RUTGERS–NEW BRUNSWICK
School of Environmental and Biological Sciences

Rutgers Agrivoltaics Program
New Jersey Agricultural Experiment Station

Economics of Agrivoltaics

Considerations for Northeast Agricultural Producers

Presented at

Technical Assistance Program for Agrivoltaics

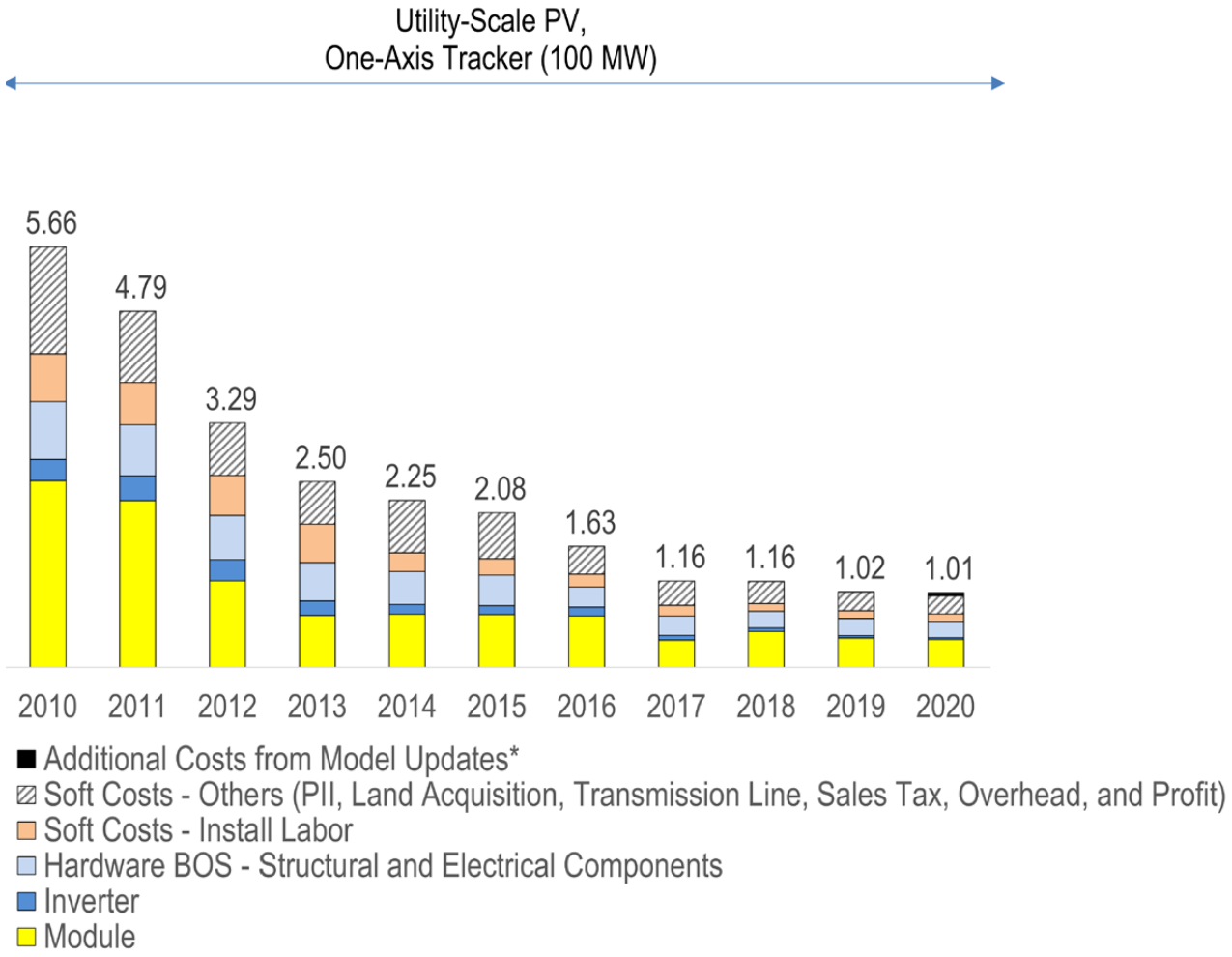
August 13, 2024
Rutgers Agricultural Research and Extension Center
Bridgeton, NJ

