SOLAR CONTRACTS AND ASSOCIATED ECONOMICS

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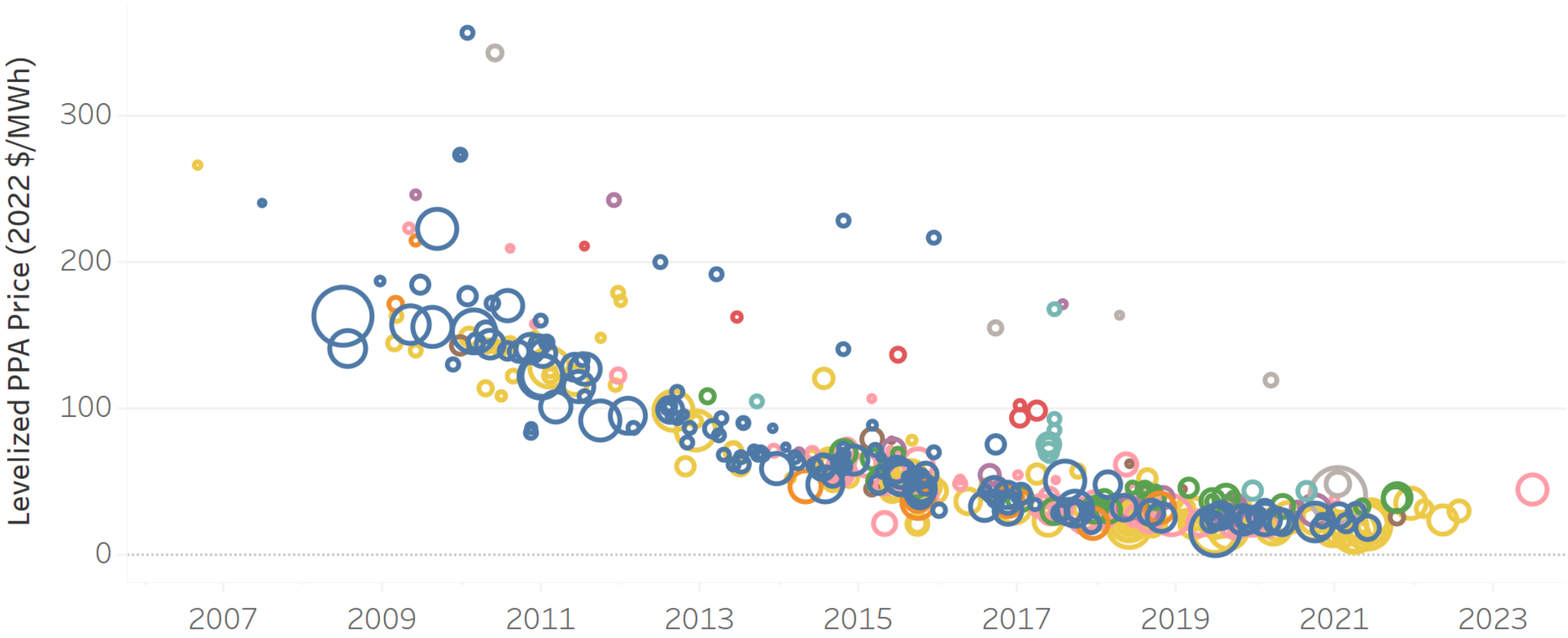
Analysis part of NSF-funded project lead by Dr. Rakesh Agrawal, and including Mitch Tuinstra, Peter Bermel, Margaret Gitau, and Jonathan Turnley.

Outline of Presentation

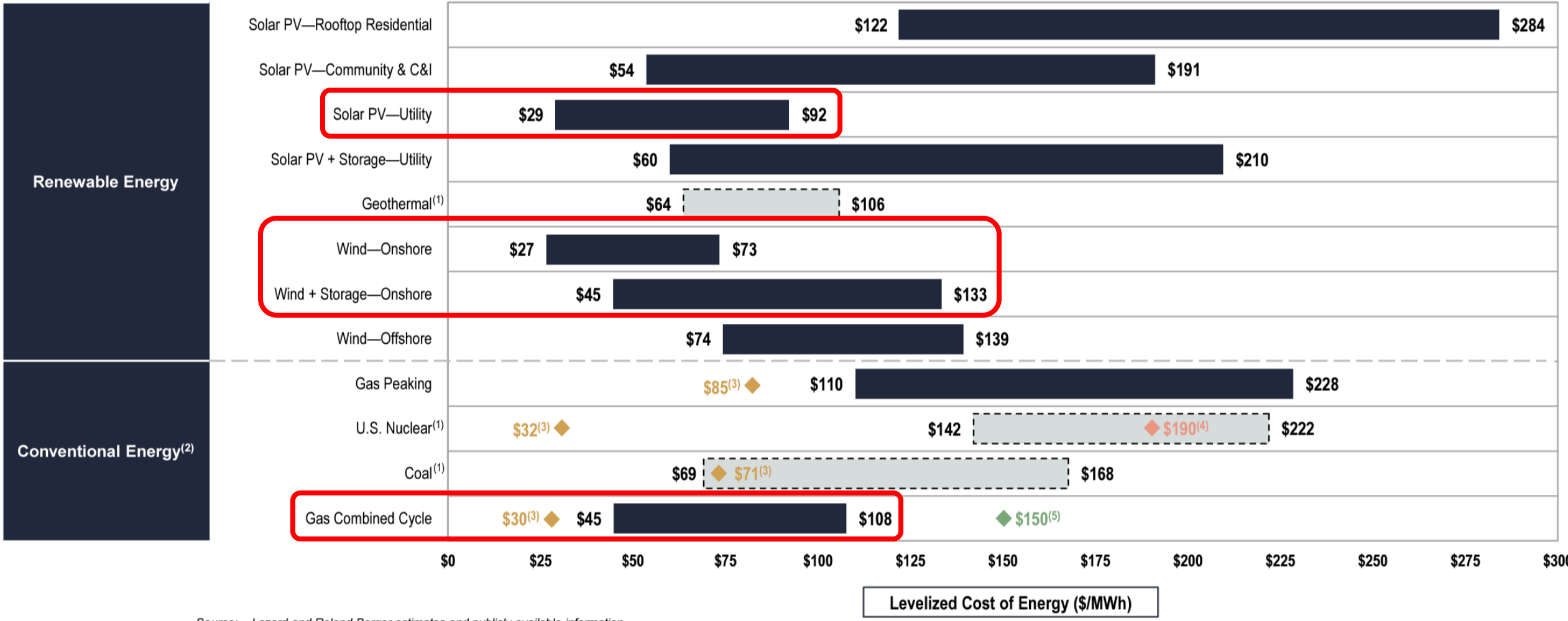
- Solar is coming…or rather already here
- It’s coming to farms
- Food versus fuel debate…on steroids
- Regulations to protect agriculture
- Agrivoltaics…what configurations are viable?

