



MN Solar Panel Recycling & Reuse Policy Work

MN SWAA

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Background and Recap



MN solar panel stakeholder process – end of life options

Goal Statement:

Collaborate to develop and implement PV panel end of life management policy and programs that conserve resources, protect health, promote renewable energy, and support PV panel recycling infrastructure and technology

Recap of goal and process

All webinars and surveys were open to anyone interested in participating.

Seven webinars over 18 months:

- June 27, 2019: Introduction, white paper, first survey on issues
- Oct. 9, 2019: National/Regional overview - SEIA, IL STC, NREL
- Dec. 11, 2019: PV forecasts & LCA, urban mining - NREL, manufacturers, recyclers
- March 18, 2020: Product Stewardship 101 and EPEAT
- June 11, 2020: Program options/survey, Commerce/Decommissioning, local govt
- Dec. 10, 2020: NREL - R&D Roadmap for PV Recycling; EOL/circular economy, local govt
- Dec. 17, 2020: Expanded discussion of program options, followed by a survey

4 Policy Models discussed

- Commerce/PUC Decommissioning model extended to solar facilities under 50 MW, plus reuse/recycling requirement: permittee individual responsibility
- Product Stewardship model: permittee pays stewardship assessment to manufacturer/Product Stewardship Organization at purchase; manufacturers/PSO operate statewide program
- Rate payer funded/statewide program model
- Permittee funded/statewide program model

Minnesota Decommissioning Framework for solar

State decommissioning framework: all energy facilities >50MW plus wind >5MW

- Plans must be updated every 5 years or at ownership change; financial assurance starts at year 10
- ~1.6 GWdc solar installed (end of 2023)
- 80 percent of capacity in installations <50MW, not covered by decommissioning
 - Three facilities >50MW currently permitted and operating [262 MW]
- Facilities >50MW in process:
 - Xcel Energy Sherco permitted for 460 MW [replacing Sherco coal]
 - Hayward, Byron, others in permitting process or recently permitted

Counties issue permits and require decommissioning plans and financial assurance for all facilities <50MW

Challenges and Feedback



Challenges

- Counties
 - Counties receiving varying recycling decommissioning estimates from developers
 - Can't rely on estimates of future scrap value and commodity markets to offset recycling costs
- Developers/Installers
 - Thin margins
 - Tough to find panels for projects
- Manufacturers
 - Worry about any additional money put on the price for a panel that would go towards recycling at EOL
 - Perceived barriers to MN installations
 - Future: Design to be less toxic, easy to recycle, but durable to withstand the elements
- Collection, reuse, recycling
 - Limited collection and recycling infrastructure in MN and the US *[changing in 2024-2025]*
 - Lack of data on MN discards *[Eunomia report estimates]*
 - How to ensure high recovery for high value materials that can go back into new panels, e.g., rare earths *[MPCA Critical Materials Task Force and other initiatives]*
 - Cost of recycling *[dropping]*
 - Reuse: certification, warranty, value, market

Feedback from the industry

- Perceived barriers that
 - increased costs will prevent many companies from doing business in MN (installations)
 - solar module manufacturers might choose not to do business in MN
 - a Product Stewardship model on a regional, national or international scale would mitigate any competitive disadvantage
 - Coal, nuclear, natural gas, wind don't have to follow Product Stewardship
- Prefer market based or private sector-led strategy
- This isn't an issue for another 15-20 years.
- Industry will recycle without needing a law (industry over 50 MW)

Consensus policy ideas raised by stakeholders in webinar conversations and written comments

1. require recycling and reuse with landfill ban;
 2. manufacturers tied in for design;
 3. costs internalized to the project or developer (permittee);
 4. no costs that create disadvantages for anyone;
 5. consistent and predictable approach for everyone;
 6. applies to all installations, residential to utility scale
- Survey results showed strong preference for permittee-funded options, in part because this is the funding/responsibility model in the solar sector.
 - All of the models, except ratepayer funded, represent a type of permittee funded model.

Minnesota Legislative Proposal, 2022

MPCA proposed a Product Stewardship (PS) model for solar module legislation that most closely aligns with the criteria expressed by stakeholders in our surveys and webinar discussions, including:

- PS covers all solar modules regardless of manufacturer, purchaser, user, date of installation or the regulatory body with jurisdiction over siting, zoning, operations, and decommissioning
- A stewardship assessment fee on each solar module is visible, fair, and equitable to everyone – manufacturers, installers, permittees [internalized costs are an option]
- PS is the only model that ties in manufacturers for solar module design and material considerations, which affect end of life costs, technologies, etc.
- PS provides one end-of-life management program for the entire state that isn't dependent upon individual responsibilities or decisions by permittees, or permittee compliance

Cost of collection and recycling

- Today, it costs \$20 to transport and process a solar panel in the USA. (cost depends on condition, type, brand and location of the solar panels.)
- In France, the total cost of collection and recycling is between €6 and €7 (\$6.50 and \$7.50) per module, but the contribution fee on new modules is only around €0.53 (\$0.57) on average

Cost of panel recycling compared to lifetime income

Cost of residential panel recycling in context of lifetime income from panels:

2 or 3 panels have rated capacity of 1 kilowatt [350 watt or ~500 watt panels]

In Twin Cities, Minnesota, estimated annual generation from 1 kilowatt of panels is 1259 kwh/year, with 25 year panel life and payment of 0.11/kwh *[rate likely to increase over 25 year panel life]*

