



Drivers, Facility Considerations and Economics of the Zero Emission Transition in Rail

FRA Decarbonization Workshop - Will Kirby



5/17/23



Agenda

- 1 Know Your Audience
- 2 Decarbonization Drivers
- 3 Definitions
- 4 Status of Our Industry
- 5 Facility Considerations
- 6 Clean Energy Options
- 7 Economics
- 8 Process & Optimization



Overall Workshop Technical Agenda

- 1 Rail Decarbonization Strategies from Around the World, Part I & II
- 2 Advancing Clean Energy Technologies and Strategies for Rail Applications
- 3 Moving North American Rail Industry Towards Decarbonization, I & II
- 4 Global Trek Towards Decarbonization
- 5 Infrastructure & Resiliency – The Missing Link!
- 6 “Standing Up” the Standards
- 7 Optimizing Current Technologies and Operations for More Efficient Rail

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- 6 “Standing Up” the **Standards**
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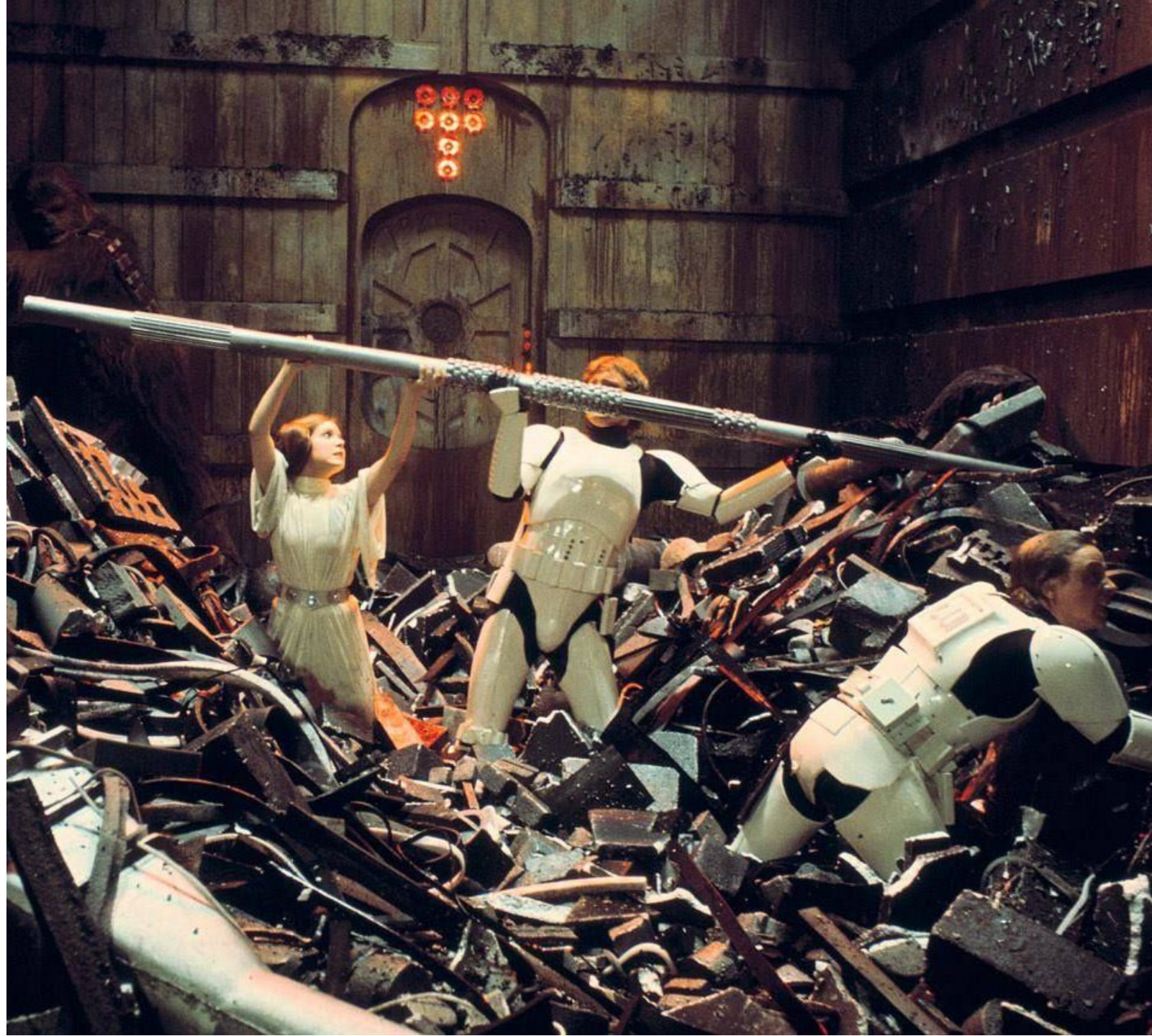
Pulse of the Industry Audience Poll

- Presented on similar topics already this year?
- Presenting on similar topics yet this year?
- Presenting outside of this industry?
- Led or participated in internal workshops or strategy meetings on this topic?

Why Decarbonization?

Looking Outside the Walls

- Regulations
- Shareholder or Owner Pressure
- Community & Stakeholder Input
- Customer Requests
- New Opportunities





Why Decarbonization?

Looking Inward

- Business Growth/Client Opportunities
- Innovation & Technology Opportunities
- Improve Resiliency
- Employee Recruitment & Retention
- It's the "Right Thing"



Zero Emissions vs.

Net Zero Emissions vs.

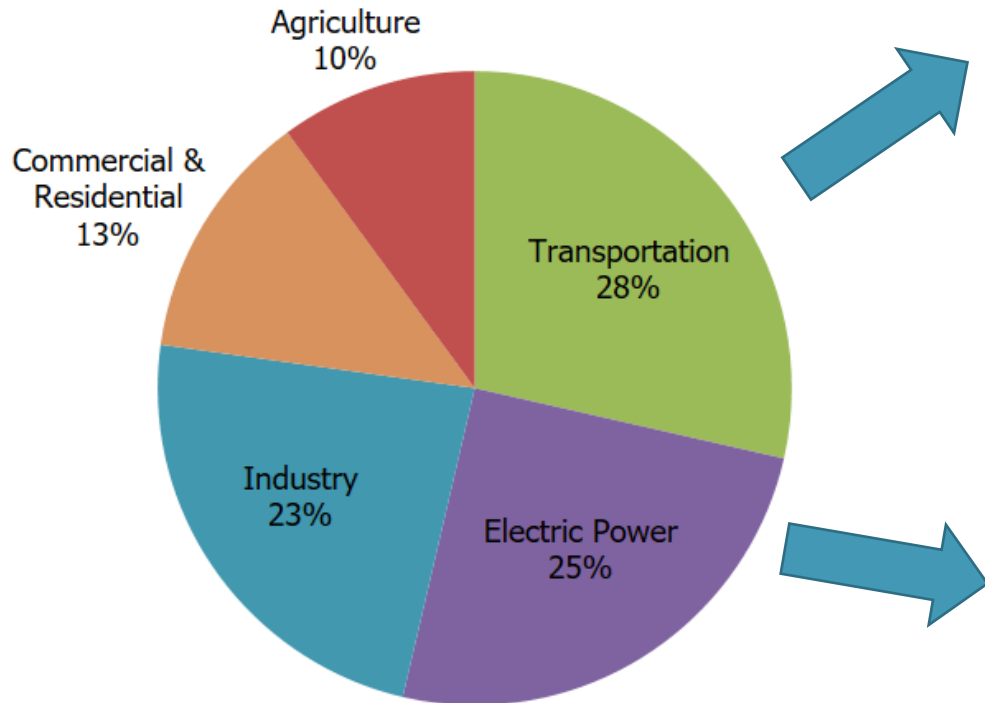
Electrification vs.