SOLAR IS COMING…

LCOE of Solar Energy over Time
(source: https://emp.lbl.gov/pv-ppa-prices)



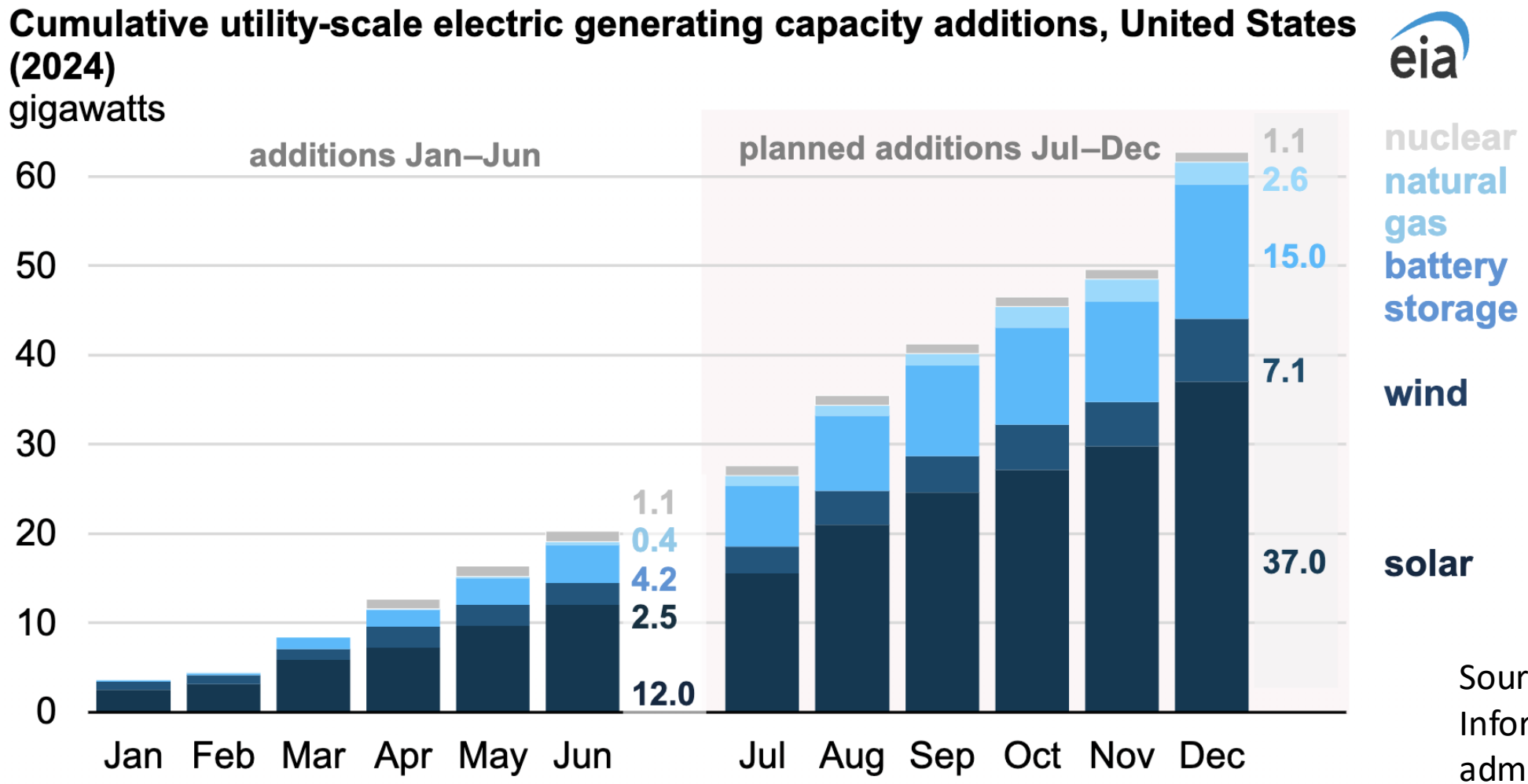
Wholesale Price of Solar Energy vis-à-vis other sources (source: https://www.eia.gov/todayinenergy/detail.php?id=45436)



Source: Lazard and Roland Berger estimates and publicly available information.

…OR RATHER ALREADY HERE

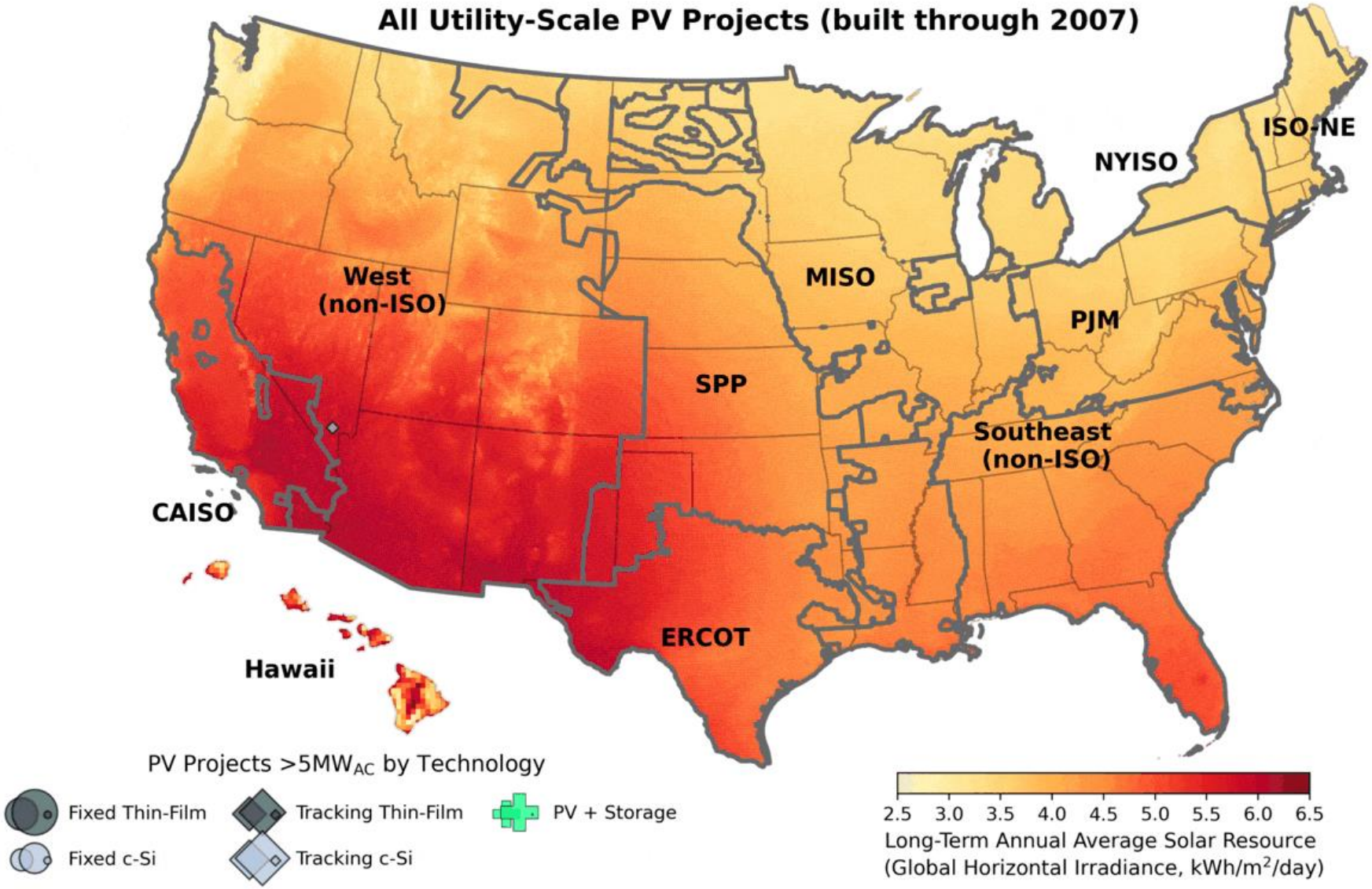
U.S. power grid added 20.2 GW of generating capacity in the first half of 2024



Source: Energy Information administration

…AND IN INDIANA

Utility-Scale PV Projects all RTOs (source: https://emp.lbl.gov/utility-scale-solar/)



Solar Projects (utility scale) in Indiana (2k MWh/MW)

Mammoth Solar Project: Doral's 13,000 acre (2,500 after setbacks/forest/wetlands) / 1.65 gigawatts (~250k homes) in Starke and Pulaski counties. Incorporates grazing sheep under the panels. Doral LLC

Flag Run Solar Project: BrightNight's proposed 500 MW project in Clark County, Indiana. Incorporates livestock grazing and pollinator habitats.

