Exh. ASR-2
Docket UE-200115
Witness: Andrew S. Rector

BEFORE THE WASHINGTON
UTILITIES AND TRANSPORTATION COMMISSION

In the Matter of the Application of **PUGET SOUND ENERGY** **For an Order Authorizing the Sale of All of Puget Sound Energy's Interests in Colstrip Unit 4 and Certain of Puget Sound Energy's Interests in the Colstrip Transmission System**	**DOCKET UE-200115**

EXHIBIT TO
TESTIMONY OF

Andrew S. Rector

STAFF OF
WASHINGTON UTILITIES AND
TRANSPORTATION COMMISSION

Lazard, "Levelized Cost of Energy Analysis – Version 13.0"

October 2, 2020

NOVEMBER 2019

LAZARD'S LEVELIZED COST OF ENERGY ANALYSIS—VERSION 13.0

LAZARD

Introduction

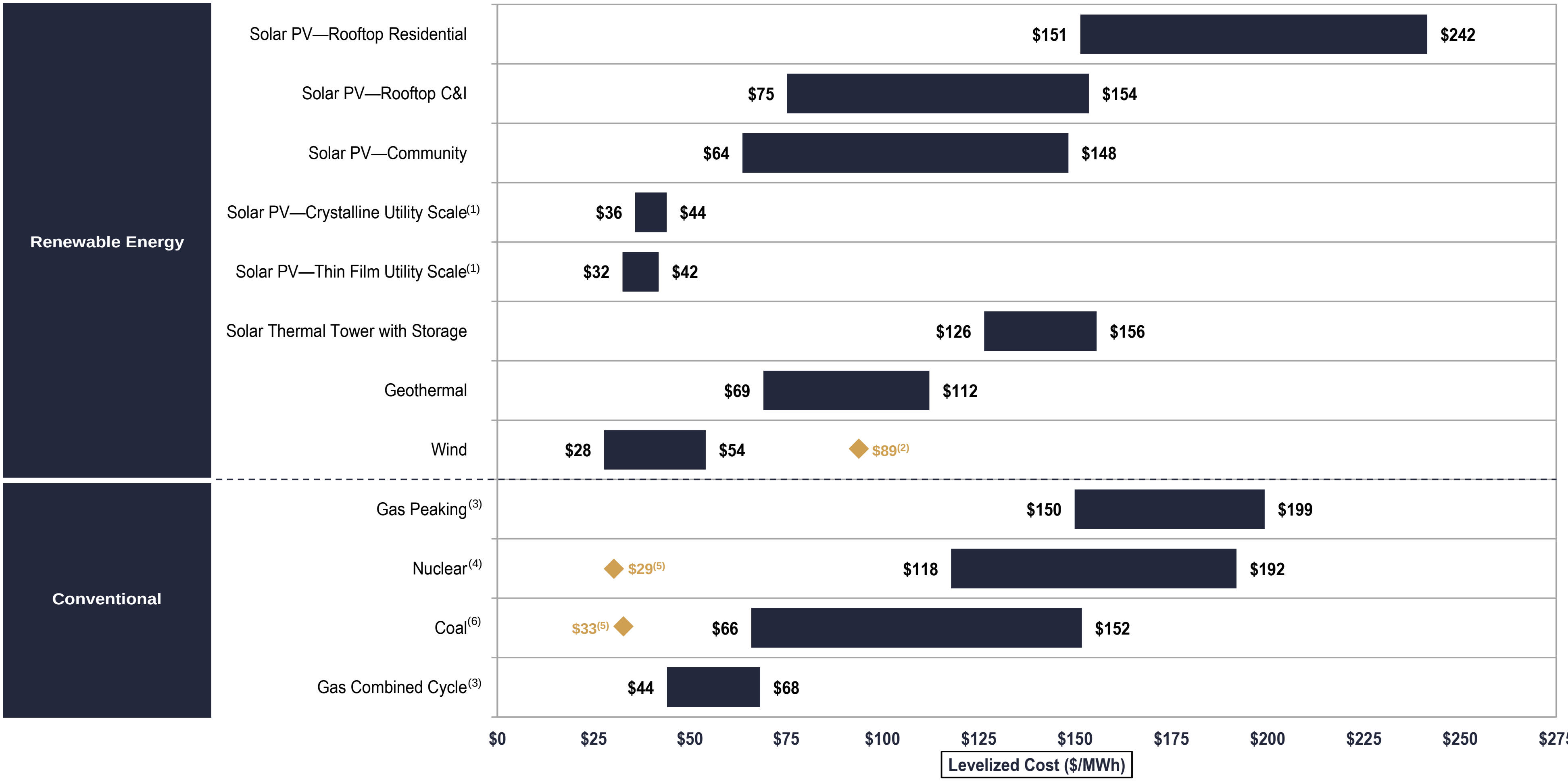
Lazard's Levelized Cost of Energy ("LCOE") analysis addresses the following topics:

- **Comparative LCOE analysis for various generation technologies on a $/MWh basis, including sensitivities for U.S. federal tax subsidies, fuel prices and costs of capital**
- **Illustration of how the LCOE of onshore wind and utility-scale solar compare to the marginal cost of selected conventional generation technologies**
- **Historical LCOE comparison of various utility-scale generation technologies**
- **Illustration of the historical LCOE declines for wind and utility-scale solar technologies**
- **Illustration of how the LCOEs of utility-scale solar and wind compare to those of gas peaking and combined cycle**
- **Comparison of capital costs on a $/kW basis for various generation technologies**
- **Deconstruction of the LCOE for various generation technologies by capital cost, fixed operations and maintenance expense, variable operations and maintenance expense and fuel cost**
- **Overview of the methodology utilized to prepare Lazard's LCOE analysis**
- **Considerations regarding the operating characteristics and applications of various generation technologies**
- **An illustrative comparison of the value of carbon abatement of various renewable energy technologies**
- **Summary of assumptions utilized in Lazard's LCOE analysis**
- **Summary considerations in respect of Lazard's approach to evaluating the LCOE of various conventional and renewable energy technologies**

Other factors would also have a potentially significant effect on the results contained herein, but have not been examined in the scope of this current analysis. These additional factors, among others, could include: capacity value vs. energy value; network upgrades, transmission, congestion or other integration-related costs; significant permitting or other development costs, unless otherwise noted; and costs of complying with various environmental regulations (e.g., carbon emissions offsets or emissions control systems). This analysis also does not address potential social and environmental externalities, including, for example, the social costs and rate consequences for those who cannot afford distributed generation solutions, as well as the long-term residual and societal consequences of various conventional generation technologies that are difficult to measure (e.g., nuclear waste disposal, airborne pollutants, greenhouse gases, etc.)

