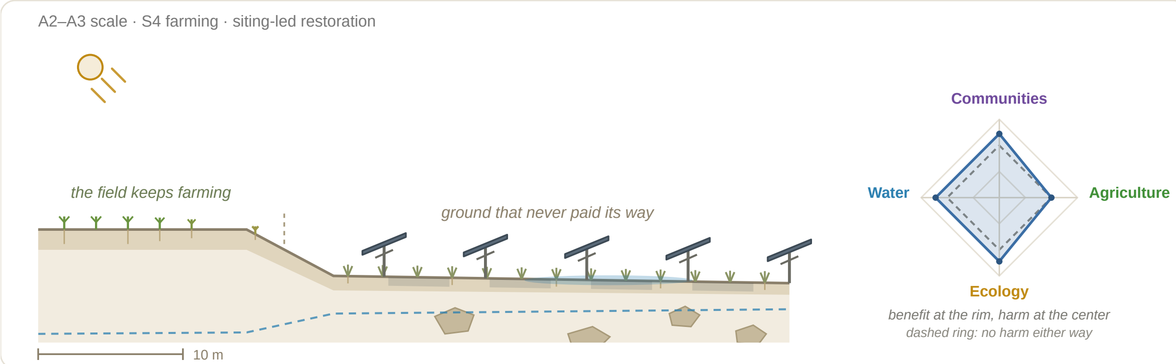

Figure 7.4: Marginal land solar in section. The siting decision is the archetype: the array takes the wet, stony corner and the field keeps farming. Communities, Water, and Ecology all sit well out toward the rim, and Agriculture is the one pulled back to the ring.

Marginal land solar takes the flood-prone corners, rocky headlands, and wet remnants that no longer pay their way, and leaves the better fields to farm. Arrays run from about 100 kilowatts to 3 megawatts on roughly 1 to 20 acres, sized by what the odd parcel will hold. The ground keeps whatever it supports, rough grazing where it drains and naturalized or pollinator cover where it does not, and where stock still walks beneath the panels the form sits on the sharing wing rather than at S4 — at S1 where the ground was already rough grazing, at S2 where it was cropped before. Orientation and layout follow the shape of the ground, not the optimum, and the power goes behind the meter or onto distribution.

What made a parcel marginal for farming often makes it marginal for solar: ballast on rock, an array elevated above a floodplain, extra cable down a long interconnect run to reach the line. Cost and financing is the pressure that dominates, for exactly that reason, and generation is what gets yielded, since ground shaped by water and stone is rarely shaped for output. What the form is for is the community & economic function, income off acres that were not paying, and that income has to clear the added cost before the array is worth building.

At Cozy Cove Farm in Gurley, Alabama, a llama-and-alpaca farm set a 50-kilowatt array on a flood-prone corner of riverside pasture, raised about seven feet so the herd grazes and shelters beneath it, and sells the power to the TVA while the pasture keeps working. *This particular site reads as S1, not S4: the siting decision was the marginal corner, but the ground was riverside pasture before the array and is riverside pasture under it, so the use it had is the use it kept. It is the archetype's sharing variant, and the reading rule in §4.1 settles it.*

7.2.4 Solar Prairie Strips

A3 scale · **S5** farming · *siting-led* restoration

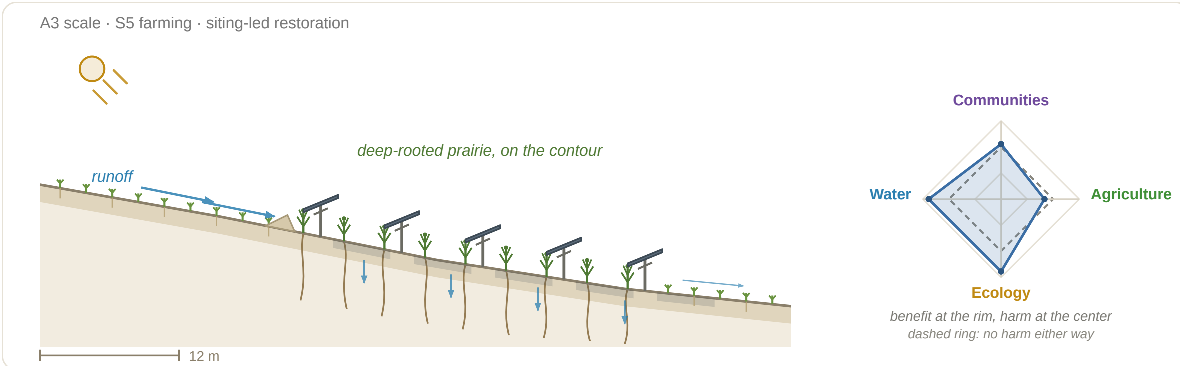

Figure 7.5: Solar prairie strips in section. Water reaches almost to the rim and Agriculture falls inside the ring, which is the trade this form makes on purpose. The mechanism is visible: runoff intercepted on the contour, sediment held at the upslope edge, roots well below crop depth.

Solar prairie strips pair a distribution-scale array, roughly one to five megawatts across six to thirty acres, with deep-rooted native prairie planted where a field sheds water: contour bands, low draws, wet corners, and wetland edges. The mix and the width of each band are sized to a named hydrologic outcome. That ground leaves production, and what grows on it slows runoff and holds sediment and nutrients, while the array, often sold as community solar, pays for the planting. STRIPS research found that converting about a tenth of a field to prairie in the right places can cut soil loss by more than 90% (Schulte et al. 2017).

What organizes the form is restorative goals, with community acceptance behind it, and what it gives up is a little generation, handed to the prairie. It also needs a place where clean water is actually paid for, since the strips cost acres and seed whether or not anyone values what they hold back. The logic does not carry to utility scale. Placement this precise is a middle-of-the-transect instrument, and at a few hundred acres the ground is chosen by the substation and the land market instead.

Minnesota has a built case in **Ramsey Renewable Station**, where 3.4 megawatts of solar and storage sit on a native ground layer that is the stormwater system itself: on that sandy soil, DOE's PV-SMaRT modeling found the planting absorbed the 2-, 10-, and 100-year design storms with no detention basins at all. The sand did much of that work. On a tighter soil, or across a block large enough to drain to a few outlets, the same planting has a harder storm to absorb.

7.2.5 Regenerative Solar Grazing

A4–A5 scale · **S1–S2** farming · *management-led* restoration

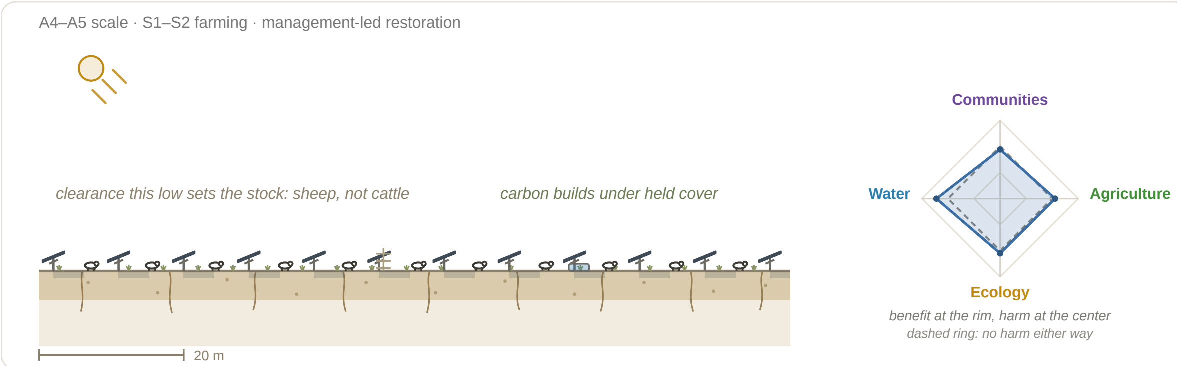

Figure 7.6: Regenerative solar grazing in section. Water reaches furthest, on held cover and year-round roots, while Communities is pulled just inside the ring, because the agriculture here is a tenancy rather than the farm's own operation. Clearance is the quiet constraint: panels this low settle the question of stock as sheep.

Regenerative solar grazing runs a planned flock rotation under a utility-scale array, 5 megawatts and up, across tens of acres to several thousand, connected at sub-transmission or transmission voltage. The ground layer is managed pasture or forage; the fence and gate lines draw the rotation cells, and clearance and water points settle what class of stock can work beneath, which in practice means sheep. The flock is usually hired in, a contracted service rather than the farm's own animals. Rotation manages vegetation, cycles nutrients, holds ground cover, and can build soil carbon under a well-managed native understory (Krasner et al. 2025).

The pressures that shape it are energy yield and operations and maintenance, and what it gives up is the farm's own agricultural production, since the grazing is a tenancy on the array's ground and not the operation of the place. Two calendars have to be reconciled: the plant wants the grass low on its own schedule, and the shepherd moves stock on the flock's. Grazing can reach cost parity with mowing (McCall et al. 2023), which is the level to plan around, because a site budgeted on the expectation of a saving will come up short.

One built case runs across Minnesota, where Aurora Solar's 150 megawatts of generation sit on sixteen sites whose grounds are kept by thousands of contracted sheep grazing a low pollinator understory.

7.2.6 Retired-Irrigation Solar

A4–A5 scale · **S5** farming · *contract-led* restoration

Retired-irrigation solar takes irrigated fields above an overdrawn aquifer out of production and puts a large array on them (Stid et al. 2025), commonly 50 megawatts and up across hundreds to many thousands of acres, connected at transmission. The panels need no water,

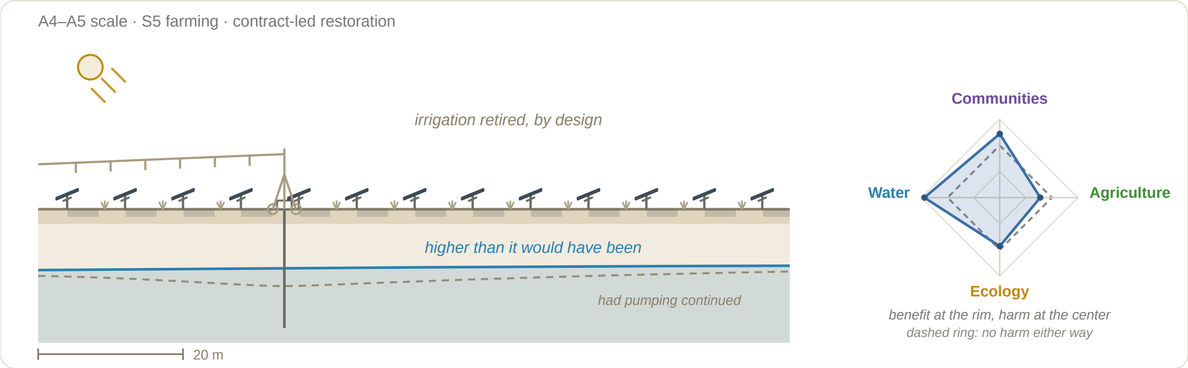

Figure 7.7: Retired-irrigation solar in section. Agriculture falls inside the ring by design and Water reaches almost to the rim. The dashed line is the counterfactual, and the claim holds only where governance keeps the saved water from being pumped somewhere else.

so a low-water cover takes the place of the crop. The land it suits is drainage-impaired, salt-affected, or otherwise marginal irrigated ground, and the unit of design is the district or the aquifer rather than the parcel, which is why the form is regional: the impairment it answers is regional too.

The design answers to a water-quantity target and to cost and financing, and it gives up agricultural production by design, since the point of the form is that the irrigation stops. That trade is worth making only where the overdraft is measured and where governance holds the saved water in the aquifer instead of letting it move to another well (Zwickle et al. 2021). That is what makes the form contract-led rather than siting-led: choosing the ground takes the fields out of production, but only retiring the water right keeps the water in the aquifer, and a right is an instrument rather than a place. Where the metering and the rules are loose, the fields still come out of production, the water does not stay saved, and a district has given up its farming for a benefit that never arrives.

In the San Joaquin Valley of California, **Westlands Solar Park** is part of a plan to convert up to ~136,000 acres of drainage-impaired, previously-irrigated land to solar and storage under the state's Sustainable Groundwater Management Act; because the panels use no water, retiring the fields eases the overdraft that irrigated farming had driven (Stid et al. 2022). *Figures are developer- and program-reported; see Sources.*

7.3 Other notable archetypes

Seven more forms, sketched rather than worked through, applying the same language to configurations the featured six do not cover. None of them rests on a run of documented projects that has settled what it delivers: each is named because someone is building or testing it and the vocabulary should reach it. That caveat covers the whole set, so the entries below say what the form is and what is still open about it, and leave the hedging here.

7.3.1 Solar Fencerows

A2–A4 scale · **S1** farming · *structure-led* restoration

Solar fencerows stand bifacial modules vertically in rows facing east and west, catching morning and evening sun and leaving the ground between them in crop. The rows run wide, around 8 m, because the machinery sets the spacing and the crop's light budget does not (Vaverková et al. 2026). That geometry gives the clean annual-arable S1 case overhead arrays miss. Frameless glass–glass modules and more posts per watt raise the build cost and thin the watts per acre, and whether an arable rotation can carry that premium on its own is unsettled.

7.3.2 Pollinator Meadow Solar

A3 scale · **S3** farming · *management-led* restoration

Pollinator meadow solar seeds the whole site to a native ground layer and times mowing or grazing around bloom (Blaydes et al. 2022). What holds the form together is the buying side: community-solar subscribers and pollinator-habitat certification give the planting a channel that pays for it (Electric Power Research Institute 2021). Establishment takes several years and costs more to manage in that window than mowed turf, and how much of the habitat value persists once the site drops into routine maintenance is the part nobody has followed long enough to say.

7.3.3 Restored-Grassland Solar

A4–A5 scale · **S3** farming · *management-led* restoration

Restored-grassland solar puts a native seed mix under a large array and runs it on deferred or rotational mowing, treating the site as grassland restoration that happens to generate (Walston et al. 2025). Row cropping ends, and the soil-carbon claim rides on the perennial cover that replaces it (Krasner et al. 2025; Carvalho et al. 2024). It is the characteristic large-scale convergence case (§4.2), and how many years a seeding needs before it reaches the condition the studies report is the open question.

7.3.4 Pivot-Corner Recharge

A2–A3 scale · **S4** farming · *siting-led* restoration

Pivot-corner recharge takes the dry corners a center pivot never reaches, ground already out of production, and grades them to send rainfall downward instead of off (Yavari et al. 2022). The corners are small and awkward, so the generation is minor and what pays is a lease on ground that earned nothing. It is the supply-side counterpart to retired-irrigation solar, which subtracts pumping demand across a district while this adds recharge on a few acres and the pivot circle keeps farming beside it. Kansas Geological Survey, Kansas State, and Michigan State researchers are testing it over the Ogallala; how much of that infiltration reaches the aquifer is the open question.

7.3.5 Farm-Load Microgrid

A3–A4 scale · **S3–S4** farming · *siting-led* restoration

A farm-load microgrid is sited against a heavy on-farm load, grain drying, cold storage, a feedlot, or a processing complex, with battery storage sized to shave peaks, ride through outages, or arbitrage time-of-use rates. The load is the offtake, which makes this the one form here organized around *when* power is used instead of around what the ground does, and the community & economic function shows up as resilience rather than as rent. The ground layer is rarely the point at an industrial yard, and the storage economics depend on rate structures that can be rewritten.

7.3.6 Vegetable Agrivoltaics

A2–A3 scale · **S1** farming · *structure-led* restoration

Vegetable agrivoltaics keeps shade-tolerant food crops growing beneath raised, widely spaced panels: greens, tomatoes, peppers, the things a market garden already sells. Clearance is set by hand work and small equipment, and row pitch by how much light the crop needs rather than by how tightly the parcel could be packed. It is the most engineering-intensive configuration named in this chapter and the most sensitive to climate, since shade past the crop's tolerance cuts yield while in hot, dry settings that same shade eases heat and water stress (Barron-Gafford et al. 2019). It is also the most studied, with Jack's Solar Garden in Colorado running 1.2 megawatts of tracking panels over four acres as a research site for NREL, Colorado State, and University of Arizona researchers. What is open is whether the form recurs once research funding is not part of the budget, because an annual rotation has to earn back permanent structure every season, which is the trade a perennial planting is not asked to make.