Decarbonization vs.

Embodied Carbon vs.....

How Does Transportation Stack up?

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2021

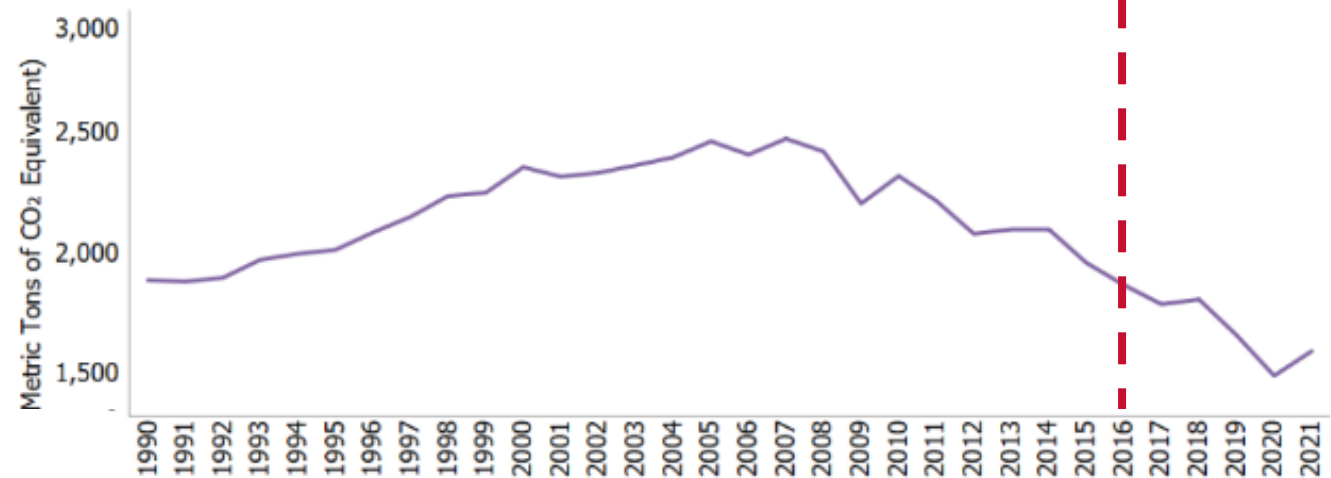


Source: EPA

Greenhouse Gas Emissions from Transportation, 1990-2021

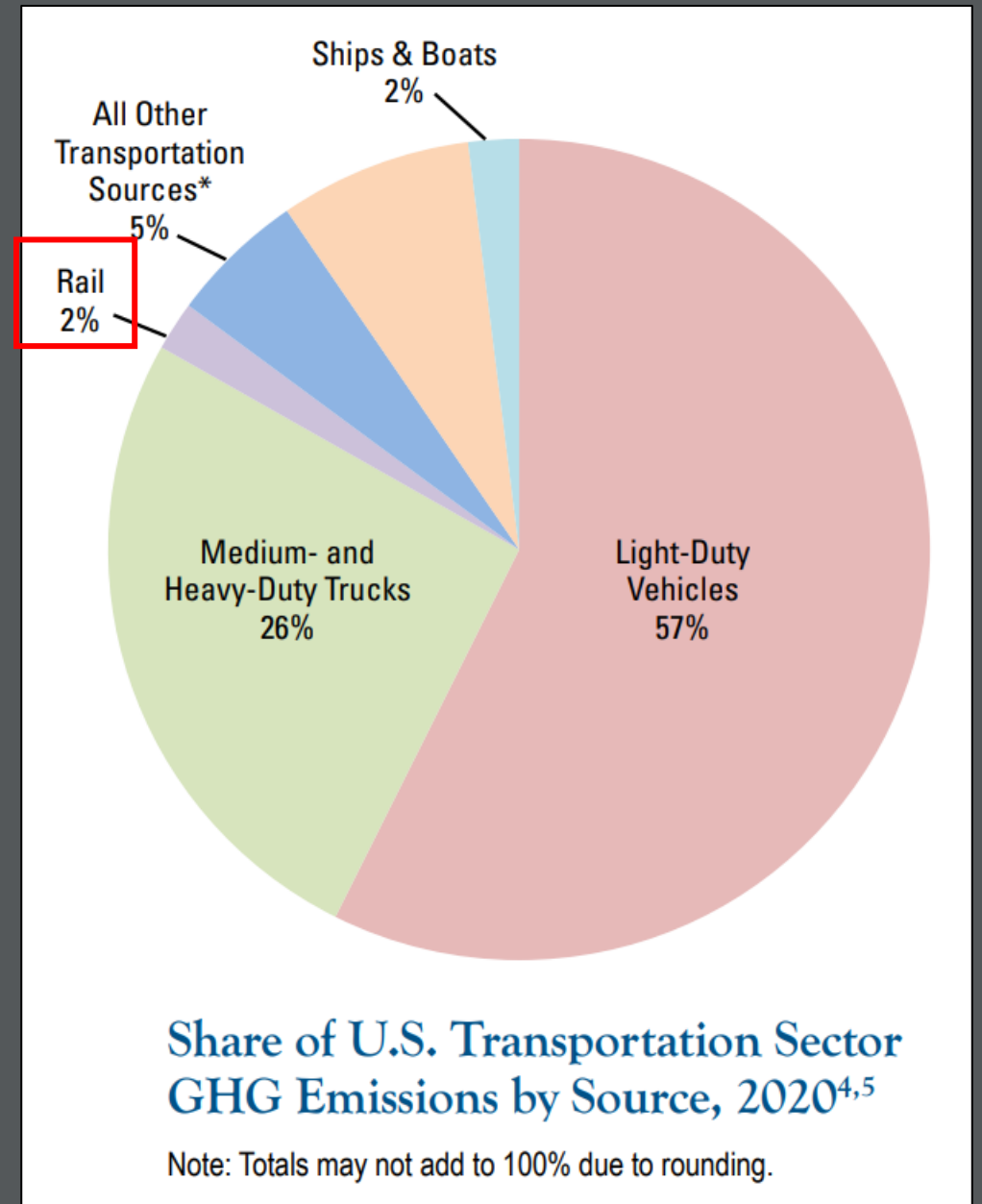
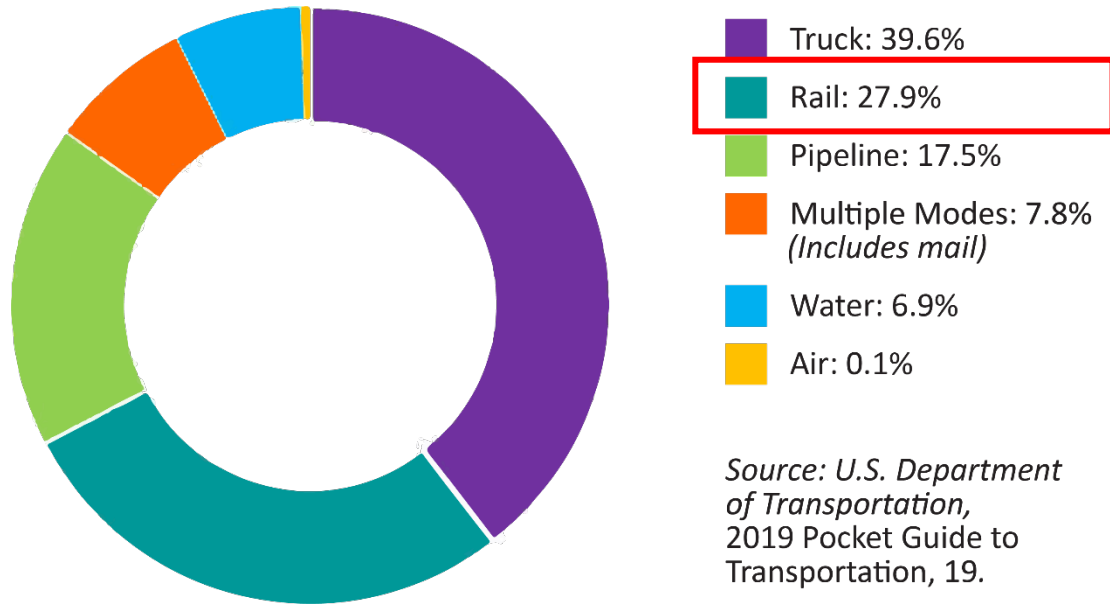


