



Pathways Toward Grid Decarbonization

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Impacts and Opportunities for Energy Customers from Several US Decarbonization Approaches



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Policy Pathways

1. Transmission Macrogrid
2. Organized Wholesale Electricity Market (OWM) Expansion
3. OWM & Supply Choice Expansion
4. Utility-led Decarbonization
5. Slow CES: 100% target by 2050
6. Fast CES: 100% target by 2035



Study Projects Effects of the Pathways on:

- Power Sector Emissions
- Benefits and Costs of Power Supply
- Commercial & Industrial Electricity Customer Access to Voluntary Green Power Purchasing Options

The pathways are complementary. Could be adopted together, and together with Inflation Reduction Act of 2022.



Key Findings:

1. Each of the pathways produces billions of dollars of projected net benefits per year.
2. Three of the policy pathways accelerate greenhouse gas (GHG) emission reductions while also reducing costs beyond current policy: macrogrid, organized wholesale electricity market expansion, supply choice expansion
3. If all vertically integrated investor-owned utilities fully decarbonized, would reduce national power sector GHG emissions a projected 38%
4. The National CES pathways provide the greatest US power sector decarbonization and net benefits, reducing GHG emissions by more than 90%
5. Combining pathways can increase net benefits. Combining macrogrid and organized wholesale market expansion with CES can more than offset costs of going from about 40% to about 80% clean generation in US.
6. Effects on low-cost voluntary green power procurement options
 - a. Organized wholesale market expansion increases them
 - b. Adding supply choice further increases them
 - c. CES and utility-led decarbonization could go either way