Idlewild Solar Project: Orion's 4,000-acre / 472 MW solar project in Jefferson County

Indiana Crossroads Solar Park: EDP Renewables' 200 MW solar farm in White County pv magazine USA

Hardy Hills Solar Project: IPA/AES/NIPSCO's 195 MW project located in Clinton County, Invenergy pv magazine USA

Ratts 1 Solar Project: Arevon's 192 MW facility in Pike County.

Fairbanks Solar Farm: Capital Dynamics and Tenaska's 150 MW facility under construction in Sullivan County. pv magazine USA

Greensburg Solar Farm: NextEra Energy Resources' 120 MW project in Decatur County. pv magazine USA

IPA Power: 1,000-acre project / 100MW in Jefferson county

Heirloom Solar Project: Arevon's 73 MW facility in Pike County.

IT’S COMING TO FARMS

Why Solar on Farms??

1. Flat, extended areas – economies of scale

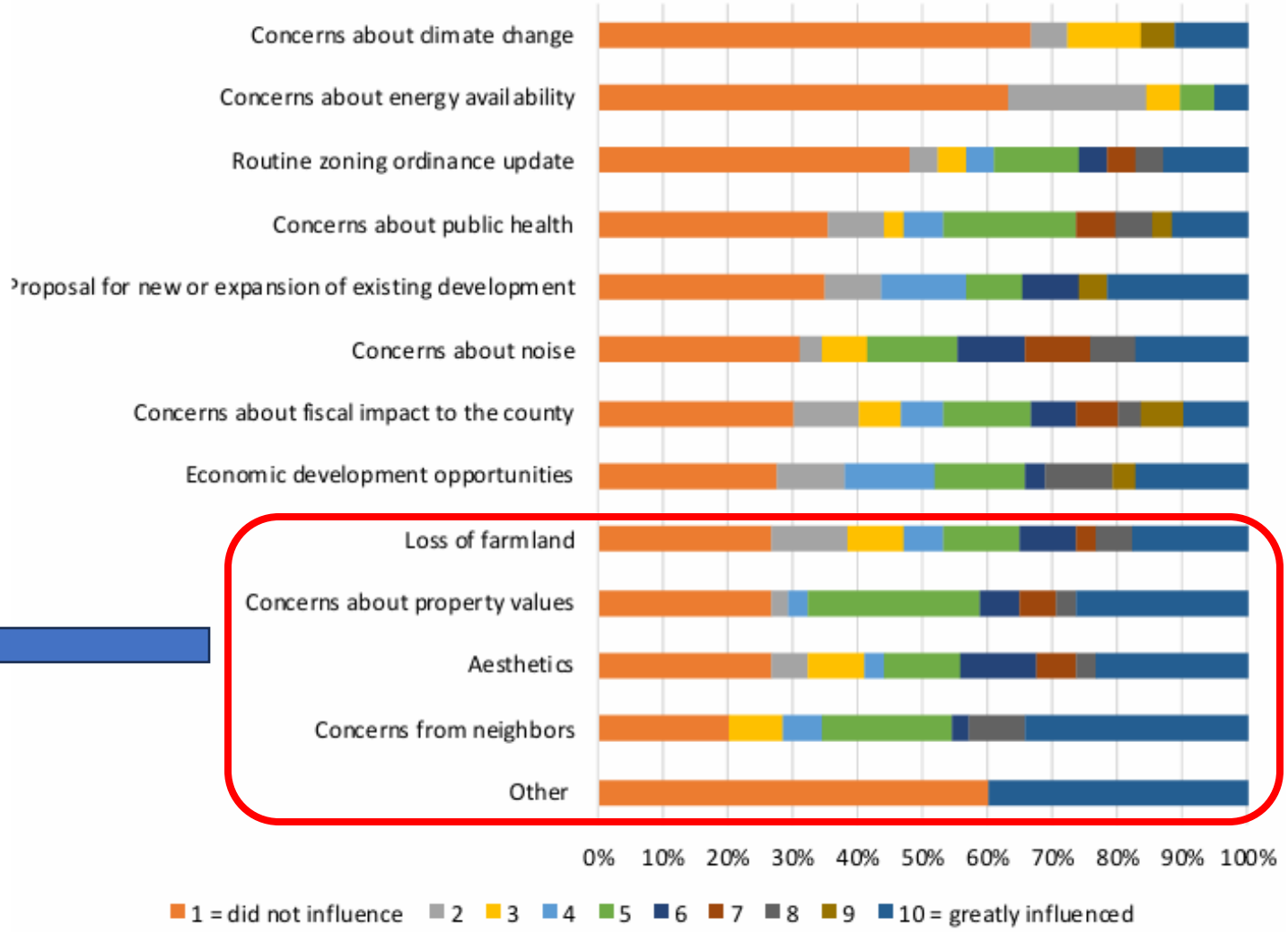
2. Close to transmission lines – especially high voltage lines

3. Ordinances (???)

Factors underlying regulations - legislative intent

FOOD VERSUS FUEL…ON STEROIDS

Figure 5: Factors influencing changes to renewable energy regulations/ordinances in the last five years.