Greenhouse Gas Emissions from Electric Power, 1990-2021



Rail – Small but Mighty?

How, What, and Where Freight Moves?



RESEARCH

PLANNING

DEVELOPMENT + DESIGN

PILOT + TEST

ANALYSIS

DESIGN ENHANCEMENT

INTRODUCTION + TRANSITION

ADAPTION

FACILITY CONSIDERATIONS

FUTURE-PROOFING FACILITIES FOR CHARGING

NETWORK PLANNING AND DESIGN

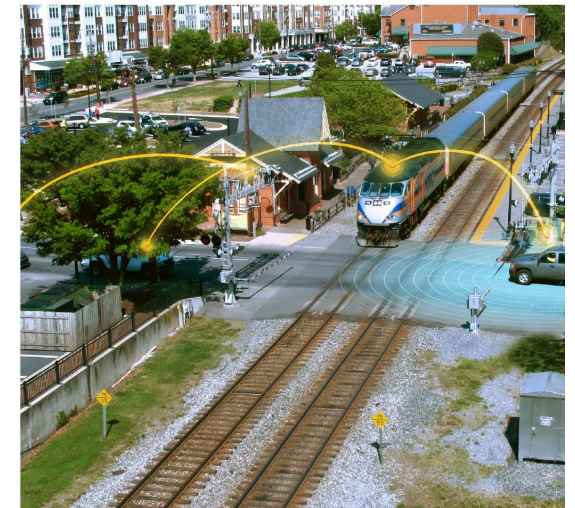
EV READINESS PLAN



ALTERNATIVE DELIVERY SUPPORT

GRANT AND CAPITAL PLANNING

ENERGY MANAGEMENT

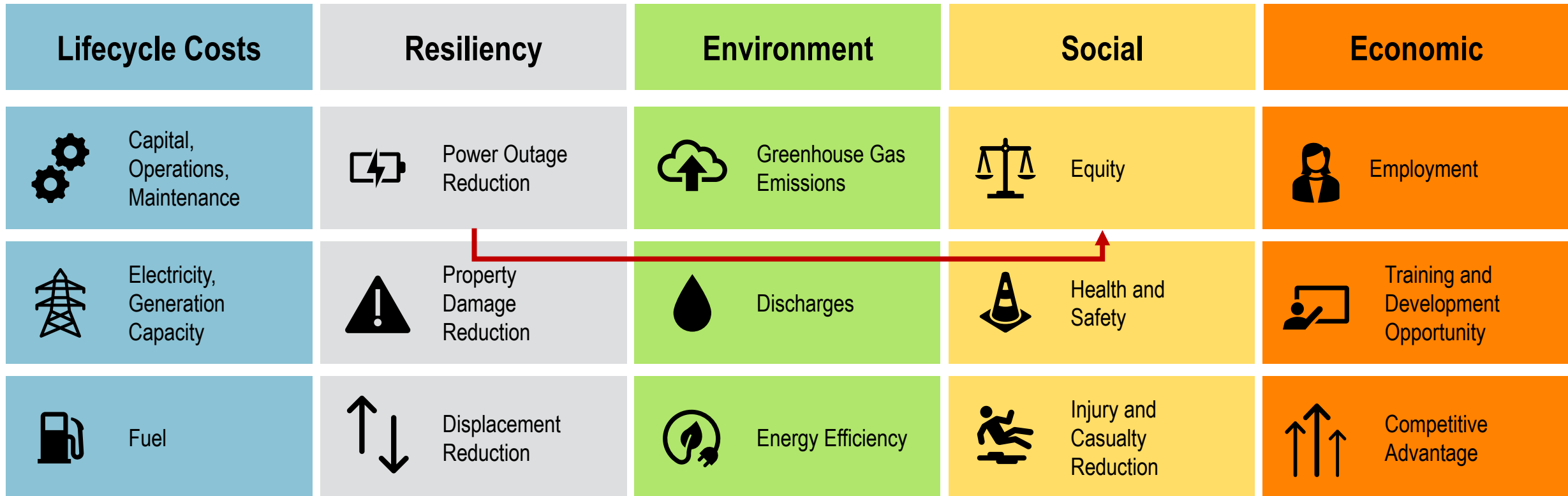


YARD OPERATIONS

OPERATIONS AND MAINTENANCE

SUSTAINABILITY

Consider the Sustainable Return on Investment (SROI) for Potential Impacts and Opportunities