Levelized Cost of Energy Comparison—Unsubsidized Analysis

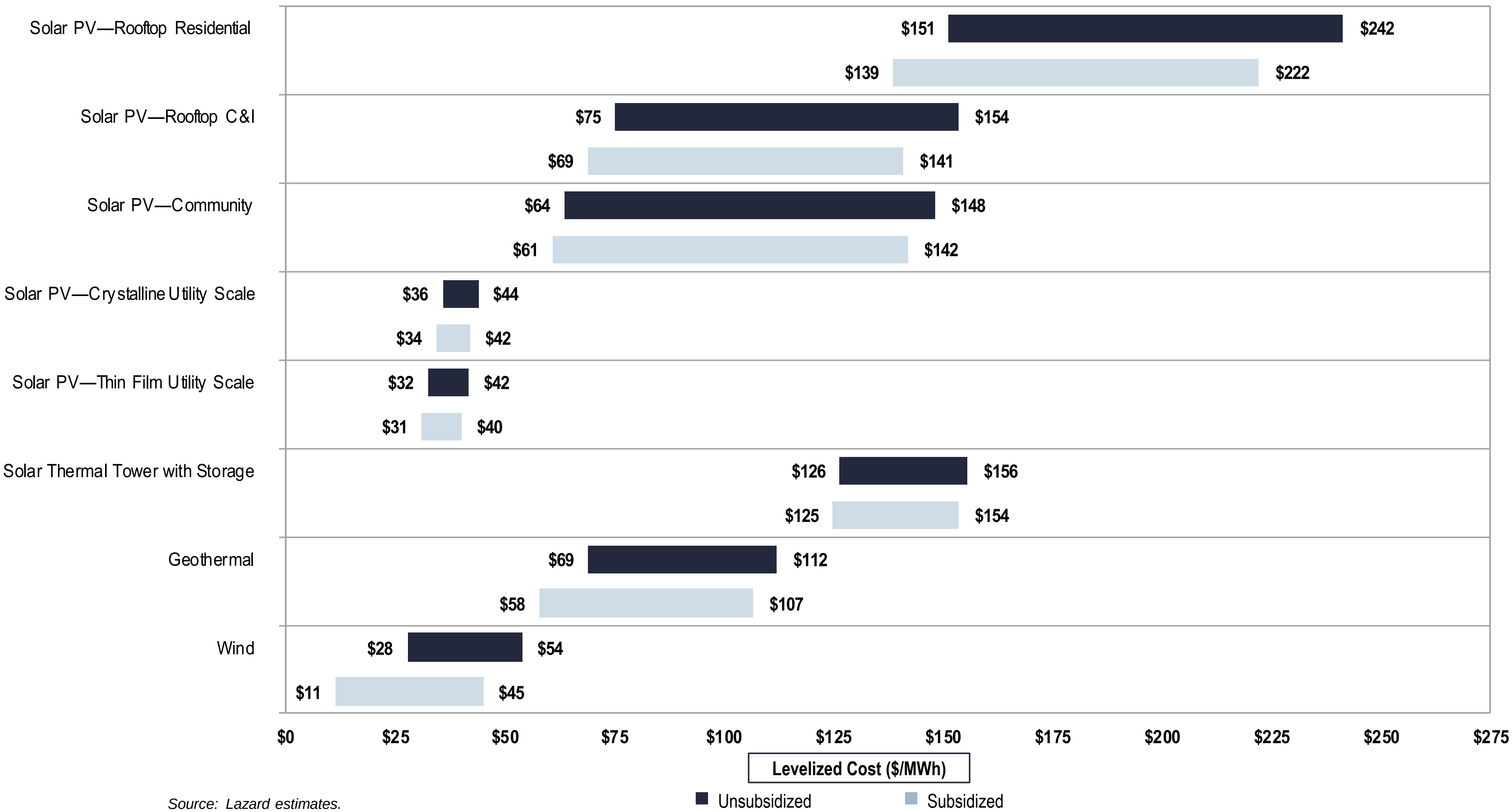
Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances



Source: *Lazard estimates.*
Note: Here and throughout this presentation, unless otherwise indicated, the analysis assumes 60% debt at 8% interest rate and 40% equity at 12% cost. Please see page titled "Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital" for cost of capital sensitivities. These results are not intended to represent any particular geography. Please see page titled "Solar PV versus Gas Peaking and Wind versus CCGT—Global Markets" for regional sensitives to selected technologies.
(1) Unless otherwise indicated herein, the low end represents a single-axis tracking system and the high end represents a fixed-tilt system.
(2) Represents the estimated implied midpoint of the LCOE of offshore wind, assuming a capital cost range of approximately $2.33 – $3.53 per watt.
(3) The fuel cost assumption for Lazard's global, unsubsidized analysis for gas-fired generation resources is $3.45/MMBTU.
(4) Unless otherwise indicated, the analysis herein does not reflect decommissioning costs, ongoing maintenance-related capital expenditures or the potential economic impacts of federal loan guarantees or other subsidies.
(5) Represents the midpoint of the marginal cost of operating coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. Analysis assumes that the salvage value for a decommissioned coal plant is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating coal and nuclear assets across the U.S. Capacity factors, fuel and variable and fixed operating expenses are based on upper and lower quartile estimates derived from Lazard's research. Please see page titled "Levelized Cost of Energy Comparison—Renewable Energy versus Marginal Cost of Selected Existing Conventional Generation" for additional details.
(6) High end incorporates 90% carbon capture and compression. Does not include cost of transportation and storage.

Levelized Cost of Energy Comparison—Sensitivity to U.S. Federal Tax Subsidies[(1)]

The Investment Tax Credit ("ITC") and Production Tax Credit ("PTC"), extended in December 2015, remain an important component of the levelized cost of renewable energy generation technologies



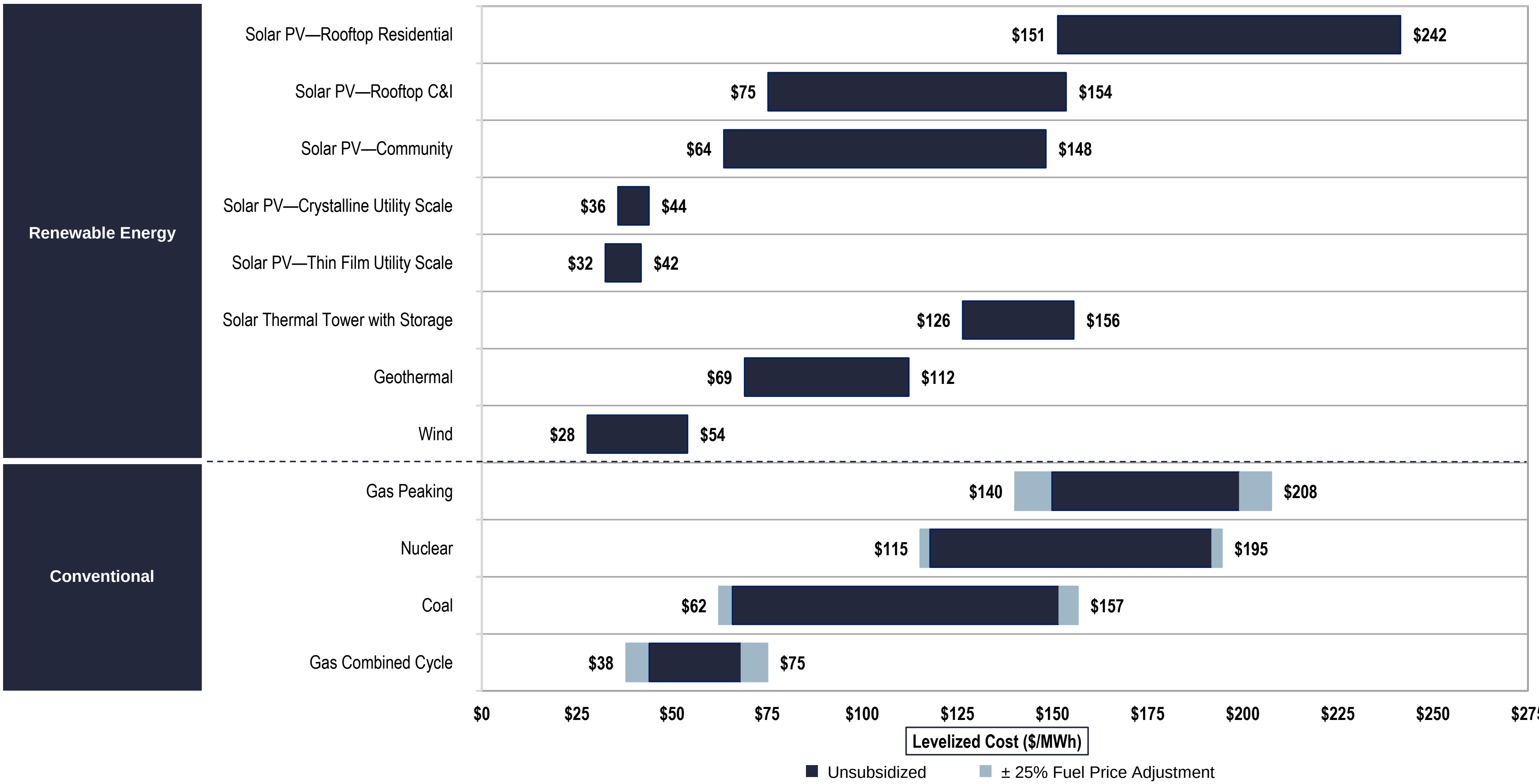
Source: *Lazard estimates.*

Note: The sensitivity analysis presented on this page also includes sensitivities related to the U.S. Tax Cuts and Jobs Act ("TCJA") of 2017. The TCJA contains several provisions that impact the LCOE of various generation technologies (e.g., a reduced federal corporate income tax rate, an ability to elect immediate bonus depreciation, limitations on the deductibility of interest expense and restrictions on the utilization of past net operating losses). On balance, the TCJA reduced the LCOE of conventional generation technologies and marginally increased the LCOE for renewable energy technologies.