Kevin P. Sullivan, Office of Research Analytics, NJAES, Rutgers University

Photo Credit: Oregon State University

Trends in Photovoltaics

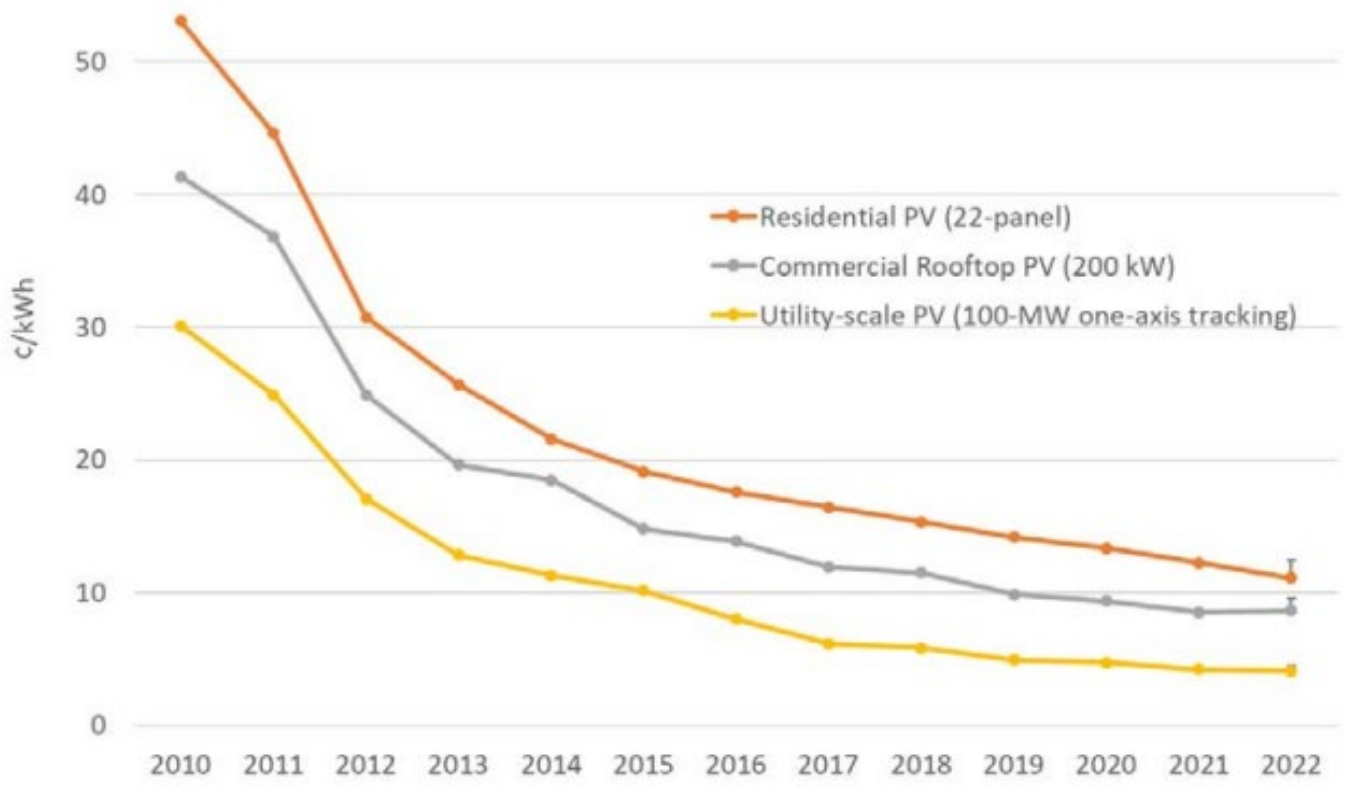
From 2010 to 2020, **the installed cost** of a utility-scale single axis tracking solar energy system **decreased by 82%.**



Source: Feldman, David, Vignesh Ramasamy, Ran Fu, Ashwin Ramdas, Jal Desai, and Robert Margolis. 2021. U.S. Solar Photovoltaic System Cost Benchmark: Q1 2020. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77324.