7.3.7 Brightfield

A3–A5 scale · **S4**, or **S0** where the ground layer is grazed · *siting-led* restoration

A brightfield puts an array on reclaimed mine land, a closed landfill, or a brownfield (Hernandez et al. 2019), ground that is cheap because nothing else will take it and welcome because the neighbors have watched it sit idle. Where remediation leaves a ground layer a flock can work, the site reads S0 rather than S4, because the array brought a use to ground that had none. Remediation drives the engineering, constraining what foundations can go in and what the ground layer can be, and constrained sites give up some generation. It is the standing S4-at-A5 exception (§4.2), and whether enough such ground sits near enough to interconnection to matter at regional scale is unresolved.

8 Terminology

Definitions are grouped by subject, in the order the chapters introduce them, and each links to its fuller treatment. The alphabetical index provides the same terms A–Z.

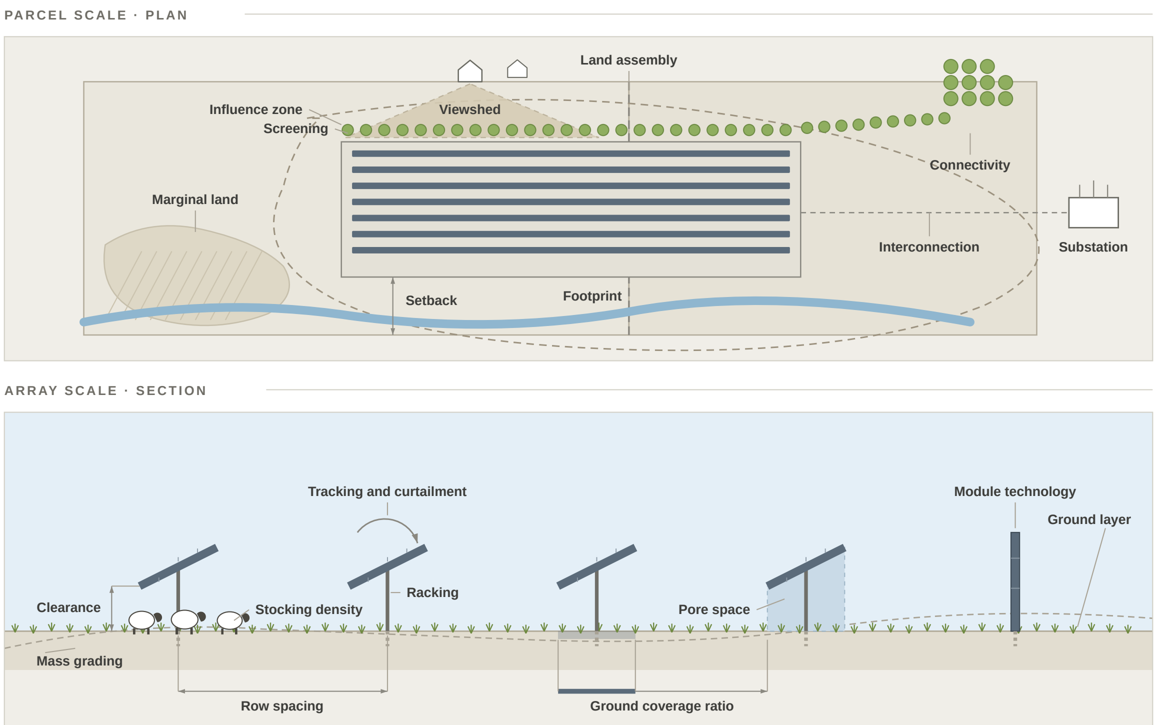

Figure 8.1: **Where the spatial vocabulary lives.** Above, the parcel in plan: footprint, setback, screening, viewshed, influence zone, marginal land, land assembly, and the line out to the substation. Below, five rows of one array in section: clearance, row spacing, tracking, ground layer, pore space, and racking.

In plan the terms mark out ground: what the array occupies, what is held open at its edge, how far its effects carry past the fence, and the line to the substation that settled how big the project could be. In section they mark out geometry, which decides what can grow and work underneath. The dashed line beneath the rows is the surface that was there before the site was graded, and the fifth row stands vertical, which is one of the module technologies rather than a drawing error. Terms defined below that name an idea rather than a place, among them agrisolar, ecovoltaics, dual use, and the land equivalent ratio, have nothing in the drawing to point at.

8.1 Design levers and pressures

Developed in §1, Design Levers and §2, Design Pressures.

8.1.1 Design pressures

The competing forces every site must resolve. Unlike axes they have direction, they conflict, and real parties advocate for them. Nine are named. See §2.1.

8.1.2 Design tension

What a resolution of the design pressures leaves unresolved. It is never nil, because the nine cannot all be satisfied at once and the project gets built regardless, so the question is how much remains and who is carrying it. Low tension is not the same as agreement: a design can be quiet because the pressures accommodated each other, or quiet because a party with a real claim stopped pressing it. The settings that leave least are the ones that recur, which is what an archetype is. See §2.2.

Coined here, and it collides. An engineer reading a racking specification will meet *design tension* as the tensile load a member is sized to carry. Nothing crosses over but the word: this one is a property of an argument, not of steel.

8.1.3 Energy yield

Pressure: maximize energy per unit land. Pushes toward dense row spacing, optimal tilt and tracking, low clearance, whole-field coverage. See §2.1.

8.1.4 Cost and financing

Pressure: minimize what the project costs to build and what it costs to finance. The first pushes toward standard racking, low clearance, minimal ground preparation, and conventional geometry. The second is a different force with the same sign: transaction costs do not scale down, so a 2 MW project carries much the same paperwork as a 200 MW one, and a small offtaker is likelier to lack a credit rating. Held under one name because a design has to clear both, and a project that pencils on capex can still fail to raise the money. It is why the zone with the most design freedom has the least access to capital (§5.3). See §2.1.

8.1.5 Operations and maintenance

Pressure: minimize management burden across a 25–40 year asset life. Pushes toward uniform, mowable or gravel ground cover, and can oppose cost and financing, since native seeding raises capex and lowers long-run opex. See §2.1.

8.1.6 Agricultural production

Pressure: keep working land working. Pushes toward high clearance, equipment access, production ground layers, farmer contracts. See §2.1.

8.1.7 Restorative goals

Pressure: make ecological, hydrological, and economic resilience a design objective co-equal with generation. The pressure this document exists to advance, and still a force among forces. See §2.1.

8.1.8 Community acceptance and benefit

Pressure: secure and sustain community acceptance *and* community benefit. **Acceptance is about process**: who was asked, when, whether the answer could still change the design, and whether the people who live with the result trust how it was reached. **Benefit is about receipts**: who ends up with money, opportunity, resilience, or protection from a harm they would otherwise carry. Held under one name because a design has to advance both, and worth holding apart because they come apart in both directions — a project can pay a community it never consulted, and consult one thoroughly while leaving it nothing. Neither substitutes for the other, and paying first is not consent (Crawford et al. 2022; Ryder et al. 2023). See §2.1.

8.1.9 Grid and market demands

Pressure: satisfy whoever is buying the power, the attributes, or the tax position. The channel through which outside parties push their requirements onto a design. See §2.1.

8.1.10 Policy and permission

Pressure: satisfy the rules that decide whether the project happens at all, and the subsidies that decide what pays. Permitting path and zoning, prime-farmland and setback rules, state programs, and federal incentives. It is the one pressure whose direction is set by the jurisdiction rather than by the site or the buyer, which is why it belongs to regionality as much as to the pressure set itself. See §2.1.

8.1.11 End-of-life responsibility

Pressure: minimize the residual footprint left after a 25–40 year asset life and preserve the option to return the ground to its prior use. For the end-of-life vocabulary itself, see Decommissioning / Repowering / Reversibility. See §2.1.

8.1.12 Design levers

The six kinds of decision a project can actually make, and the only things anyone can change: **scale**, how much ground it takes; **siting**, which ground; **structure**, what gets built; **management**, what grows and how the place is run; **ownership**, who holds the asset; and **contracts**, what the parties signed. Scale sets the frame; the three below it act on ground and are limited by how much of it there is; the last two are institutional and are not. Which lever carried the restorative work is the restoration mode. See the Design Levers chapter, and §5.2 for the levers read against the transect.

Borrowed, and turned. The six levers are the lexicon's own; the reason for sorting them this way is borrowed twice over from architecture. Brand (1994), after Frank Duffy, reads a building as layers of differing longevity and holds that a design works when the fast layers can move without tearing the slow ones, which is why management sits apart from structure here rather than inside it. Habraken (2002) adds that every level has a decision-maker of its own, which is the ownership lever stated as design theory. Neither author was writing about land, and neither has anything corresponding to siting.

8.2 Regionality

Developed in §2.3, Regionality.

8.2.1 Regionality

The claim that the design pressures resolve differently in different places, because the factors that weight them vary across space. The vocabulary is constant everywhere; which positions are available, which functions are reachable, and how hard each pressure pushes are not. See Regionality.

8.2.2 Regional factors

The six spatial factors the lexicon reads a region by: the **resource** (sun and cloud, including diffuse fraction), the **grid operator** (queue, curtailment, and the state programs that decide whether A3 exists), **aridity** (which flips the sign of the shade effect), **latitude** (which sets tilt, row spacing, and the inter-row light budget), the **cropping system** (which decides whether sharing is conceivable), and **irrigation** (which makes retirement at scale available or unavailable). See §2.3.1.

8.2.3 Regional calibration

A restatement of the lexicon's indicative values for a particular region: capacity bands, absent zones, the binding constraint, the positions realistically open. The US calibration in §2.3.2 is one such, not the general case; calibrations from other regions are additions rather than corrections. See §2.3.2.

8.2.4 Design import

The characteristic regional failure: carrying a resolution from the region where it was demonstrated into one whose factors differ, as when a shade benefit shown in the Southwest is assumed in the Midwest, a habitat specification calibrated on one establishment cost written into a contract for another. Grid and market demands is the usual vehicle, since a buyer's criterion travels further and faster than the evidence behind it. See §2.3.3.

8.2.5 Diffuse fraction

The share of irradiance arriving as diffuse rather than direct-beam light. Cloud collapses the beam component while diffuse holds up, so humid and cloudy regions run a higher diffuse fraction of light, which is non-directional, reaches under and between panels, and is most of what a ground layer lives on. It also weakens the case for tracking. See §2.3.1.

8.3 Scale

Developed in §3, The Scale Transect.

8.3.1 Scale Transect

A single gradient from farmstead (A1) to complex (A5) that most other terms are read against, defined by covarying attribute bundles rather than capacity thresholds. The zones are named for the size of the development rather than for the land unit it sits on, so that no zone name is outgrown by the array it describes. See The Scale Transect.

Borrowed, and turned. The device is the rural-to-urban Transect of the New Urbanism (Duany Plater-Zyberk & Company 2014), which is where the lexicon takes its name and its method of calibration points. One thing changes in the borrowing, and it matters: that transect is a gradient across the ground, a line you could walk from wilderness to urban core, while this one is a gradient of project size. Two A2 projects can sit a mile apart, and an A5 can surround an A1.

8.3.2 A0 — Rooftop

Arrays mounted on buildings, and by extension on carports and canopies, which take no ground at all: no siting latitude to spend, no ground layer to design, and no farming axis position to hold. It sits at the transect's origin rather than on it. See §3.1.

8.3.3 A1 — Farmstead

<100 kW, under about an acre; behind-the-meter, single owner-operator, existing farm labor and equipment. See §3.1.

8.3.4 A2 — Commercial

100 kW–1 MW, roughly 0.5–8 acres; behind-meter to distribution, landowner with possibly one lease counterparty. See §3.1.

8.3.5 A3 — Community

1–5 MW, roughly 6–30 acres of array; distribution, community solar or mid-market PPA, multi-party, purpose-built ground management. Big enough that management arrives and small enough to site deliberately, which makes it the only zone carrying both restorative instruments at once and the widest part of the feasible wedge. The zone takes its name from the trade's own **community-scale solar**, a phrase carrying several senses at once: sized to a community's load, sited where communities already are, structured so benefit reaches a community, and building community resilience through a distributed fleet. That the name is also the name of an outcomes footprint domain is not a collision but the argument: A3 is the zone where community outcomes are most likely to land. See §3.1 and §5.3.

8.3.6 A4 — Utility

5–50 MW, roughly 30–300 acres; developer-led institutional capital, contract-enterprise ground management. The zone where a project is first built to serve the grid rather than a load on the site, which is what utility-scale names in the trade. The widest band on the transect, and it probably contains a jurisdictional break near 20–25 MW, the capacity at which several states move siting from local boards to a state office. Not split yet (§3.1). See §3.1.

8.3.7 A5 — Complex

50 MW+, from roughly 300 acres to 10,000 and beyond; transmission, utility or IPP across jurisdictions, contract enterprise at ranch scale. Open-ended by design, and named for what it becomes at that size: not one array but several run as one, often across parcels that do not touch. See §3.1.

8.3.8 Siting latitude

The designer's freedom over where the array goes. What governs it migrates from opportunistic placement to land assembly and grid topology up the transect, and it peaks at A2–A3, bounded by the parcel at A1 and by the land market at A5. The constraint that makes the feasible region a wedge. See the five modes for the modes against the levers, and §5.2 for which one dominates at each zone.

8.3.9 Stocking density

Instantaneous animals per unit area at a moment; diverges from carrying capacity with forage growth, utilization, and climate. A grazing design variable to calibrate, not a fixed rate. See §3.1.

8.3.10 Carrying capacity

The season-long forage the land sustains over time, distinct from instantaneous stocking density. See §3.1.

Borrowed, and worth placing. This is range science's carrying capacity: a stocking target set by the forage a management unit grew this season and by what the manager is trying to achieve with it, so it moves from year to year and can be argued about. It is not population ecology's K, the level a population settles at when nobody is managing it, which is what a reader coming to the same site from a habitat plan will assume. Both senses can turn up in one project file, so a number is worth labeling.

8.3.11 Contract grazing

Grazing delivered as a contracted vegetation-management service by a party who does not live on site; appears at A3 and scales up into a logistics enterprise. See §3.1.

8.4 The farming axis

Developed in §4, The Farming Axis.

8.4.1 Farming Axis

The second, largely scale-independent dimension: whether the array shares land with agricultural production (**land sharing**), spares land by taking ground out of it (**land sparing**), or neither. The pair is borrowed from conservation ecology (Green et al. 2005; Phalan et al. 2011); the short form *sharing–sparing* is used for the axis, the full form in prose. Five positions, centered on S3, with a sixth past the sharing end for ground the array brings into agriculture rather than takes out of it. The names run on two stems, because the axis changes character at its middle: where farming continues the position is named for the **agriculture** left on the ground, and where it has stopped the position is named for the ground the array was **sited** on. See The Farming Axis.

Borrowed, and turned. In conservation ecology the sharing–sparing question asks how intensively to farm a landscape so that the remainder can be left to nature, argued at landscape scale against a fixed food target, with biodiversity the outcome that settles which way to go (Green et al. 2005; Phalan et al. 2011). Three things change here. The thing being placed is a power plant rather than a farming regime, the unit is one project on one parcel, and the axis records what happened to production rather than scoring an outcome. That is why it has a middle: S3 is neither sharing nor sparing, and the ecology debate has no position for it.

8.4.2 S0 — Created agriculture

A farm takes something off ground that carried no agricultural use before the array: a capped landfill or a decommissioned industrial parcel grazed under panels, previously developed urban and peri-urban ground put back to stock. It is the only position recording a use that began rather than one kept, stepped down, or lost, which puts it past the sharing end and on the starting a benefit side of the split rather than the harm-reduction side the other five share. Uncommon, and no claim about quality. See §4.1.

8.4.3 S1 — Primary agriculture

The agricultural use continues essentially as it was, with the array added over or between it: a vineyard still a vineyard, a pasture still a pasture, a row crop still cropped between the rows. This is agrivoltaics in the strict sense, and the test is comparison with what the ground did before rather than with what the array needs. See §4.1.

8.4.4 S2 — Secondary agriculture

The ground still carries an agricultural use, but a lesser one than it carried before: cropland grazed instead of cropped, or a sown layer worked for forage, hay, or hives. Agriculture continues; its value is stepped down. Available at every scale, and with S1 and S3 the spine of the feasible wedge, since grazing splits across S1 and S2 by what the ground carried before. See §4.1.