Total Revenue: $1259 \times 25 \times 0.11 = \3462

Recycling cost for 2 panels: $\$40/\$3462 = .012$ or 1.2% of lifetime revenue

Recycling cost for 3 panels: $\$60/\$3462 = .017$ or 1.7% of lifetime revenue

PV Panel recycling costs in context of installation costs

PV Recycling/Transportation Costs:

\$20-\$24 per 300 Wdc panel or \$0.066-\$0.08 per Wdc;

Equivalent to cost of inverter in installation and <5% of system installation cost

PV Life Cycle Income:

Unknown

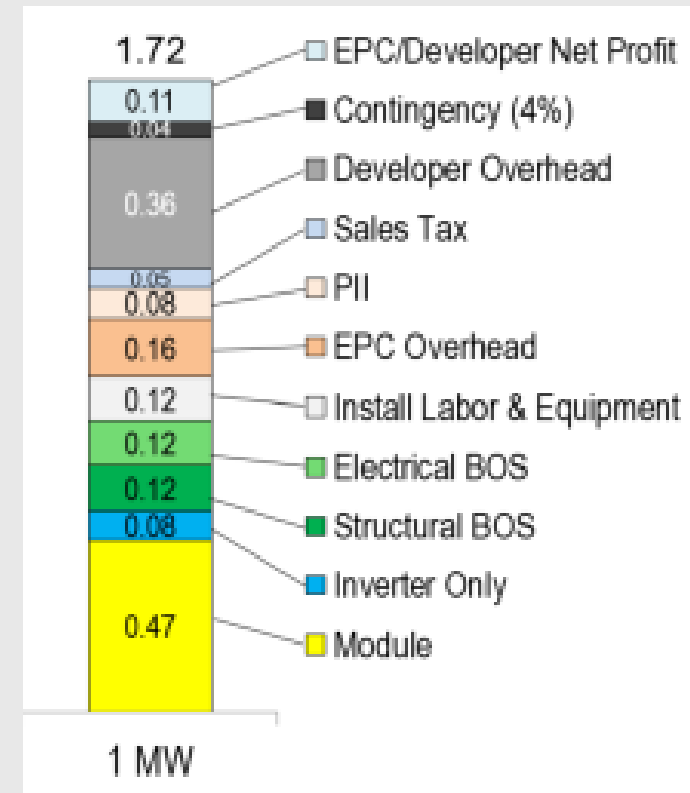
PV Decommissioning Costs:

Unknown

(Wdc = Watts dc)

PV Installation Costs per Wdc:

2018 Commercial PV system cost*



*Credit for graphic and data in previous slide

Graphic is excerpt of:

Figure 20. Q1 2018 U.S. benchmark: commercial PV system cost (2018 USD/Wdc)

U.S. Solar Photovoltaic System Cost Benchmark: Q1 2018.

Ran Fu, David Feldman, and Robert Margolis

National Renewable Energy Laboratory

NREL Technical Report NREL/TP-6A20-72399, November 2018

2023 solar module recycling study and policy working group



2023 solar module recycling study and policy working group

A report on the development of a system to reuse and recycle solar photovoltaic modules and installation components in Minnesota in consultation with the commissioners of commerce, and employment and economic development, provided to the 2025 legislature.

The report must include:

Options for a **plan to collect, reuse, and recycle solar photovoltaic modules and installation components at end of life that is convenient and accessible throughout the state, recovers 100 percent of discarded components, and maximizes value and materials recovery, including analysis of:**

- a) the reuse and recycling values of solar photovoltaic modules, installation components and recovered materials;
- b) system infrastructure and technology needs;
- c) how to maximize in-state employment and economic development;
- d) determination of net costs for the program;
- e) potential benefits and negative impacts of the reuse and recycling system on environmental justice and tribal communities.

The report must include a survey of solar photovoltaic modules and installation components coming out of service now and projected into the future in Minnesota, including a description of how they are currently being managed at end of life, and how they would likely be managed in the future without the proposed reuse and recycling system.

2023 solar module recycling study and policy working group

MPCA contracted with Eunomia and subcontractor Product Stewardship Institute (PSI) to develop the report analyzing the system options and forecasting installations and end of life in 10-year increments 2025-2055.

MPCA contracted with the MMB management analysis division to facilitate the Policy Working Group.

Policy Working Group representation:

- MnSEIA
- SEIA
- Local governments: MACPZA, Townships
- Manufacturers: Heliene, First Solar
- Recyclers: SolarCycle, Dynamic Lifecycle Innovations, IRT, Cosmic Recycling
- Great Plains Institute
- Utilities: Xcel Energy, Minn Power
- Department of Commerce
- Department of Employment and Economic Development
- Tribal representatives
- EDF Renewables
- BlueGreen Alliance
- Conservation Minnesota
- Clean Energy Economy Minnesota
- CURE MN
- Midwest Renewable Energy Association

Eunomia scenarios analyzed by the PWG in Oct/Nov 2024

Draft scenarios analyzed:

Scenario 1: Decommissioning/recycling requirement with a lower threshold (e.g. 1 MW) than the current >50 MW; disposal ban only requirement for installations under the threshold

Scenario 2: Decommissioning/recycling requirement same as scenario 1; universal disposal ban with recycling targets for panels in all other installations