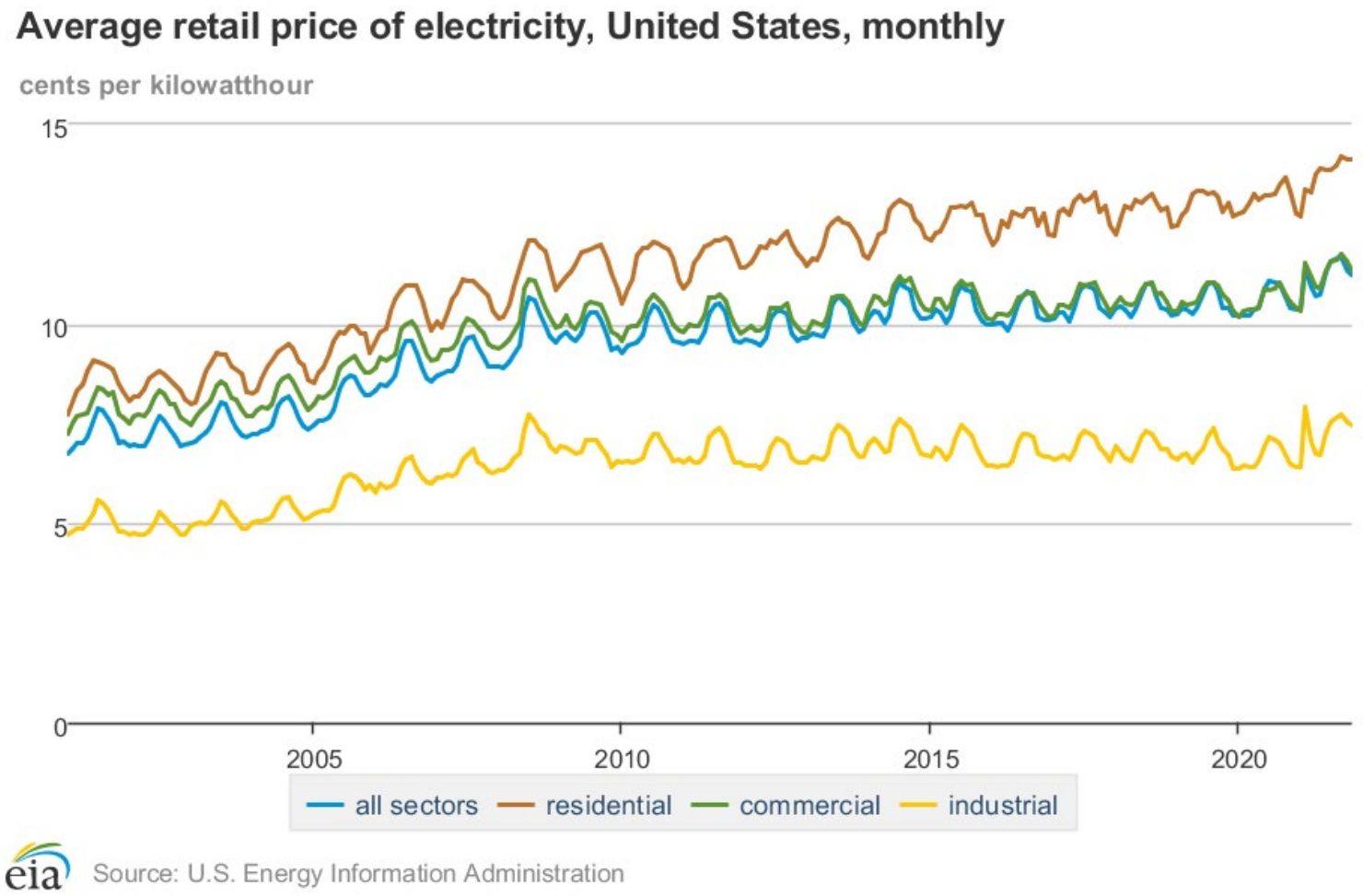
Trends in Photovoltaics

Levelized cost of energy (LCOE)



Source: Ramasamy, Vignesh, Jarett Zuboy, Eric O'Shaughnessy, David Feldman, Jal Desai, Michael Woodhouse, Paul Basore, and Robert Margolis. 2022. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-83586.