8.4.5 S3 — Ordinary-land siting

Neither sharing nor sparing: the array takes ordinary productive ground outright and the revenue sustains the farm enterprise holding it, so the restoration is socioeconomic before it is biophysical. Where the rent reaches a non-farming owner and the operation ends, the site is bare conversion instead. The center of the axis, and where most projects sit. See §4.1.

8.4.6 S4 — Low-productivity siting

The array takes ground that was already idle, marginal, or chronically low-yielding, so nothing in production was displaced to build it. The name records the ground taken, which can be checked on site. The benefit — that productive land elsewhere went unbuilt — is a landscape claim and is carried by the definition rather than by the name, because it cannot be read at the site. See §4.1.

8.4.7 S5 — Impaired-land siting

The array takes ground that carried a measurable off-site burden such as high runoff, nutrient or pesticide export, or irrigation draw beyond the aquifer's budget, or ground positioned where such a burden can be intercepted. Unlike S4, the act works on the ground taken itself: production ends and the burden ends with it. See §4.1.

8.4.8 Bare conversion

Ordinary ground converted with the farm operation ended: the same ground fact as S3 without the restorative one. The non-restorative baseline the axis is read against, not a position on it. See §4.1.

8.4.9 Feasible wedge

The feasible region across scale and sharing, and it is not symmetric. The sharing edge runs flat across the whole transect, because farming carries on under panels at every size, from the operator's own yard at A1 to a contracted flock on former pasture at A5. It is the sparing edge that opens with scale, from almost nothing at A1 to the full range by A3. Only S4 thins toward A5, because land assembly cannot collect scattered remnants. Each thinned corner has a documented exception. See §4.2.

Coined here, and it collides. A reader from energy or climate work will hear Pacala and Socolow's stabilization wedges (Pacala and Socolow 2004), where a wedge is a slice of avoided emissions widening to a gigaton of carbon a year and the point of the picture is that the slices add up. Nothing carries across but the shape word. This wedge is a region on the scale-by-sharing plane showing which positions are actually available, and it narrows toward both of its ends.

8.5 Restoration modes

Developed in §5, Restoration Modes and Potential.

8.5.1 Restoration mode

Which design lever a design commits to carry the restorative work: the choice of ground, the array's geometry, how the array is run, who holds the asset, or what the parties signed. Each mode names a lever, so there are five modes for six levers. Scale has none, because deciding how big to build is not itself a way of doing restorative work, only what settles which ways stay available. The first three are done physically and shift along the transect as siting latitude rises and falls (§5.2). The last two are institutional and trade against each other: ownership-led is free at the farmstead and unavailable at utility scale, and contract-led runs the opposite way. Five modes:

- **Siting-led** — the restorative work is done by the choice of ground; requires the A2–A3 latitude to choose it.
- **Structure-led** — array geometry does the work: clearance, row spacing, module transmissivity.
- **Management-led** — placement is a given, and the ground cover, grazing regime, and operational schedule carry everything. The dominant mode at A4–A5.
- **Ownership-led** — the work is done by who holds the asset, and no agreement is needed because the parties were never opposed. Strongest at A1–A2, where the operator owns both the array and what stands under it, and effectively unavailable once the owner is absentee.
- **Contract-led** — the work is done in the lease, the ordinance, or the benefit agreement rather than anywhere on the site. The mode the community and economic function runs on, and the one that decides whether the tenant is still farming in year twenty (§6.4).

Borrowed, and turned. The phrase is already in use in ecological restoration and land reclamation, where a restoration mode is a package of restoration techniques matched to a site's degree of degradation (Zha et al. 2025). Here it names which lever carries the work instead, which is why two of the five are institutional rather than anything done to the ground. The nearest existing framework for sorting interventions by the instrument that delivers them is the IUCN and CMP conservation actions classification (Salafsky et al. 2008), whose top categories line up with four of these five and have no equivalent of structure-led. Two collisions are worth naming for this audience. In the solar trade *site restoration* is a decommissioning obligation, what a lease owes when it ends, so a mode here is a choice made at design rather than a phase at the end of life. And *ownership-led* means the restorative work is carried by how the asset is held, not that the owner is running the project.

See the five modes for the modes against the levers, and §5.2 for which one dominates at each zone.

8.6 Restorative functions

Developed in §6, Restorative Functions.

8.6.1 Restorative function

A restorative capacity a project can be designed to deliver, obtainable to varying degrees from many structural positions at once, the columns laid over the archetypes as rows (§6). Two are biophysical, one agricultural, and one socioeconomic. See Restorative Functions.

Not ecosystem services renamed. An ecologist will read the four as the Millennium Assessment's categories in new clothes, and the overlap is real, but the sorting principle is different: services are grouped by what an ecosystem supplies, and these by what a design can be built to deliver. One of the four is socioeconomic, food production sits on the farming axis instead of among the functions, and a function here is an objective a project is held to rather than an account of what a place already does. Service classifications are plural and built for the purpose at hand (Costanza 2008); this is one more of them.

8.6.2 Hydrologic function

Water quantity and quality as design objectives. On **quantity**: infiltration and recharge raised, soil moisture buffered, and at scale consumptive use retired from a basin's budget. On **quality**, two routes needing opposite ground: **avoided loading**, siting on the ground that is doing the leaching, which the water-quality literature calls a critical source area, so the fertilizer and pesticide programs stop with the cropping, and **interception**, siting on the flow path below it so runoff gives up its nutrients and sediment before reaching a channel. See §6.1.

8.6.3 Ecological function

What can live on the ground and what can move through it. Habitat is built from the ground layer up, through floral resources, nesting substrate, and vegetation structure, with mowing and grazing *timing* as decisive as the seed mix; connectivity is the other half. Reachable across S1–S5, which is why it is a function and not a position: a grazed array on former pasture is S1 and can still carry a pollinator understory. See §6.2.

8.6.4 Connectivity

Whether organisms can move into, through, and out of a site, as against whether the site can feed them once they arrive. It is designed at four scales at once: inside the array by fencing, roads, and mown strips; at the edge by whether the planting meets an existing corridor; across a landscape by the choice between a few large arrays and many small ones; and at regional range by whether a fleet of sites falls within dispersal distance of one another. Connectivity is a property of the arrangement rather than of any one patch, and the scale on which it matters is set by the disperser, so a connectivity claim means little until it names the taxon. See §6.2.

Borrowed unchanged, and it collides. Landscape ecology's term, meaning the degree to which a landscape helps or hinders movement among resource patches, defined by the organism doing the moving rather than by the map (Taylor et al. 1993). The lexicon takes that sense whole, including the demand that a claim name its species. What it declines is the structural reading in which connectivity is adjacency measured off a drawing, because a hedgerow can run unbroken on the plan and stop at a stock fence. On the electrical side of the same project the word means the connection to the grid, which is interconnection here.

8.6.5 Agriculture and soils function

What the array does *for* farming, on its own ground and on the fields around it: pollination and pest regulation carried by the ground layer beyond the fence, forage and stock shelter under the panels, and the lease revenue that keeps the operation running. Not the farming axis restated, which records whether production continues in the footprint rather than what the project gives farming. Its benefit delivery splits: the soil half stays in place, while the service to farming travels along living things, which makes that half the most dependent on what surrounds the site. See §6.3.

8.6.6 Community & economic function

The one socioeconomic function: the durable local income, the livability, and the question of whether the burdens and the benefits land on the same people, the outcomes footprint's Communities domain read as an outcome, and distinct from the social-license pressure and community-benefit lever that aim at it. Only legible once the recipients are named separately. See §6.4.

8.6.7 Benefit delivery

How a function's benefit reaches whoever receives it. The useful question is not how far it goes but **which route it takes**, since nearly every function reaches from the panel to the region along some path. Three routes. **In place**, where provider and beneficiary are the same ground. **Along a connection**, where the benefit travels a network: water carries runoff, sediment, and recharge downslope; living things carry pollination, pest regulation, and dispersal; institutions carry lease, tax, and subscription along tenure, contract, and jurisdiction. And **by preservation**, where nothing moves and the benefit is ground elsewhere that stayed as it was. The route decides who can verify a claim and who captures it. See §6.5.

Prior names. The distinction is borrowed, not coined. Hernandez et al. (2019) call an outcome that overlaps the generation site *sympatric* and one spatially separated from it *disjunct*, and assign each a *serviceshed*, the largest ecological scale at which it contributes goods and services. This lexicon splits the disjunct side into bands and adds delivery by preservation, which a service-based scheme cannot express.

8.6.8 Delivery by preservation

The mode in which a benefit consists of ground nearby remaining as it was. It is what land sparing delivers. It is proximate, because a developer assembling acreage near a substation chooses among parcels within a fairly narrow radius, so the ground spared is realistically ground in the same county. What it is not is observed: the claim rests on a counterfactual, and it is tested against the local land market and the sites genuinely in play rather than against an unbounded alternative. See §6.5.

8.6.9 Co-benefit

The field's usual word for what this lexicon calls a restorative function. Recorded here because it is what practitioners will say, and used here only to describe how others frame the same ground. The term carries acknowledged definitional ambivalence, and its grammar demotes what it names, since a *co*-benefit arrives alongside the real objective (Mayrhofer and Gupta 2016). This document argues these capacities are objectives, so it does not adopt the word. *Cf.* **techno-ecological synergy**, the literature's own attempt at a framing that does not subordinate them (Hernandez et al. 2019).

8.6.10 outcomes footprint

A whole-project reading across four domains, Communities, Agriculture, Water, and Ecology, each running from causing harm at the center, through avoiding harm, out to promoting benefit at the rim, so a larger shape is a better project (§5.4). Evaluative by design, but the ring where harm ends is a zero point rather than a pass mark. See Restorative Functions.

8.7 Archetypal forms

Developed in §7, Archetypal Forms.

8.7.1 Archetype

A recurring way the design pressures have been resolved at a particular scale zone and sharing position, carrying particular functions. Used in its plain sense, meaning a characteristic, transformable pattern rather than an exhaustive set. See Archetypes.

Plain sense, deliberately. Sustainability research runs a formal method under this word, *archetype analysis*, which sorts many cases into recurrent configurations of causal factors and tests the groupings against data (Eisenack et al. 2021). These archetypes are not that. They were assembled from practice rather than derived from a sample, they are not claimed to be exhaustive, and a real project can sit between two of them. The entry says "plain sense" to keep the stronger, methodological claim from being read into the word.

8.7.2 Overhead and interspace systems

The engineering standards' hardware typology (DIN SPEC 91434; the NREL / InSPIRE configuration taxonomy): *overhead* systems mount modules above the working surface, *interspace* systems mount them low with the crop or cover between the rows. It classifies the structure, where an archetype classifies the resolution of pressures. See Archetypes.

8.8 Field terms and metrics

The vocabulary the lexicon adopts from the wider field and pins down for use here.

8.8.1 Agroenergy

Energy infrastructure that occupies or interacts with agricultural land functioning and operation, whether or not the interaction was intended. The broadest umbrella in this lexicon, non-solar-specific, and carries no requirement of design intent or outcome.

Term collision, flagged deliberately. Elsewhere "agroenergy" (and *agro-energy*) most often means agriculture-*derived* **bioenergy**: energy crops, crop residue, biogas, and biomass, meaning farmland as a fuel source. This lexicon repurposes the word for the converse: energy *infrastructure* placed on and integrated with agricultural land. The reuse is intentional but worth naming, so a reader arriving from the bioenergy literature is not misled. The infrastructure sense is live in the peer-reviewed literature: Stid et al. (2025) define agrisolar as the integration and co-management of solar photovoltaics, agriculture and ecosystem services **within agroenergy landscapes**.

8.8.2 Agrisolar

They key tenet of this lexicon, agroenergy specific to solar photovoltaics (PV): Solar PV that occupies or interacts with agricultural land functioning and operation. A neutral umbrella across the whole farming axis (S1–S5), intent- and outcome-agnostic like agroenergy and including any subsequent form of agricultural co-location.

Agrisolar potential can be technically defined from siting and management alone, as one or more of: * **occupies:** an array whose footprint was predominantly agricultural land before installation * **adjacentTo:** an array sitting substantially within or adjacent to neighboring land that is currently agricultural * **managed:** an array containing land inside the footprint that is under active agricultural management

An array meeting none, or that cannot be evaluated, is **noCurrent**. These record potential, not practice: attributing practice needs an array's direct contribution to a farm, which siting and management do not resolve alone.

Syn.: multi-use solar (narrower: excludes S3–S5 without an ecological ground layer).

Source: Stid et al. (2025) — Sources SolarPower Europe (ADD CITE).

8.8.3 Agrivoltaics

Crop or livestock production within the array footprint (S1–S2). Crop response to shade is climate- and crop-dependent; a synthesis of 367 paired observations found yield response turning positive only in hotter conditions (Merheb et al. 2025).

The idea is older than the word. Goetzberger and Zastrow (1982) proposed running solar conversion and plant cultivation on one field and worked the geometry out, collectors about two meters up and rows spaced at roughly three times their height, which left about two-thirds of open-field radiation on the ground. That was decades before anyone built one at scale. The word itself arrived with Dupraz et al. (2011), whose modeling of crops under partial shade also brought the land equivalent ratio into the field. Neither the term nor the metric belongs to this lexicon.

Syn.: agrophotovoltaics (German); photovoltaic agriculture (Chinese); solar sharing (Japanese); agri-PV; PV agriculutre; aglectric.

Source: AFT Policy Reccommendations; SB 2931; NLR

8.8.4 Rangevoltaics

Grazing under and between panels. Its position turns on what the ground carried before: a flock on land that was already pasture is S1, and the same flock on former cropland is S2. The everyday name is **solar grazing**; the literature also uses *rangevoltaics* (Merheb et al. 2025). Species and clearance must be matched to the racking, which in practice means sheep (§5.2). Shade is also a benefit that can be a requirement: Humane Farm Animal Care certification mandates shade where temperatures run consistently above 22 °C, which makes an array a compliance instrument as well as a pasture.

Syn.: solar grazing; cattelvoltaics.

8.8.5 Ecovoltaics

Solar development that co-prioritizes ecosystem function with generation through siting, layout, ground-layer design, operations, and a viable business model (Sturchio and Knapp 2023; Tölgyesi et al. 2023). This lexicon treats its ecological ground layer as a restorative function, not an axis position. The framework favors repair of disturbed ground over conversion of intact native ecosystems (Sturchio et al. 2025).

The definitional dispute. AFT advances a production-based definition of dual use; critics argue it excludes ecosystem benefits and imposes a one-size-fits-all instrument on farmland protection. Both terms are defined precisely above, and both map to positions on the farming axis, which locates the disagreement where it belongs, as a genuine conflict between agricultural production and restorative goals (§2.2) rather than as a misuse of words. This document describes that dispute; it does not adjudicate it.

Syn.: nature positive renewables.

Source: Sturchio and Knapp (2023) — Sources.

8.8.6 Dual Use

A production-based term: co-location that keeps *active agricultural production* within the array footprint across the project's life, which is American Farmland Trust's criterion. Structurally a mandate for S1–S2. Distinct from ecovoltaics, whose ecological ground layer is a function rather than production; the two are the poles of the definitional dispute the lexicon holds open rather than adjudicates (§4.2).

8.8.7 Restorative

The frame of this entire lexicon rather than a dimension within it. Applied when ecological, hydrological, or economic ground-layer function is a design objective co-equal with generation, not an incidental byproduct. US arrays are designed primarily to maximize output and minimize cost; co-benefits arrive incidentally or through a patchwork of state and local policy (Hernandez et al. 2014; McCall et al. 2023). *Restorative* names the deliberate alternative.

Borrowed, and worth placing. The word comes from restorative design (Reed 2007), where it sits one rung below *regenerative*: restorative returns a system to health, regenerative leaves it able to keep renewing itself. The lexicon keeps that modesty deliberately and widens the scope, so the word covers hydrologic, agricultural, and community function and not ecology alone. It is not the solar trade's *site restoration*, which is what a decommissioning plan owes when a lease ends, and not restoration to a reference ecosystem in the sense ecological restoration uses. The compound *restorative agrisolar* is the lexicon's own.

8.8.8 Co-location vs. Integration

The pair that makes agrisolar the superset and agrivoltaics one member of it.