Scenario 3: Decommissioning/recycling requirement same as scenario 1 and permittee/owner pays; recycling requirement and permittee/owner pays for all installations below 1 MW [modeled with limited and comprehensive recycling]

Scenario 4: Decommissioning/recycling requirement same as scenario 1; EPR to manage panels from all installations

Scenario 5: Decommissioning/recycling requirement for utilities only – low threshold (e.g. 1 MW); EPR to manage all panels not subject to decommissioning

Reuse/recycling requirement applies to decommissioned installations under scenarios 1 and 2 and to all installations under scenarios 3, 4 and 5

MPCA solar recommendations

February 2025

Recommendation

Statewide disposal ban for all solar installations

- ✓ Includes ban on landfilling, incineration, and improper disposal
- ✓ Implemented now

Recommendation

Statewide reuse or recycling requirements for all solar installations

- ✓ Implemented now; phase in comprehensive recycling
- ✓ Includes two approaches

Approach A

Decommissioning requirements

- Above 1 MW DC
- Co-located CSGs

- ✓ Funded by permittees
- ✓ Requires reuse or recycling
- ✓ Lowers current decommissioning threshold from 50 MW DC to above 1 MW DC
- ✓ Includes all co-located CSG's
- ✓ Includes previous and future installations
- ✓ Harmonized decommissioning standards across jurisdictions
- ✓ Working group recommendations

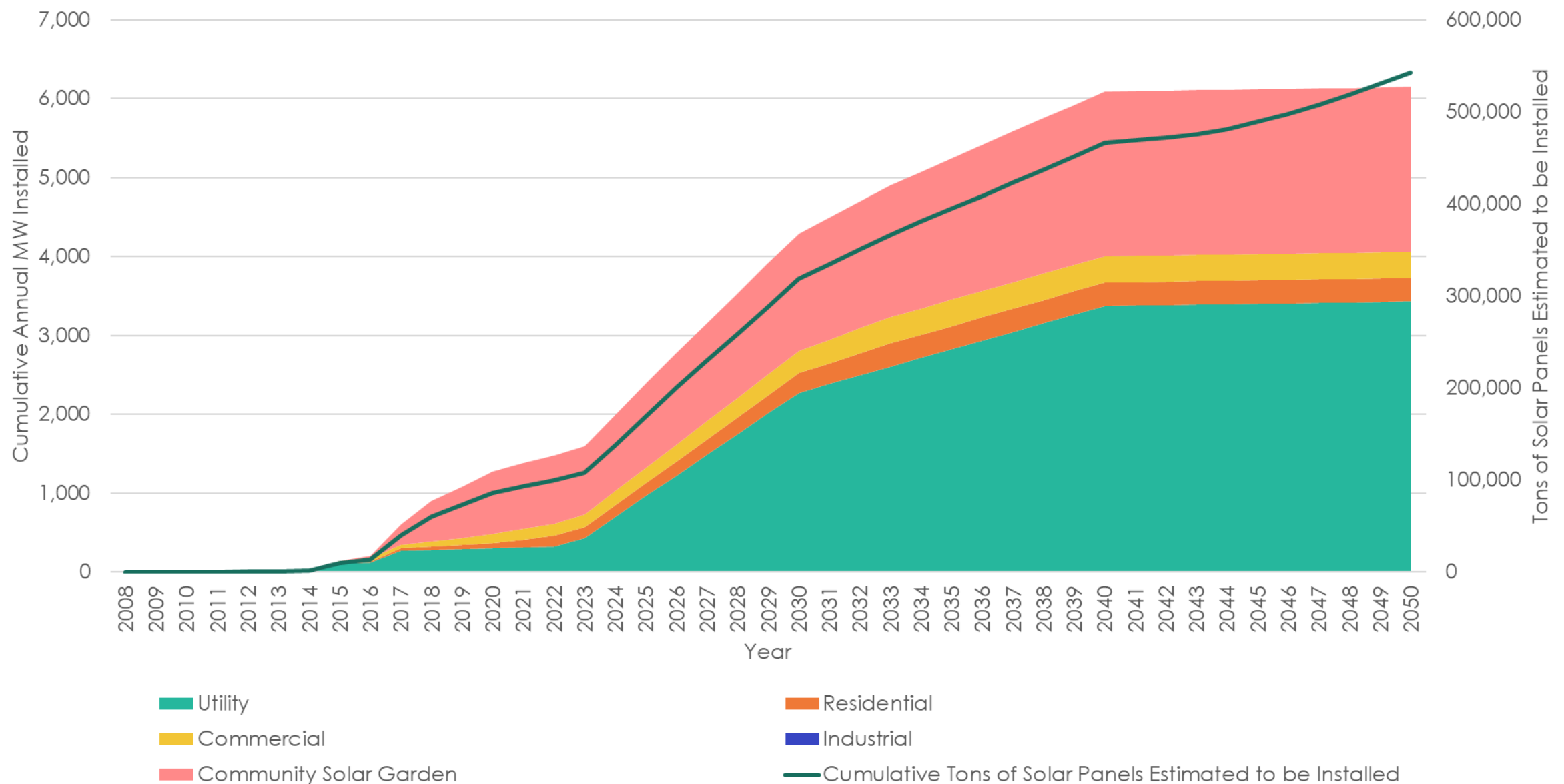
Approach B

Creation of a Central Management Organization (CMO)