Trends in Photovoltaics



Assessing System Cost

Installed capital costs

- **Direct capital costs**
- directly associated with the system, clearly assigned to specific equipment or a component

- **Indirect capital costs**
- soft costs associated with building the system

Operation and maintenance costs

- ongoing expenses required to maintain, service, and/or replace critical components of the system

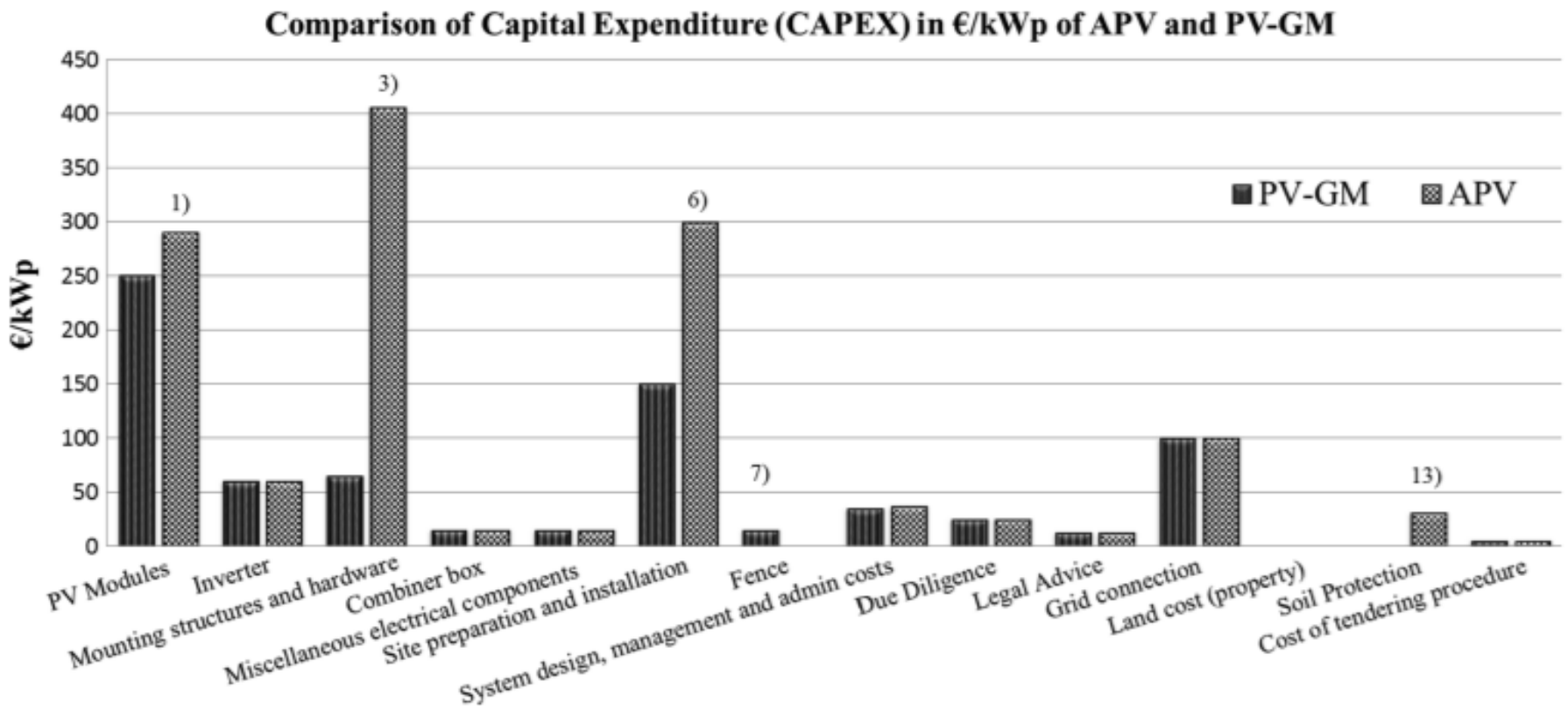
Comparing Proposals