Co-location — solar and an agricultural land use share a landscape without functional interdependence. Stid et al. (2025) call this *lateral* or *adjacent* co-location: agricultural land is replaced, and the two sit side by side.

Integration — the two share the same ground and the same light: panel height set by livestock clearance, row spacing by forage light requirements, tracking schedule by photosynthetic timing. Stid et al. (2025) call this *vertical* or *coincident* co-location — agrivoltaics proper.

Read against the axis, that is the whole set relation in one line: **integration is S1–S2; co-location without integration is S3 and below.** Agrivoltaics is the integrated subset of agrisolar, which is why this document needs the wider word.

Integration is also the line a design crosses to be restorative in the structural sense rather than in name only, though S3 is the reminder that a project can restore an enterprise without integrating anything.

Usage caution: Stid et al. (2025) use "agrisolar" in two senses: broadly, for the superset covering both cases, and narrowly, where "agrisolar co-location" means the adjacent case alone. **This lexicon uses the broad sense throughout.**

8.8.9 Footprint vs. Influence Zone

Footprint: land physically occupied by racking, panels, access infrastructure. **Influence Zone**: the larger, typically asymmetric area whose hydrology, microclimate, soil, wildlife movement, or visual presence (viewshed) is measurably affected. The solar-siting literature already splits *footprint* the same way, into the **array/direct footprint** (panels and racking) versus the **facility/fenceline footprint** (the whole permitted parcel), and the ecovoltaic siting research makes the distinction matter: several small sites carry higher aggregate edge-to-area ratio than fewer large ones, amplifying both inward effects (pesticide drift) and outward ones (pollination, pest control). **Fragmentation geometry is a first-order design variable.**

The zone can also act through *economics* rather than through hydrology or sightlines. Stid et al. (2025) document intentional fallowing of irrigated cropland **adjacent to** arrays, 968 ha across 58 utility-scale installations in California's Central Valley, about 27% of those arrays' own area, apparently funded by array revenue, and call the practice **solar fallowing** where the aim is reducing water use. The array changes what happens on ground it never occupies.

Neither sense should be confused with the outcomes footprint, which is not an area at all but a reading of a project across Communities, Agriculture, Water, and Ecology (§6).

8.8.10 Screening

The management of the array's outward visual presence: perimeter setbacks, vegetative buffers (hedgerows, tree/shrub belts), earthen berms, fencing treatment, and glint/glare control. It acts on the *visual* portion of the Influence Zone. Screening is dual-function, since the same vegetative buffer that buys community acceptance can carry habitat and connectivity value, so it is pushed by both community acceptance and restorative goals, while costing generation (edge shade), land, and sometimes agricultural production; its habitat value is greatest where the surrounding landscape is otherwise bare of hedgerows. Descriptive only: the lexicon names the lever, not a required buffer width, berm height, or setback.

8.8.11 Setback

The ground held open between the array and whatever it is measured from: the property line, the road, or a dwelling. It is the dimension local ordinances fix most often, which makes it the commonest way a township rule reaches inside a project, and the land it holds back is where screening gets planted and where a hedgerow can carry connectivity. Named here as a decision; no distance is proposed for it.

8.8.12 Viewshed

The ground from which the array can be seen. It is the part of the influence zone that reaches people rather than water, soil, or wildlife, and the only part of a project's influence a neighbor meets directly, which is why it carries more of the community acceptance argument than its physical extent suggests. It is what screening acts on.

8.8.13 Community Benefit

The instruments through which a project returns value to its host community: community-benefit or host-community agreements (CBA / HCA), payments in lieu of taxes (PILOT) and tax revenue, good-neighbor / abutter payments, community-solar subscription, local hiring, co-ownership or locally-owned models, and decommissioning bonds as a community-protection instrument. These instruments are the receipts half of the community acceptance and benefit pressure, whose entry sets out why the process half cannot be bought, so the community acceptance pressure holds both as forces in tension rather than treating a check as consent.

8.8.14 Microclimate

The array's reshaping of the near-surface energy balance: shade lowers daytime soil and canopy temperature and the vapor-pressure deficit under the panels, while longwave sheltering lifts nighttime minima, so the microenvironment swings less far across the day (Sturchio and Knapp 2023; Pinos et al. 2026; Barron-Gafford et al. 2019). It is a **mechanism rather than a function**, and the lexicon stopped listing it as one because its results are already counted elsewhere: retained moisture is the water function, thermal refuge is ecology, and relief for a shade-tolerant crop, shelter for stock, and shade for the people working there are agriculture. Its sign flips with climate and crop, and it is carried by the structure lever throughout. See §6.

8.8.15 Ground Layer

Whatever occupies the surface beneath and between panels. Primary carrier of restorative function. The solar and agronomic literatures also call this the **understory** or the **ground cover / vegetation layer**; "ground layer" is used here because it stays neutral about whether that surface is planted, grazed, gravelled, or bare.

Syn.: understory; ground cover; vegetation layer.

8.8.16 Marginal / Previously Disturbed Land

The low-value ground that low-productivity siting (S4) presupposes: consistently low-yielding cropland, and previously disturbed land such as reclaimed mine land, landfills, and brownfields ("brightfields"). Marginality is partly a property of the ground and partly of the market, so claims of marginal-land siting deserve scrutiny about what fraction of a footprint is genuinely marginal (§4.2).

8.8.17 Pore Space

(borrowed) — The three-dimensional volume between modules and between modules and ground. Names the thing that "panel height" and "row spacing" only hint at, and treats it as habitat and working room rather than leftover gap.

One word, two spaces. To an agronomist, a soil scientist, or a hydrologist, pore space is the void fraction of the soil, and this document argues about soil on nearly every page. Toledo and Scognamiglio lifted the word up out of the ground and gave it to the volume between and under the modules (Toledo and Scognamiglio 2021), and the lexicon keeps it there. Where both senses are live on one site, the compaction question belongs to the space below the surface and the habitat question to the space above it.

Source: Toledo and Scognamiglio (2021) — Sources. Toledo & Scognamiglio's "descriptive model towards a sustainable landscape vision" is a direct predecessor to this lexicon's own describe-the-landscape stance, reading array geometry through landscape-ecology's patch–matrix–corridor lens rather than as a yield problem alone.

8.8.18 Ground Coverage Ratio (GCR)

The ratio of module area to total ground area, which is the density of the array. High GCR packs more capacity per acre and pushes with energy yield and cost and financing; low GCR opens the pore space and inter-row that agrivoltaics and a working ground layer need. GCR is the single number behind much of the row-geometry ground-layer coupling (§5.2).

8.8.19 Module Technology

The panel itself as a structure lever: *monofacial* vs *bifacial* (both faces generate); *vertical bifacial* (east–west, leaving the inter-row open to machinery, extending sharing to larger scale (Vaverková et al. 2026)); *semitransparent / transmissivity-tuned* (passing some light to a crop below); and *spectrally selective* (transmitting the wavelengths plants use while harvesting the rest). Module choice sets how much light, and of what kind, reaches the ground layer.

8.8.20 Tracking Schedule & Curtailment

Two management levers. *Tracking schedule* is how a single- or dual-axis array is steered through the day, normally to maximize generation, but an ecovoltaic operation may orient panels partly for the light, water, or temperature reaching the ground (Knapp and Sturchio 2024). *Curtailment* is the deliberate reduction of output for grid, price, or ecological reasons. Both are decisions about how the array is *run*, the instrument of management-led restoration at A4–A5 (§5.2).

8.8.21 Land Equivalent Ratio (LER)

The standard dual-use productivity metric: the land a monoculture would need to match what the co-located system yields on one unit of ground (LER $> 1 =$ a land-productivity gain). It captures *production* co-yield well but is silent on ecological, hydrologic, and community function, and it handles the non-production ground layers of S3–S5 poorly and has no term for the restorative functions or for the outcomes footprint domains beyond food and energy. Its blind spots are given alongside it because it is the metric most likely to be taken as the measure of success by default. No single success metric is endorsed here (§6.6).

Borrowed twice, and the blind spots came from the first borrowing. LER was defined for intercropping, to say how much sole-crop land two species grown together would otherwise have needed (Mead and Willey 1980). Dupraz et al. (2011) carried it into agrivoltaics by treating electricity as the second crop. Both moves keep the founding assumption, that the two outputs are yields, comparable per unit of the same ground. That is what fails at S3–S5, where the second output is habitat, infiltration, or a lease payment, and it is why the metric's silences are structural rather than an oversight anyone can patch.

8.8.22 Decommissioning / Repowering / Reversibility

The end-of-life questions a 25–40-year asset raises: *decommissioning* (removing the array and restoring the ground), *repowering* (replacing modules to extend the site), and *reversibility* (how completely the prior land use can return). Foundation type, soil disturbance, and financial assurance (decommissioning bonds) set how reversible a project is; reversibility is often the crux of the farmland-protection argument, and is itself one of the nine design pressures (§2.1).

8.9 The trade's vocabulary

Terms the lexicon uses but does not own. They come from the solar industry, from utility practice, and from the USDA soil survey, and they are given here in the sense a developer or a county planner would use them, so that a reader meeting one in these pages is not sent elsewhere to find out what it means.

8.9.1 Interconnection

The physical and legal connection between an array and the electric grid: the line it ties into, the equipment that ties it, and the utility's permission to energize. The wait in an interconnection queue routinely runs years, and it commonly settles a project's size and its site before any design question is asked.

8.9.2 Substation

The facility where voltage is stepped between distribution and transmission. Nearness to one is the siting criterion farming does not share, which is why it pulls large arrays toward ground chosen for the grid rather than for the soil.

8.9.3 Offtake

The contract naming who buys the power and at what price: a utility power purchase agreement, a corporate buyer, a subscriber list, or the farm's own meter. It sets project size more directly than the solar resource does.

8.9.4 Behind-the-meter

Generation serving a load on the customer's side of the utility meter, so the power offsets a bill rather than being sold. The milking parlor, the cold store, and the well pump are behind-the-meter loads.

8.9.5 Utility-scale

Not a fixed threshold. In ordinary use it means an array selling wholesale rather than serving a local load, which begins somewhere above A3 and is routine at A4 and A5. Berkeley Lab splits its two national datasets at 5 MW-AC.

8.9.6 Community solar

A distribution-connected array whose output is subscribed by households and businesses that cannot host panels of their own. Program caps commonly sit at 5 MW, which is one reason A3 tops out where it does. The phrase carries at least four distinct meanings in current circulation (§5.3).

8.9.7 Clearance

The vertical gap between the ground and the lowest edge of a panel. It decides what can work underneath, from nothing at all, to sheep, to a tractor, and buying more of it costs steel. The lexicon names clearance as a lever and declines to fix a number for it.

8.9.8 Row spacing

The distance from one row of panels to the next, normally measured centerline to centerline rather than as the open gap between rows. With clearance it settles what equipment can work inside the array, and with panel size it sets the ground coverage ratio.

8.9.9 Racking

The steel carrying the modules: posts, beams, and the fasteners between them. Foundation type, usually driven pile, ground screw, or surface ballast, governs how much soil is disturbed at construction and how completely the ground can be returned at end of life.

8.9.10 Tracker

Racking that rotates the modules through the day, almost always about a single north–south axis. Trackers raise output and cost, need more room between rows, and their rotation schedule is a design lever in its own right, because it decides how much light reaches the ground and at what hour.

8.9.11 Mass grading

Reshaping an entire site with earthmoving equipment before construction, rather than setting foundations to the existing contour. It is the most consequential single decision for soil carbon and site hydrology, and it is usually taken on cost grounds.

8.9.12 Land assembly

Putting together enough contiguous acreage, often across several owners, to make a large project financeable. It is what removes siting latitude at A4 and A5: the array lands where parcels could be assembled near a substation, not where the ground most wanted it.

8.9.13 Prime farmland

A USDA classification for land whose physical and chemical properties can sustain high yields under ordinary management. It is a property of the soil map unit rather than of the field's realized yield, which is why a parcel classed prime can still carry persistently unproductive ground (§5.3).

Not a description. A rule. Prime farmland is defined in federal regulation, at 7 CFR 657.5, and NRCS maps it onto soil map units (U.S. Department of Agriculture, Natural Resources Conservation Service 2026). That is what gives it force in a siting decision: the Farmland Protection Policy Act attaches review to federal actions that convert it, and township and county ordinances name the class directly when they decide where an array may go. It is the one term in this glossary that can by itself stop a project. The lexicon uses it in the regulatory sense and takes no position on the thresholds.

9 Evidence Base and Research Needs

Grassland birds are more abundant on planted solar sites than on the farmland around them, and that is known because people went out and counted them (Walston et al. 2025). A seeded ground layer under an array holding sediment and nitrogen out of the creek below is a claim of a different kind: it is the prairie-strip result from corn and soybean fields (Schulte et al. 2017), carried onto ground nobody has sampled. Both appear in this document, and the sentences that carry them look alike.

Every judgement this document makes about how well something is known lives here. The other chapters describe what agrisolar design is and what it can do; this one says what is established, what is inferred, and what nobody has measured. Keeping it in one place lets a reader weigh the whole document at once, and stops any chapter from quietly upgrading its own confidence.

It is arranged by remedy rather than by topic, because some gaps need a season of instrumentation, some need somebody to go to a primary table, and some need a project that does not exist yet to be built and reported.

9.1 What the evidence supports

Read this as the confidence behind each chapter, stated once rather than repeated as a caveat wherever a claim appears.

Water (§6.1). The dryland moisture link is **verified** (Barron-Gafford et al. 2019; Sturchio and Knapp 2025; Pinos et al. 2026), though bounded at some sites (Kannenberg et al. 2023), and infiltration and recharge at depth remain **thin** (Yavari et al. 2022). Interception is documented for prairie strips in cropland (Schulte et al. 2017), never yet from beneath an array; avoided loading is **arithmetic rather than measurement**, following from application rates on retired acreage rather than from a monitored stream.

Ecology (§6.2). **Verified** for grassland-bird gains (Walston et al. 2025), insect-community response (Walston et al. 2024), and bee diversity in pollinator-planted arrays (Bruninga-Socolar et al. 2025); scorecards codify the choices, though what each credits differs (Electric Power Research Institute 2021). The gain is **context-dependent**, largest where the surrounding landscape is already sparse in semi-natural habitat, so its size is set by what the site would otherwise have been rather than by the planting alone.

Agriculture and soils (§6.3). On the farming side, pollinator movement into adjacent crops is **verified** (Walston et al. 2024) and the farmland inside foraging distance has been mapped (Walston et al. 2018), while pest regulation is **inferred, not measured** at solar sites and a yield or input-cost change attributable to an array is **not established anywhere**. On the soil side, early gains are **verified** for ecovoltaic grassland restoration (Krasner et al. 2025), long-run accumulation is thinly measured (Carvalho et al. 2024), and the size of the construction debt is the least measured part of the ledger and among the likeliest to decide its sign, because the reported gains come from sites whose earthworks are not described.

Communities and economy (§6.4). The design principle is **verified** in the ecovoltaic frameworks themselves, where Tölgyesi et al. (2023) make a viable business model with embedded stakeholder engagement one of five co-equal pillars. The burden side is better measured than the benefit side (Bessette et al. 2024; Elmallah et al. 2023). Which structures deliver durable, fairly-shared benefit is still thinly evidenced.

The community scale, A3 (§5.3). Thin, and thinner than the confidence with which the middle is usually discussed. The capacity arithmetic is solid and federal. The delivery mechanism for pollination is measured, at two sites, for one function. Everything else is inference. Nobody has run the several-small-versus-one-large comparison at matched capacity and management, nobody has regressed land quality on project capacity at sub-parcel resolution, and no evaluation exists of whether the agricultural and pollinator adders in state incentive programs changed what actually got built. The outcomes footprint is under-evidenced at every zone on this transect, not only here. This section argues about where the decision still sits. It does not report where restoration has already happened.

The regional calibration (§2.3). The quantitative figures in this chapter are *trace before citing*: they come from secondary and program sources and have not been checked against primary records. The regional argument does not depend on any one figure.

What the siting studies show. Wu et al. (2026) is a study of utility-scale projects, at a 1 MW floor, and it treats each project as a single observation. It does not test whether siting drivers differ by project size, so it establishes what large-project siting responds to without establishing the contrast this section draws against smaller projects. That contrast still rests on Macknick et al. (2022) and Randle-Boggis et al. (2020) and on the archetypes, which is weaker evidence than a size-stratified analysis would be, and is why the peak of siting latitude remains an open question. Owusu-Obeng et al. (2025) is a preprint and has not been through review.