(1) The sensitivity analysis presented on this page assumes that projects qualify for the full ITC/PTC and have a capital structure that includes sponsor equity, tax equity and debt.

Levelized Cost of Energy Comparison—Sensitivity to Fuel Prices

Variations in fuel prices can materially affect the LCOE of conventional generation technologies, but direct comparisons to "competing" renewable energy generation technologies must take into account issues such as dispatch characteristics (e.g., baseload and/or dispatchable intermediate capacity vs. those of peaking or intermittent technologies)

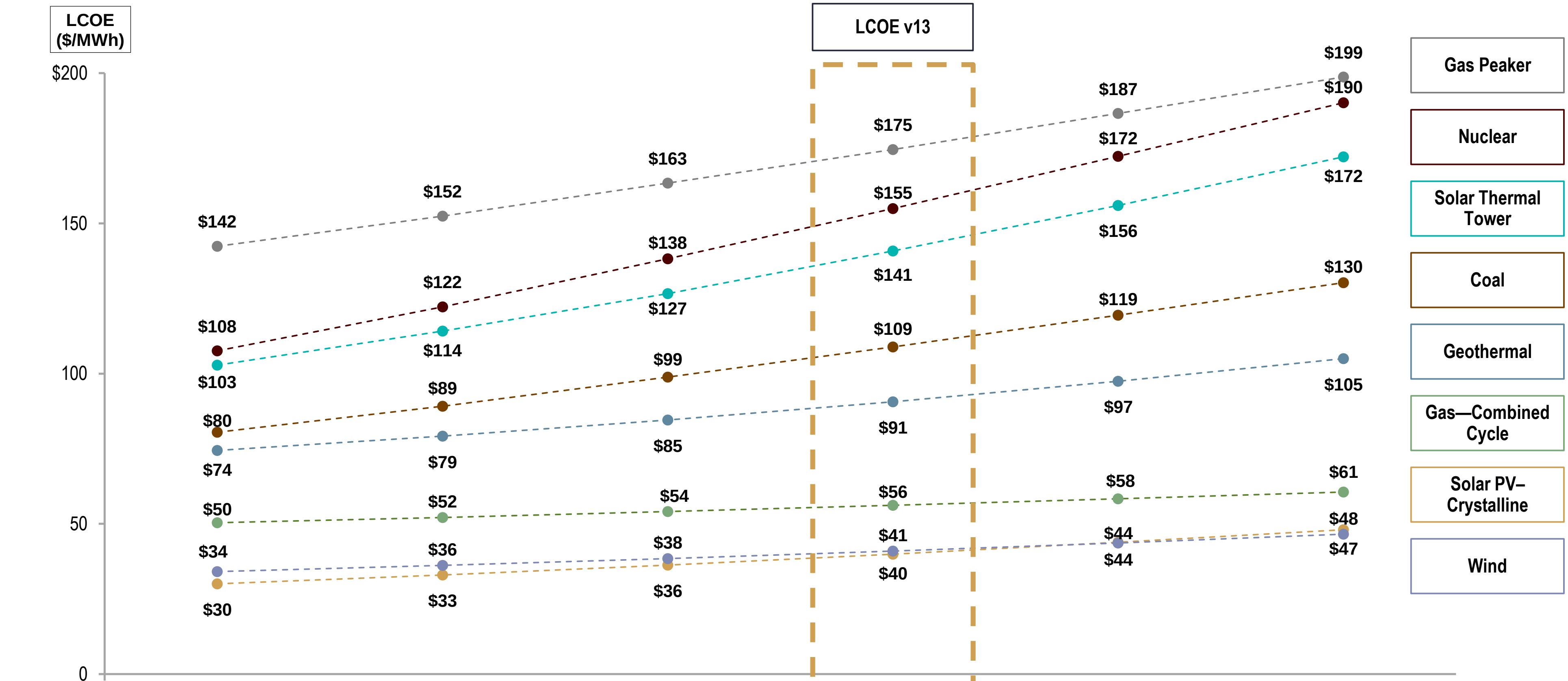


Source: Lazard estimates.
Note: Unless otherwise noted, the assumptions used in this sensitivity correspond to those used in the global, unsubsidized analysis as presented on the page titled "Levelized Cost of Energy Comparison—Unsubsidized Analysis".

Levelized Cost of Energy Comparison—Sensitivity to Cost of Capital

A key consideration in determining the LCOE values for utility-scale generation technologies is the cost, and availability, of capital[(1)]; this dynamic is particularly significant for renewable energy generation technologies

Midpoint of Unsubsidized LCOE[(2)]

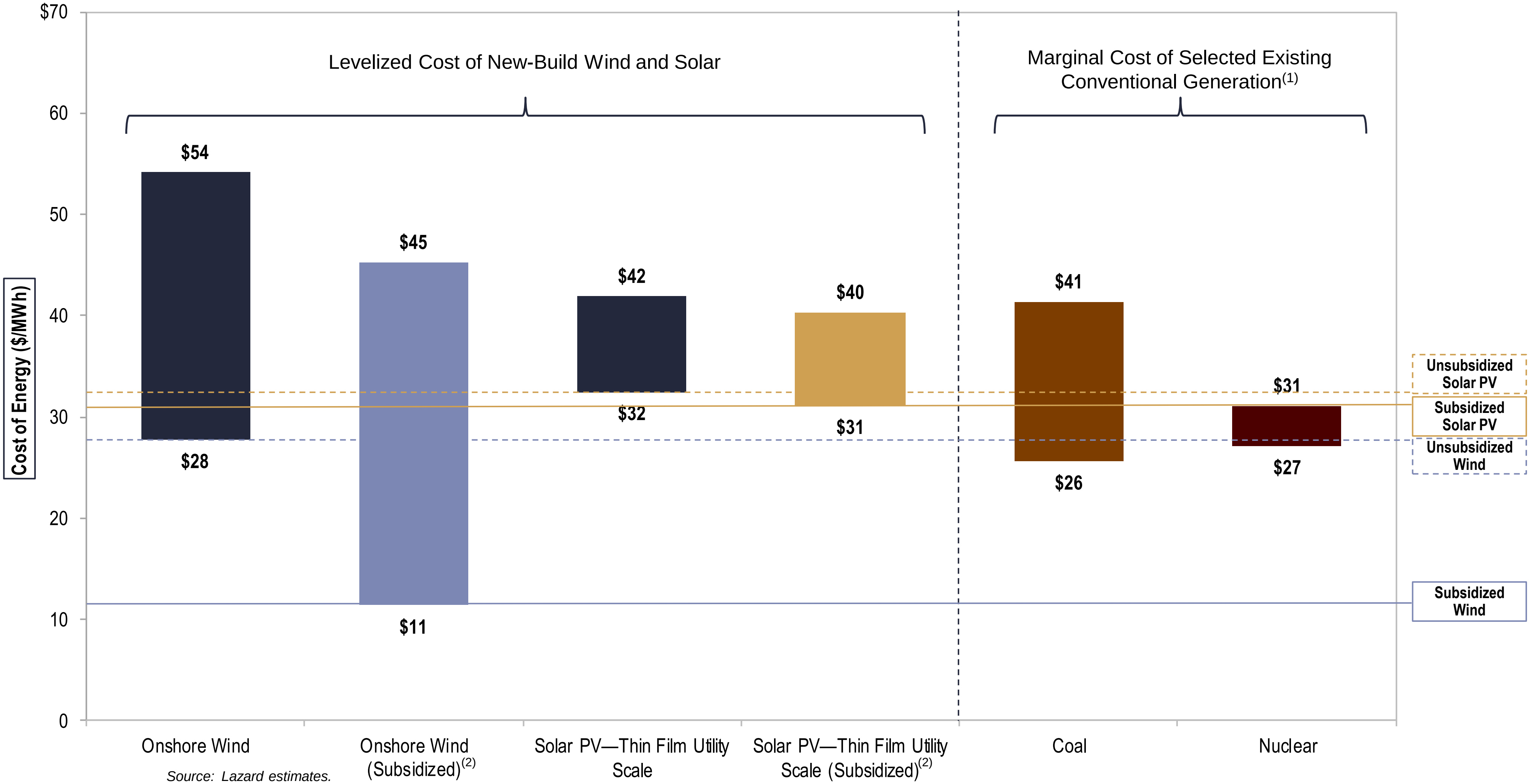


After-Tax IRR/WACC	5.4%	6.2%	6.9%	7.7%	8.4%	9.2%
Cost of Equity	9.0%	10.0%	11.0%	12.0%	13.0%	14.0%
Cost of Debt	5.0%	6.0%	7.0%	8.0%	9.0%	10.0%