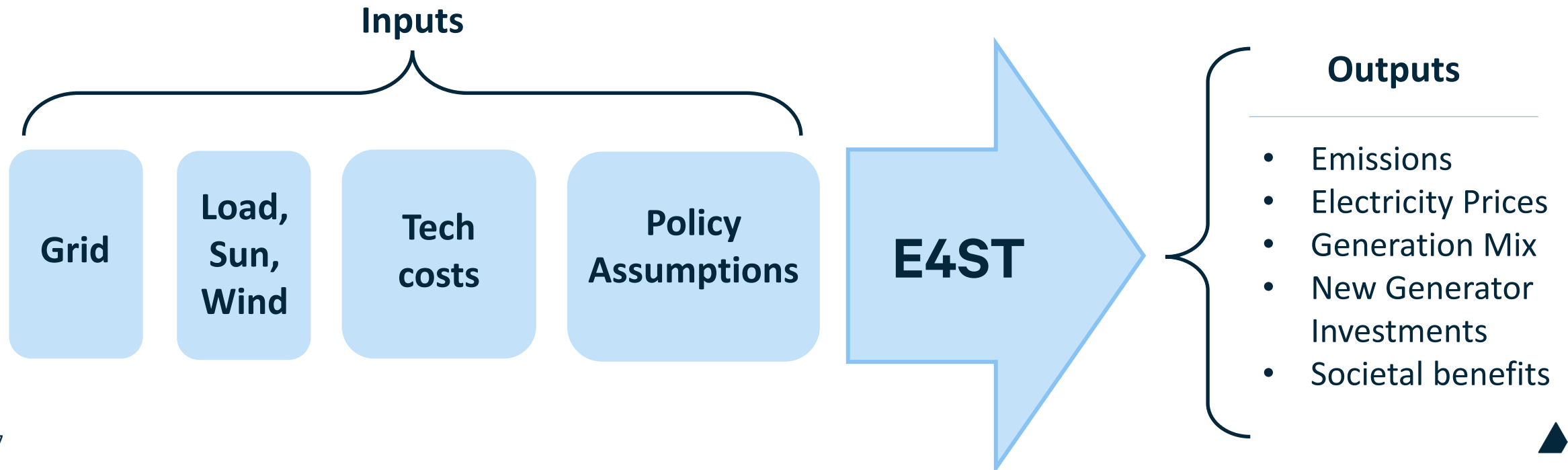


Power Sector Model Used

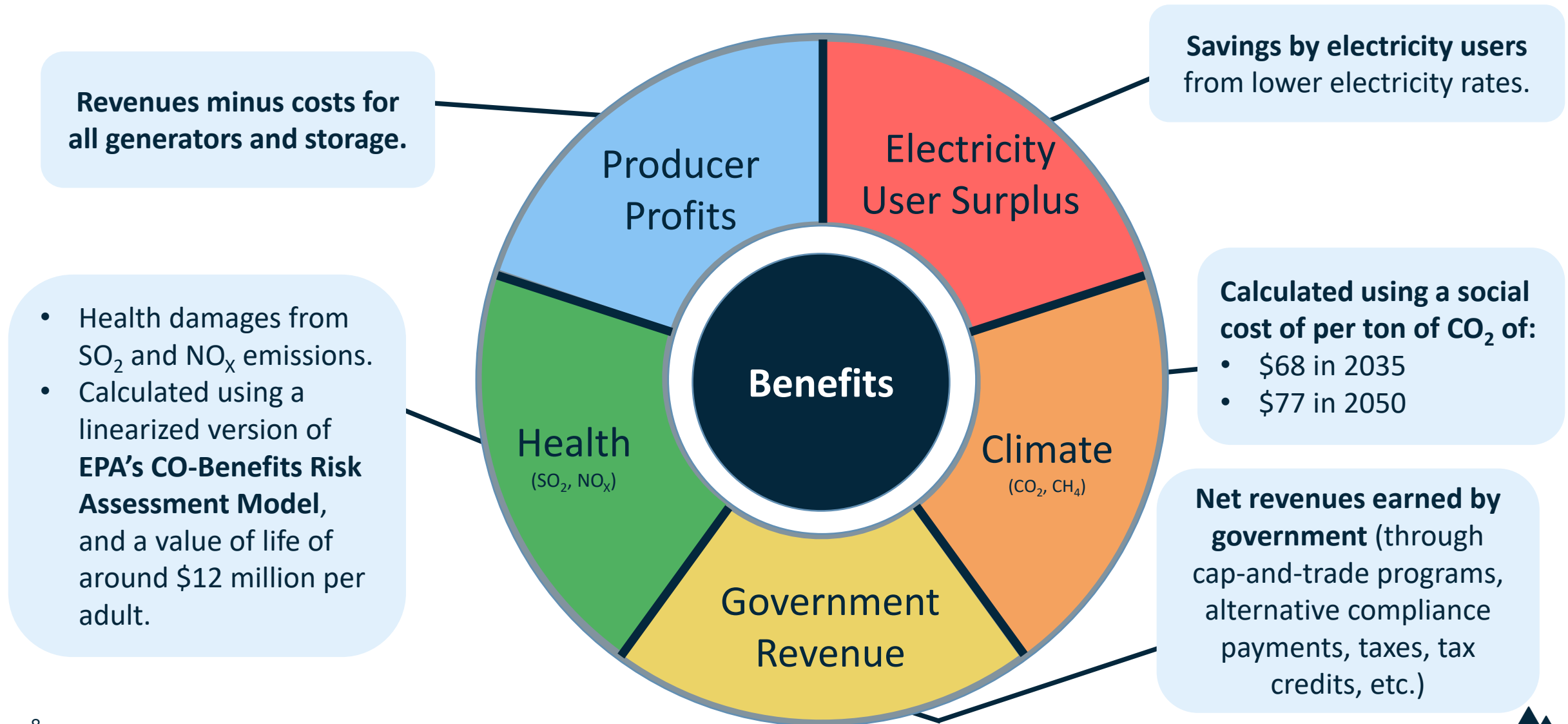


Power Sector Model

- Use RFF's **Engineering, Economic, and Environmental Electricity Simulation Tool (E4ST)**