The prime-farmland argument. Studies that score solar facilities against soil quality find distribution-scale projects disproportionately on good land, and it is tempting to read that as careless siting. Two things complicate it.

The first is a confound. Community-scale solar goes where the load is, the load is where the people are, and the people are where the good soil was, because settlement followed arable land. Metropolitan areas hold a disproportionate share of the nation's prime farmland for that reason, and development pressure has concentrated on the best soils for a century (Dillman and Cousins 1982). A fleet sited near load will sit on prime soil whether or not anyone was careless.

The second is resolution. A parcel classed as prime farmland is not uniformly productive. Across 338 US Midwest fields and 1,625 yield maps, about half of field area was high and stable, **32% was persistently low-yielding**, and 18% swung with the weather, with the unstable ground concentrated in wet depressions (Maestrini and Basso 2018). Roughly a third of a prime field never performs. That 32% is exactly what siting latitude at A3 acts on, and a study that scores a facility by the soil class of its parcel cannot see whether the array took the good part or the bad part. The claim that mid-scale projects site carelessly and the claim that they site well are, at present, both untested at the resolution that would settle them.

9.2 Measurements nobody has made yet

Table 9.1: The measurements that would settle claims this document has to make on inference. Each is flagged where the chapters raise it, so a reader can check the claim rather than take the priority on faith.

Gap	Flagged at	What would close it
Nutrient and sediment interception under an array. Whether a seeded solar ground layer performs like a prairie strip.	§6.1	Paired monitoring above and below an array sited on a flow path, against a strip or an unplanted control.
Recharge and the water balance at depth. Panel drip, altered cover, and what reaches the aquifer.	§6.1	Measured drip and runoff, soil-moisture profiles, and coupled surface–groundwater modeling on instrumented sites.
Cumulative effect on one watershed. Whether arrays scattered through the same watershed add up, cancel out, or miss each other, and how much of the ground has to drain through them before a gauge can tell.	§6.1	Gauged watersheds filling up with solar, against comparable ones without, and routing models built on those rather than one site at a time.

Gap	Flagged at	What would close it
Soil carbon over decades. Early gains are measured; the multi-decade curve is not.	§6.3	Re-sampling the early ecovoltaic sites on a decadal schedule, which needs a commitment longer than a grant cycle.
The construction debt, and how long it takes to repay. How much carbon mass grading costs a site, against how much a minimally graded build keeps.	§6.3	Paired sampling before and after construction across projects with contrasting earthworks, which needs the earthworks recorded at the time.
Pest regulation from an array. Natural-enemy habitat is established for perennial refuge, never demonstrated from a solar site.	§6.3	Natural-enemy and pest counts in fields at increasing distance from a planted array.
A yield or input-cost change attributable to the array. The step a farmer actually cares about.	§6.3	Paired fields near and far from a planted array, with pollination and pest pressure measured alongside yield.
Whether a regional fleet of arrays functions as a connected network. Compatible seed mixes and calendars make one on paper; nothing establishes that dispersal actually happens between sites.	§6.2	Mark–recapture or genetic work on a taxon whose dispersal distance is known, across arrays at a range of separations, with unbuilt patches as controls.
Whether co-located ground supports biodiversity the way unbuilt ground does.	§6.2, and the stated gap in Brock et al. (2026)	Comparative survey across co-located, conventional, and unbuilt sites in the same landscape.
Which benefit structures deliver durable, fairly-shared benefit. The instruments are known; their outcomes are not.	§6.4	Longitudinal work on host communities rather than one-time acceptance surveys, with landowner and tenant reported separately.

The first of these is the one with the most resting on it. Interception is the water-quality route most projects could actually adopt, since it asks for a seed mix and a placement rather than for the retirement of a working field, and it is currently supported entirely by analogy.

9.3 Numbers that circulate without a traceable source

Some of this work is reading rather than measurement. The Sources chapter splits what has been checked from what has not, and the unverified block is not a list of doubts so much as a list of errands.

The grazing-cost figures are actively misquoted. Stewart et al. (2025) report McCall et al. (2023)'s $279/ha/yr as the median cost of sheep grazing, where in McCall's Table 4 it is the median *mowing* cost at sheep-grazed sites; grazing itself ran about $50/acre/yr (§3.1). Both readings now coexist in the literature, and the per-hectare conversion compounds it. Anyone quoting a grazing cost should go to McCall's table directly, and anyone who has already quoted the transposed figure should check which one they used.

The regional figures in §2.3 are the largest block of untraced material: irradiance ranges, queue and curtailment magnitudes, community-solar capacities, ground-coverage thresholds, and the acreages under SGMA and over the Ogallala. The argument in that chapter does not depend on any single one of them, which is why they were kept, but none should appear in a filing or a paper before it is traced. The community-benefit and grazing-economics material sits in gray literature for the same reason: real, widely practiced, and not yet synthesized anywhere citable.

9.4 Claims that a counterexample would test

The document makes several claims that could be wrong, and is more useful if the thing that would break them is named.

- **Sparing does not assemble at scale.** §4.2 holds that S4 thins toward A5 because idle remnants are scattered. A utility-scale project assembled from scattered marginal remnants on ordinary farmland, rather than from uniformly pre-disturbed ground, would reopen that corner. None is documented here, and one would be worth reporting.
- **Both hand-offs fall at A3.** Figure 5.1 places the structure-to-management crossing and the ownership-to-contracts crossing at the same zone, which is the load-bearing claim behind A3 being treated as the widest point for design. Whether the peak sits at A2 or A3 is argued from the archetypes rather than measured, and the curves are schematic. Moving the peak one zone left moves two claims, not one, so a set of real siting decisions that puts either crossing elsewhere would be worth reporting.

- **Regions resolve the pressures differently.** The calibration in §2.3.2 is a set of hypotheses. A region doing something its profile says it should not is the most useful single contribution the chapter can receive.
- **The six levers are complete and non-overlapping.** Every decision a project makes should land in exactly one of scale, siting, structure, management, ownership, and contracts. A decision that lands in none of them would mean the list is short; one that lands in all six would mean the categories are not cutting anything. The edge is the known partial exception, split deliberately between structure and management because a berm and a hedgerow fail differently (§1.2).
- **The A3 ceiling rests on one untested number.** The zone tops out near 5 MW because a restorative community-scale array is taken to occupy at most about a third of its parcel (§5.3). That fraction is the load-bearing number in the whole scheme and has not been tested against built projects: at half a parcel the same fields carry 3 to 7 MW and the case for a higher ceiling partly returns. A set of built restorative community-scale arrays with their occupied fractions measured would settle it.
- **The vocabulary describes a site, and sparing is a claim about a landscape.** Nothing here says where the array went instead. Statewide optimization shows the gap has teeth, since siting New York's 2050 build to preserve farmland spares roughly 80% of the farmland a least-cost build would take and opens more than 41,000 hectares of forest doing it (Gallaher et al. 2026). The global models have the mirror-image problem: Brock et al. (2026) allocate land one sector to a pixel and say plainly that they could not represent co-location, which makes their land-demand figures upper bounds and leaves the space this lexicon describes invisible to them. A landscape-level accounting that can carry both would test whether the axis needs a companion term.
- **Positions are exclusive.** The two-question reading rule (§4.1) should place any real project in exactly one position. A project that genuinely resists placement is a defect in the axis, not in the project.

9.5 What would make the evidence easier to build

These are recommendations about reporting, not about design. The document prescribes an aim and leaves the dimensions to the site, and none of what follows is a dimension.

1. **Report acreage alongside capacity.** Megawatts are how a project is filed; acres are how the ground experiences it, and the two come apart with tracking and clearance (§3.1).
2. **Name the benefit delivery when claiming a function.** A hydrologic claim that does not say whether it means moisture under the panels or nitrogen kept out of a creek cannot be checked, and the two need different evidence (§6.5).
3. **Separate the landowner from the tenant.** Nearly 40% of Central Valley agricultural land is leased, and a conversion that sustains an owner can end the operation of the person

farming the ground. Aggregate farm-income figures hide exactly the party most at risk (§6.4).

4. **Publish the counterfactual behind a sparing claim.** Sparing is a claim about land that was not taken, so it is only checkable against the local market and the sites genuinely in play (§4.1).
5. **State the prior land cover and the earthworks when reporting soil carbon.** Perennialization against a tilled baseline and conversion of existing grassland are opposite transactions, and the sign of the result depends on which one happened. How much the site was graded belongs alongside it, because a gain measured on ground that was never stripped and a gain measured on ground rebuilding from a stockpile are not the same number (§6.3).
6. **Give the region and the crop when reporting a shade-yield result.** The sign flips with ambient temperature, so an unlocated yield figure travels further than the evidence behind it (§2.3.1).
7. **Report what did not work.** Establishment failures, seed mixes that did not take, and grazing arrangements that fell apart are absent from the literature and present on the ground, and their absence is why cost expectations are unreliable (§3.1).

Sources

Verification status as of July 2026. Entries under *Verified* were checked against publisher records or indexed metadata and have a `references.bib` entry with a resolved DOI. Entries under *Unverified — trace before citing* are real sources whose full citation has not been confirmed, gray literature (unrefereed reports, tools, fact sheets), or moving conventions — recorded here so the claim can be traced, but they should be handled with care before they appear in a proposal or publication. Gray literature stays in the second block even where its `references.bib` entry is complete: the caution is about the source, not the citation.

Verified

Ecovoltaics

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- Sturchio, M.A. & Knapp, A.K. (2025). Evidence of photovoltaic aridity mitigation in semi-arid grasslands. *Environmental Research Letters* 20(6):064047. DOI 10.1088/1748-9326/add94d.
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- Carvalho, F., Healing, S. & Armstrong, A. (2024). Enhancing soil carbon in solar farms through active land management: a systematic review of the available evidence. *Environmental Research: Ecology* 3(4):042001. DOI 10.1088/2752-664X/ad8ce4. — *source for §6.3's "multi-decade curve is still open" reading: direct long-run soil-carbon measurements at solar farms are scarce. Note the venue — Environmental Research: Ecology, not Environmental Research Letters.*

Design theory the lexicon borrows from

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- Reed, B. (2007). Shifting from 'sustainability' to regeneration. *Building Research & Information* 35(6):674–680. DOI 10.1080/09613210701475753. — *source for the restorative/regenerative distinction behind* **Restorative** *(§8); in Reed's trajectory restorative sits one rung below regenerative, which is the modesty the lexicon keeps deliberately. Verified against Crossref.*

Agrivoltaic typology

- Toledo, C. & Scognamiglio, A. (2021). Agrivoltaic systems design and assessment: a critical review, and a descriptive model towards a sustainable landscape vision (three-dimensional agrivoltaic patterns). *Sustainability* 13(12):6871. DOI 10.3390/su13126871. — *source for pore space and 3D pattern.*
- Vaverková, M.D., Kousal, M., Kosakiewicz, M., Krysiańska, K. & Winkler, J. (2026). Agrivoltaics for sustainable land use: a critical review of synergistic and antagonistic effects. *Renewable and Sustainable Energy Reviews* 226:116482. DOI 10.1016/j.rser.2025.116482. — *source for the elevated / vertical bifacial / tracking / semitransparent typology. A corrigendum (RSER 226:116496, DOI 10.1016/j.rser.2025.116496) corrects this article; confirm any specific figure against it before quoting.*
- Maity, R., Hariram, N.P., Quazi, M.M. & Kumarasamy, S. (2025). Agrivoltaic systems for sustainability: an overview of emerging trends and practices. *Solar Compass* 16:100148. DOI 10.1016/j.solcom.2025.100148. — *source for the livestockvoltaics / crop-based / aquavoltaics / zoovoltaics taxonomy.*
- Oudes, D., van den Brink, A. & Stremke, S. (2022). Towards a typology of solar energy landscapes: mixed-production, nature based and landscape inclusive solar power transitions. *Energy Research & Social Science* 91:102742. DOI 10.1016/j.erss.2022.102742. — *the nearest existing typology of solar energy landscapes; §4.1 positions the farming axis as cutting across its types rather than replacing them.*

Crop response, shade tolerance, and microclimate

- Zhang, W., Hendriks, P.-W., Uchanski, M., Page, S., Renwick, A., Maxwell, T., Kaiser, C., Dong, J. & de Koning, W. (2025). Climatic and design tipping points in agrivoltaic crop production systems. A meta-analysis. *Agronomy for Sustainable Development* 45:69. DOI 10.1007/s13593-025-01060-z. — *source for shade-tolerance responses (physiology-dependent rather than a fixed sensitive/tolerant scheme) and climatic/design tipping points.*
- Weselek, A., Ehmann, A., Zikeli, S., Lewandowski, I., Schindele, S. & Högy, P. (2019). Agrophotovoltaic systems: applications, challenges and opportunities. A review. *Agronomy for Sustainable Development* 39:35. DOI 10.1007/s13593-019-0581-3.
- Barron-Gafford, G.A., Pavao-Zuckerman, M.A., Minor, R.L., Sutter, L.F., Barnett-Moreno, I., Blackett, D.T., Thompson, M., Dimond, K., Gerlak, A.K., Nabhan, G.P.

& Macknick, J.E. (2019). Agrivoltaics provide mutual benefits across the food–energy–water nexus in drylands. *Nature Sustainability* 2:848–855. DOI 10.1038/s41893-019-0364-5.

- Adeh, E.H., Selker, J.S. & Higgins, C.W. (2018). Remarkable agrivoltaic influence on soil moisture, micrometeorology and water-use efficiency. *PLoS ONE* 13(11):e0203256. DOI 10.1371/journal.pone.0203256. — *source for raised water-use efficiency under shaded pasture (§6.1).*
- Wu, C., Liu, H., Yu, Y., Zhao, W., Liu, J., Yu, H. & Yetemen, O. (2022). Ecohydrological effects of photovoltaic solar farms on soil microclimates and moisture regimes in arid Northwest China: a modeling study. *Science of The Total Environment* 802:149946. DOI 10.1016/j.scitotenv.2021.149946. — *modeling counterpart to the measured dryland soil-moisture response in §6.1; results are modeled, not observed.*

Hydrologic function and water budgets (§6.1)

- Yavari, R., Zaliwciw, D., Cibin, R. & McPhillips, L. (2022). Minimizing environmental impacts of solar farms: a review of current science on landscape hydrology and guidance on stormwater management. *Environmental Research: Infrastructure and Sustainability* 2(3):032002. DOI 10.1088/2634-4505/ac76dd. — *source for the infiltration / recharge / stormwater-runoff side of the hydrologic function (§6.1) and for the recharge-enhancement archetype (§7). Formerly listed as unconfirmed; the entry is now complete and cited, and the venue and volume reported here are the confirmed ones.*
- Stid, J.T., Shukla, S., Kendall, A.D., Anctil, A., Hyndman, D.W., Rapp, J. & Anex, R.P. (2025). Impacts of agrisolar co-location on the food–energy–water nexus and economic security. *Nature Sustainability* 8:702–713. DOI 10.1038/s41893-025-01546-4. — *REAL team publication; the demand-side, basin-scale water-saving logic in §6.1 and the water-sustainability archetype (§7).*
- Zwickle, A., Feltman, B.C., Brady, A.J., Kendall, A.D. & Hyndman, D.W. (2021). Sustainable irrigation through local collaborative governance: evidence for a structural fix in Kansas. *Environmental Science & Policy* 124:517–526. DOI 10.1016/j.envsci.2021.07.021. — *REAL team publication; source for the governance condition on a retired-irrigation saving (§6.1, §7) — the saving only counts where it is not pumped elsewhere.*
- Partridge, T., Winter, J., Kendall, A., Basso, B., Pei, L. & Hyndman, D. (2023). Irrigation benefits outweigh costs in more US croplands by mid-century. *Communications Earth & Environment* 4(1):274. DOI 10.1038/s43247-023-00889-0. — *REAL team publication; background on the irrigation economics that the demand-side water case is argued against.*

Solar grazing and vegetation management

- McCall, J., Macdonald, J., Burton, R. & Macknick, J. (2023). Vegetation management cost and maintenance implications of different ground covers at utility-scale solar sites. *Sustainability* 15(7):5895. DOI 10.3390/su15075895. Also NREL/TP-6A20-85418. —

source for §3.1 cost figures. Table 4 reports activity costs by ground cover: median mowing cost was $113/acre/yr ($279/ha) at sheep-grazing sites, $121/acre ($299/ha) at native-vegetation sites, and $203/acre at turfgrass sites; median herbicide at gravel sites was $293/acre ($724/ha); the grazing activity itself had a median of $50/acre/yr. Stewart et al. (2025) relabels the $279/ha mowing figure as "the median cost for sheep grazing" — a transposition; McCall's table is the arbiter.