Conduct a comparison of multiple system costs by calculating the installed cost per watt.

Example of Comparing Multiple System Proposals

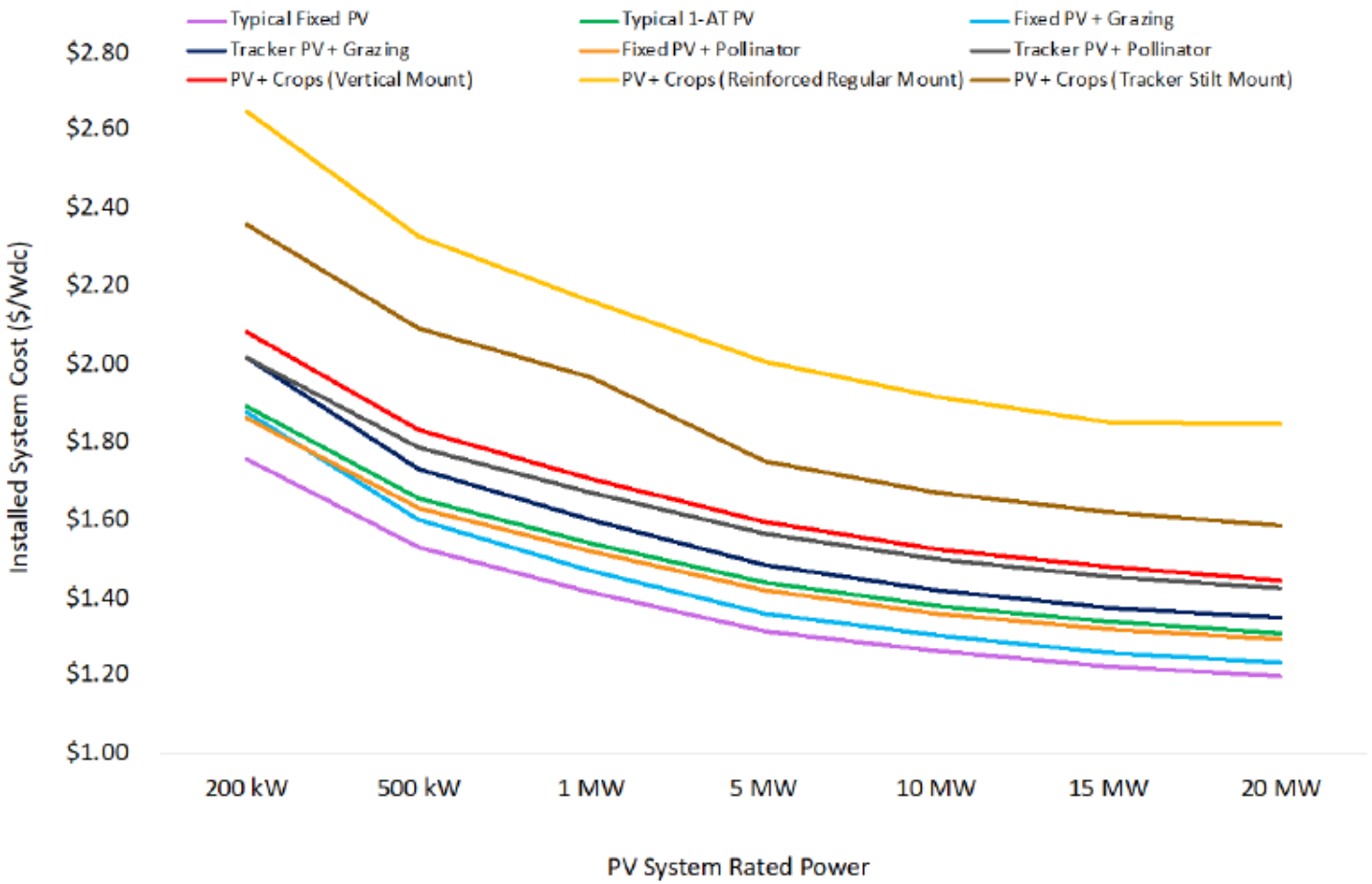
Proposal #	1	2	3
System Size(kW)	1,000	900	820
Convert kilowatts to watts	**1,000,000**	**900,000**	**820,000**
Direct Capital Cost	$1,660,000	$1,391,600	$1,460,000
Indirect Capital Cost	$1,150,000	$828,400	$1,300,000
Total Installed Cost	**$2,810,000**	**$2,220,000**	**$2,760,000**
Installed Cost Per Watt (pre-incentive)	**$2.81**	**$2.47**	**$3.37**