Source: *Lazard estimates.*
Note: Analysis assumes 60% debt and 40% equity. Unless otherwise noted, the assumptions used in this sensitivity correspond to those used in the global, unsubsidized analysis as presented on the page titled "Levelized Cost of Energy Comparison—Unsubsidized Analysis".
(1) Cost of capital as used herein indicates the cost of capital applicable to the asset/plant and not the cost of capital of a particular investor/owner.
(2) Reflects the average of the high and low LCOE for each respective cost of capital assumption.

Levelized Cost of Energy Comparison—Renewable Energy versus Marginal Cost of Selected Existing Conventional Generation

Certain renewable energy generation technologies are approaching an LCOE that is competitive with the marginal cost of existing conventional generation



Source: Lazard estimates.

Note: Unless otherwise noted, the assumptions used in this sensitivity correspond to those used in the global, unsubsidized analysis as presented on the page titled "Levelized Cost of Energy Comparison—Unsubsidized Analysis".

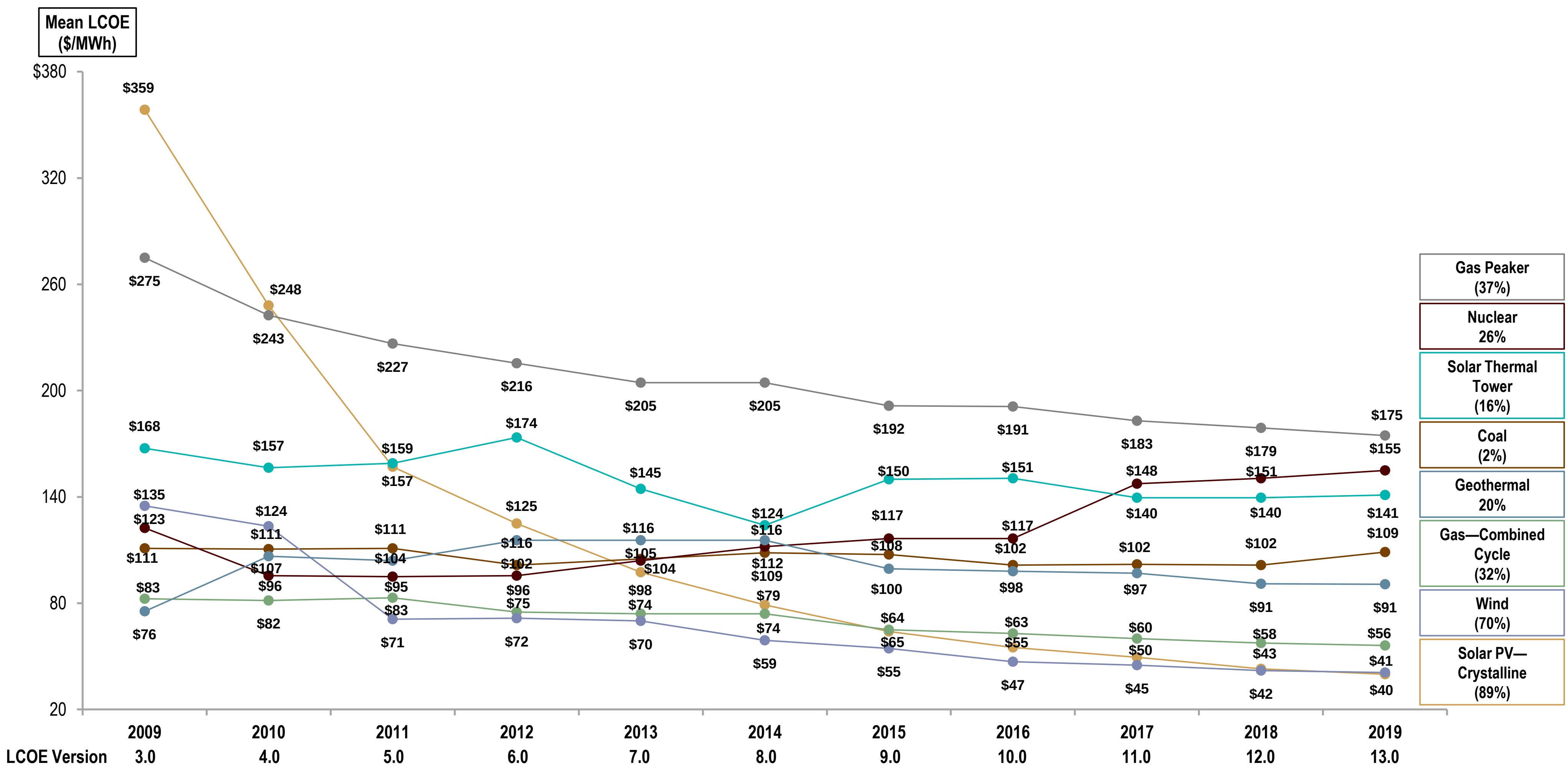
(1) Represents the marginal cost of operating coal and nuclear facilities, inclusive of decommissioning costs for nuclear facilities. Analysis assumes that the salvage value for a decommissioned coal plant is equivalent to its decommissioning and site restoration costs. Inputs are derived from a benchmark of operating coal and nuclear assets across the U.S. Capacity factors, fuel and variable and fixed operating expenses are based on upper and lower quartile estimates derived from Lazard's research.

(2) The subsidized analysis includes sensitivities related to the TCJA and U.S. federal tax subsidies. Please see page titled "Levelized Cost of Energy Comparison—Sensitivity to U.S. Federal Tax Subsidies" for additional details.

Levelized Cost of Energy Comparison—Historical Utility-Scale Generation Comparison

Lazard's unsubsidized LCOE analysis indicates significant historical cost declines for utility-scale renewable energy generation technologies driven by, among other factors, decreasing capital costs, improving technologies and increased competition

Selected Historical Mean Unsubsidized LCOE Values(1)