- Stewart, W.C., Scasta, J.D., Maierle, C., Ates, S., Burke, J.M. & Campbell, B.J. (2025). Vegetation management utilizing sheep grazing within utility-scale solar: agro-ecological insights and existing knowledge gaps in the United States. *Small Ruminant Research* 243:107439. DOI 10.1016/j.smallrumres.2025.107439.
- Andrew, A.C., Antoszewski, K., Goldberg, Z.A., Barter, J., Hain, L., DeSario, A., White, A., Roszell, C., Cole, E., Peterson, S. & Meys, B. (2025). Sheep grazing as sustainable vegetation management for solar energy production in the northeastern USA. *Frontiers in Sustainable Food Systems* 9. DOI 10.3389/fsufs.2025.1625483. — *authorship spans ASGA, American Farmland Trust, and NYSERDA; useful for §4 positioning.*
- Bacon, et al. (2025). Agrivoltaic grazing systems for a sustainable future: a multidisciplinary review and gap analysis. *Earth's Future*. DOI 10.1029/2024EF005429.

Land sharing / land sparing

- Green, R.E., Cornell, S.J., Scharlemann, J.P.W. & Balmford, A. (2005). Farming and the fate of wild nature. *Science* 307(5709):550–555. DOI 10.1126/science.1106049. — *canonical anchor for the sharing/sparing framing in §4.*
- Phalan, B., Onial, M., Balmford, A. & Green, R.E. (2011). Reconciling food production and biodiversity conservation: land sharing and land sparing compared. *Science* 333(6047):1289–1291. DOI 10.1126/science.1208742.

Deployment scale, land use, and cropland displacement

- Kruitwagen, L., Story, K.T., Friedrich, J., Byers, L., Skillman, S. & Hepburn, C. (2021). A global inventory of photovoltaic solar energy generating units. *Nature* 598(7882):604–610. DOI 10.1038/s41586-021-03957-7. — *one of the three sources behind §4's "roughly half of US ground-mounted solar was built on former cropland."*
- Fujita, K.S., Ancona, Z.H., Kramer, L.A., Straka, M., Gautreau, T.E., Robson, D., Garrity, C., Hoen, B. & Diffendorfer, J.E. (2023). Georectified polygon database of ground-mounted large-scale solar photovoltaic sites in the United States. *Scientific Data* 10(1):760. DOI 10.1038/s41597-023-02644-8. — *the USGS site-polygon database underlying the same §4 land-cover figures.*
- Stid, J.T., Shukla, S., Anctil, A., Kendall, A.D., Rapp, J. & Hyndman, D.W. (2022). Solar array placement, electricity generation, and cropland displacement across California's Central Valley. *Science of The Total Environment* 835:155240. DOI 10.1016/j.scitotenv.2022.155240. — *REAL team publication; source for cropland displacement in §4 and for the co-location share read in §4.2. Scope is California's Central Valley, not the nation: where the text carries a US-wide figure it is written as*

an estimate ("on the order of"), and the national land-cover fractions rest on Fujita et al. (2023) and Kruitwagen et al. (2021).

- Hernandez, R.R., Easter, S.B., Murphy-Mariscal, M.L., Maestre, F.T., Tavassoli, M., Allen, E.B., et al. (2014). Environmental impacts of utility-scale solar energy. *Renewable and Sustainable Energy Reviews* 29:766–779. DOI 10.1016/j.rser.2013.08.041. — *source for §8's baseline claim that US arrays are designed primarily to maximize output and minimize cost.*
- Jenkins, J.D., Mayfield, E.N., Larson, E.D., Pacala, S.W. & Greig, C. (2021). Mission net-zero America: the nation-building path to a prosperous, net-zero emissions economy. *Joule* 5(11):2755–2761. DOI 10.1016/j.joule.2021.10.016. — *the peer-reviewed companion to the Net-Zero America report, which is the gray-literature source of the land-area figure in the introduction.*
- Markwith, S. (2025). Solar parking lot capacity: an abundant dual-use alternative to meet demand for the renewable energy transition. *Environmental Research: Infrastructure and Sustainability* 5(1):015004. DOI 10.1088/2634-4505/adaa9a. — *the built-surface alternative to farmland siting; single-author paper.*

Ecosystem services and techno-ecological framing

- Hernandez, R.R., Armstrong, A., Burney, J., Ryan, G., Moore-O'Leary, K., Diédhiou, I., et al. (2019). Techno-ecological synergies of solar energy for global sustainability. *Nature Sustainability* 2(7):560–568. DOI 10.1038/s41893-019-0309-z. — *source for restorative goals as a design objective co-equal with generation (§2), and for the ecovoltaic side of the dual-use dispute (§4) and the brightfield archetype (§7). Also the prior art for §6.5: it sorts techno-ecological outcomes into* sympatric* (overlapping the site of generation) and *disjunct* (spatially separated from it), and assigns each a *serviceshed*, which is the distinction the lexicon relabels as benefit delivery.*
- Randle-Boggis, R.J., White, P.C.L., Cruz, J., Parker, G., Montag, H., Scurlock, J.M.O. & Armstrong, A. (2020). Realising co-benefits for natural capital and ecosystem services from solar parks: a co-developed, evidence-based approach. *Renewable and Sustainable Energy Reviews* 125:109775. DOI 10.1016/j.rser.2020.109775. — *cited as `@boggis2020`; the lead author's surname is Randle-Boggis. Source for §5.2's observation that utility-scale restorative practice is largely ground cover and grazing.*
- Semeraro, T., Scarano, A., Santino, A., Emmanuel, R. & Lenucci, M. (2022). An innovative approach to combine solar photovoltaic gardens with agricultural production and ecosystem services. *Ecosystem Services* 56:101450. DOI 10.1016/j.ecoser.2022.101450.

Community response, siting, and community acceptance (§2, §6.4)

- Moore, S., Graff, H., Ouellet, C., Leslie, S. & Olweean, D. (2022). Can we have clean energy and grow our crops too? Solar siting on agricultural land in the United States. *Energy Research & Social Science* 91:102731. DOI 10.1016/j.erss.2022.102731. — *source for §4's claim that the public argument about solar on farmland is conducted without the axis.*

- Crawford, J., Bessette, D. & Mills, S.B. (2022). Rallying the anti-crowd: organized opposition, democratic deficit, and a potential social gap in large-scale solar energy. *Energy Research & Social Science* 90:102597. DOI 10.1016/j.erss.2022.102597. — *REAL team publication; source for §2's "organized rather than diffuse" local veto.*
- Ryder, S., Walker, C., Batel, S., Devine-Wright, H., Devine-Wright, P. & Sherry-Brennan, F. (2023). Do the ends justify the means? Problematizing social acceptance and instrumentally-driven community engagement in proposed energy projects. *Socio-Ecological Practice Research* 5(2):189–204. DOI 10.1007/s42532-023-00148-8. — *source for §2's warning that benefit offered without a fair process reads as a bribe.*
- Bessette, D.L., Hoen, B., Rand, J., Hoesch, K., White, J., Mills, S.B. & Nilson, R. (2024). Good fences make good neighbors: stakeholder perspectives on the local benefits and burdens of large-scale solar energy development in the United States. *Energy Research & Social Science* 108:103375. DOI 10.1016/j.erss.2023.103375. — *REAL team publication; the burden side of §6.4 — who gains and who bears the costs.*
- Elmallah, S., Hoen, B., Fujita, K.S., Robson, D. & Brunner, E. (2023). Shedding light on large-scale solar impacts: an analysis of property values and proximity to photovoltaics across six US states. *Energy Policy* 175:113425. DOI 10.1016/j.enpol.2023.113425. — *the property-value evidence cited in §6.4; scope is six states, not national.*
- Susskind, L., Chun, J., Gant, A., Hodgkins, C., Cohen, J. & Lohmar, S. (2022). Sources of opposition to renewable energy projects in the United States. *Energy Policy* 165:112922. DOI 10.1016/j.enpol.2022.112922.
- Buckley Biggs, N., Shivaram, R., Acuña Lacarieri, E., Varkey, K., Hagan, D., Young, H. & Lambin, E.F. (2022). Landowner decisions regarding utility-scale solar energy on working lands: a qualitative case study in California. *Environmental Research Communications* 4(5):055010. DOI 10.1088/2515-7620/ac6fbf. — *cited as `@biggs2022`; the lead author's surname is Buckley Biggs. A qualitative California case study — do not generalize the landowner findings nationally.*
- O'Shaughnessy, E., Wiser, R., Hoen, B., Rand, J. & Elmallah, S. (2022). Drivers and energy justice implications of renewable energy project siting in the United States. *Journal of Environmental Policy & Planning* 25(3):258–272. DOI 10.1080/1523908X.2022.2099365. — *published online 2022; the issue is dated 2023, so year-of-record differs by style.*
- Swanson, T., Seay-Fleming, C., Gerlak, A.K. & Barron-Gafford, G.A. (2025). "Enough is enough, we like our farms": the role of landscape ideology in shaping perceptions of solar energy and agrivoltaics in the rural American Southwest. *Journal of Rural Studies* 114:103572. DOI 10.1016/j.jrurstud.2025.103572.
- Pascaris, A.S., Schelly, C., Burnham, L. & Pearce, J.M. (2021). Integrating solar energy with agriculture: industry perspectives on the market, community, and socio-political dimensions of agrivoltaics. *Energy Research & Social Science* 75:102023. DOI 10.1016/j.erss.2021.102023.
- Pascaris, A.S., Gerlak, A.K. & Barron-Gafford, G.A. (2023). From niche-innovation to mainstream markets: drivers and challenges of industry adoption of agrivoltaics in the U.S. *Energy Policy* 181:113694. DOI 10.1016/j.enpol.2023.113694.

Where the terms came from (§8) — traced for the provenance notes on individual glossary entries.

- Goetzberger, A. & Zastrow, A. (1982). On the coexistence of solar-energy conversion and plant cultivation. *International Journal of Solar Energy* 1(1):55–69. DOI 10.1080/01425918208909875. — *the agrivoltaic concept, with its geometry, nearly thirty years before the English word. Often miscited as 1981; the published issue is 1982.*
- Dupraz, C., Marrou, H., Talbot, G., Dufour, L., Nogier, A. & Ferard, Y. (2011). Combining solar photovoltaic panels and food crops for optimising land use: towards new agrivoltaic schemes. *Renewable Energy* 36(10):2725–2732. DOI 10.1016/j.renene.2011.03.005. — *the English coinage of* agrivoltaic, *and what carried the land equivalent ratio into the field.*
- Mead, R. & Willey, R.W. (1980). The concept of a 'land equivalent ratio' and advantages in yields from intercropping. *Experimental Agriculture* 16(3):217–228. DOI 10.1017/S0014479700010978. — *where LER was defined, for intercropping, which is where its assumption of commensurable yields comes from.*
- Taylor, P.D., Fahrig, L., Henein, K. & Merriam, G. (1993). Connectivity is a vital element of landscape structure. *Oikos* 68(3):571–573. DOI 10.2307/3544927. — *landscape ecology's functional sense of* connectivity, *which this lexicon uses unchanged and which collides with both the map-adjacency and the electrical senses.*
- Pacala, S. & Socolow, R. (2004). Stabilization wedges: solving the climate problem for the next 50 years with current technologies. *Science* 305(5686):968–972. DOI 10.1126/science.1100103. — *not a source for anything here; cited because the* feasible wedge *is coined in this document and will be heard against these wedges.*
- Eisenack, K., Oberlack, C. & Sietz, D. (2021). Avenues of archetype analysis: roots, achievements, and next steps in sustainability research. *Ecology and Society* 26(2):31. DOI 10.5751/ES-12484-260231. — *the formal method this lexicon's* archetypes *are deliberately not.*
- Salafsky, N., Salzer, D., Stattersfield, A.J., Hilton-Taylor, C., Neugarten, R., Butchart, S.H.M., Collen, B., Cox, N., Master, L.L., O'Connor, S. & Wilkie, D. (2008). A standard lexicon for biodiversity conservation: unified classifications of threats and actions. *Conservation Biology* 22(4):897–911. DOI 10.1111/j.1523-1739.2008.00937.x. — *the IUCN-CMP conservation actions classification, the nearest prior art for sorting interventions by the instrument that delivers them.*

Regulatory frameworks

- US Department of Agriculture. *Prime and Unique Farmlands*, 7 CFR Part 657 (657.5). https://www.ecfr.gov/current/title-7/subtitle-B/chapter-VI/subchapter-F/part-657 — *the federal definition behind* prime farmland; *a rule rather than a description, and the one glossary term that can by itself stop a project. Current eCFR text as accessed July 2026.*

- McDonnell, N. (2025). The multi-functionality of ecovoltaics: comparative analysis of large-scale solar regulatory frameworks in New South Wales and England. *Journal of Energy & Natural Resources Law* 43(3):401–423. DOI 10.1080/02646811.2025.2540700.

Prairie strips

- Luther, Z.R., Swinton, S.M. & Van Deynze, B. (2022). Potential supply of Midwest cropland for conversion to in-field prairie strips. *Land Economics* 98(2):274–291. DOI 10.3368/le.98.2.082020-0129R1. — *KBS LTER publication.*
- Schulte, L.A., Niemi, J., Helmers, M.J., Liebman, M., Arbuckle, J.G., James, D.E., et al. (2017). Prairie strips improve biodiversity and the delivery of multiple ecosystem services from corn–soybean croplands. *Proceedings of the National Academy of Sciences* 114(42):11247–11252. DOI 10.1073/pnas.1620229114. — *the STRIPS result behind §4's S5 example and the solar-prairie-strips archetype (§7); previously recorded only inside the §7 exemplar note below.*

Land-use allocation and multi-use synthesis

- Merheb, C., Macknick, J., Davatzes, N. & Ravi, S. (2025). Synergies and trade-offs of multi-use solar landscapes. *Nature Sustainability* 8:857–870. DOI 10.1038/s41893-025-01600-1. — *the field's umbrella review; source of the* multi-use solar *term and its three-way split into agrivoltaics, rangevoltaics, and ecovoltaics (§8), the temperature-dependent shade–yield synthesis (n = 367) behind §4 and §2.3, the grazing species-compatibility findings (§3.1), and the grassland soil-carbon-debt caution (§6.3).*
- Sturchio, M.A., Gallaher, A. & Grodsky, S.M. (2025). Ecologically informed solar enables a sustainable energy transition in US croplands. *Proceedings of the National Academy of Sciences* 122(17):e2501605122. DOI 10.1073/pnas.2501605122. — *the corn-ethanol land-efficiency and nutrient-load argument behind §4's S5 case and §6.1; also the ecovoltaic siting tenet of avoiding intact native ecosystems (§8).*
- Gallaher, A., Koch, T., Kalies, E.L., Woodbury, P.B. & Grodsky, S.M. (2026). Sustainability trade-offs at the nexus of solar energy, agriculture, and biodiversity. *Geography and Sustainability* 7:100483. DOI 10.1016/j.geosus.2026.100483. — *the New York State optimization behind §4's displacement boundary, §2.2's 0.17% cost result, and §2.3's prior-land-cover contrast.*
- Brock, C., Roehrdanz, P.R., Beringer, T., Chaplin-Kramer, R., Enquist, B.J., Frazier, A.E., et al. (2026). Balancing land use for conservation, agriculture, and renewable energy. *Nature Communications* 17:3623. DOI 10.1038/s41467-026-69952-6. — *global multi-sector land allocation; cited in §9 for its explicit inability to represent co-location, which is the space this lexicon describes.*

Siting drivers and land-class economics (§5.2)