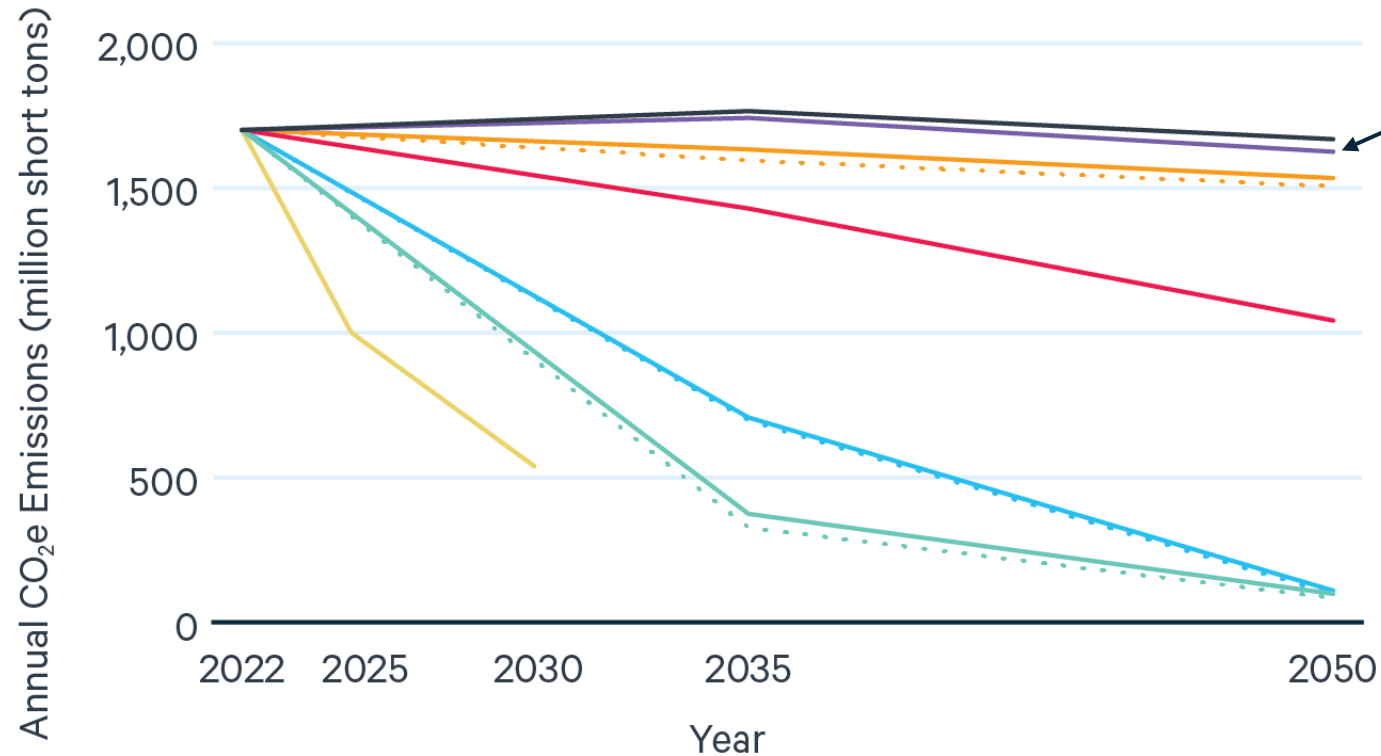
Output: Holistic View of Benefits



Emission & Health Effects of the Pathways



Pathways Reduce U.S. Power Sector Greenhouse Gas Emissions



Even for this apparently small reduction, estimated value is a couple billion dollars per year by 2050

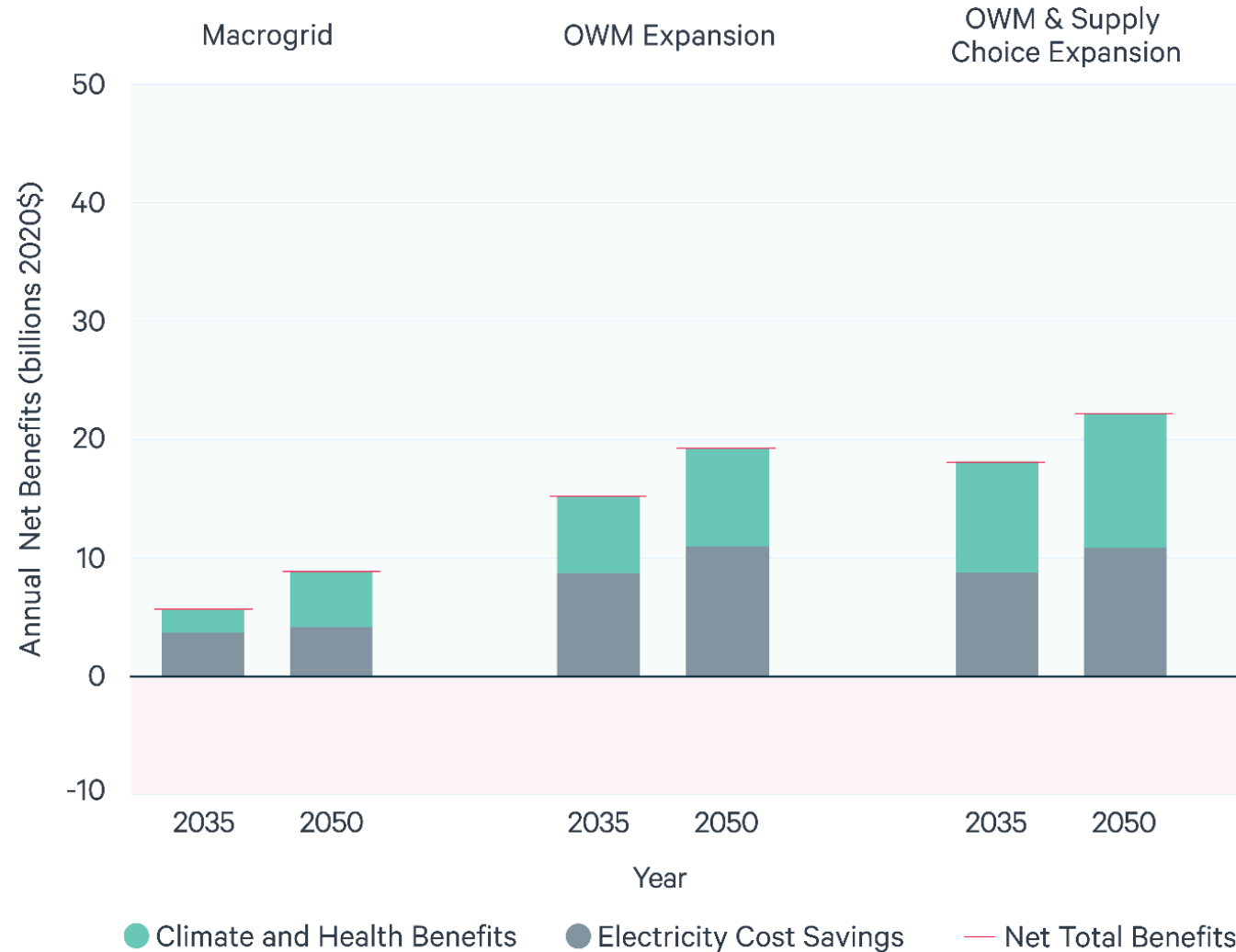
- Reference
- Macrogrid
- OWM
- OWM & Supply Choice
- Utility-led Decarbonization
- Slow CES
- Slow CES & Macrogrid
- Fast CES
- Fast CES & Macrogrid
- 80x30 CES