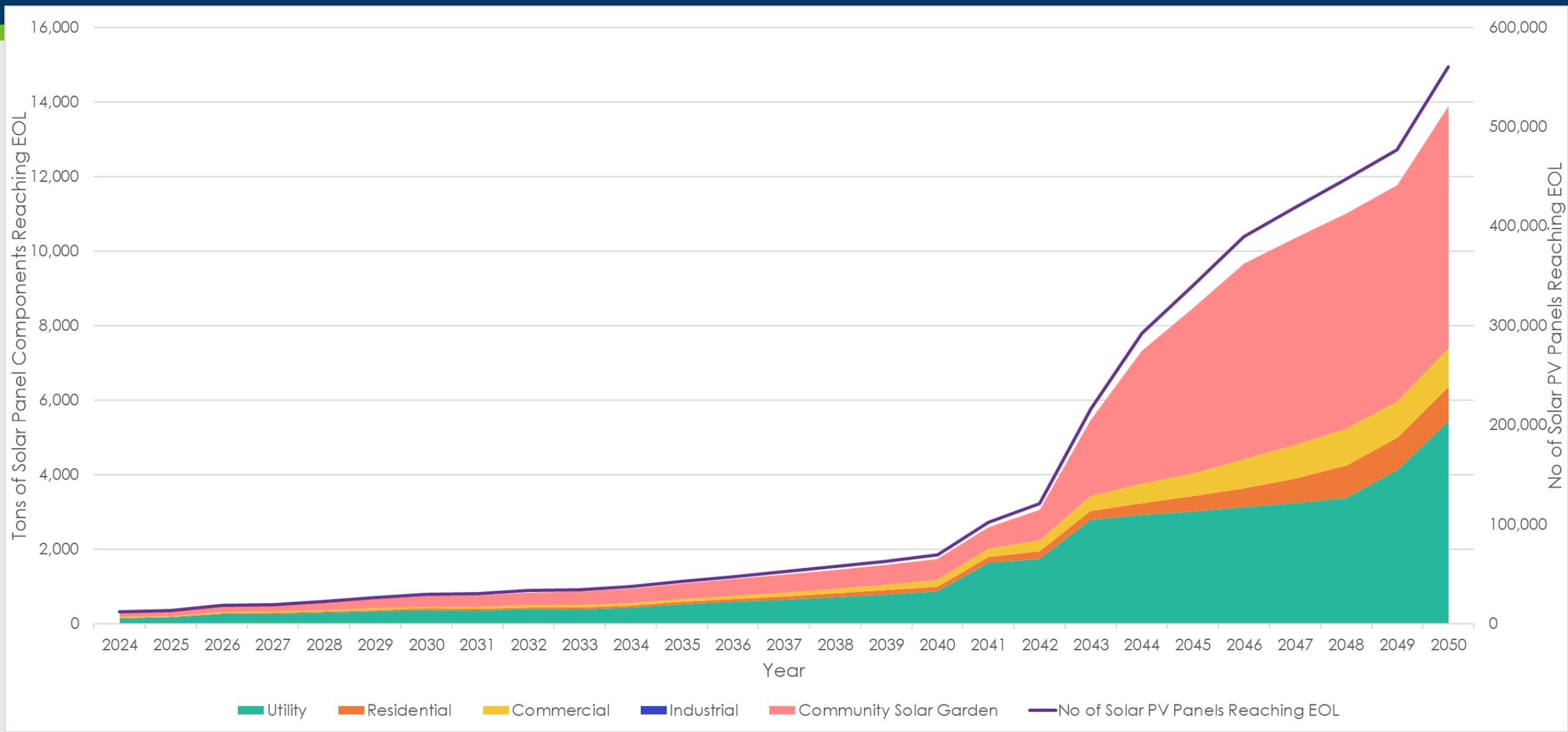
- 1 MW DC and below

- ✓ Could be funded by one or multiple options: permittee, producer, wholesaler, ratepayer, utilities
- ✓ Requires reuse or recycling
- ✓ CMO provides logistical and operational support to help small installations comply with recycling requirements
- ✓ Implemented within 12-24 months
- ✓ Working group recommendations