- Wu, G.C., Min, Y., Deshmukh, R., Cartwright, P., DeCesaro, J., Kerstan, D., Somasundaram, D. & Strecker, H. (2026). Factors shaping the siting of utility-scale solar and wind projects in the United States. *Environmental Research Letters* 21(9):094003. DOI 10.1088/1748-9326/ae5faa. — *what utility-scale siting actually responds to: roads, transmission, substations, population density, non-forested cover, flatter terrain. Cited for the mechanism behind assembly-driven placement. Note the limit: the study uses a 1 MW floor and treats each project as one observation, so it does not test whether siting drivers differ by project size, and cannot on its own support the contrast this document draws with smaller projects.*

Design theory borrowed from architecture (§1)

- Brand, S. (1994). *How Buildings Learn: What Happens After They're Built.* Viking, New York. — *the shearing-layers argument, after Frank Duffy: a building is several layers of differing longevity, and a design works when the fast layers can move without tearing the slow ones. The lexicon borrows the pattern rather than the layers, to explain why management is both the most powerful lever at utility scale and the most fragile.*
- Habraken, N.J. (2002). The uses of levels. *Open House International* 27(2). — *open-building levels, each with its own decision-maker. Originally a keynote to the UNESCO Regional Seminar on Shelter for the Homeless, Seoul 1988, and re-issued in 2002; cite the 2002 re-issue and note the 1988 delivery. The source for the claim that a decision category implies a decider, which is the ownership lever stated as design theory.*

Permanent-crop agrivoltaics (§7, emerging)

- Yu, L. et al. (2022). Rain shelter cultivation and downy mildew in table grape. *Plants.* — *leaf wetness duration down 85% and 76%, downy mildew delayed 28 and 21 days, disease index down 82–83%. A plastic rain shelter, not PV. Volume and DOI unconfirmed; trace before citing.*
- Scalisi, A. et al. (2026). Overhead photovoltaic shading of blush pear, Victoria, Australia. *Horticulturae.* — *four seasons; sunburn 7.0% control against under 1.2% shaded in the hottest season. Volume and DOI unconfirmed; trace before citing.*
- Caravia, L., Collins, C., Petrie, P.R. & Tyerman, S.D. (2016). Shade treatments during Shiraz berry ripening. *Australian Journal of Grape and Wine Research.* — *62% overhead shade lowered alcohol without significant anthocyanin loss; the Brix drop reflects preserved turgor rather than delayed ripening. Volume and DOI unconfirmed; trace before citing.*
- Haidegg agri-PV orchard, Styria, Austria (340 kWp; apple, pear, cherry, apricot, peach, plum). Austrian Klima- und Energiefonds final report. — *the source for two corrections in §7: metal flashing between modules was necessary before rain protection appeared, and after the 2023 and 2024 hail seasons the array did not protect the orchard beneath, deflecting stones into the next row. German-language project reporting, not peer-reviewed; trace before citing.*
- Fraunhofer ISE apple agri-PV, Gelsdorf, Rhineland-Palatinate (258 kWp, eight varieties, five variants including hail-net and foil-roof controls). — *the trial designed to separate shelter from shade. Published output so far is electrical; agronomic results not yet*

available. The widely quoted "70% less pesticide" belongs to a different site, Obsthof Bernhard at Kressbronn, and is attributed there to reduced leaf wetness.

- Elamri, Y. et al. (2018). *Hydrology and Earth System Sciences. — at about 30% panel cover, rainfall redistribution gave a coefficient of variation of 2.13, with the dripline collecting roughly eleven times the control depth. The basis for the claim that a sparse array redistributes rain rather than excluding it. Trace before citing.*

Unverified — trace before citing

- **Current build-out figures on the landing page.** The counts used in the introduction — roughly 15,000 ground-mounted arrays over some 3,000 km², about half of it former cropland and another third agricultural grassland, and agrivoltaics at under two percent of built practice — are as-stated in this group's REAL vision draft, which cites a cluster of sources for them. They are attributed here to Stid et al. (2022) and Sturchio et al. (2025) as the nearest fit, and **that attribution has not been checked claim by claim**. Confirm which figure comes from which source before any of them appears in a proposal or paper, and re-check the totals: installed capacity and area both move every year.
- **"Utility-scale" as a definitional convention, not a single threshold.** No one primary document fixes the cutoff. SEIA/EIA usage commonly treats projects above ~1 MW as utility-scale, while NREL and LBNL analyses generally use a ~5 MW(AC) floor; other market and regulatory definitions vary more widely. The lexicon uses the term as a rough band, not a fixed number — the specific MW figures are conventions to be checked against whichever edition is finally cited (needs-verification). Anchor documents: SEIA "Land Use & Solar Development" (seia.org) and the LBNL/NREL *Utility-Scale Solar* report series (emp.lbl.gov).
- **Kochendoerfer, N., Hain, A. & Thonney, M.L. (2019).** The agricultural, economic and environmental potential of co-locating utility-scale solar with grazing sheep. Atkinson Center for a Sustainable Future, Cornell University, Ithaca, NY. — *research report / gray literature (no DOI); title and author trio traced via the Cornell grazing-program publications page. Not promoted to the peer-reviewed tier.*
- **Bock Agricultural Law and Policy Program, University of Illinois (2023).** The Economics of Solar Grazing. Survey conducted early 2023, distributed via the American Solar Grazing Association with NREL support. — *traced gray literature (non-peer-reviewed); cite the program report directly rather than pv-magazine trade coverage. Specific per-operation figures (e.g., ~55 acres / 125 sheep) not confirmed against the primary report — verify before citing.*
- **Hartman, D. (2026).** Sheep grazing to maintain solar energy sites in Pennsylvania. Penn State Extension (updated 13 April 2026). — *extension guidance / gray literature; source for §3.1's Northeast stocking line — "for mature ewes, experience in New York and Michigan indicates that a typical stocking rate is 3 ewes/acre."*

- **Center for Rural Affairs (2025).** Opportunities for solar energy on marginal agricultural lands [fact sheet]. Lyons, NE; released March 2025, institutionally authored (no individual byline — do not supply one). — *gray literature (cfra.org).*
- **Michigan State University / KBS LTER (2024).** Prairie strips partial budget tool [Excel tool], accompanying the "Budgeting for prairie strips" bulletin (MiSTRIPS program). — *gray literature / tool; the bulletin date (reported 10 June 2024) and MiSTRIPS attribution are not independently confirmed — verify before citing.*

Program and agency literature now in `references.bib` — these entries are complete and citable; they sit in this block because they are gray literature (unrefereed program reports and agency pages), not because the citation is in doubt.

- **Larson, E., Greig, C., Jenkins, J., Mayfield, E., Pascale, A., et al. (2021).** *Net-Zero America: Potential Pathways, Infrastructure, and Impacts.* Princeton University (netzeroamerica.princeton.edu). — *source for the 60,000–90,000 km² land-area figure in the introduction; a university research report, not a refereed paper. The peer-reviewed companion is Jenkins et al. (2021), listed above.*
- **Macknick, J., Hartmann, H., Barron-Gafford, G., Beatty, B., Burton, R., et al. (2022).** *The 5 Cs of Agrivoltaic Success Factors in the United States: Lessons From the InSPIRE Research Study.* NREL/TP-6A20-83566, Golden, CO. DOI 10.2172/1882930. — *NREL program report; source for the utility-scale ground-cover-and-grazing pattern (§5.2) and for the co-location share in §4.2. Widely used, but a program output rather than a refereed synthesis.*
- **Electric Power Research Institute (2021).** *Pollinator-Friendly Solar Scorecards: Comprehensive Analysis of Scorecard Attributes.* EPRI 3002022121, Palo Alto, CA. — *source for the offtake-conformity pressure (§2) and for §6.2's point that scorecard programs differ in what they credit; institutionally authored (no individual byline — do not supply one).*
- **Bessette, D.L., White, J., Mills, S.B., Hoen, B., Rand, J., Nilson, R. & Hoesch, K. (2024).** *Supporting community-centered solar development: a guide to hosting community conversations about large-scale solar development.* Michigan State University & Lawrence Berkeley National Laboratory (CCSD guidebook). — *REAL team publication; the community-benefit guidance behind §6.4, which the chapter is careful to label gray literature.*
- **Gagnon, P., Margolis, R., Melius, J., Phillips, C. & Elmore, R. (2016).** *Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment.* NREL/TP-6A20-65298, Golden, CO. DOI 10.2172/1236153. — *the rooftop alternative to ground-mount siting; a 2016 assessment, so check it against a current edition before quoting a number.*
- **U.S. Energy Information Administration (2024).** Today in Energy: solar and battery storage to make up 81% of new US electric-generating capacity in 2024 (eia.gov). — *agency web page; a single-year projection that is superseded annually — re-check the current release before citing.*

Land-class cost premiums (§5.2)

- Owusu-Obeng, P.Y., Shi, M., Vanatta, M. & Craig, M.T. (2025). *Beyond Prime Farmland: Solar Siting Tradeoffs for Cost-Effective Decarbonization.* arXiv:2511.07323. — *greenfield and prime agricultural land give the lowest levelized cost, roughly $39–57/MWh, while contaminated land carries a 14–33% premium and limited technical potential. The source for the claim that the ground restoration most wants taken is the ground a cost model most wants avoided. Preprint, not peer-reviewed; trace to the published version before citing.*

Landscape-architecture prior art on maintenance (§1)

- Douglas, S. & Deming, M.E. (2015). *From the Field: Maintenance, the Missing Link.* Landscape Architecture Foundation, Case Study Investigation. https://www.lafoundation.org/news/2015/06/csi-uiuc — *the field named this before the lexicon did: parts of many projects fail in the first year or two because maintenance staff have no voice during design and the designer's scope ends at the final walkthrough. Cited for that priority. Professional-foundation web article, unrefereed and undated on the page beyond its URL; trace to a dated version before citing in a paper.*

Working-landscapes framing (§6) — still not in `references.bib`

- **Corridor and connectivity experiments (Haddad and colleagues).** The claim in §6.2 that connected patches exchange more individuals and accumulate more species than isolated patches of equal area rests on the long-running corridor experiments in fragmented landscapes, with butterflies as the model organism for movement. The best-known are sited at the Savannah River Site. **No citation is given in `references.bib` yet and none of the specific results are quoted here**, precisely because the primary papers have not been checked from this environment; the paragraph is written to the shape of the finding rather than to any number. Trace and cite the primary experiments before this passage is used anywhere it matters.
- **Kremen, C. (2015).** Working-landscapes framing behind the archetype × function matrix — reframing the land-sparing/land-sharing debate for biodiversity conservation. Venue (reportedly *Annals of the New York Academy of Sciences*) and full citation **unconfirmed**; trace before citing.
- **Grass et al. (2019).** Working-landscapes / connectivity framing (land-farming axis for ecosystem services and biodiversity), reportedly *People and Nature*. Full citation **unconfirmed**; trace before citing.

Archetype exemplars (the Application: cases in §7) — real projects, mostly documented in developer pages, NGO case studies, and extension case studies (gray literature); trace named figures to these before citing.

- **Barnyard Shelter Solar — WCROC dairy**, University of Minnesota West Central Research and Outreach Center, Morris, MN (30 kW ground-mount raised over pasture, 2018, shading 30–40 grazing cows and serving the milking parlor; later 240 kW and 500 kW additions). Clean Energy Resource Teams and WCROC renewable-energy program pages; gray literature — trace the capacity figures before citing. Peer-reviewed heat-abatement evidence: Sharpe, K.T. et al. (2021), Evaluation of solar photovoltaic systems to shade cows in a pasture-based dairy herd, *Journal of Dairy Science* 104(3):2794–2806 (DOI 10.3168/jds.2020-19274) — shaded cows showed lower body temperature and reduced respiration rate; not in `references.bib`. Poultry variation: Technique Solaire / INRAE photovoltaic-aviary trials, Lot-et-Garonne, France (PV shelters linked by nets; birds range farther and longer under cover) — developer/press reporting, *trace before citing.* Practitioner framing: Center for Rural Affairs, "cattle-voltaics" fact sheet.
- **Perennial Crop Canopy — Maces Pond**, Rockport, ME (4.2 MW on ~10 acres of wild blueberry; built 2021, developed by BlueWave, owned by Navisun, EPC by CS Energy; ~5 acres given to a University of Maine dual-use study under Lily Calderwood running three construction treatments, with the early result that the stand recovered best where construction took the most care). Developer and trade reporting plus UMaine Extension pages; capacities as-reported, *trace before citing.* Tall-canopy variants at the other end of the same form: Colorado State University's chardonnay plot at Grand Junction and a peach-orchard installation at Talbott Farms, both press-reported only, *trace before citing.* Peer-reviewed protection evidence: Scalisi et al. (2026) (apple sunburn), Caravia et al. (2016) (acidity via turgor), Yu et al. (2022) (rain exclusion does not carry from continuous covers).
- **Vegetable Agrivoltaics — Jack's Solar Garden**, Boulder County, CO (1.2 MW single-axis tracking, ~4 acres; chard, greens, and tomatoes grown by partner farmers). NREL / InSPIRE, Colorado State, and University of Arizona research site; NCAT AgriSolar Clearinghouse case study. Dryland shade-benefit evidence: Barron-Gafford et al. (2019).
- **Marginal Land Solar — Cozy Cove Farm**, Gurley, AL (50 kW / 208 panels, elevated ~7 ft, TVA offtake). NCAT AgriSolar Clearinghouse case study.
- **Solar Prairie Strips — Ramsey Renewable Station** (Connexus Energy), Ramsey, MN. Fresh Energy case study and the DOE **PV-SMaRT** project (University of Minnesota stormwater modeling); the no-detention-basin result is from PV-SMaRT modeling. Prairie-strip science (the STRIPS project, Iowa State): Schulte et al. (2017), now a full entry under **Prairie strips** above.
- **Regenerative Solar Grazing — Aurora Solar**, Minnesota (150 MW-dc, 16 sites, operational 2017). Enel Green Power project page; Fresh Energy case study; NREL InSPIRE pollinator research. Soil gains under managed solar native cover: Krasner et al. (2025).
- **Retired-Irrigation Solar — Westlands Solar Park (demand side) & Pivot-Corner Recharge, High Plains (supply side).** Arid / demand: Westlands Water District Valley Clean Infrastructure Plan, repurposing up to ~136,000 acres of drainage-impaired, previously-irrigated San Joaquin Valley land to solar under SGMA — PPIC,

Solar Energy and Groundwater in the San Joaquin Valley (ppic.org). Semi-arid / supply: solar in center-pivot corners for Ogallala recharge — Kansas Geological Survey / Kansas State / Michigan State (FFAR-funded). Both *trace before citing*; the peer-reviewed anchor for the demand-side water saving is Stid et al. (2025), listed above.

Regionality (§2.3) — every figure in that chapter, assembled from secondary and program sources and *not* checked against primary records. The chapter says so in its own evidence-status note. Each item below names where the number came from and where it should be traced.

- **Solar resource ranges.** NREL's National Solar Radiation Database and solar resource maps (nrel.gov, nsrdb.nrel.gov) are the primary product — satellite-derived GHI/DNI/DHI at ~4 km. The ranges quoted (roughly 5.5–6.5 kWh/m^2/day GHI in the desert Southwest, 3.5–4.5 in the Northeast and Pacific Northwest, 4–6 across most of the country) are from secondary summaries of those products. Read the NSRDB directly before quoting a number for a specific place.
- **Interconnection queues and curtailment.** Berkeley Lab's *Queued Up* series (emp.lbl.gov) is the primary source for queue volumes, and the ISO/RTO market-monitor reports for curtailment. The magnitudes used here — MISO carrying 170+ GW awaiting interconnection, ERCOT 2,000+ active requests, SPP curtailment up roughly sixfold since 2020, a comparable jump in PJM in 2024 — come from 2025 trade and consultancy commentary rather than those primary datasets. Trace before citing.
- **Community-solar capacity by state.** ILSR's Community Solar Tracker (ilsr.org) and Wood Mackenzie/SEIA market reports. The figures used (New York ~2.6 GW$_{ac}$; Maine, Minnesota, and Massachusetts each near 0.9–1.0 GW; Illinois well below; Maine's program closing at the end of 2025) are as-reported in trade coverage, and state program status changes fast enough that any of them may be stale by the time it is read.
- **Aridity and the sign of the shade effect.** The direction of this claim is supported by sources already in the verified list (Barron-Gafford et al. (2019), Sturchio and Knapp (2025), Knapp and Sturchio (2024)). The added specifics — irrigation savings of 30–40% in arid agrivoltaic settings, mixed-to-negative yield outcomes for staple grains in humid settings, relief of midday depression in drylands — come from recent reviews and a 2025 *npj Sustainable Agriculture* paper on dryland midday depression whose full citation is **unconfirmed**. Trace before citing.
- **Latitude and ground coverage ratio.** Reported thresholds — fixed-tilt reaching ~0.55 GCR within 2.5% shading loss at lower latitudes, tracked ~0.22 and vertical ~0.10 at the same loss, guidance spanning 17°N–75°N, bifacial wanting slightly lower GCR than monofacial — are from a 2023 *Solar Energy* paper on optimal ground coverage ratios for latitudes to 75°N. Author list, volume, and DOI **unconfirmed**.
- **USDA Farm Resource Regions.** USDA Economic Research Service, *Farm Resource Regions*, Agricultural Information Bulletin No. 760 (ers.usda.gov) — nine regions built from county-level commodity specialization. The regional characterizations used here are from ERS chart-gallery summaries rather than the bulletin text; read the bulletin

before quoting shares.