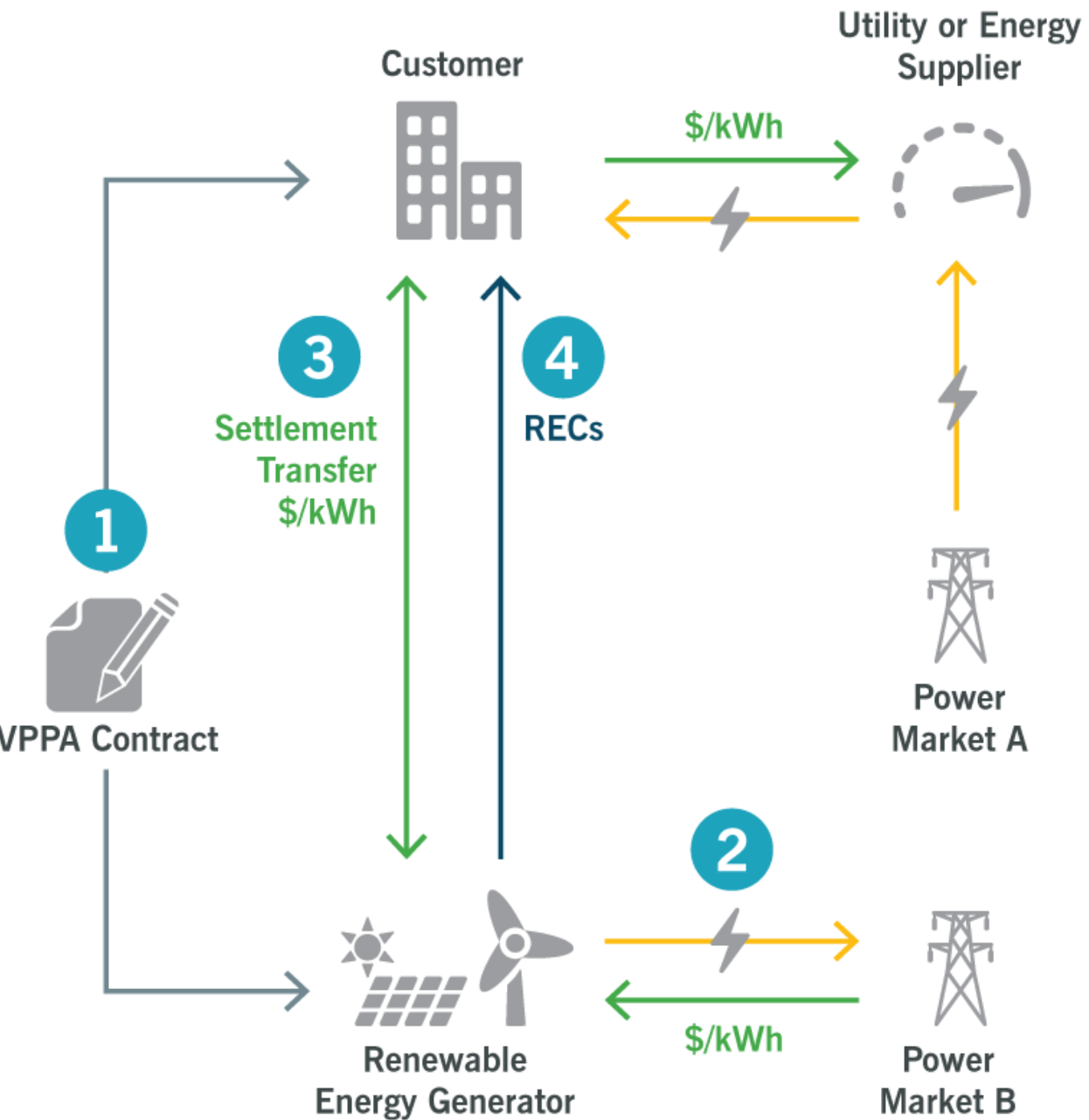


Identify Impacts & Co-benefits Between Groups and Silos!



Clean Energy and Zero Emission Options

- Solar
- Wind
- +Battery Energy Storage
- “Other” – Hydrogen, Fuel Cell, Biofuels, etc.