Cumulative Installed Solar Capacity 2008-2050



Projected Quantities of Solar PV Panels Reaching End of Life

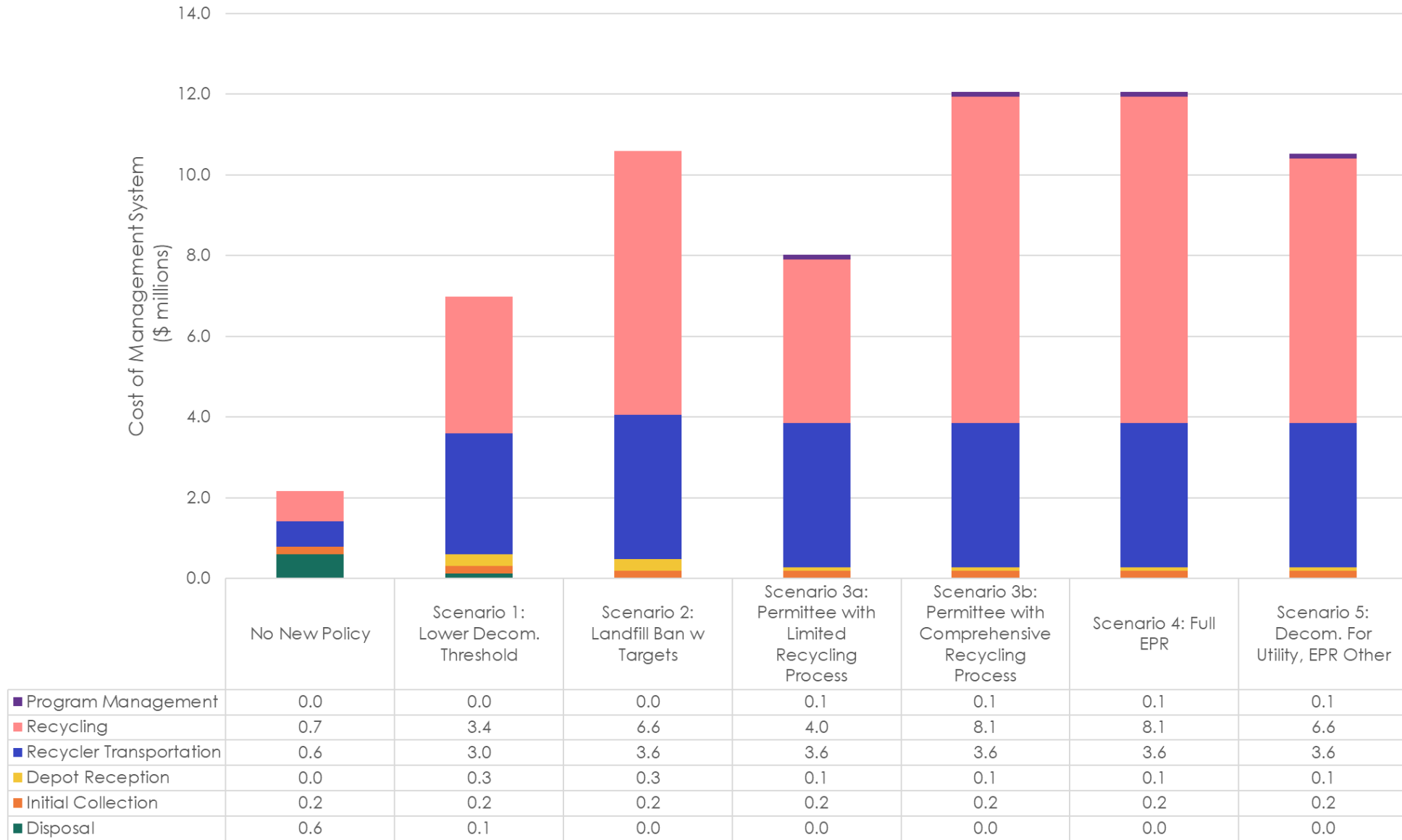


Estimated Annual Number of Solar Panels Reaching EOL (1000 Panels)

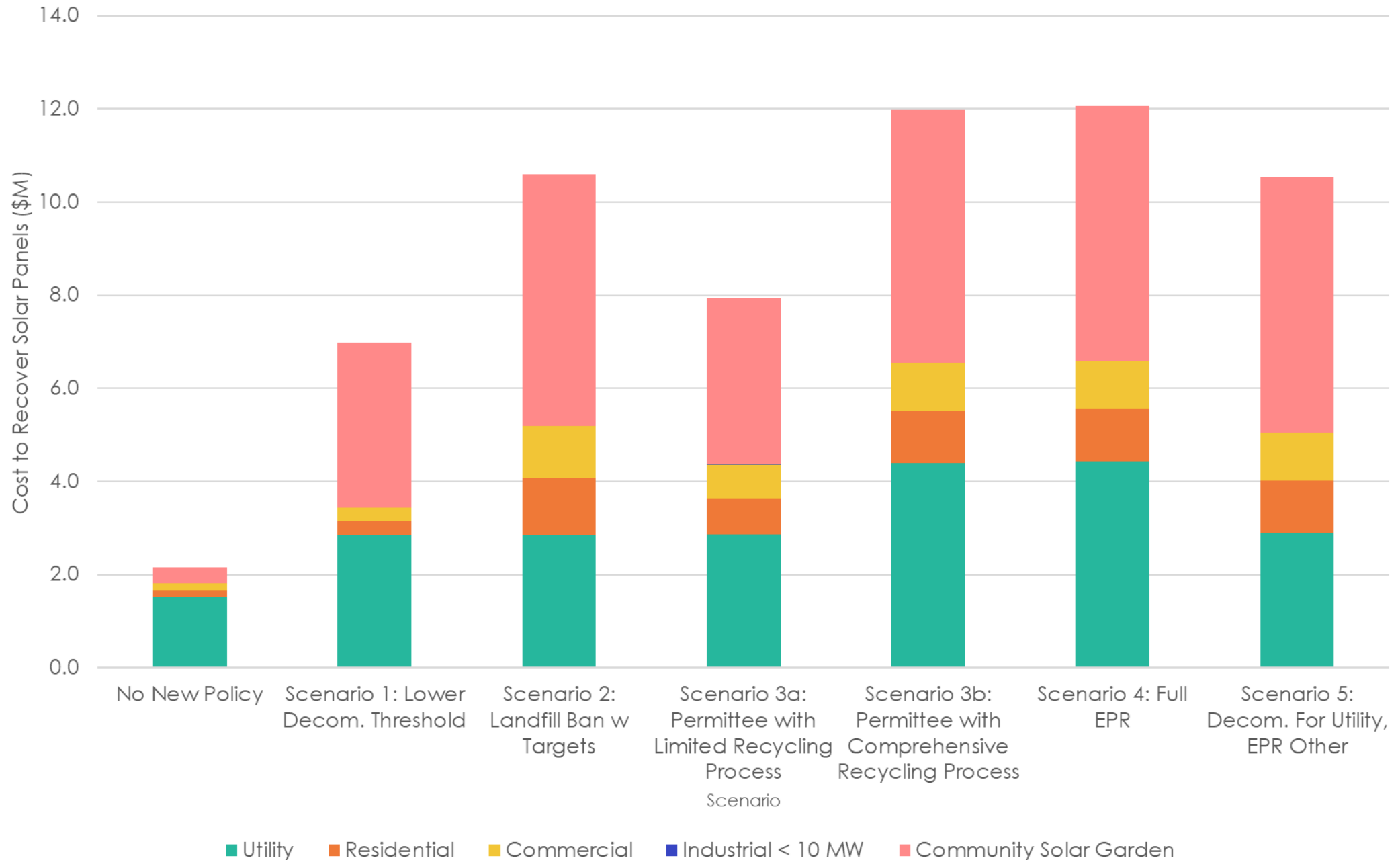
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Utility	5	7	10	10	11	13	14	13	15	14	16	20	22	25
Residential	1	1	1	1	1	2	2	2	3	3	3	3	4	4
Commercial	1	1	1	1	2	2	2	2	3	3	3	3	3	4
Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Community Solar Garden	5	5	7	7	8	10	12	13	13	14	16	17	18	20
Total	12	13	19	20	23	26	30	31	33	35	38	43	48	52