Pathways 1-3: Cost-Reducing Pathways



Annual Net Benefits of Cost-Reducing Pathways



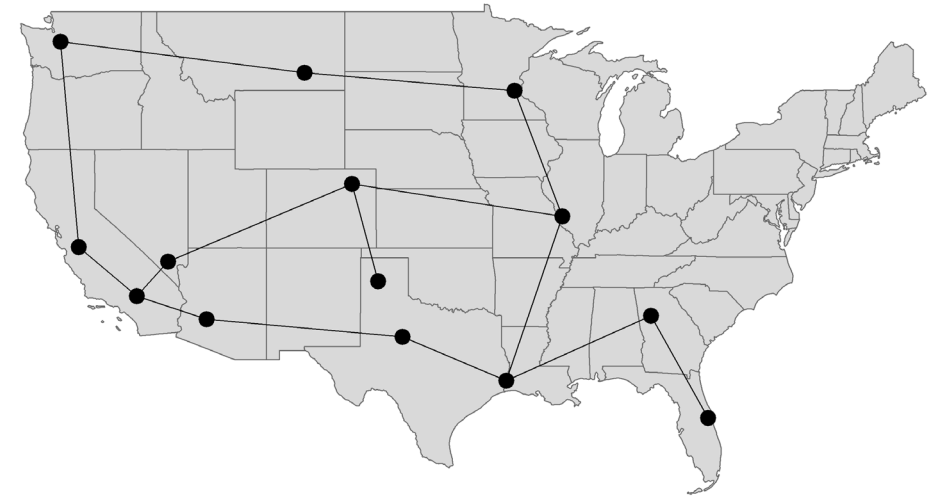
Pathway 1: National Transmission Macrogrid

A national high-voltage DC transmission macrogrid is constructed by 2035.



Transmission Macrogrid

- We model a high-voltage DC macrogrid similar to in NREL seams study
- All corridors have capacity of 8066 MW. Total of 63,150 GW-miles.
- \$5 billion to \$10 billion in net benefits
- Benefits of macrogrid are 3-4 times its costs
- Benefits are about half from cost savings and half from reducing emission damages
- Lowers retail electricity prices 0.8%-1.3%
- Results remarkably similar to those of NREL seams study