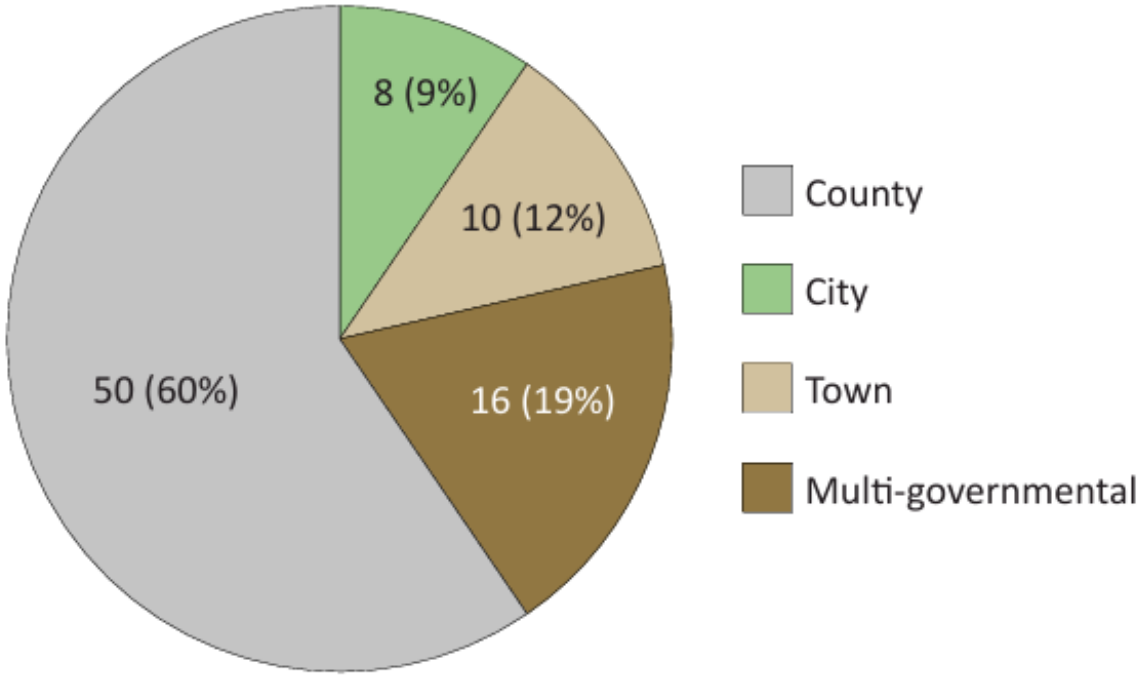


FOOD (AG) VERSUS FUEL DEBATE RE-SPARKED BY PV SYSTEMS ON FARMLAND

SOURCE: Ogle, T., and Salazar, K. Indiana Renewable Energy Community Planning Survey and Ordinance Inventory Summary.

Local Regulations - Indiana

Figure 1: Type of government unit affiliation for community planning



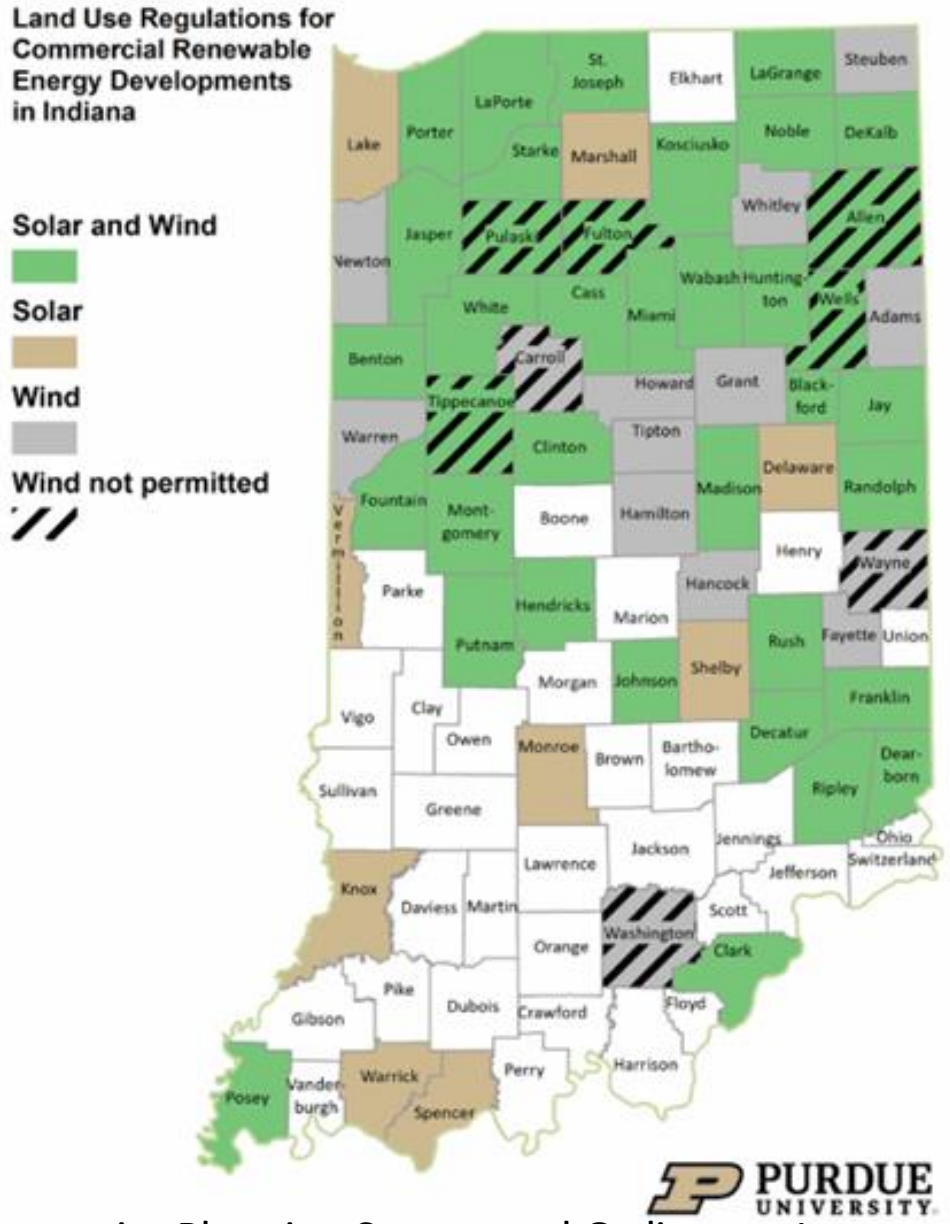
Indiana General Assembly passed Senate Bill 411 in the spring of 2022, creating voluntary commercial solar regulation standards (• setbacks, height, and buffers • ground cover • fencing • underground cables and aboveground infrastructure • glare minimization • signal interference • sound level limitations • drainage repair • decommissioning, abandonment, and "force majeure event").

SOURCE: Ogle, T., and Salazar, K. Indiana Renewable Energy Community Planning Survey and Ordinance Inventory Summary.