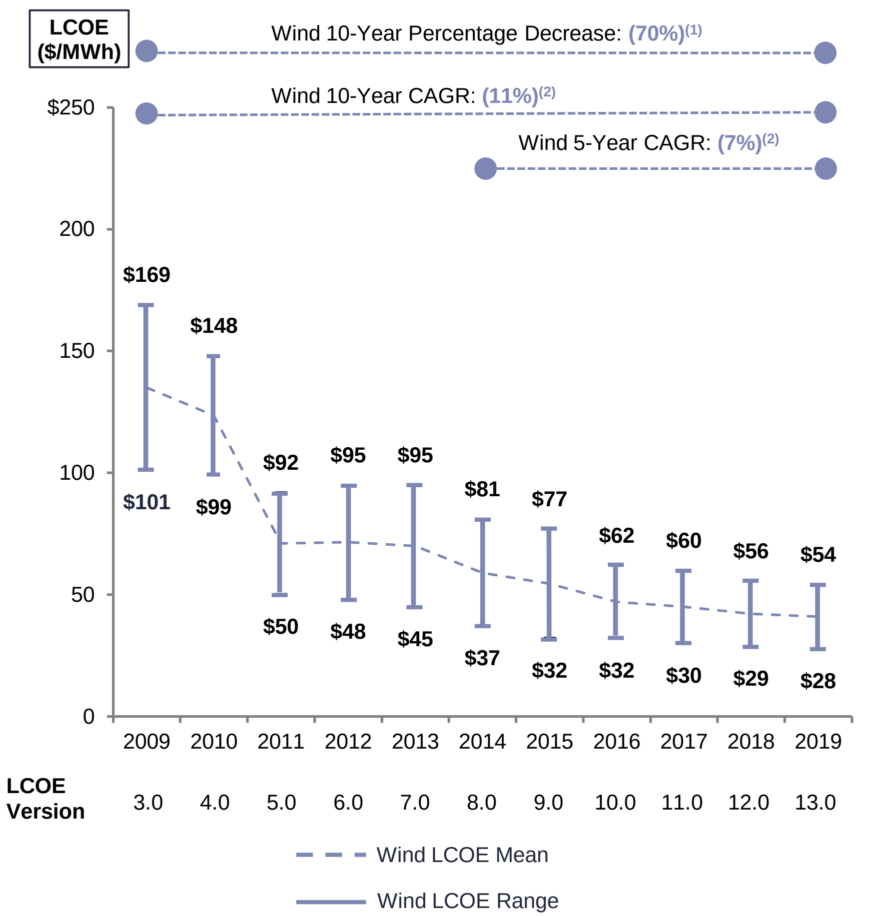
Source: Lazard estimates.

(1) Reflects the average of the high and low LCOE for each respective technology in each respective year. Percentages represent the total decrease in the average LCOE since Lazard's LCOE—Version 3.0.

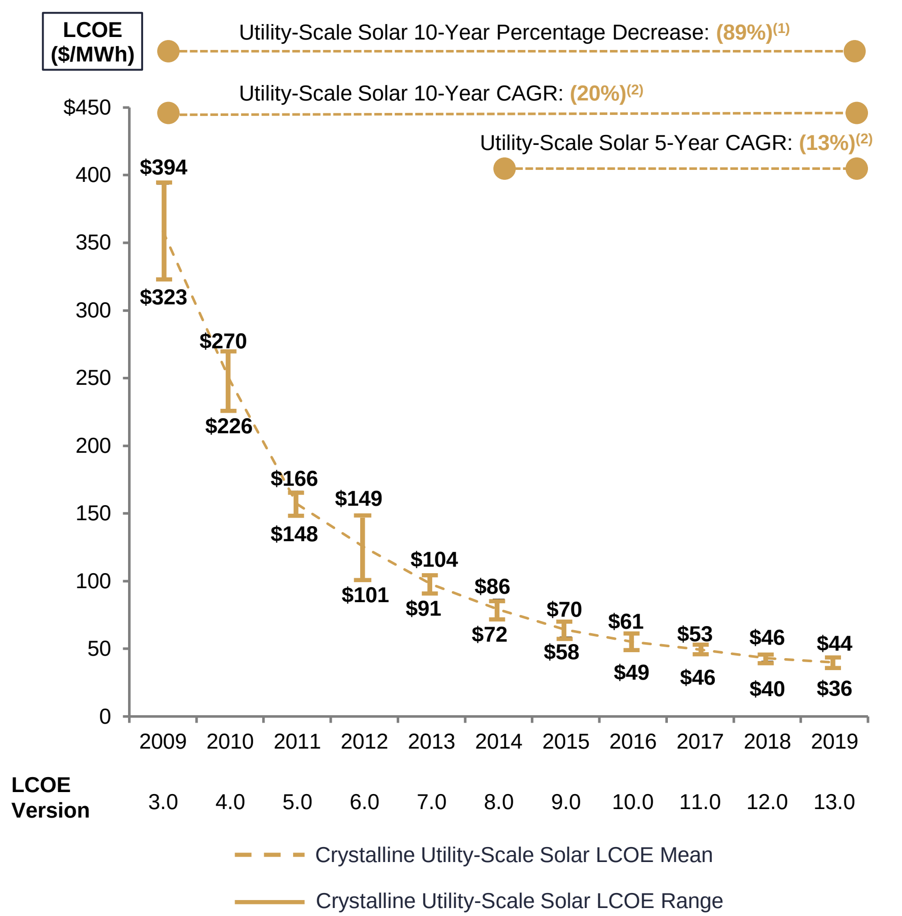
Levelized Cost of Energy Comparison—Historical Renewable Energy LCOE Declines

In light of material declines in the pricing of system components and improvements in efficiency, among other factors, wind and utility-scale solar PV have exhibited dramatic LCOE declines; however, as these industries mature, the rates of decline have diminished

Unsubsidized Wind LCOE



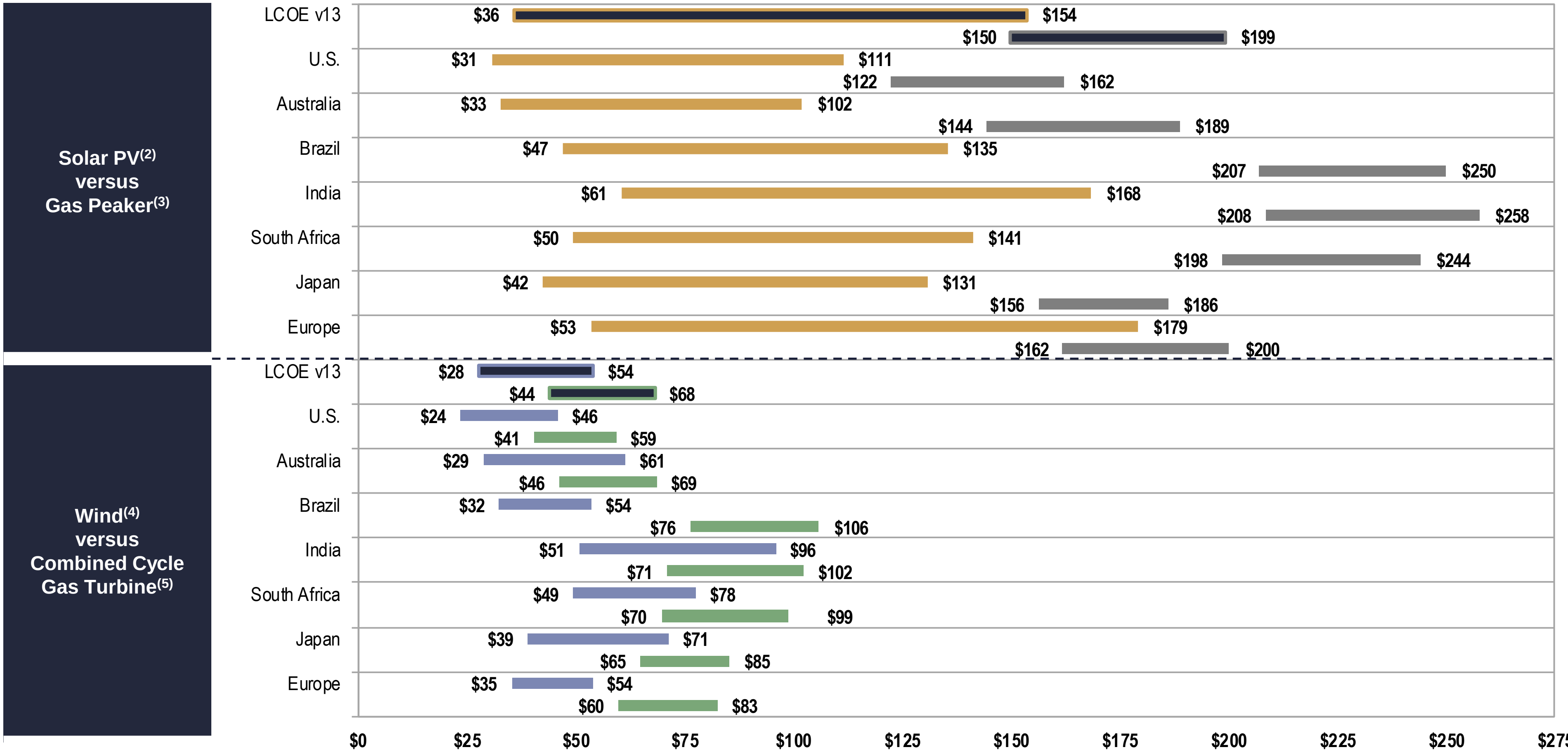
Unsubsidized Solar PV LCOE



Source: Lazard estimates.
(1) Represents the average percentage decrease of the high end and low end of the LCOE range.
(2) Represents the average compounded annual rate of decline of the high end and low end of the LCOE range.