Pathway 2: Organized Wholesale Market Expansion to the Southeast and West

OWMs established where they are now absent:
SE and part of West

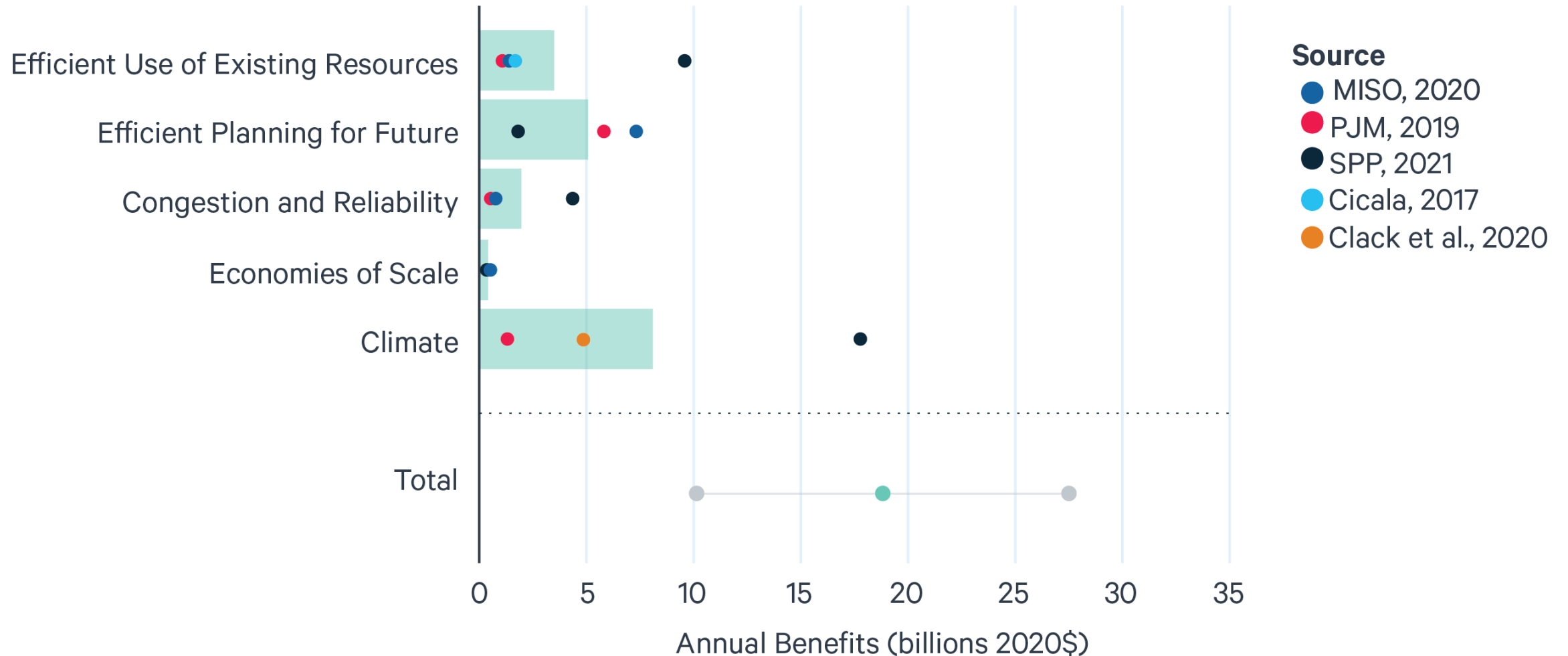


Expanded Organized Wholesale Markets (OWMs)