REGULATIONS TO PROTECT AGRICULTURE

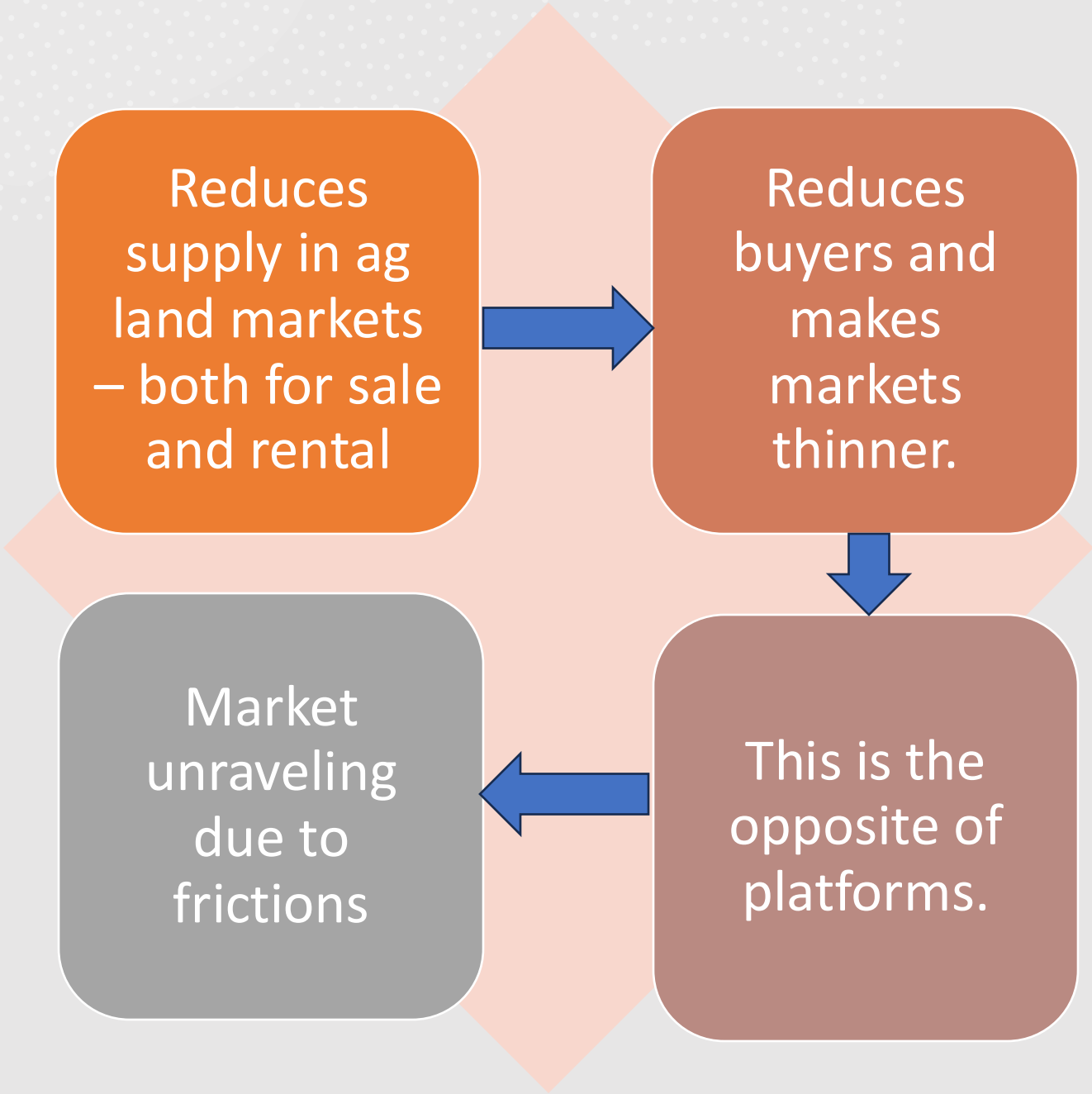
- Sixteen counties permit commercial solar energy systems (CSESs) by right in an agricultural district.
  - Of these counties, Clark County is the only county that does not require additional use standards.
- Twenty-three counties permit CSESs by special exception in an agricultural district (plan commission, PC, or board of zoning appeals, BZA).
- Seven counties would require rezoning to permit a CSES (hearing with PC and 1. variance from BZA or 2. decision by legislative body)
  - Five of these counties use overlay districts, and one would need a special exception after rezoning.

Figure 8: Map of land use regulations for commercial renewable energy developments in Indiana



SOURCE: Ogle, T., and Salazar, K. Indiana Renewable Energy Community Planning Survey and Ordinance Inventory Summary.

Market effects of scaling up solar: Ag land markets



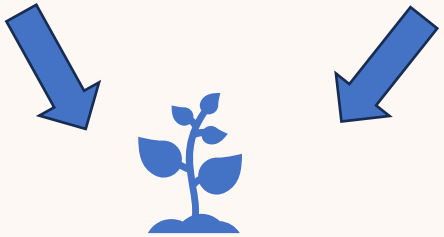
Market effects of scaling up solar: agricultural markets

Reduces ag input demand

Input suppliers may leave the area if <u>price</u> falls below AC or if <u>demand</u> falls below AC curve

Reduces crop supply

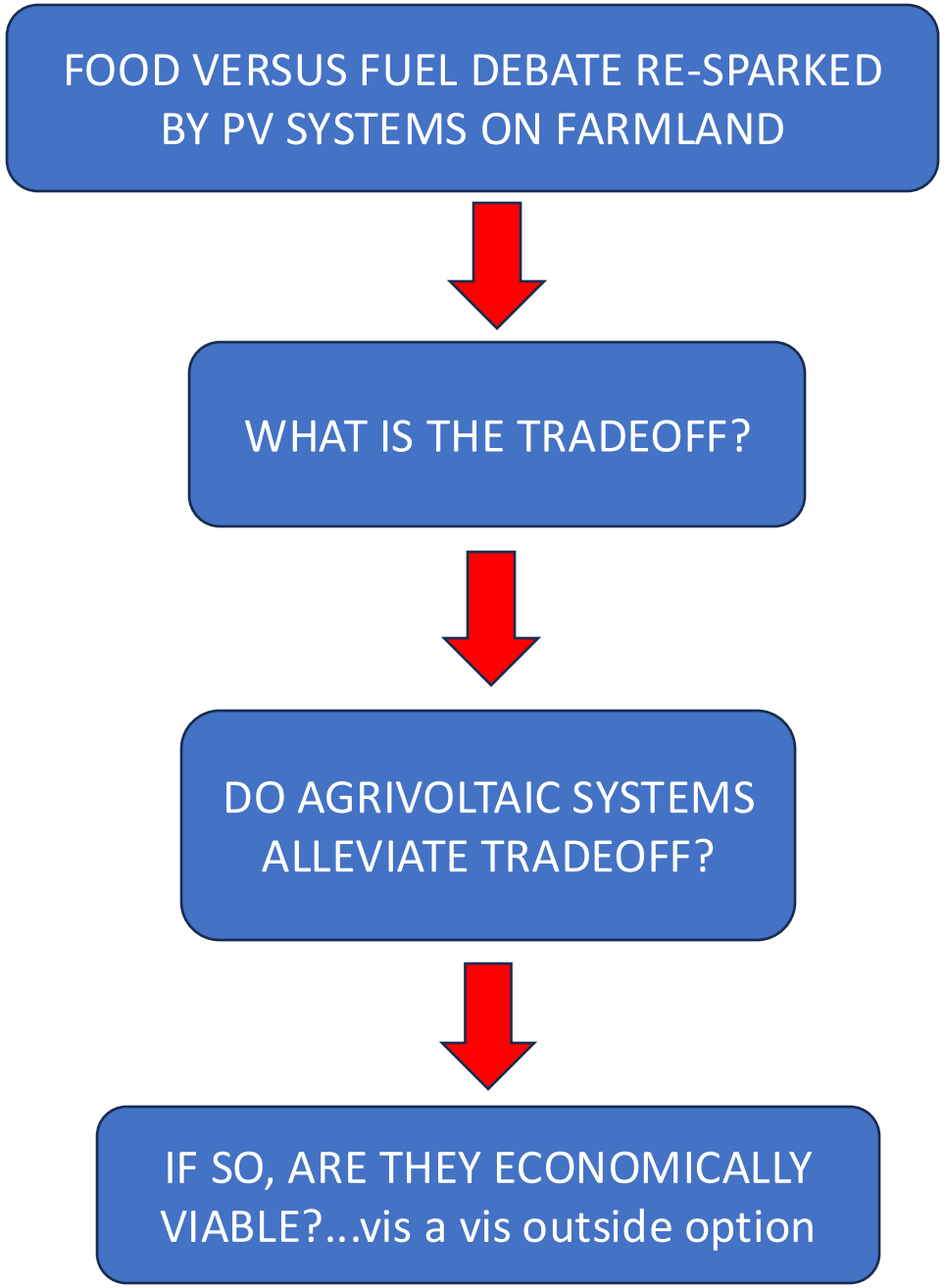
Crop buyers (mainly elevators) may leave the area if <u>cost</u> climbs above price.