	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	
Utility	27	30	33	62	66	105	110	113	118	121	127	155	205	
Residential	5	5	6	8	10	13	16	21	26	34	44	44	47	
Commercial	5	6	7	9	13	16	21	25	32	37	41	40	44	
Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0	
Community Solar Garden	21	22	23	23	33	83	145	181	214	227	236	237	265	
Total	58	63	70	102	121	216	292	340	390	419	448	477	561	

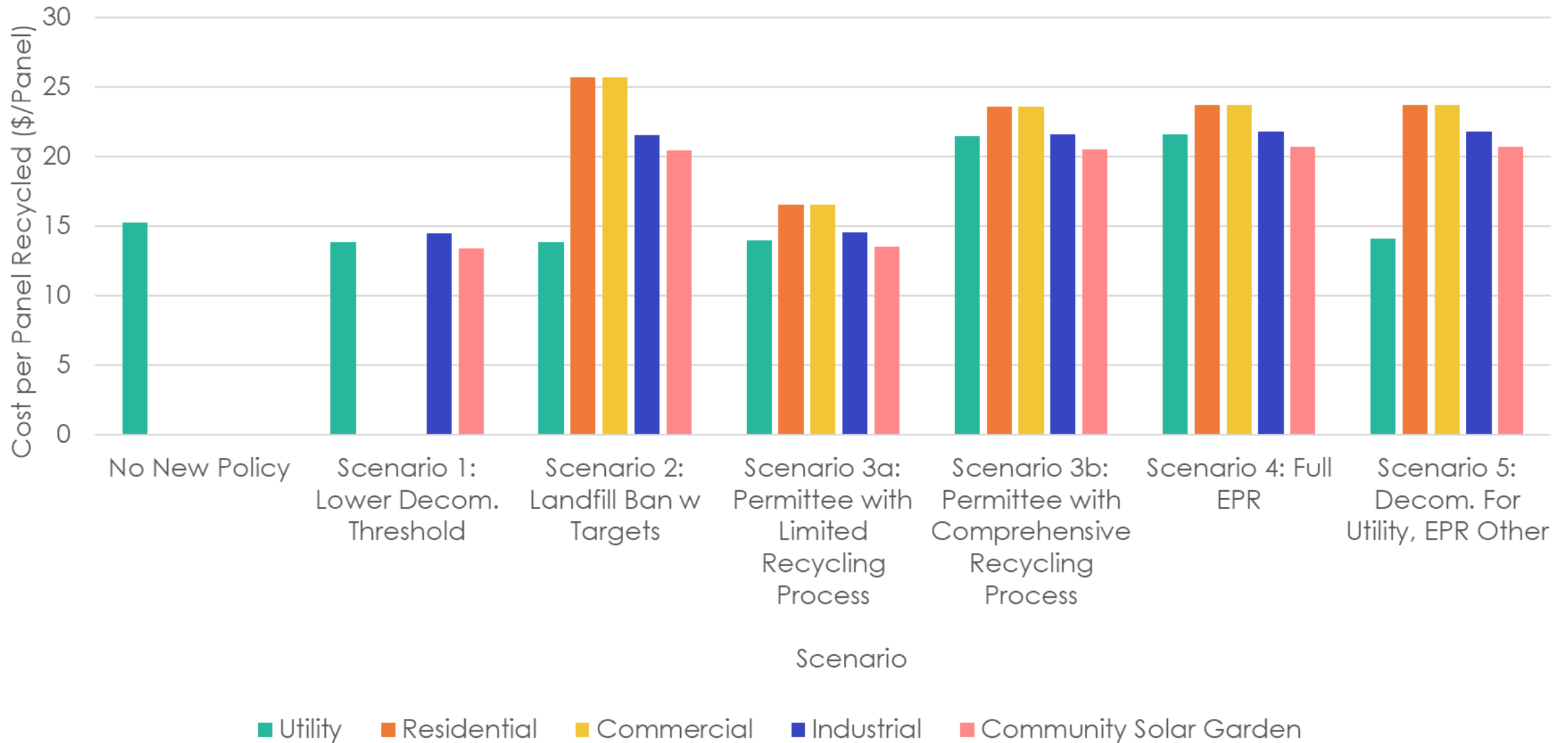
Total Annual Costs by Activity in 2050



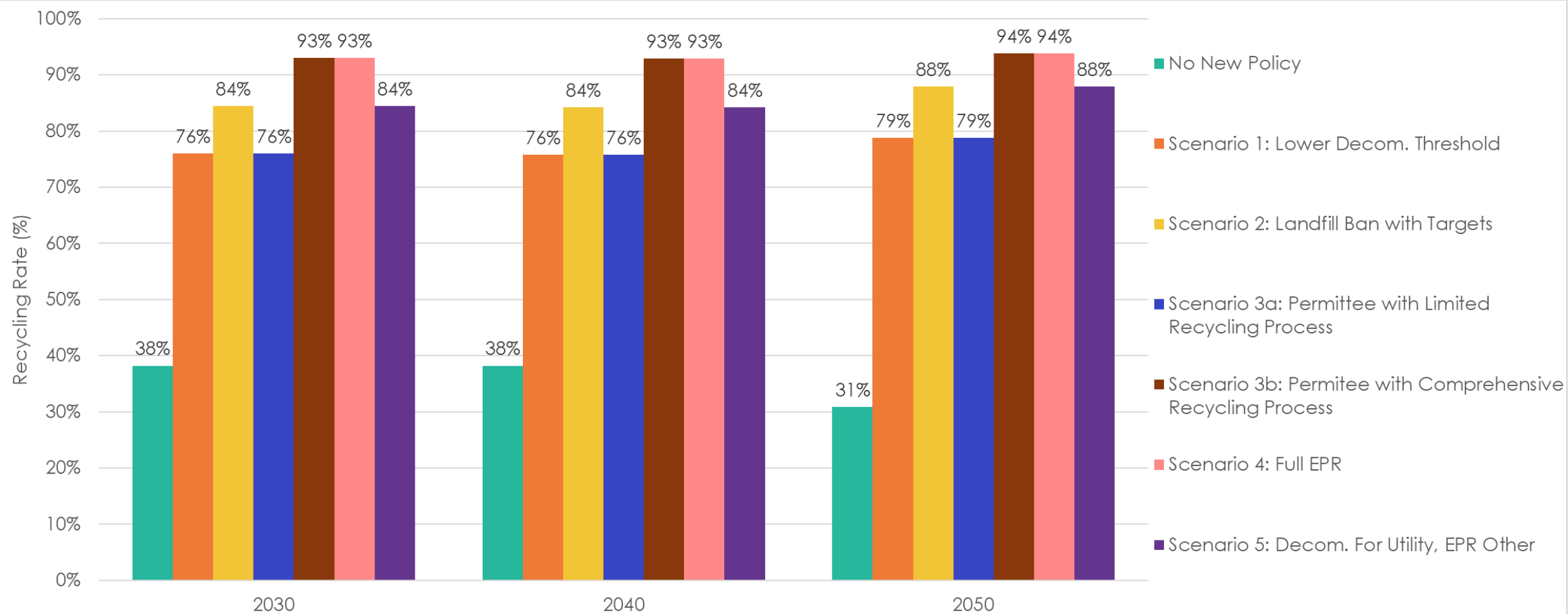
Total Annual Costs by Sector in 2050



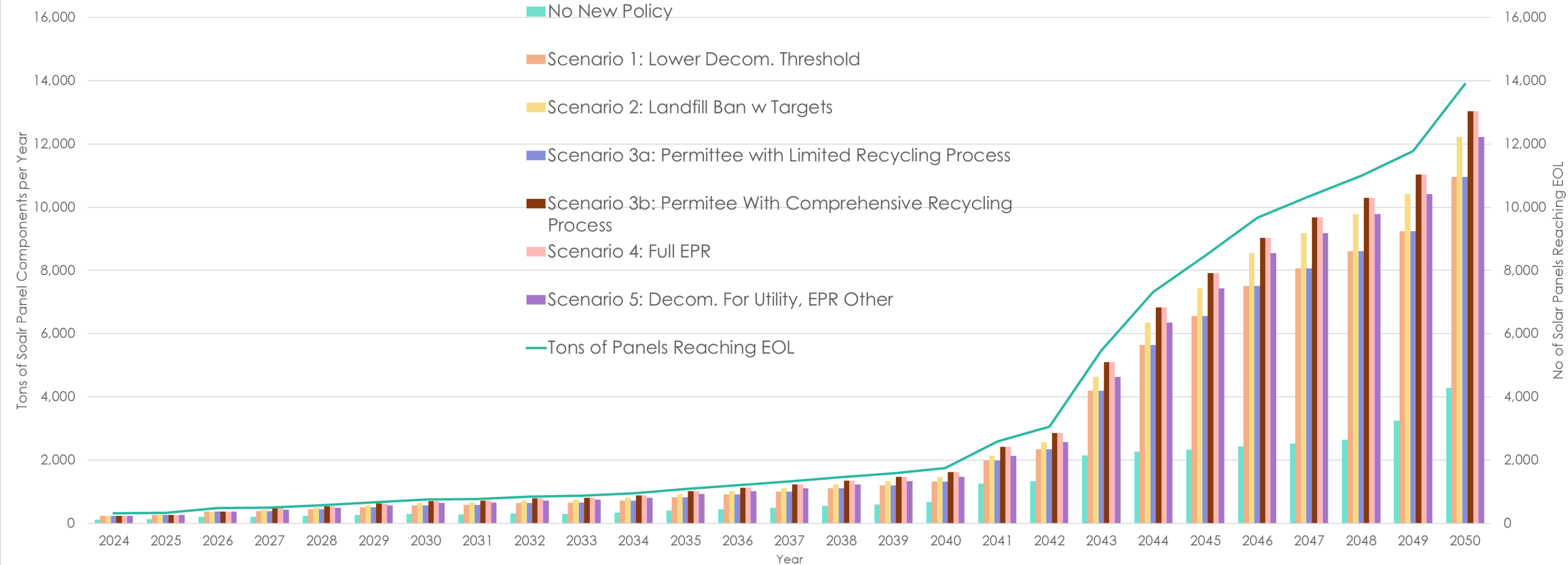
Cost per Panel of Recovering Solar PV Panels in 2050, by Sector