- **Where agrivoltaic practice actually is.** NREL/InSPIRE agrivoltaics map and the OpenEI dataset: roughly 596 sites, 65,699 acres, and 10,473 MW identified as of early 2025, with grazing concentrated in Massachusetts, New York, and California, pollinator habitat in Minnesota and Illinois, cropping in the Northeast, West Coast, and Colorado, and greenhouses in Colorado, California, and Georgia. As-reported; the tallies move as the database updates.
- **SGMA and San Joaquin Valley acreage.** PPIC's San Joaquin Valley water and land-transition work (ppic.org), already cited for the Westlands case in §7 — at least 500,000 acres (about a tenth of valley cropland) potentially leaving irrigated production, and up to ~136,000 acres in the Westlands Valley Clean Infrastructure Plan.
- **Ogallala.** Roughly 13.6 million irrigated acres and water-table declines of 100–200 ft in the thinner southern reaches. These figures circulate widely in secondary coverage; USDA Climate Hubs and the Kansas Geological Survey are where to trace them.

Design typologies & program frameworks (§6–§7) — standards and program literature acknowledged in the terminology; trace to the current edition before citing.

- **DIN SPEC 91434 (2021).** *Agri-Photovoltaic Systems — Requirements for Primary Agricultural Use.* Beuth/DIN, Berlin. — source for the **overhead** (Category I, elevated) vs. **interspace** (Category II, ground-level between rows) structural typology in §7; a German technical specification, not a peer-reviewed source — verify category wording against the standard.
- **Fraunhofer ISE.** *Agrivoltaics: Opportunities for Agriculture and the Energy Transition* (guideline). Freiburg. — widely-cited design guideline; edition/year moves (2020, updated) — confirm the edition before citing.
- **NREL / DOE InSPIRE** (Innovative Site Preparation and Impact Reductions on the Environment). *Low-Impact Solar Development* resources and the agrivoltaics research library, openei.org / nrel.gov. — program source for the "low-impact solar development" framing (§6) and the configuration taxonomy; gray literature / program output. The InSPIRE synthesis that is in `references.bib` is Macknick et al. (2022), above.
- **NCAT AgriSolar Clearinghouse** (agrisolar.org). DOE SETO-funded. — existing usage of "agrisolar" (§8) and the source of several §7 exemplar case studies; gray literature.
- **US EPA RE-Powering America's Land** (epa.gov/re-powering). — federal program siting renewables on contaminated land, landfills, and mine sites; background for the marginal / brightfield land vocabulary (§8) and the Brightfield archetype (§7); gray literature.
- **Ecosystem services — regulating & supporting.** The restorative-functions framing (§6) parallels the ecosystem-services categories of the Millennium Ecosystem Assessment (2005) and later national ecosystem assessments. Named for orientation, not cited for a specific figure; use a current assessment if a formal citation is needed.

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Index — Alphabetical

Every defined or coined term in the lexicon, ordered A–Z. This is the alphabetical view of the Terminology chapter (§8), which holds the same set grouped by subject. Use this one when you know the word, that one when you want the neighborhood it belongs to.

Each entry gives a short gloss and two links: **§8** for the definition, and, where a chapter develops the term, the section that does so. The built-in site search (top of every page) complements both, since search finds a word anywhere in the prose, while this list is the curated set of terms the document actually defines.

Zone codes **A0–A5** are grouped under **A**; farming axis positions **S1–S5** under **S**.

A

Agriculture and soils function — restorative function: what the array does for farming, on its ground and the fields around it, via pollination, pest regulation, forage and shelter, and the lease that keeps the operation running; not the farming axis restated — Terminology · Agriculture and soils

Agrisolar — agroenergy specific to photovoltaics; the lexicon's working umbrella (after NCAT's AgriSolar Clearinghouse usage), broadened to be neutral across the farming axis — Terminology

Agrivoltaics — crop or livestock production within the array footprint (S1–S2); *cf.* agrophotovoltaics, photovoltaic agriculture — Terminology

Agroenergy — energy infrastructure designed to interact intentionally with agricultural or ecological land function; umbrella term — Terminology

Archetype — a way the design pressures have been resolved at a particular scale zone and sharing position — Terminology · Archetypal Forms

B

Bare conversion — ordinary ground converted with the farm operation ended: the same ground fact as S3 without the restorative one. The non-restorative baseline the axis is read against, not a position on it — Terminology · The positions

Benefit delivery — which route a function's benefit takes to whoever receives it: in place, along a connection (water, living things, or institutions), or by preservation; the route, not the distance, decides who can check the claim — Terminology · Where benefits are delivered

C

Carrying capacity — season-long forage the land sustains over time; a grazing design variable — Terminology · Worked example: grazing

Coexistence — retired as a position name; *see* S3 — Ordinary-land siting, the center of the farming axis, neither sharing nor sparing — Terminology · The positions

Co-benefit — the field's usual word for a restorative function; recorded but not adopted, because its grammar demotes what it names to something arriving alongside the real objective — Terminology

Co-location — panels and a land use share a parcel without functional interdependence; *cf.* integration — Terminology

Community & economic function — the socioeconomic restorative function: durable local income, livability, and whether the burdens and the benefits land on the same people, built for the host community; the outcomes footprint's Communities domain read as an outcome, distinct from the social-license pressure and community-benefit lever — Terminology · Community and economy

Community acceptance and benefit — design pressure: secure and sustain community acceptance *and* community benefit — two forces that can come apart, held in one pressure — Terminology · The pressures

Community Benefit — instruments returning value to the host community (CBA/HCA, PILOT, good-neighbor payments, community-solar subscription, co-ownership, decommissioning bond); distinct from acceptance — Terminology

Connectivity — whether organisms can move into, through, and out of a site; designed at four scales, from fencing and mown strips to whether a regional fleet falls within dispersal distance — Terminology · Ecology

Contract grazing — grazing delivered as a contracted vegetation-management service by a party who does not live on site — Terminology · Worked example: grazing

Contract-led — restoration mode: the work is done in the lease, the ordinance, or the benefit agreement rather than anywhere on the site; the mode the community and economic function runs on — Terminology · Community and economy

Cost and financing — design pressure: minimize what the project costs to build and what it costs to finance — Terminology · The pressures ## D {.unnumbered}

Decommissioning / Repowering / Reversibility — end-of-life questions: removing and restoring, replacing modules, and how completely the prior land use can return — Terminology

Delivery by preservation — the mode in which nothing moves and the benefit is ground nearby that stayed as it was; proximate, because development pressure is local, but counterfactual rather than observed — Terminology · Where benefits are delivered

Design import — the characteristic regional failure: carrying a resolution from the region where it was demonstrated into one whose factors differ; grid and market demands is the usual vehicle — Terminology · What follows

Design levers — the six kinds of decision a project can make, and the only things anyone can change: scale, siting, structure, management, ownership, contracts — Terminology · Design Levers

Design pressures — the competing forces every site must resolve; unlike axes they have direction, conflict, and advocates — Terminology · Design Pressures

Design tension — what a resolution of the design pressures leaves unresolved; never nil, so the question is how much remains and who carries it, and the settings that leave least are the ones that recur — Terminology · Where the pressures collide

Diffuse fraction — the share of irradiance arriving as diffuse rather than direct-beam light; higher under cloud, non-directional, and most of what a ground layer lives on — Terminology · Six factors

Dual Use — production-based criterion: active agricultural production in the footprint across the project life (AFT's definition); S1–S2 — Terminology

E

Ecological function — restorative function: what can live on the ground and what can move through it; habitat from the ground layer up, plus connectivity — Terminology · Ecology

Ecovoltaics — solar development incorporating ecological understanding into array design and management, co-prioritizing ecosystem function with generation; its ecological ground layer is a restorative function rather than an axis position, most often built at S3 — Terminology

End-of-life responsibility — a design pressure: minimize the residual footprint and preserve the option to return the ground to its prior use — Terminology · The pressures

Energy yield — design pressure: maximize energy per unit land — Terminology · The pressures

F

Feasible wedge — the feasible region across scale and sharing: the sharing edge runs flat across the whole transect, the sparing edge opens with scale, and only S4 thins toward A5 — Terminology · Which positions scale allows

Footprint — land physically occupied by racking, panels, and access infrastructure; paired with influence zone — Terminology

G

Grid and market demands — design pressure: satisfy the criteria of whoever buys the power, attributes, or tax position — Terminology · The pressures

Ground Coverage Ratio (GCR) — ratio of module area to ground area; the array's density; the number behind the row-geometry ground-layer coupling — Terminology

Ground Layer — whatever occupies the surface beneath and between panels; primary carrier of restorative function; *syn.* understory, ground cover — Terminology

H

Hydrologic function — restorative function: water quantity (infiltration, recharge, soil moisture, and at scale consumptive use retired from a basin's budget) and water quality by two routes needing opposite ground, avoided loading on the ground that leaches and interception on the flow path below it — Terminology · Water

I

Influence Zone — the larger, typically asymmetric area whose hydrology, microclimate, soil, or wildlife movement is measurably affected — Terminology

Integration — functional interdependence — panel height set by livestock clearance, spacing by forage light, tracking by photosynthetic timing — Terminology

L

Land Equivalent Ratio (LER) — standard dual-use productivity metric; handles the non-production ground layers of S3–S5 poorly — Terminology

Land sharing — production continues on the ground the array occupies; the sharing wing of the axis (S1–S2). Borrowed from conservation ecology — Terminology · The Farming Axis

Land sparing — ground comes out of production so other ground can be left alone; the sparing wing of the axis (S4–S5). Borrowed from conservation ecology — Terminology · The Farming Axis

M

Management-led — restoration mode: placement is a given; ground cover, grazing regime, and operational schedule carry everything — Terminology · The five modes

Marginal / Previously Disturbed Land — the low-value ground that low-productivity siting (S4) presupposes: low-yielding cropland, reclaimed mine land, landfills, brownfields ("brightfields") — Terminology

Module Technology — the panel as a lever: monofacial/bifacial, vertical bifacial, semitransparent, spectrally selective — Terminology

Multi-use solar — the field's competing umbrella (Merheb et al. 2025), covering agrivoltaics, rangevoltaics, and ecovoltaics; narrower than *agrisolar* as used here, which also covers S3–S5 — Terminology

O

Operations and maintenance — design pressure: minimize management burden across a 25–40 year asset life — Terminology · The pressures

Overhead and interspace systems — the engineering standards' hardware typology (DIN SPEC 91434; NREL/InSPIRE): modules above the working surface, or low with the crop between rows; classifies structure, where an archetype classifies the resolution of pressures — Terminology · Archetypal Forms

Ownership-led — restoration mode: the work is done by who holds the asset, with no agreement needed because the parties were never opposed; strongest at A1–A2 and unavailable once the owner is absentee — Terminology · The five modes

P

Policy and permission — design pressure: satisfy the rules that decide whether the project happens at all, and the subsidies that decide what pays; the one pressure whose direction the jurisdiction sets — Terminology · The pressures

Pore Space — the three-dimensional volume between modules and between modules and ground; frames clearance as habitat and working space — Terminology

R

Rangevoltaics — grazing under and between the panels, S1 on ground that was already pasture and S2 on former cropland; the field's ecological-literature name for solar grazing, workable with sheep but not with goats, cattle, or horses; *syn.* solar grazing — Terminology · Worked example: grazing

Regional calibration — a restatement of the lexicon's indicative values for a particular region: capacity bands, absent zones, the binding constraint, the positions realistically open — Terminology · A worked calibration

Regional factors — the six spatial factors a region is read by: resource, grid operator, aridity, latitude, cropping system, irrigation — Terminology · Six factors

Regionality — the claim that the design pressures resolve differently in different places, because the factors that weight them vary across space; the vocabulary is constant, the weights are not — Terminology · The same pressures, weighted by place

Restoration mode — which design lever carried the restorative work — Siting-led, Structure-led, Management-led, Ownership-led, or Contract-led — Terminology · The five modes

Restorative — the frame of the whole lexicon: ground-layer function as a design objective co-equal with generation — Terminology

Restorative goals — design pressure: make ecological, hydrological, and economic resilience co-equal with generation — Terminology · The pressures

Restorative function — a restorative capacity a project can be designed to deliver, reachable across many structural positions; two biophysical (water, ecology) plus one agricultural (agriculture and soils) and one socioeconomic (community and economy) — Terminology · Restorative Functions

S

S0 — Created agriculture — a farm takes something off ground that carried no agricultural use before the array; the one position that records a use beginning rather than one displaced — Terminology · The positions

S1 — Primary agriculture — the agricultural use continues essentially as it was, with the array added over or between it — Terminology · The positions

S2 — Secondary agriculture — a farm still works the ground, at a lower value than it carried before; grazing on former cropland, forage, hay, hives — Terminology · The positions

S3 — Ordinary-land siting — neither sharing nor sparing: the array takes ordinary ground outright and the revenue sustains the farm enterprise holding it, so the restoration is socioeconomic rather than biophysical; the center of the axis — Terminology · The positions

S4 — Low-productivity siting — the array takes ground already idle, marginal, or chronically low-yielding, so nothing in production was displaced to build it; arrays on buildings take no ground and hold no position (A0) — Terminology · The positions

S5 — Impaired-land siting — the array takes ground that carried a measurable off-site burden (low yields, high runoff, nutrient export, irrigation draw beyond the aquifer's budget), or that sits where such a burden can be intercepted — Terminology · The positions

outcomes footprint — a whole-project reading across four domains (Communities, Agriculture, Water, Ecology), each running from causing harm at the center, through avoiding harm, out to promoting benefit at the rim; the ring is a zero point, not a pass mark — Terminology · The outcomes footprint

Scale Transect — a single gradient from farmstead to complex that most other terms are read against; defined by covarying bundles, not capacity — Terminology · The Scale Transect

Screening — management of the array's outward visual presence (setbacks, buffers, berms, fencing, glint/glare); acts on the visual portion of the influence zone; dual-function — Terminology

Setback — the ground held open between the array and the property line, road, or dwelling; the dimension local ordinances fix most often, and where screening gets planted — Terminology

Siting Axis — retired as the axis name; *see* Farming Axis — Terminology · The Farming Axis

Farming Axis — the scale-orthogonal dimension: whether the array shares land with production (*land sharing*), spares land by taking ground out of it (*land sparing*), or neither; five positions centered on S3 — Terminology · The Farming Axis

Siting latitude — the designer's freedom over where the array goes; peaks at A2–A3, bounded by the parcel at A1 and by the land market and grid topology at A5 — Terminology · Scale constrains design leverage

Siting-led — restoration mode: the restorative work is done by the choice of ground; requires A2–A3 latitude — Terminology · The five modes

Solar grazing — *see* Rangevoltaics — Terminology

Stocking density — instantaneous animals per unit area at a moment; diverges from carrying capacity — Terminology · Worked example: grazing

Structure-led — restoration mode: array geometry is the instrument — clearance, row spacing, module transmissivity — Terminology · The five modes

T

Tracking Schedule & Curtailment — operational-regime levers: how the array is steered through the day, and deliberate output reduction — Terminology

V

Viewshed — the ground from which the array can be seen; the part of the influence zone that reaches people rather than water, soil, or wildlife, and what screening acts on — Terminology