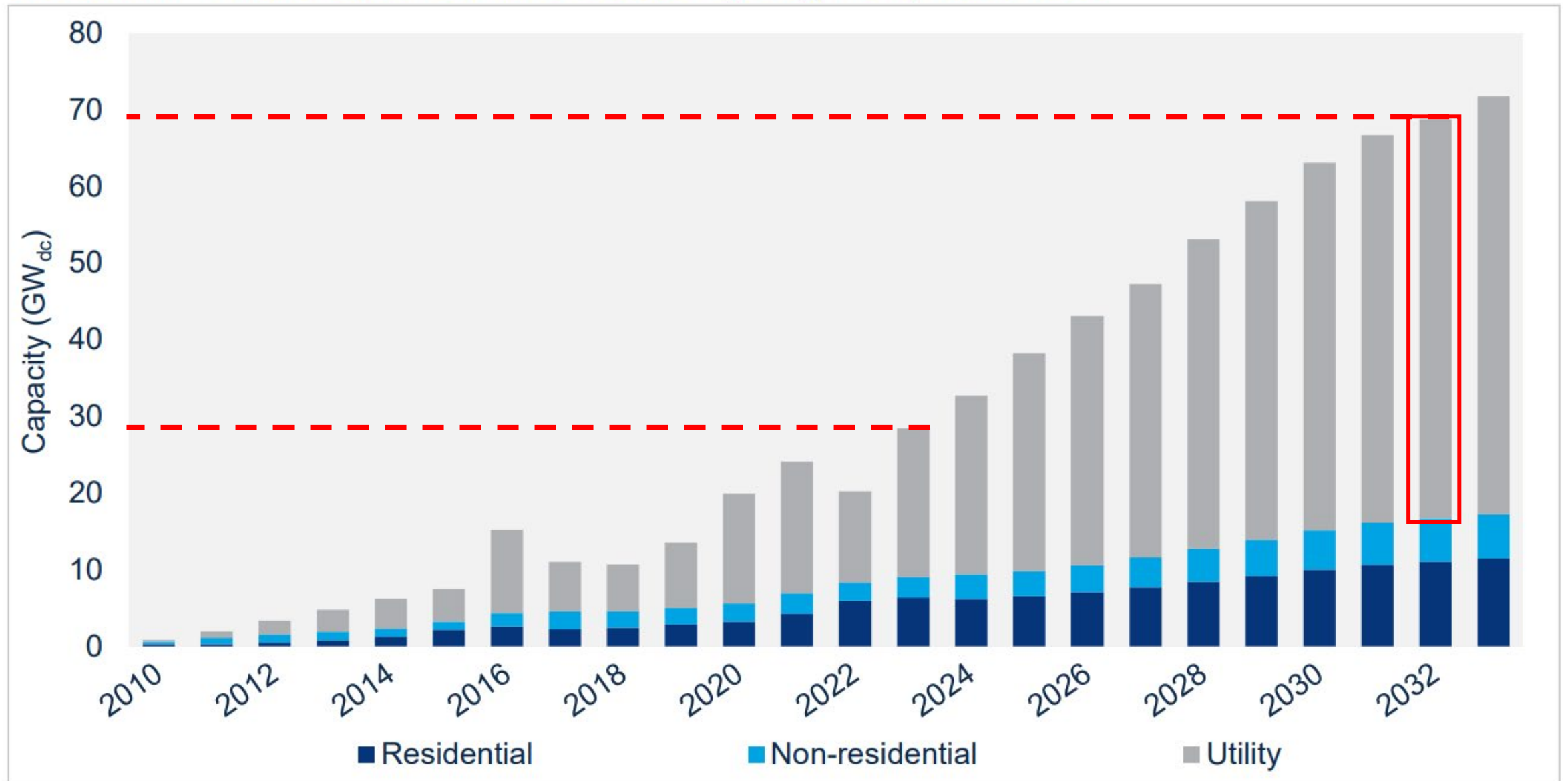


Source: Christopher Kent, US Environmental Protection Agency (EPA) Webinar

Onsite vs. Virtual Agreements

- PPA vs. VPPA
- Consider the stakeholders involved
- Understand your need
- Identify your goals
- Weigh the Pros and Cons

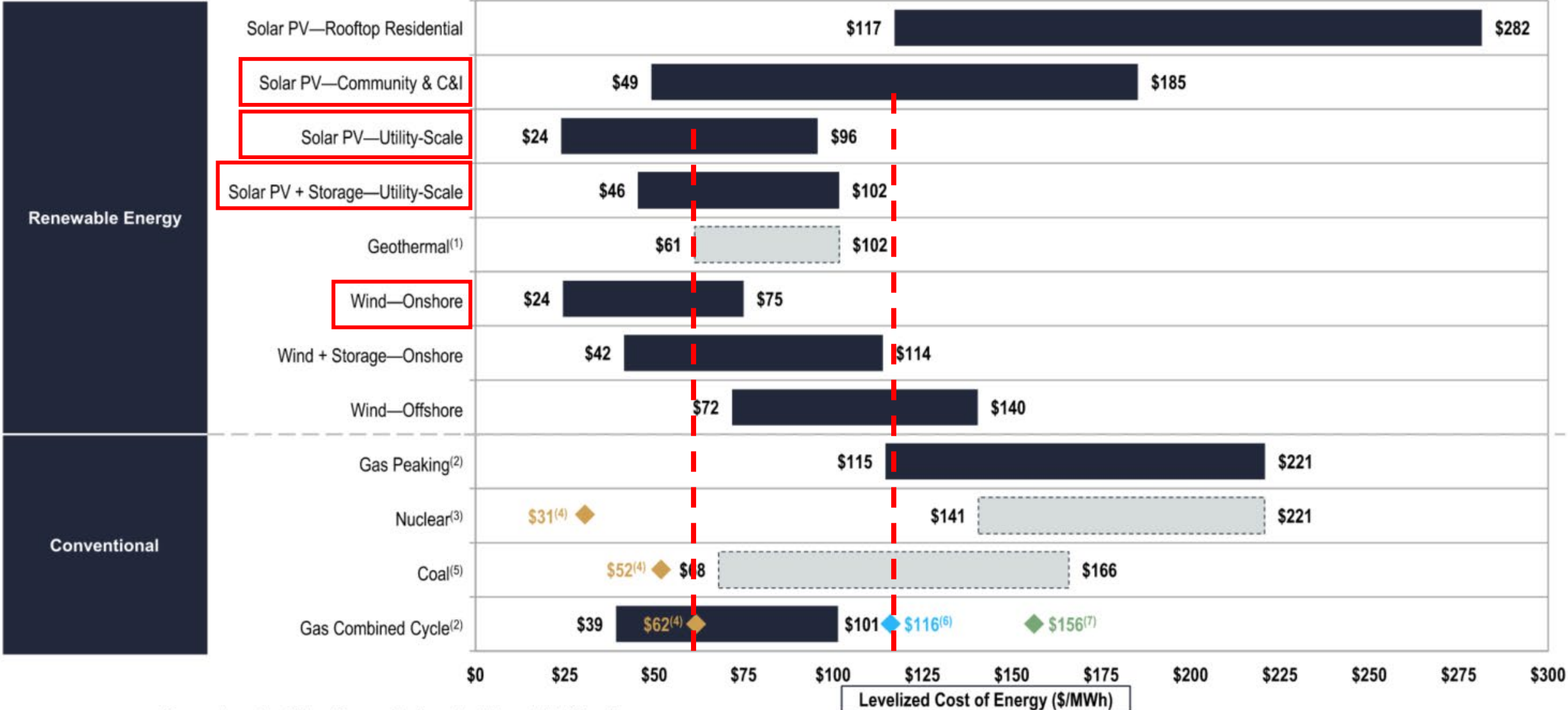
US solar PV installations and forecasts by segment, 2020-2033