Combination raises cost for farmers and reduces revenue

Unraveling of the ag economy

SO FAR….


FOOD VERSUS FUEL DEBATE RE-SPARKED BY PV SYSTEMS ON FARMLAND
WHAT IS THE TRADEOFF?
DO AGRIVOLTAIC SYSTEMS ALLEVIATE TRADEOFF?
IF SO, ARE THEY ECONOMICALLY VIABLE?...vis a vis outside option

Agrivoltaics: Most Prevalent Configurations

Grazing and Solar Panels: Livestock, typically sheep, graze under and around solar panels

Common in the Midwest

Specialty Crops Under Solar Panels: Shade-tolerant crops such as lettuce, herbs, berries, and certain vegetables are grown beneath elevated solar panels.

Most common in California

Pollinator-Friendly Solar Farms: Solar farms are planted with native wildflowers and vegetation to support pollinator habitats.

Dual-Use Row Cropping: Solar panels are spaced far enough apart to allow for the cultivation of traditional row crops like corn, soybeans, or wheat.

Elevated Solar Arrays for Mechanized Farming: Solar panels are installed at higher elevations (up to 14 feet) to accommodate tractors and other farm equipment.

Solar panels and Sheep Grazing

1. **Energy-related Payment** (20 to 40 years annual rent payments or royalties. Rate: 0.7-1.2k/ac with escalation clauses)
2. **Land Use Provisions** (grass maintenance and ag activity)
3. **Energy Production Terms** (ownership and placement)
4. **Termination and Renewal** (decommissioning)
5. **Risk and Liability** (insurance & ag loss compensation)
6. **Environmental and Regulatory Compliance**
7. **Community and Local Benefits** (energy sharing/local hiring)

Economics: regular PV & mowing savings + sheep revenue

(Tax treatment, Title 6 – per DLGF, land assessed at solar rate)

Dual-Use Row Cropping

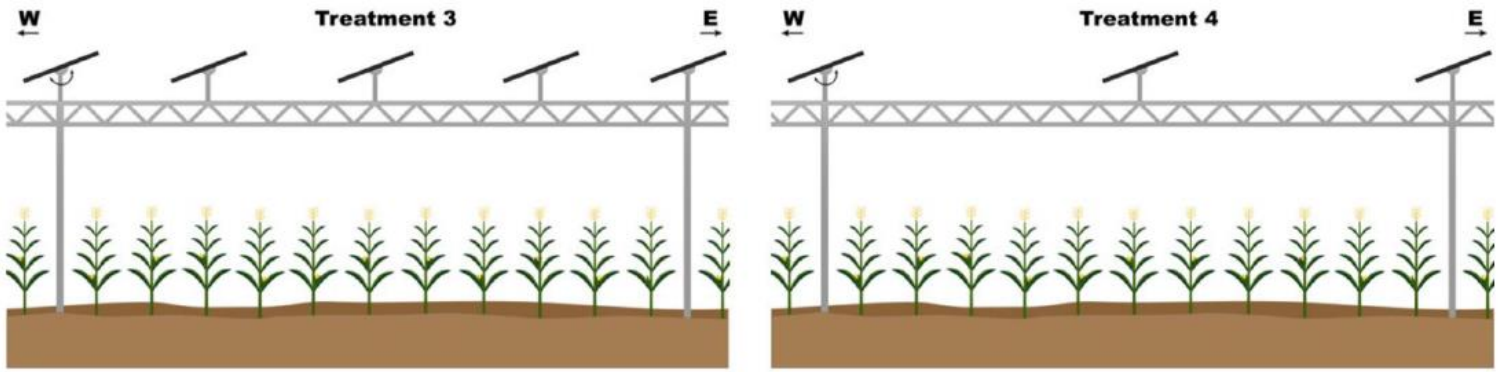
Economics of density – conditional on # of panels:

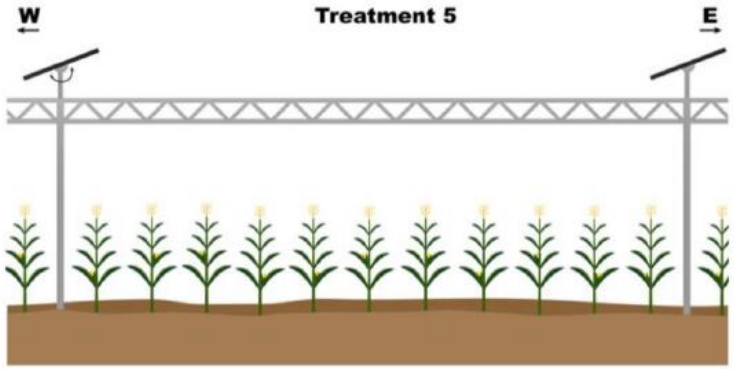
- Lower density (panels further apart) reduces shadow and increases yield.
- Lower density increases wiring costs

Economics of density and # of panels:

- Lower density limits total number of panels – large cost!
- NPV? Will come back to this…