Solar PV versus Gas Peaking and Wind versus CCGT—Global Markets[1]

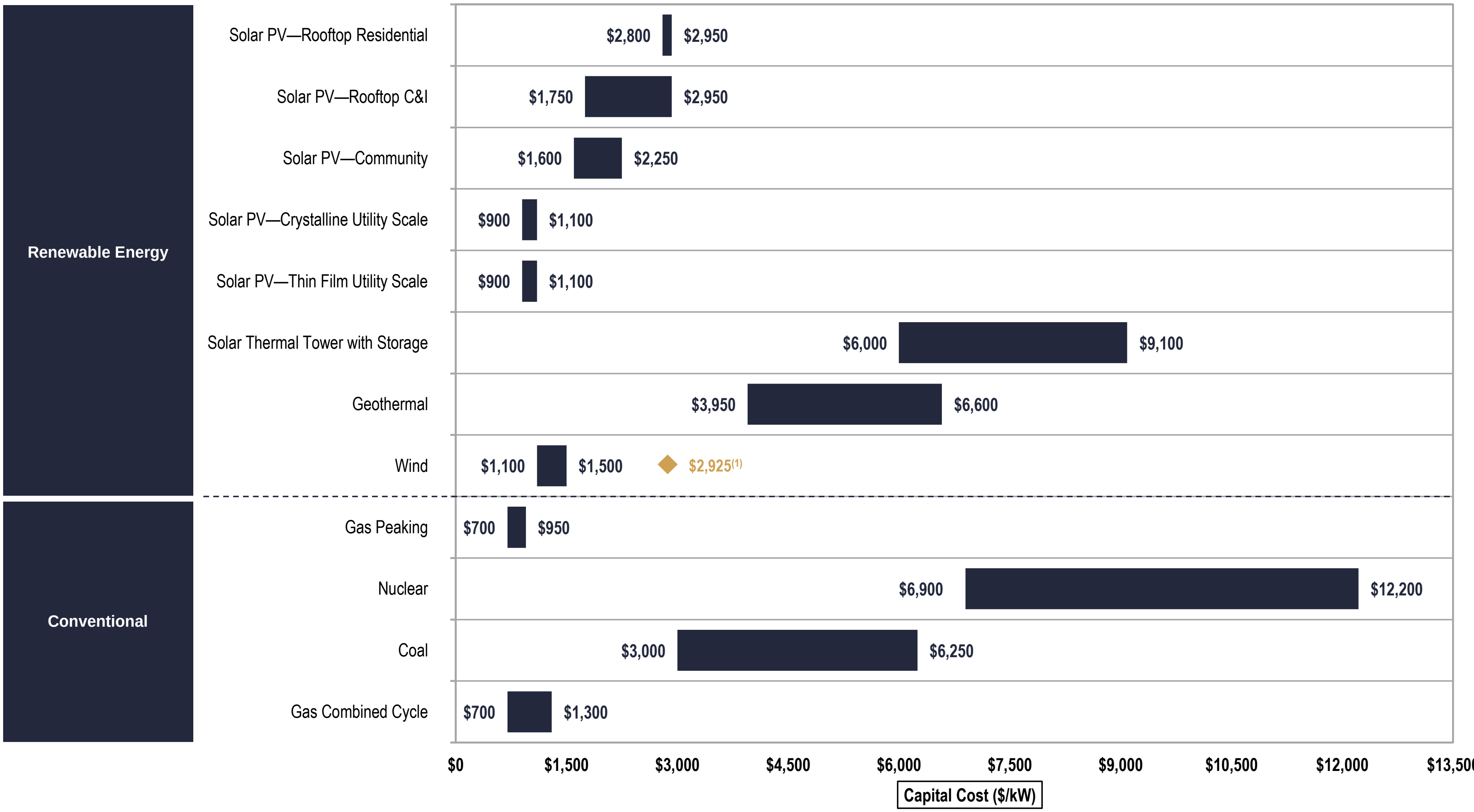
Solar PV and wind have become increasingly competitive with conventional technologies with similar generation profiles; without storage, however, these resources lack the dispatch characteristics, and associated benefits, of such conventional technologies



Source: *Lazard estimates.*
Note: The analysis presented on this page assumes country-specific or regionally-applicable tax rates.
(1) Equity IRRs are assumed to be 10.0% – 12.0% for Australia, 15.0% for Brazil and South Africa, 13.0% – 15.0% for India, 8.0% – 10.0% for Japan, 7.5% – 12.0% for Europe and 7.5% – 9.0% for the U.S. Cost of debt is assumed to be 5.0% – 5.5% for Australia, 10.0% – 12.0% for Brazil, 12.0% – 13.0% for India, 3.0% for Japan, 4.5% – 5.5% for Europe, 12.0% for South Africa and 4.0% – 4.5% for the U.S.
(2) Low end assumes crystalline utility-scale solar with a single-axis tracker. High end assumes rooftop C&I solar. Solar projects assume illustrative capacity factors of 21% – 28% for the U.S., 26% – 30% for Australia, 26% – 28% for Brazil, 22% – 23% for India, 27% – 29% for South Africa, 16% – 18% for Japan and 13% – 16% for Europe.
(3) Assumes natural gas prices of $3.45 for the U.S., $4.00 for Australia, $8.00 for Brazil, $7.00 for India, South Africa and Japan and $6.00 for Europe (all in U.S.$ per MMBtu). Assumes a capacity factor of 10% for all geographies.
(4) Wind projects assume illustrative capacity factors of 38% – 55% for the U.S., 29% – 46% for Australia, 45% – 55% for Brazil, 25% – 35% for India, 31% – 36% for South Africa, 22% – 30% for Japan and 33% – 38% for Europe.
(5) Assumes natural gas prices of $3.45 for the U.S., $4.00 for Australia, $8.00 for Brazil, $7.00 for India, South Africa and Japan and $6.00 for Europe (all in U.S.$ per MMBtu). Assumes capacity factors of 55% – 70% on the high and low ends, respectively, for all geographies.