Installed Capital Cost vs Traditional



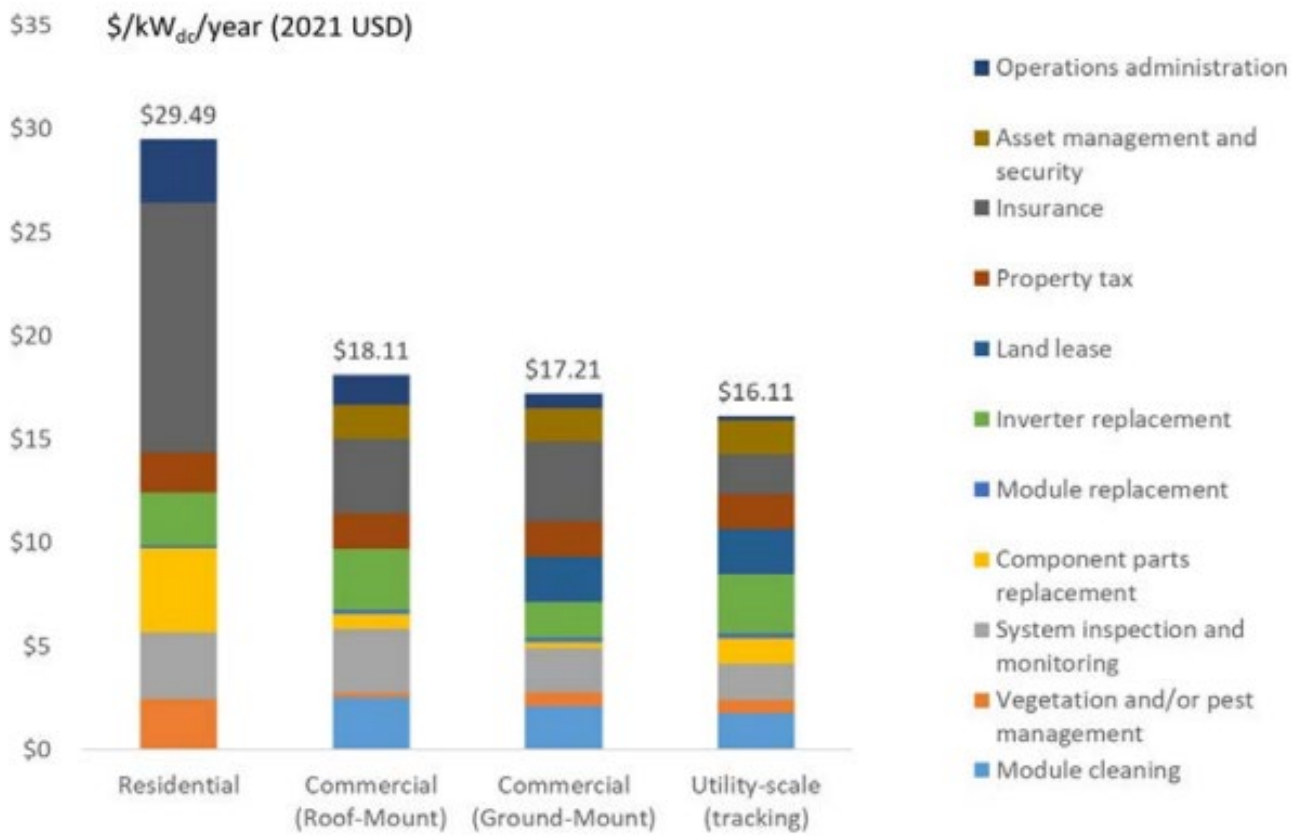
Source: Schindele, et al. Applied Energy 265 (2020)