Source: Wood Mackenzie

Levelized Cost of Energy Comparison—Unsubsidized Analysis

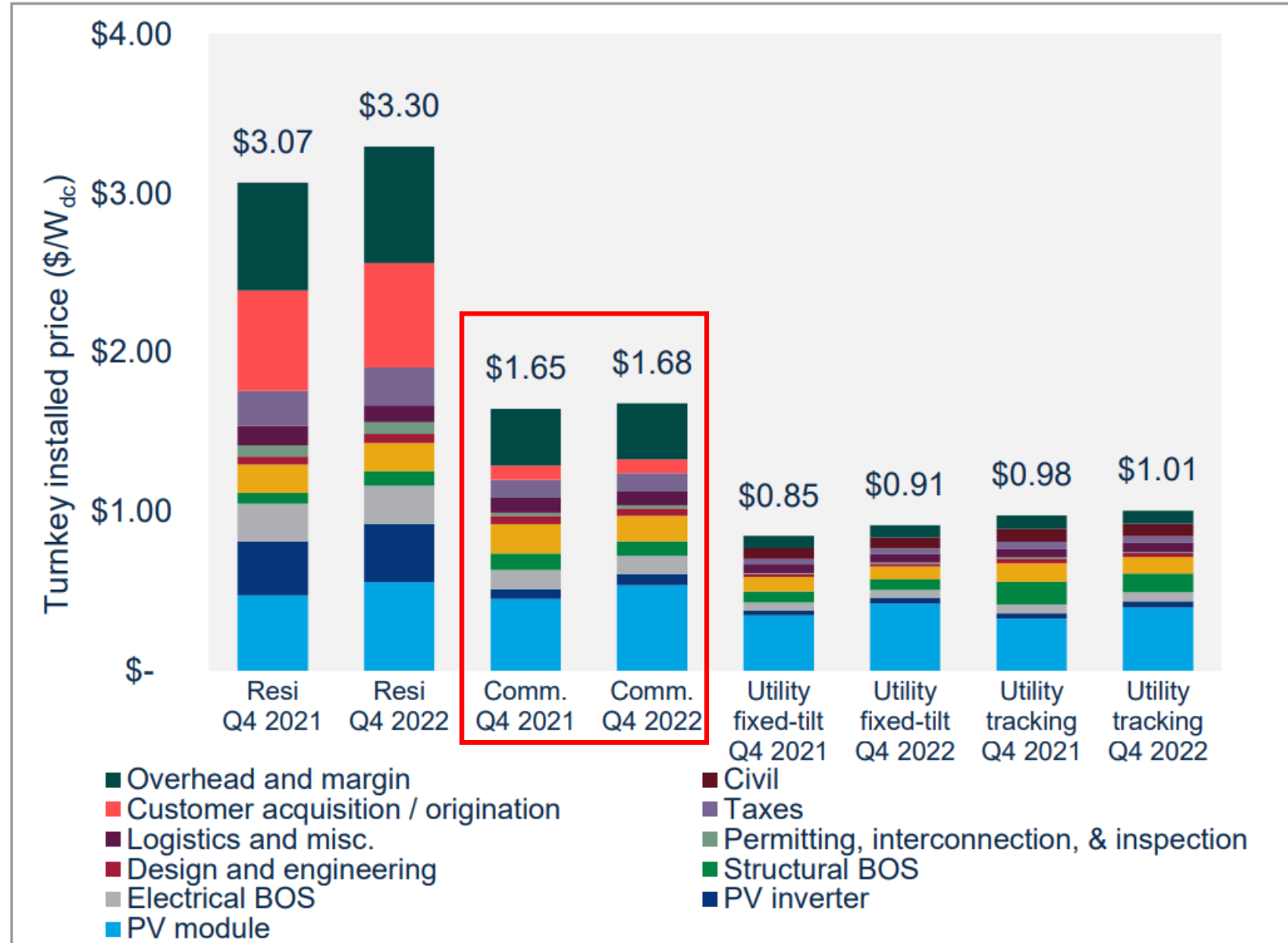
Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



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

Solar Turnkey Costs 2021-22

Modeled US national average system prices by market segment, Q4 2021 and Q4 2022

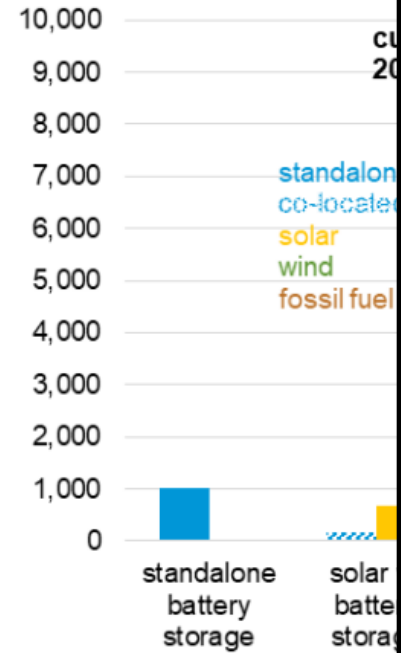


Source: Wood Mackenzie

Battery Storage Growth and Pricing Trends

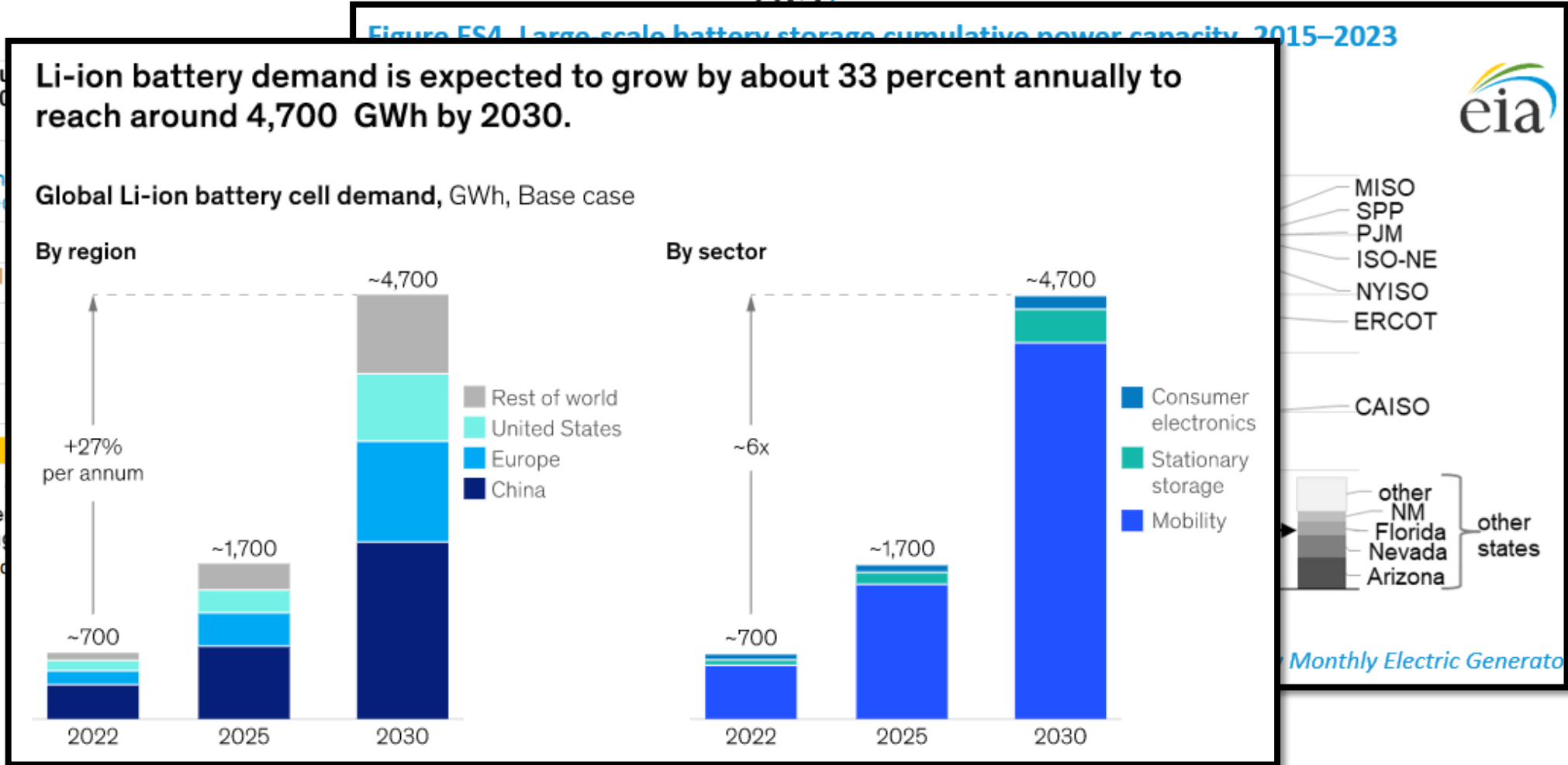
Figure 15. U.S. large-scale battery storage power capacity, standalone and co-located