Elevated Solar Arrays for Mechanized Farming

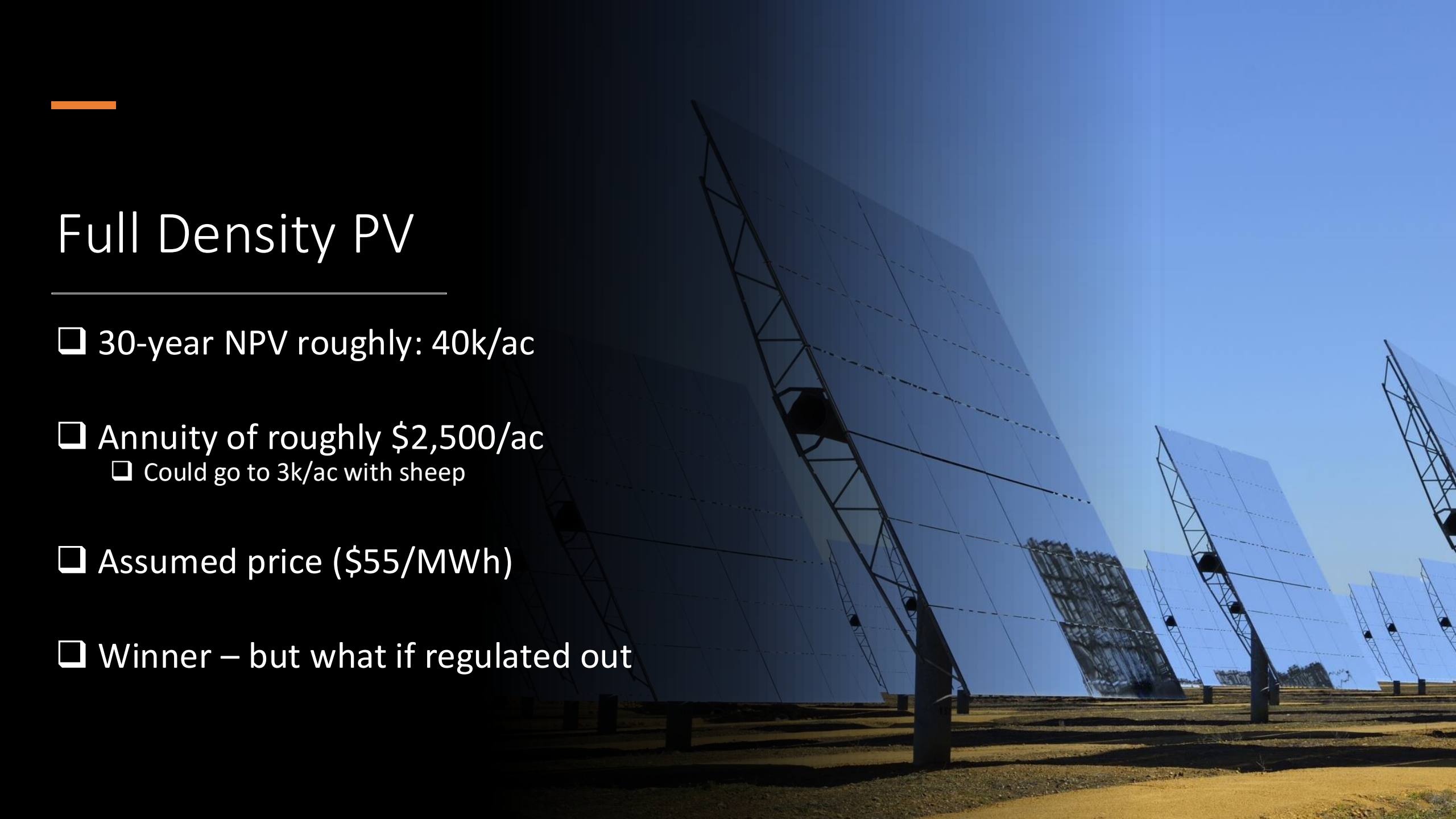




Source: Turnley, J.W., Grant, A., Schull, V.Z., Cammarano, D., Sesmero, J. and Agrawal, R., 2024. The viability of photovoltaics on agricultural land: Can PV solve the food vs fuel debate?. *Journal of Cleaner Production*, *469*, p.143191.

Full Density PV

- 30-year NPV roughly: 40k/ac
- Annuity of roughly $2,500/ac
  - Could go to 3k/ac with sheep
- Assumed price ($55/MWh)
- Winner – but what if regulated out

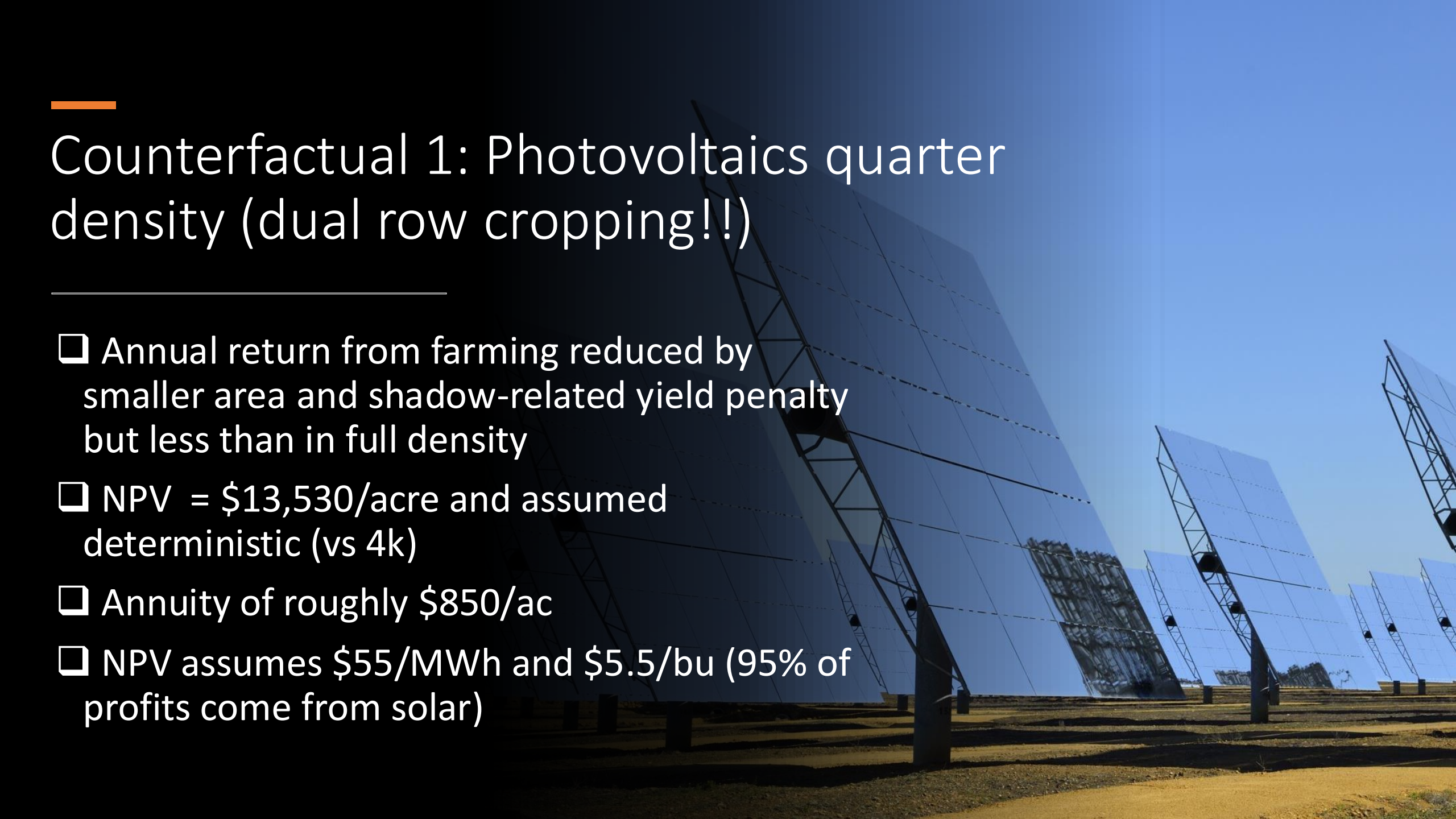


Baseline: Corn/soybean rotation

- (median) NPV = $3,700/acre
- Annuity of roughly $240/ac
- NPV calculated based on price and yield trends