PV installed system costs



Source: Horowitz, Kelsey, Vignesh Ramasamy, Jordan Macknick and Robert Margolis. 2020. *Capital Costs for Dual-Use Photovoltaic Installations: 2020 Benchmark for Ground-Mounted PV Systems with Pollinator-Friendly Vegetation, Grazing, and Crops*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77811.

Operation and Maintenance Costs



Source: Ramasamy, Vignesh, Jarett Zuboy, Eric O'Shaughnessy, David Feldman, Jal Desai, Michael Woodhouse, Paul Basore, and Robert Margolis. 2022. U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, With Minimum Sustainable Price Analysis: Q1 2022. Golden, CO: National Renewable Energy Laboratory. NREL/TP-7A40-83586.

Assessing Land Cost

Agrivoltaic system effects on agricultural operation

- What are the costs and benefits to the agricultural operation?
  - **Reduced land** in production (-)
  - **Increased shading** effect on yield, crop specific (+/- ?)
  - **Production costs** (+/- ?)

$$\textbf{Annual Land Cost} = \boldsymbol{Producer\ price} \times \Delta \boldsymbol{Yield} - \Delta \boldsymbol{Production\ Costs}$$

Assessing Effect on Agriculture

Examples of Shading Effects on Crop Yields

Reference	Crop Type	Location	Agrivoltaic System Effect on Yield
Schindele, et al (2020)	Potatoes (organic)	Germany	-11.5% *
Schindele, et al (2020)	Potatoes (conventional)	Germany	-20.0% *
Schindele, et al (2020)	Winter wheat	Germany	-16.1% *
Amaducci et al.(2018)	Corn for grain	Simulation	-17.7%**
Artru et al. (2017)	Wheat	Belgium	-25% to -45%**
* Effect from shading and land loss			
** Effect from shading only			

Incentives

Incentives can come from federal, state and local government, and utility companies.

Example Incentives for Solar Energy Projects on Agricultural land

Name	Description	Eligible Technologies
Business Energy Investment Tax Credit (ITC)	Eligible projects that begin construction after 2021 and before 2025 can receive the full tax credit of **30%**.	All renewable energy technologies
Rural Energy for America Program Renewable Energy Systems	Grants for up to 25 percent of project costs. Loans up to 75 percent of total eligible project costs.	Small and large solar generation
Net Metering	Receive the retail rate for production up to total consumption and pays avoided cost for excess production.	All renewable energy technologies
Solar Renewable Energy Credits (SRECs) [NJ transitioning to successor program]	Each 1,000 kilowatt-hour (kWh) of solar generation earns one SREC.	All solar energy technologies
Modified Accelerated Cost-Recovery System	5-year depreciation schedule	All solar energy technologies

The Department of Energy provides a comprehensive list of renewable energy incentives:

www.dsireusa.org

Estimating System Energy Production

National Renewable Energy Lab's (**NREL's**) online tool "**PVWatts"** estimates system production and allows customization of

- size of solar array,
- location,
- slope, and
- orientation.