Capital Cost Comparison

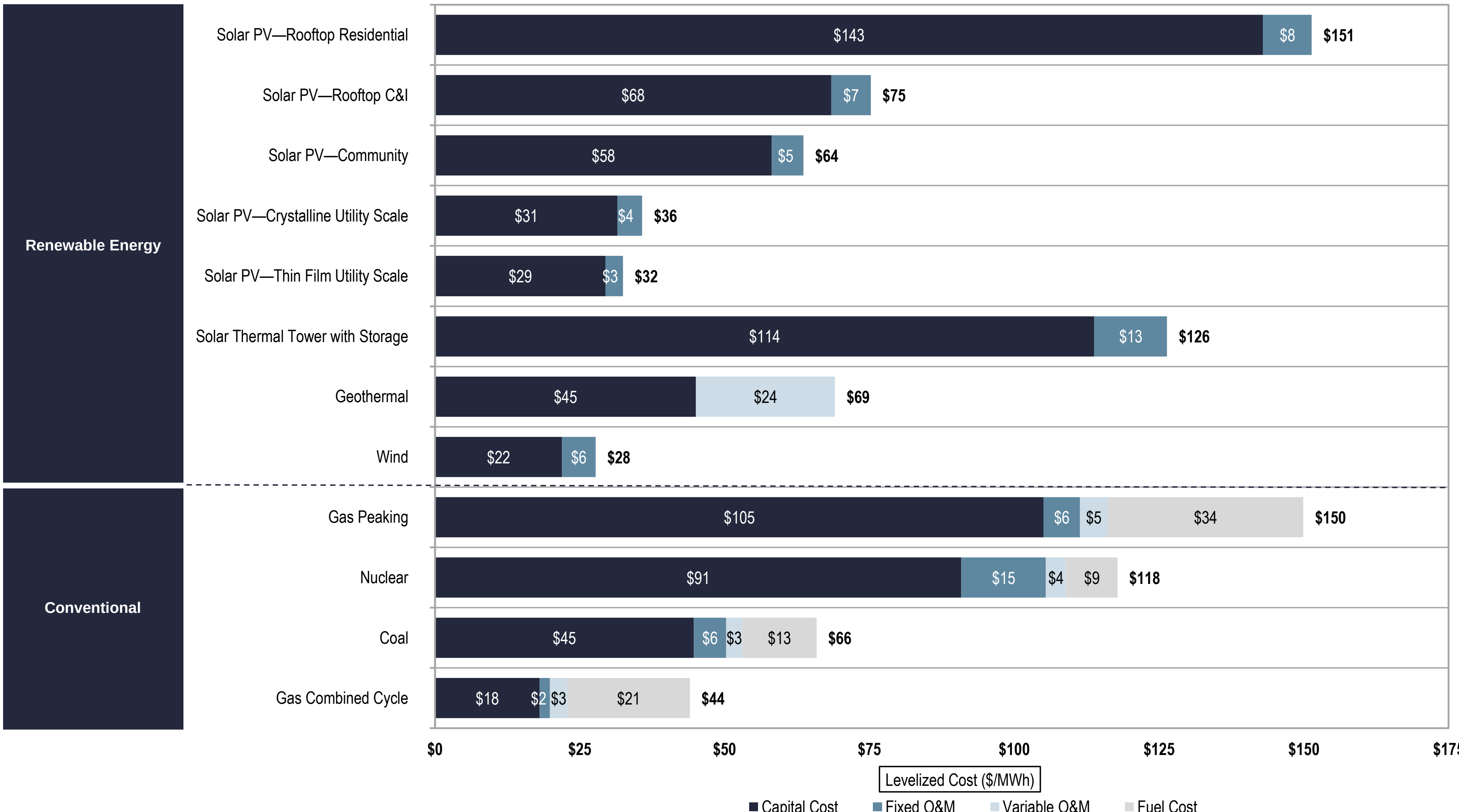
In some instances, the capital costs of renewable energy generation technologies have converged with those of certain conventional generation technologies, which coupled with improvements in operational efficiency for renewable energy technologies, have led to a convergence in LCOE between the respective technologies



Source: Lazard estimates.
(1) Represents the estimated midpoint of the total capital cost for offshore wind.

Levelized Cost of Energy Components—Low End

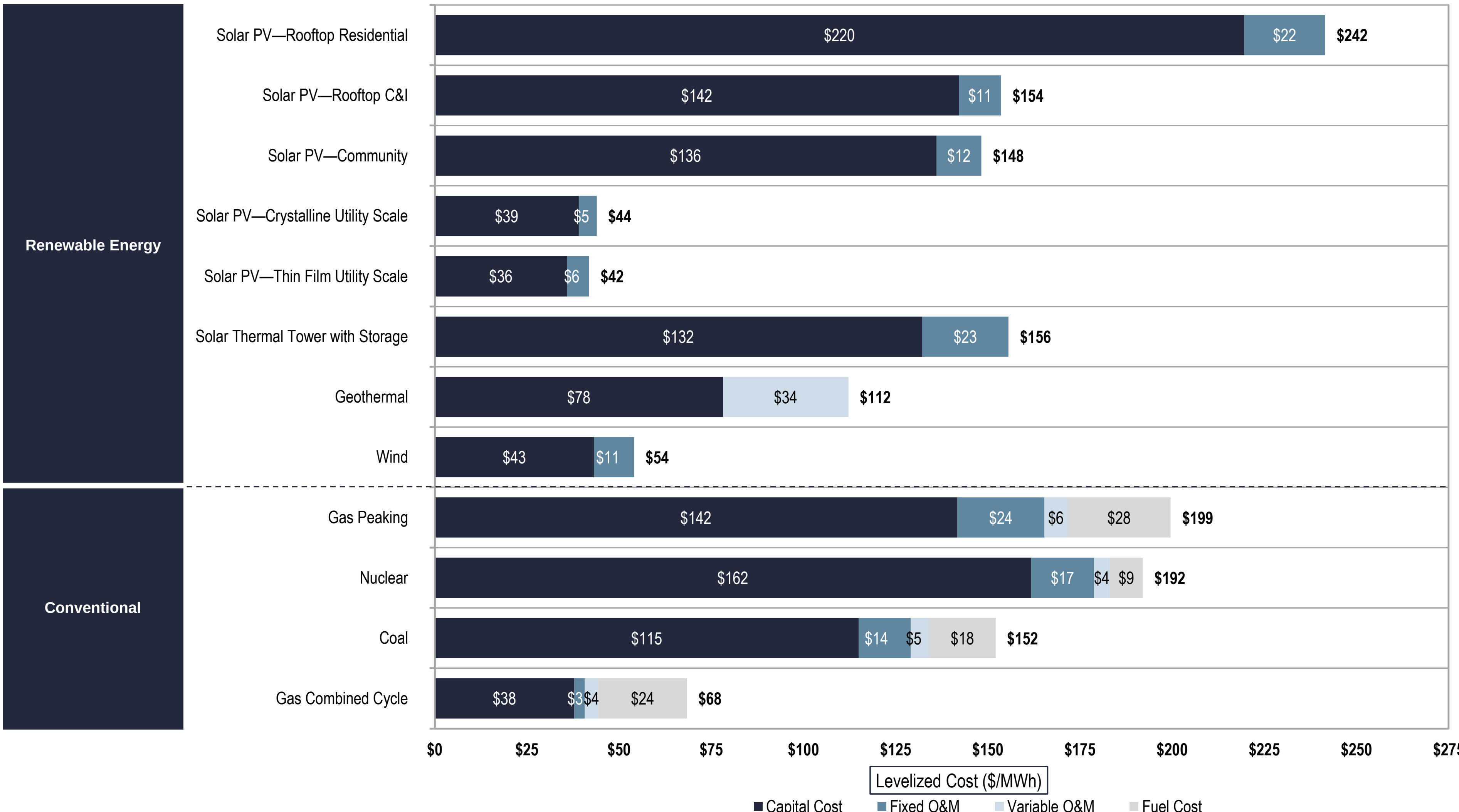
Certain renewable energy generation technologies are already cost-competitive with conventional generation technologies; a key factor regarding the continued cost decline of renewable energy generation technologies is the ability of technological development and industry scale to continue lowering operating expenses and capital costs for renewable energy generation technologies



Source: Lazard estimates.

Levelized Cost of Energy Components—High End

Certain renewable energy generation technologies are already cost-competitive with conventional generation technologies; a key factor regarding the continued cost decline of renewable energy generation technologies is the ability of technological development and industry scale to continue lowering operating expenses and capital costs for renewable energy generation technologies



Source: Lazard estimates.

Levelized Cost of Energy Comparison—Methodology

($ in millions, unless otherwise noted)

Lazard's LCOE analysis consists of creating a power plant model representing an illustrative project for each relevant technology and solving for the $/MWh value that results in a levered IRR equal to the assumed cost of equity (see subsequent "Key Assumptions" pages for detailed assumptions by technology)