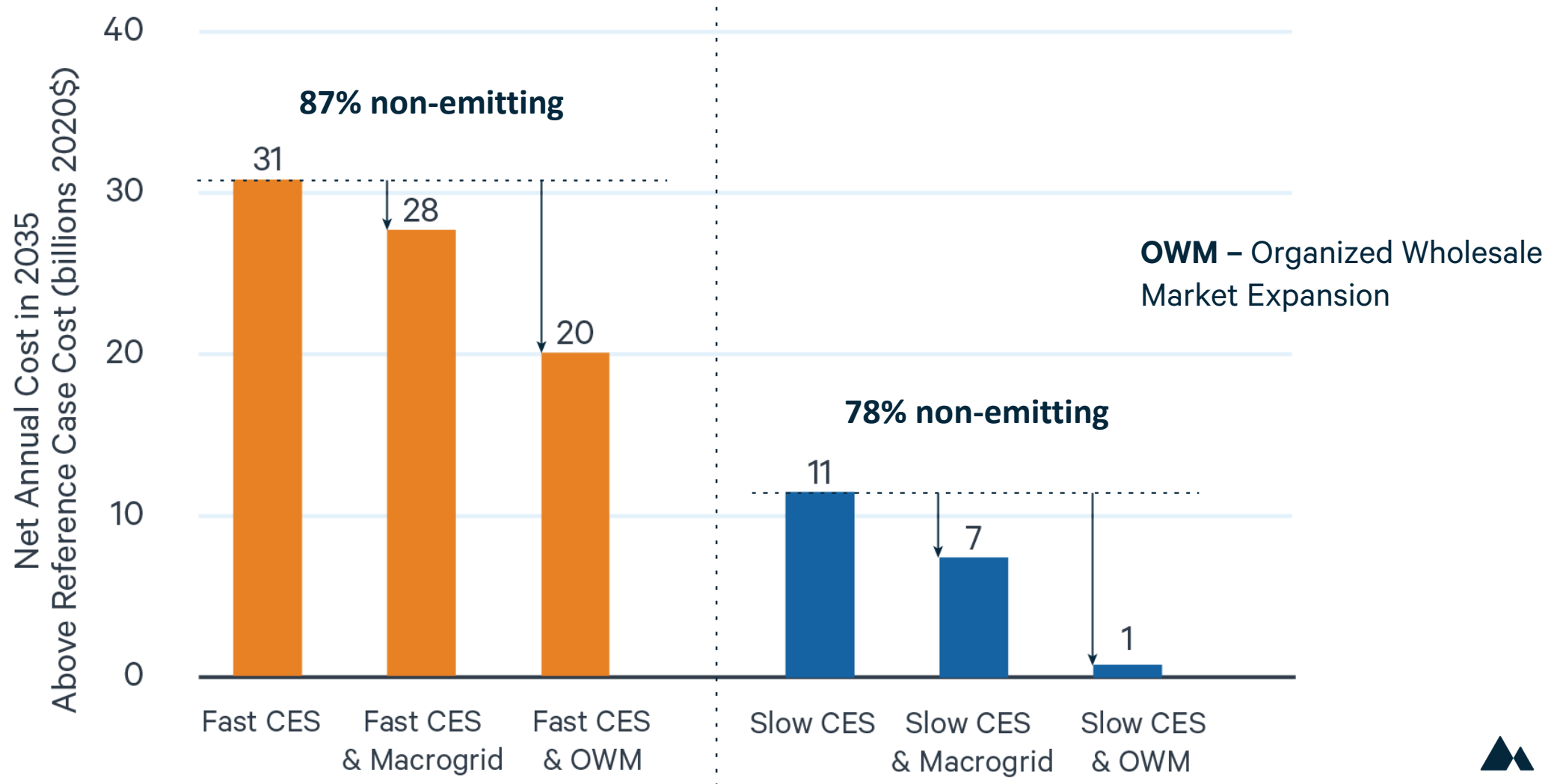
- Able to estimate only some of the benefits of OWM expansion, so conducted meta-analysis of prior studies
- OWMs estimated to result in more efficient integration of renewable energy, planning for future, and use of existing resources
- A central estimate of cost-savings benefits of expanding OWMs is \$11 billion per year in 2035, and \$13 billion in 2050.
- Estimated climate benefits similar to these non-environmental benefits
- Benefits might be less in presence of vertically integrated utilities
- Did not estimate health benefits



Estimated Benefits of Expanding OWMs to Southeast and West



Cost-Reducing Pathways Can Offset Costs of Decarbonization



Pathway 3: Supply Choice Expansion for C&I Customers, on top of OWM Expansion

OWM Expansion + C&I electricity supply choice expanded to investor-owned utilities (IOUs) that don't have it



Projected Voluntary Green Power Purchasing in U.S. as Percentage of Total Electricity Consumption

Based on Historical Growth Rate of Voluntary Green Power and Projected Growth of CESs and RPSs

Pathway	2035	2050
Reference	8.1 %	10.0%
OWM Expansion	9.2%	11.4%
OWM & Supply Choice Expansion	12.0%	15.5%