megawatts



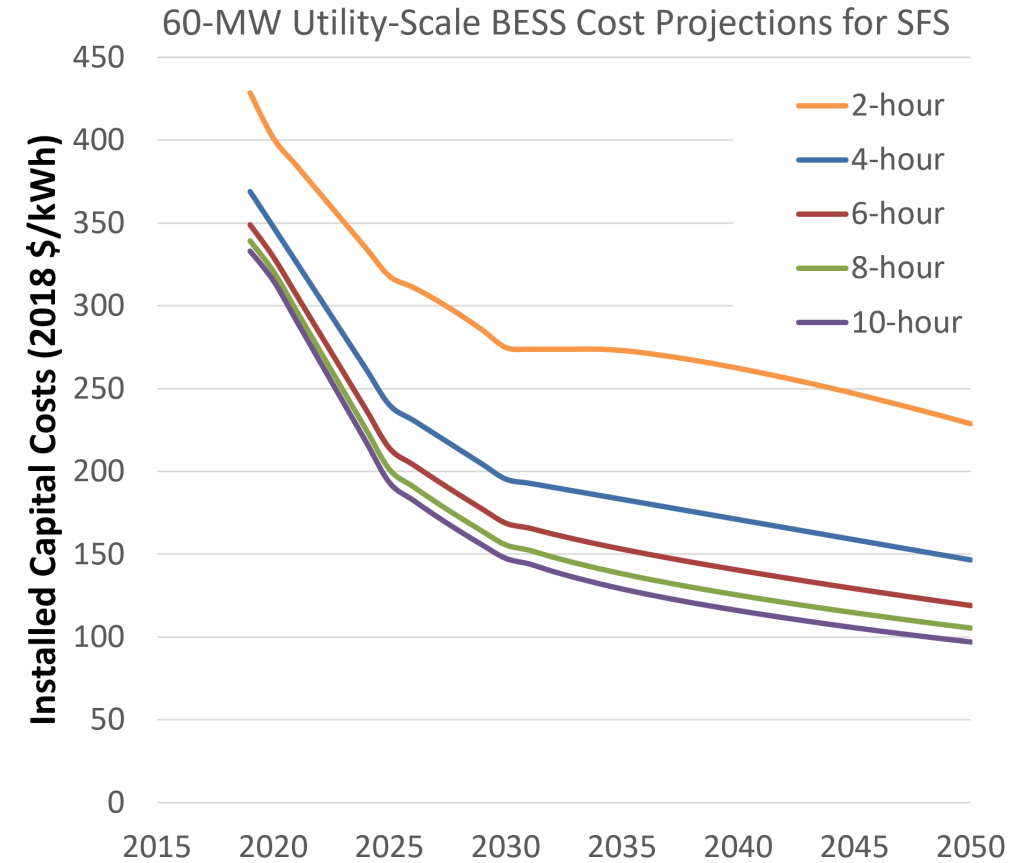
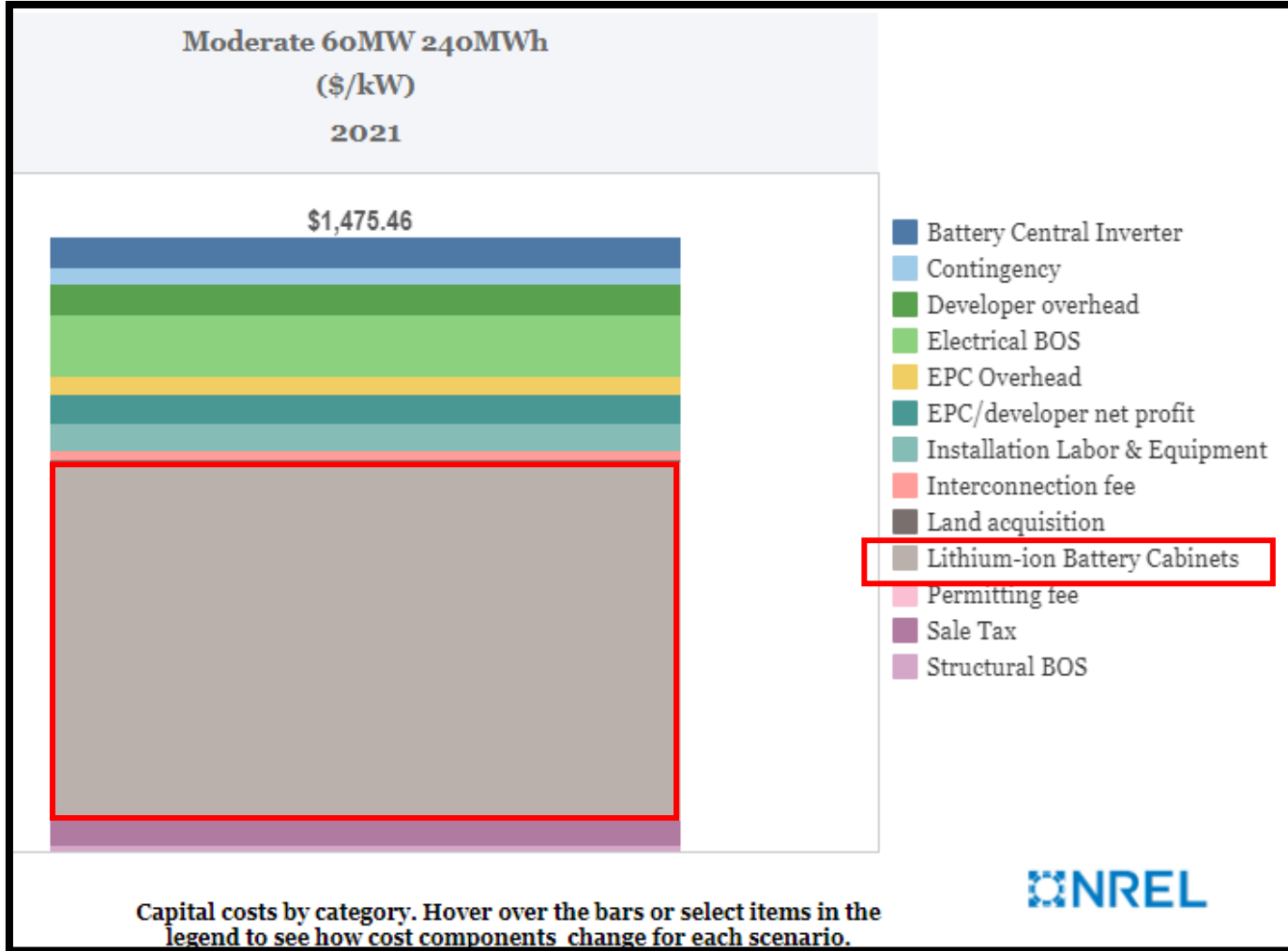
Source: U.S. Energy Information Administration