The PVWatts tool can be found at:

http://pvwatts.nrel.gov

RESULTS

Print Results

381,767 kWh/Year*

System output may range from 357,678 to 398,183 kWh per year near this location.
Click HERE for more information.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)
January	2.73	18,148
February	3.88	23,006
March	5.23	33,659
April	6.59	39,871
May	6.96	41,661
June	7.47	42,720
July	8.08	47,129
August	6.92	40,442
September	5.80	33,584
October	4.20	26,068
November	3.12	19,417
December	2.44	16,062
Annual	5.29	381,767

Value of Electricity

Understand the farm‘s **rate structure** to determine any specific charges that will remain after solar system installation.

Rate structures usually include:

- a fixed (basic) charge,
- energy charge,
- demand charge, and
- possibly others.

Investing in any photovoltaic system involves **hedging against future energy prices**.

Evaluating Economic Return

System Advisor Model (SAM) from NREL

- A comprehensive model that evaluates critical variables to simulate detailed financial metrics over the energy system's lifetime.

- SAM allows a detailed analysis of renewable energy systems, providing:
  - payback period,
  - net present value, and
  - levelized cost of energy.

SAM is available for download at: https://sam.nrel.gov

Economic Model Simulation - 250kw agrivoltaic array on 1.5 acres

Economic Model Specifications

Cost of System		**Incentives**	
Total system size (kW DC)	**250**	*SREC value / Mwh*	**$90.0**
Cost / W DC	$3.50	*Solar Investment Tax Credit (ITC)*	**30.0%**
Installed Cost to owner	**$875,000**		
Operation and maintenance costs / kW DC	**$20.00**	**Financing**	
		Debt interest rate (%)	**7.0%**
Cost of Land		*Debt fraction (%)*	**50.0%**
Land needed (acres)	1.5	*Debt term (years)*	**15**
Land rent or opportunity cost / acre ($)	**$1,500.0**		
		General	
Energy Production		*Discount rate for NPV calculations*	**2.5%**
Annual production (kWh/yr) per kW DC	1,400	*Marginal tax rate (corporate)*	**23.0%**
Initial annual production (kWh)	350,000	*Analysis period (years)*	25
System degradation /Yr	**1.00%**		
Energy value / kWh	**$0.110**		
Energy price escalation / Yr	**0.50%**		

Economic Model Simulation - 250kw agrivoltaic array on 1.5 acres

Economic Model Results

Costs			
Installed Cost	$875,000	***Return on investment (ROI) (%)***	**16.7%**
Maintenance & Op costs over 25 yrs ($20 / kW DC)	$125,000	*Annualized ROI (%)*	0.6%
Land rental fee over 25 years	$56,000	*Payback period (years)*	Year 5
Financing	$283,000		
Total costs	**$1,339,000**	***Internal rate of return (IRR)(%)***	**8.6%**
Revenues			
Solar Investment Tax Credit (ITC)	$263,000	*Real (inflation adjuated) costs ($)*	$1,139,500
SRECs ($90/mWh) over 15 years	$441,000	*Real net revenue ($)*	$123,500
Energy production value for 25 yrs ($0.11/kWh)	$859,000	*Real ROI (%)*	10.8%
Total revenues	**$1,563,000**	*Annualized Real ROI (%)*	0.4%
Net revenue ($)	**$224,000**	***Levelized cost of electricity (LCOE)($/kWh)***	**$0.147**

Review: Key Questions

- Do energy production estimates account for shading, orientation, angle, and temperature?
- Do energy production estimates include annual declines from degradation?
- What is the installed cost per watt?
- Are operations and maintenance costs clearly defined?
- Is the energy value based on average utility rate, or are fixed fees, demand and energy charges considered separately?
- What escalation rate is used to calculate energy savings/revenues? Is it real or nominal?
- What are the impacts (costs and benefits) to the agricultural operation?

Final Considerations

- **Agrivoltaics is a major investment** that will influence future profitability / viability of farms.
- **Use of land** – consider amount of land
- **Other important considerations**
  - farm tenancy arrangement
  - decommissioning
  - alternative investments
- **As with any major investment…**
  - consult a qualified tax/accounting professional (to ensure eligibility for tax deductions and incentives),
  - and get legal counsel prior to signing any contract.

Thank you!

Kevin Sullivan
kps@njaes.rutgers.edu