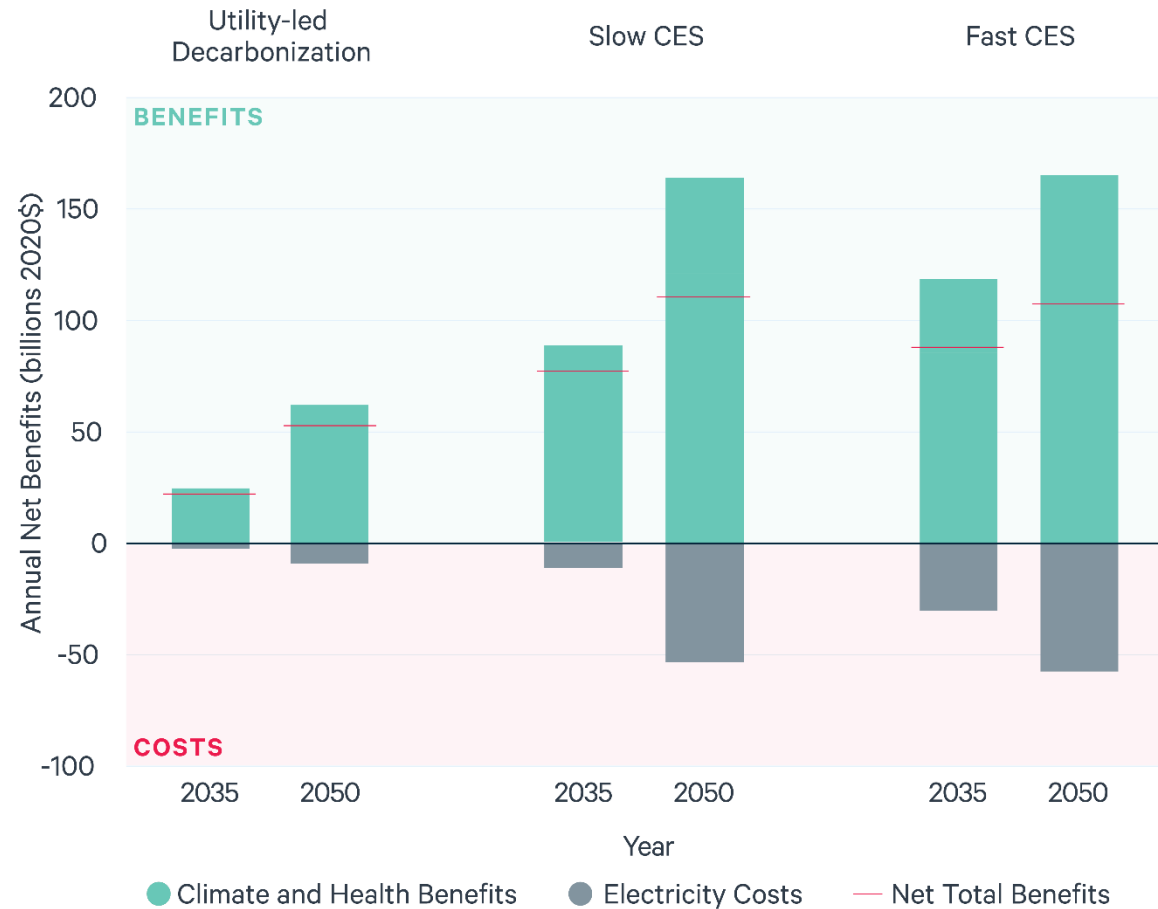
Result for Supply Choice Expansion is that it reduces U.S. power sector greenhouse gas emissions an additional 2% beyond the reduction caused by OWM expansion.



Pathways 4-5: Pathways that Can Be Used for Deep Decarbonization, Locally or Nationally



Annual Benefits and Costs of Utility-led Decarbonization and CESs



Pathway 4: 100% Decarbonization by Vertically Integrated Investor-Owned Utilities

All vertically integrated IOUs achieve 70% clean generation by 2035 and 100% by 2050



Pathway 4: 100% Decarbonization by Vertically Integrated Investor-Owned Utilities

- Such utilities supply 42% of U.S. electricity.
- There is a trend of decarbonization goal setting by some such utilities.
- Would reduce 2050 U.S. power-sector GHG emissions by 38%.
- Ratio of estimated environmental benefits to non-environmental costs is 7 to 1.
- In the absence of any federal tax credits for clean energy, would raise average electricity rates 2.6% by 2050.
- Tax credits like those in IRA would likely reduce the electricity rate impacts of utility decarbonization and of CESs considerably.



Pathway 5: Clean Electricity Standard (CES)

Fast national CES with a target of 100% clean in 2035;
price cap \$54 in 2035, \$85 in 2050;
and no credit for NG.

Slow national CES with a target of 78% clean in 2035, 100% in 2050;
price cap \$46 in '35, \$85 in 2050;
and no credit for NG.



Pathway 5: Clean Electricity Standard (CES)

- Neither Slow CES nor Fast CES quite reaches its 100% target because they have cost ceilings, but they come close.
- Both produce estimated annual net benefits of approximately \$80 billion by 2035 and \$110 billion by 2050.
- Slow CES increases projected 2035 clean generation from 42% in the reference scenario (and less than 40% at present) to 78%, while increasing the projected national average retail electricity rate by just 3% in the absence of any tax credits. (IRA would be likely to significantly reduce that rate impact.)