Figure ES4. Large-scale battery storage cumulative power capacity, 2015–2023



Monthly Electric Generato

Battery Storage Growth and Pricing Trends



Source: NREL

Understanding Impacts with the Fleet + Energy Modeling Tools



VEHICLE DETAILS

- Dimensions
- Weight
- Power Train
- Fuel Supply
- Etc.



ROUTE DETAILS

(GTFS or GPS)

- Path
- Stops
- Etc.



ZERO+ INPUT MODULE

- USGS Elevation
- Acceleration
- Speed Limits
- Etc.



ZERO+ SIMULATOR

(Customized FASTSim)

- Energy Consumption
- Fuel Consumption
- Energy Efficiency



ZERO+ SCHEDULER

- Vehicle Assignments
- Managed Charging
- Multiple Scenarios



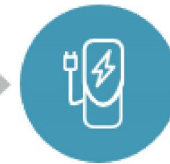
ENERGY CONSUMPTION

- Electric or Hydrogen
- By Trip/Block/Vehicle
- By Fueling Location



EN-ROUTE CHARGING INFRASTRUCTURE

- Power Level
- Location(s)



FACILITY CHARGING INFRASTRUCTURE

- Power Level
- Location
- Number



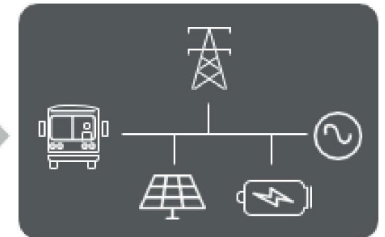
OPERATIONAL IMPACTS

- Hours and Miles
- Number of Vehicles
- Vehicle Swaps
- GHG Emissions



E_{con}MOVES DECISION SUPPORT TOOL

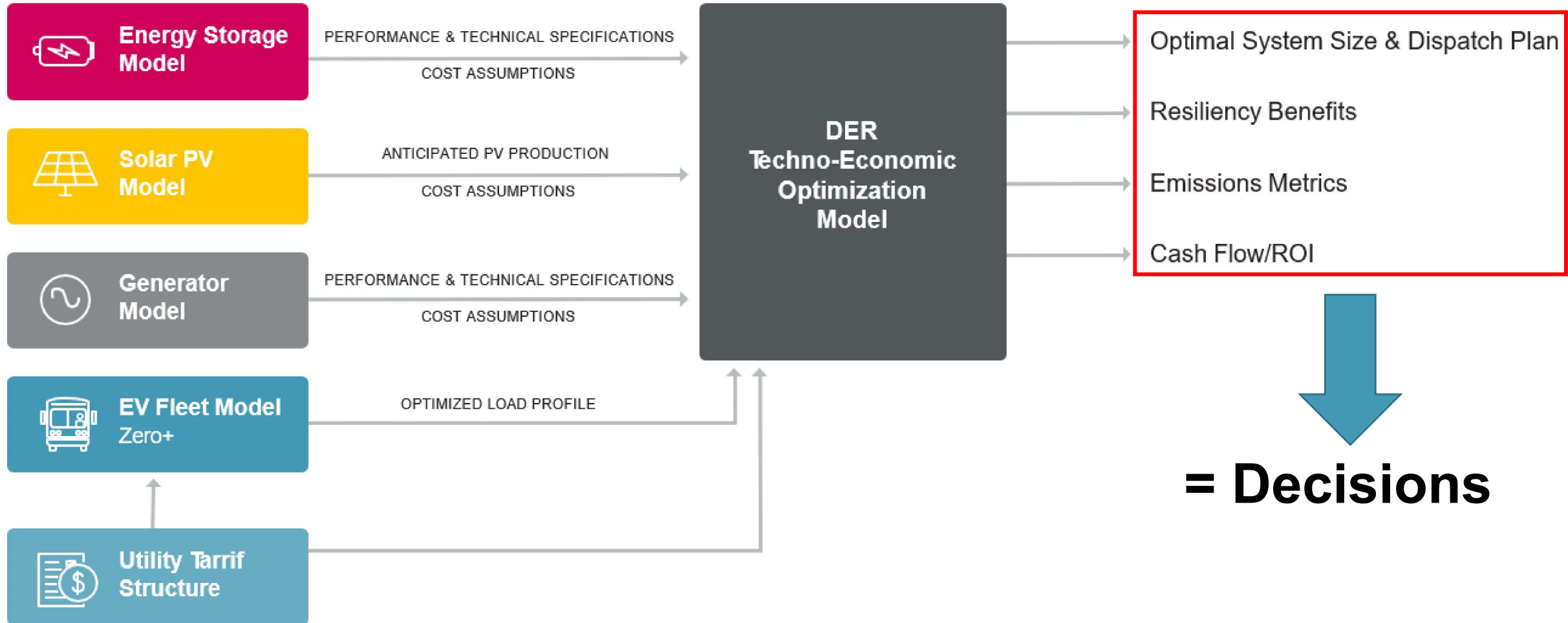
- Implementation Scenarios
- ROI and Break-Even Analysis
- Financial Planning



DER ANALYSIS

- Solar
- Energy Storage
- Firm Generation
- Resiliency, Emissions, and Economic Assessment

Optimizing Energy Resources with Power Needs





**What's
around the
bend?**

Closing Thoughts



Thanks!

Questions?

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