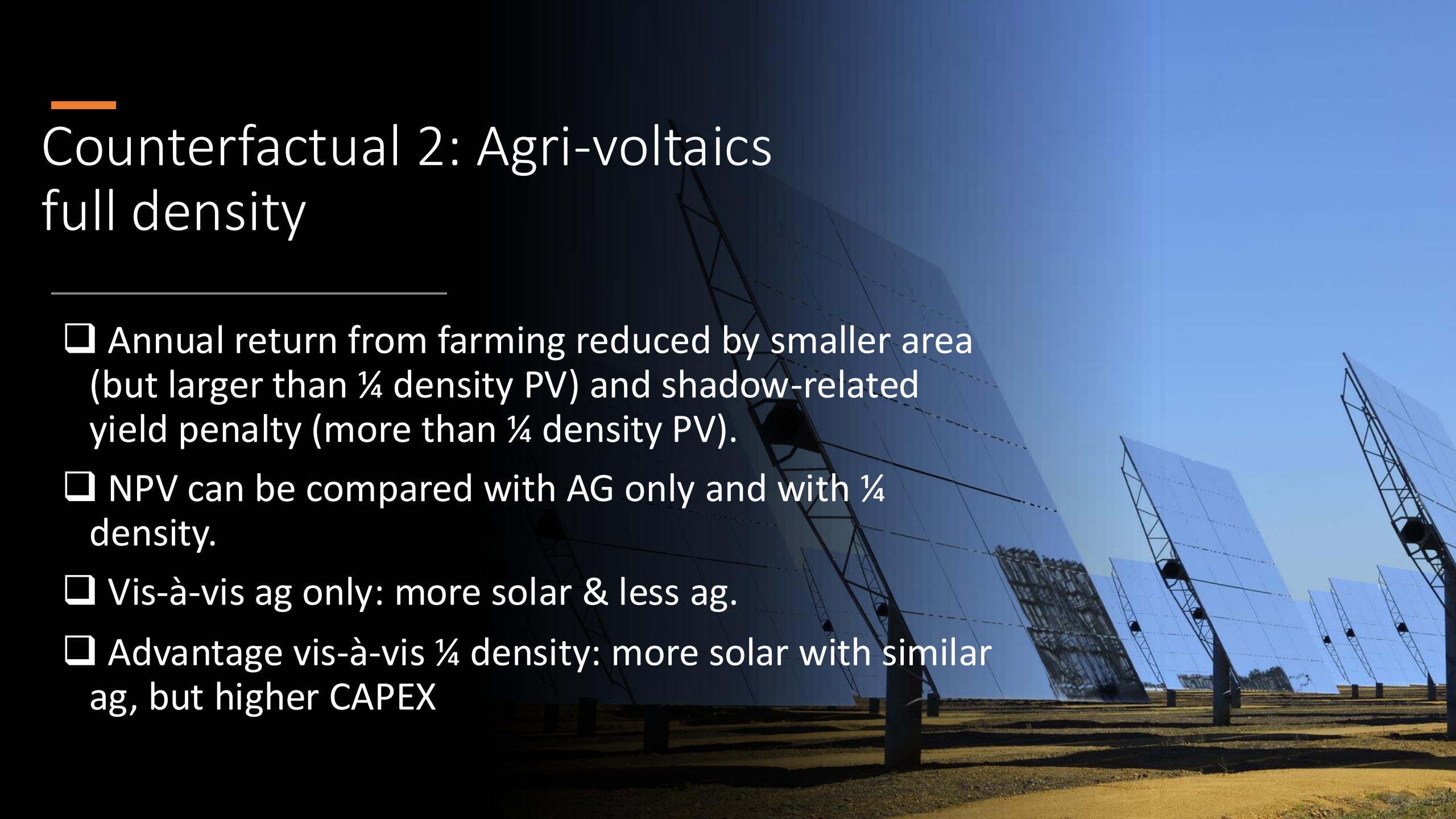
Counterfactual 1: Photovoltaics quarter density (dual row cropping!!)

- Annual return from farming reduced by smaller area and shadow-related yield penalty but less than in full density
- NPV = $13,530/acre and assumed deterministic (vs 4k)
- Annuity of roughly $850/ac
- NPV assumes $55/MWh and $5.5/bu (95% of profits come from solar)



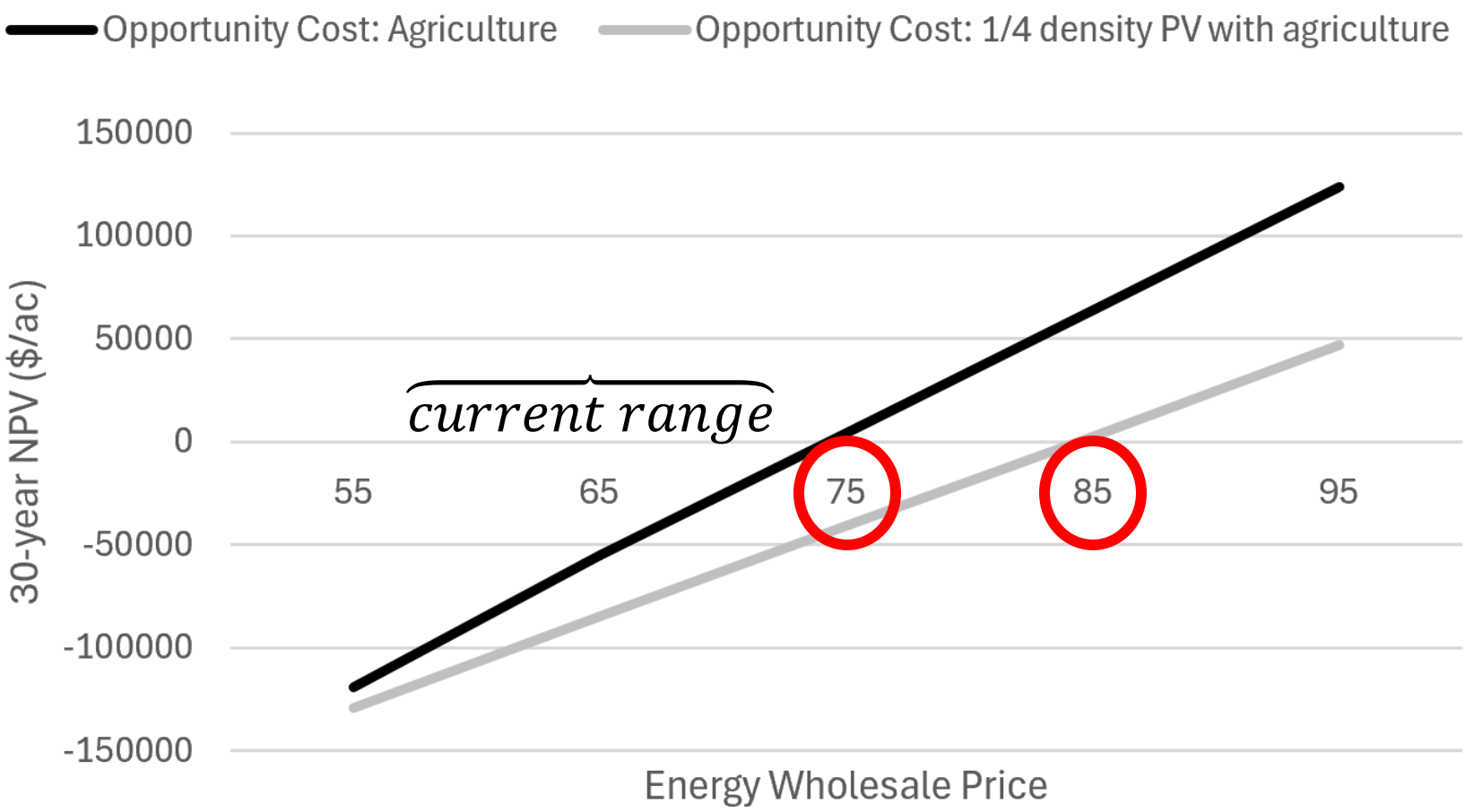
Counterfactual 2: Agri-voltaics full density

- Annual return from farming reduced by smaller area (but larger than ¼ density PV) and shadow-related yield penalty (more than ¼ density PV).
- NPV can be compared with AG only and with ¼ density.
- Vis-à-vis ag only: more solar & less ag.
- Advantage vis-à-vis ¼ density: more solar with similar ag, but higher CAPEX



Economic comparison

AV full density breakeven with and without opportunity cost



Source on prices: https://www.eia.gov/electricity/wholesale/

Conclusions on Solar Policies and Regulations

- Food versus fuel all over again
- Heightened land competition between uses
- Policies protecting agricultural land
- Agrivoltaics can help circumvent restrictions
- Can mean very different configurations with very different effects on agricultural economy