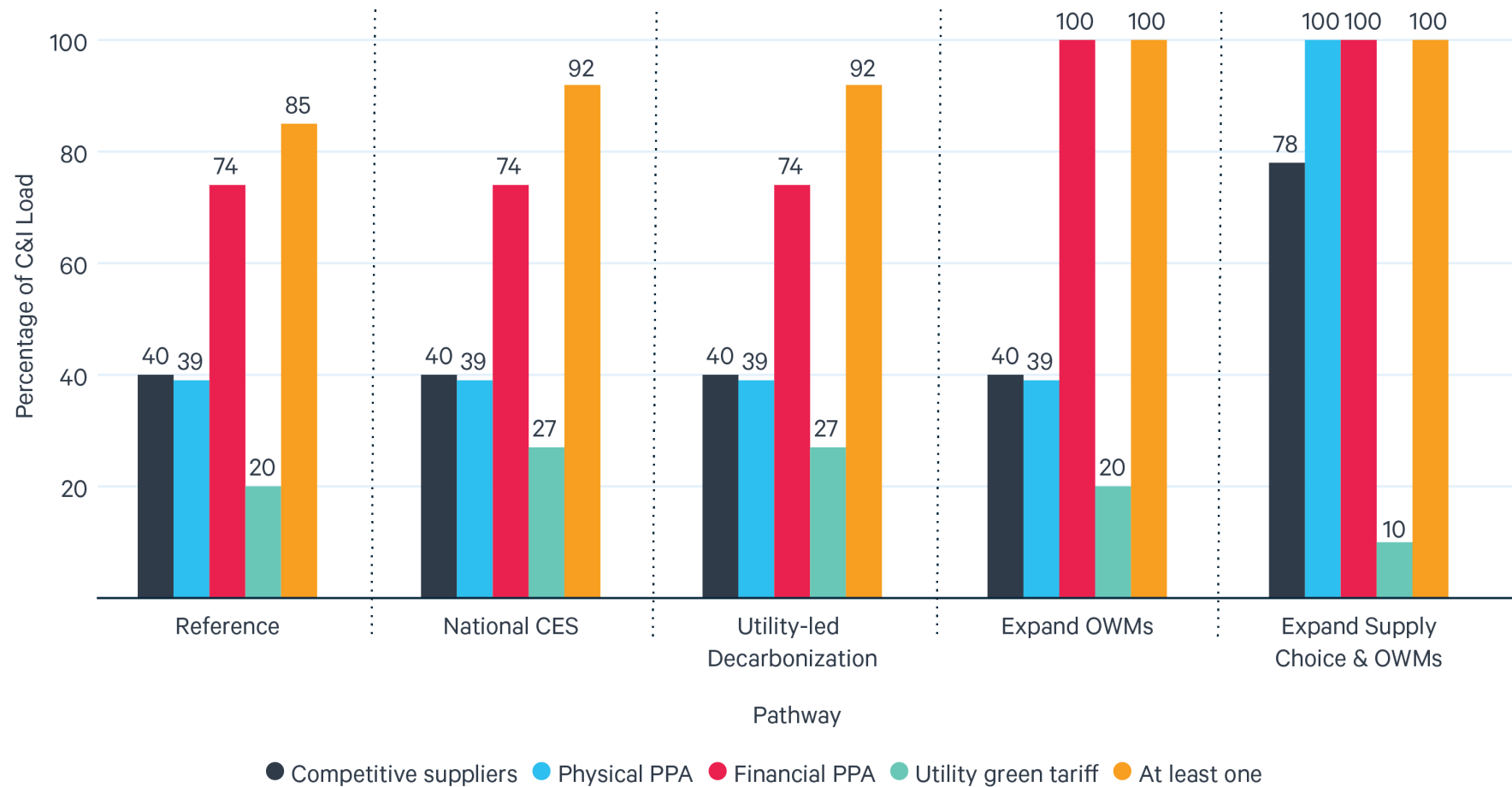
Effects on Access to Options for Voluntary Purchasing of Clean Power



Organized market and supply choice expansion improve voluntary green power options, while CES and utility-led decarbonization could go either way

- Expanding organized wholesale electricity markets increases C&I voluntary clean power access, particularly through financial PPAs.
- Expanding C&I supply choice combined with wholesale electricity markets further increases C&I voluntary clean power access, particularly through competitive suppliers and physical PPAs.
- CES and utility-driven clean energy procurement increases clean energy for ALL customers but might reduce or increase C&I customer low-cost voluntary clean power procurement, depending on whether local electric utilities reduce, retain, or improve customer offerings.







Thank you.

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