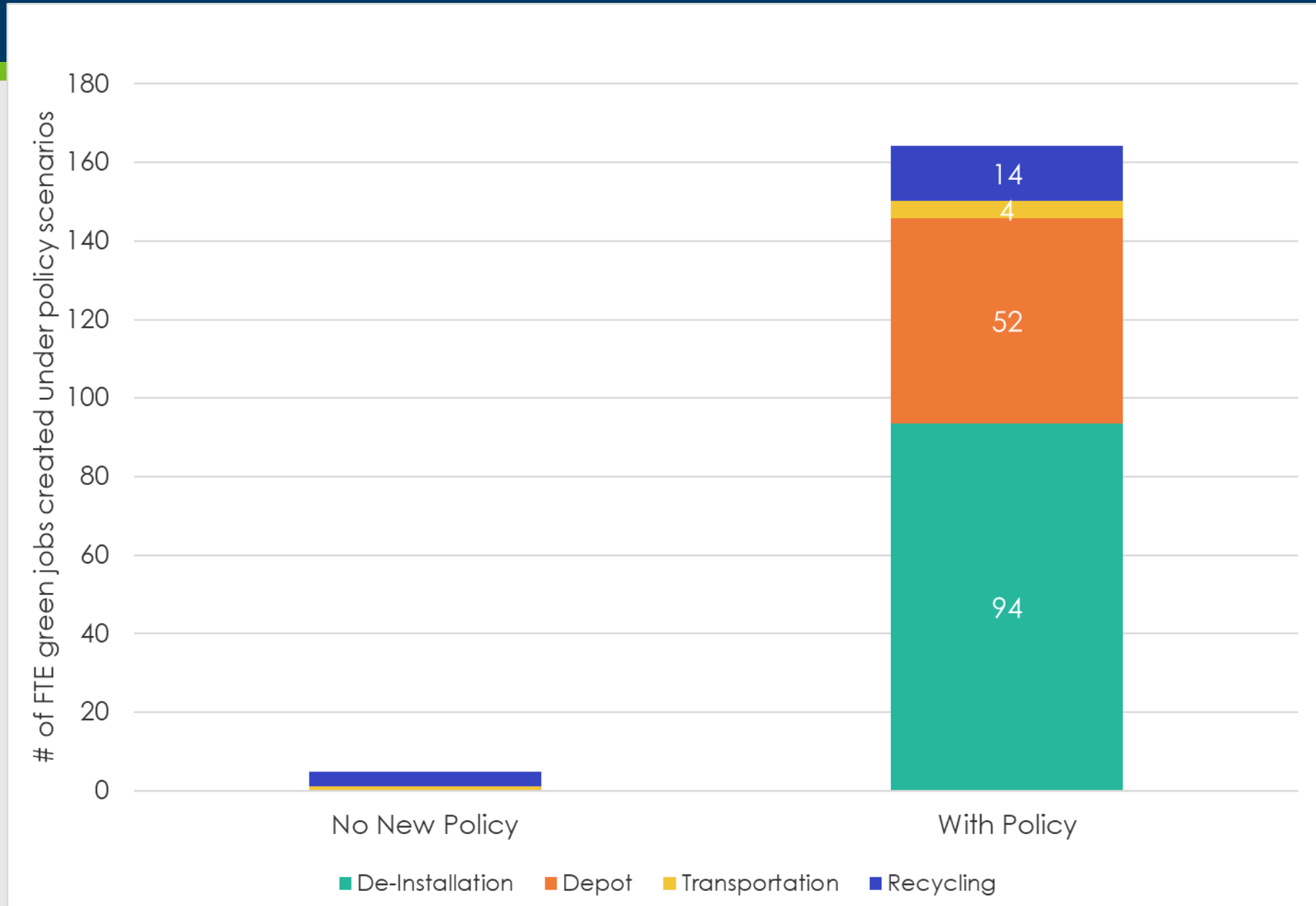
Recycling Rates in 2030, 2040, and 2050 under Different Scenarios



Tons of Solar PV Panel Components being Recycled Vs Tons of EOL Solar PV Panels



Green Jobs in 2050 Under Policy Versus No New Policy



Thank you!

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