Unsubsidized Wind — High Case Sample Illustrative Calculations

Year[1]		*0*	*1*	*2*	*3*	*4*	*5*	*20*
Capacity (MW)	(A)		150	150	150	150	150	150
Capacity Factor	(B)		38%	38%	38%	38%	38%	38%
Total Generation ('000 MWh)	(A) x (B) = (C)*		499	499	499	499	499	499
Levelized Energy Cost ($/MWh)	***(D)***		***$54.1***	***$54.1***	***$54.1***	***$54.1***	***$54.1***	***$54.1***
Total Revenues	**(C) x (D) = (E)***		**$27.0**	**$27.0**	**$27.0**	**$27.0**	**$27.0**	**$27.0**
Total Fuel Cost	(F)		--	--	--	--	--	--
Total O&M	(G)*		5.4	5.6	5.7	5.8	5.9	8.5
Total Operating Costs	**(F) + (G) = (H)**		**$5.4**	**$5.6**	**$5.7**	**$5.8**	**$5.9**	$8.5
EBITDA	**(E) - (H) = (I)**		**$21.6**	**$21.5**	**$21.3**	**$21.2**	**$21.1**	**$18.5**
Debt Outstanding - Beginning of Period	(J)		$135.0	$132.3	$129.4	$126.3	$122.9	$12.5
Debt - Interest Expense	(K)		(10.8)	(10.6)	(10.4)	(10.1)	(9.8)	(1.0)
Debt - Principal Payment	(L)		(2.7)	(2.9)	(3.1)	(3.4)	(3.6)	(12.5)
Levelized Debt Service	(K) + (L) = (M)		($13.5)	($13.5)	($13.5)	($13.5)	($13.5)	($13.5)
EBITDA	**(I)**		$21.6	$21.5	$21.3	$21.2	$21.1	$18.5
Depreciation (MACRS)	(N)		(45.0)	(72.0)	(43.2)	(25.9)	(25.9)	--
Interest Expense	(K)		(10.8)	(10.6)	(10.4)	(10.1)	(9.8)	(1.0)
Taxable Income	**(I) + (N) + (K) = (O)**		**($34.2)**	**($61.1)**	**($32.2)**	**($14.8)**	**($14.7)**	**$17.5**
Tax Benefit (Liability)[2]	**(O) x (tax rate) = (P)**		**$13.7**	**$24.5**	**$12.9**	**$5.9**	**$5.9**	**($7.0)**
After-Tax Net Equity Cash Flow	**(I) + (M) + (P) = (Q)**	**($90.0)**[3]	**$21.8**	**$32.4**	**$20.7**	**$13.7**	**$13.5**	**($2.0)**
IRR For Equity Investors		**12.0%**						

Key Assumptions[4]	
Capacity (MW)	150
Capacity Factor	38%
Fuel Cost ($/MMBtu)	$0.00
Heat Rate (Btu/kWh)	0
Fixed O&M ($/kW-year)	$36.5
Variable O&M ($/MWh)	$0.0
O&M Escalation Rate	2.25%
Capital Structure	
Debt	60.0%
Cost of Debt	8.0%
Equity	40.0%
Cost of Equity	12.0%
Taxes and Tax Incentives:	
Combined Tax Rate	40%
Economic Life (years)[5]	20
MACRS Depreciation (Year Schedule)	5
Capex	
EPC Costs ($/kW)	$1,500
Additional Owner's Costs ($/kW)	$0
Transmission Costs ($/kW)	$0
Total Capital Costs ($/kW)	$1,500
Total Capex ($mm)	$225

Technology-dependent
Levelized

Source: *Lazard estimates.*
Note: Wind—High LCOE case presented for illustrative purposes only.
* Denotes unit conversion.
(1) Assumes half-year convention for discounting purposes.
(2) Assumes full monetization of tax benefits or losses immediately.
(3) Reflects initial cash outflow from equity investors.
(4) Reflects a "key" subset of all assumptions for methodology illustration purposes only. Does not reflect all assumptions.
(5) Economic life sets debt amortization schedule. For comparison purposes, all technologies calculate LCOE on a 20-year IRR basis.

Energy Resources—Matrix of Applications

Despite convergence in the LCOE between certain renewable energy and conventional generation technologies, direct comparisons must take into account issues such as location (e.g., centralized vs. distributed) and dispatch characteristics (e.g., baseload and/or dispatchable intermediate capacity vs. those of peaking or intermittent technologies)

- **This analysis does not take into account potential social and environmental externalities or reliability-related considerations**

		Carbon Neutral/ REC Potential	Location			Dispatch			
			Distributed	Centralized	Geography	Intermittent	Peaking	Load-Following	Baseload
Renewable Energy	Solar PV[1]	✓	✓	✓	Universal[2]	✓	✓		
	Solar Thermal	✓		✓	Rural	✓	✓	✓	
	Geothermal	✓		✓	Varies				✓
	Onshore Wind	✓		✓	Rural	✓			
Conventional	Gas Peaking	✗	✓	✓	Universal		✓	✓	
	Nuclear	✓		✓	Rural				✓
	Coal	✗		✓	Co-located or rural				✓
	Gas Combined Cycle	✗		✓	Universal			✓	✓

Source: Lazard estimates.
(1) Represents the full range of solar PV technologies; low end represents thin film utility-scale solar single-axis tracking, high end represents the high end of rooftop residential solar.
(2) Qualification for RPS requirements varies by location.

Value of Carbon Abatement Comparison

As policymakers consider ways to limit carbon emissions, Lazard's LCOE analysis provides insight into the economic value associated with carbon abatement offered by renewable energy technologies. This analysis suggests that policies designed to shift power generation towards wind and utility-scale solar could be a particularly cost-effective means of reducing carbon emissions, providing an abatement value of $36 – $41/Ton vs. Coal and $23 – $32/Ton vs. Gas Combined Cycle

- **These observations do not take into account other environmental and social externalities, reliability or grid-related considerations**

		Conventional Generation			Renewable Energy Generation			
	Units	**Coal**	**Gas Combined Cycle**	**Nuclear**	**Wind**	**Solar PV Rooftop**	**Solar PV Utility Scale**	**Solar Thermal with Storage**
Capital Investment/KW of Capacity [1]	$/kW	$2,975	$700	$6,900	$1,100	$2,800	$900	$9,100
Total Capital Investment	**$mm**	**1,993**	**560**	**4,209**	**1,111**	**8,232**	**1,476**	**7,462**
Facility Output	MW	670	800	610	1,010	2,940	1,640	820
Capacity Factor	%	83%	70%	91%	55%	19%	34%	68%
MWh/Year Produced [2]	**GWh/yr**	**4,888**	**4,888**	**4,888**	**4,888**	**4,888**	**4,888**	**4,888**
Levelized Cost of Energy	$/MWh	$66	$44	$118	$28	$151	$32	$126
Total Cost of Energy Produced	**$mm/yr**	**$322** (2)	**$215**	**$576**	**$136** (1)	**$740**	**$159**	**$618**
CO_2 Equivalent Emissions	Tons/MWh	0.92	0.51	—	—	—	—	—
Carbon Emitted	mm Tons/yr	4.51	2.50	—	—	—	—	—
Difference in Carbon Emissions	mm Tons/yr							
vs. Coal		—	2.01	4.51	4.51 (3)	4.51	4.51	4.51
vs. Gas		—	—	2.50	2.50	2.50	2.50	2.50
Difference in Total Energy Cost	$mm/yr							
vs. Coal		—	($107)	$254	($187) (4)	$418	($163)	$296
vs. Gas		—	—	$361	($80)	$525	($56)	$403
Implied Abatement Value/(Cost)	$/Ton							
vs. Coal		—	$53	($56)	$41 (5)	($93)	$36	($66)
vs. Gas		—	—	($144)	$32	($210)	$23	($161)

: Favorable vs. Coal/Gas : Unfavorable vs. Coal/Gas

Implied Carbon Abatement Value Calculation (Wind vs. Coal)—Methodology

(4) Difference in Total Energy Cost (Wind vs. Coal) = (1) – (2) = $136 mm/yr (Wind) – $322 mm/yr (Coal) = ($187) mm/yr

(5) Implied Carbon Abatement Value (Wind vs. Coal) = (4) ÷ (3) = $187 mm/yr ÷ 4.51 mm Tons/yr = $41/Ton

Source: Lazard estimates.
(1) Assumptions utilized for the technologies presented in this analysis correspond to those associated with the Low LCOE cases.
(2) All facilities illustratively sized to produce 4,888 GWh/yr.

Levelized Cost of Energy—Key Assumptions

	Units	Solar PV				
		Rooftop—Residential	Rooftop—C&I	Community	Utility Scale—Crystalline [2]	Utility Scale—Thin Film [2]
Net Facility Output	MW	0.005	1	5	100	100
EPC Cost	$/kW	$2,800 – $2,950	$1,750 – $2,950	$1,600 – $2,250	$1,100 – $900	$1,100 – $900
Capital Cost During Construction	$/kW	—	—	—	—	—
Other Owner's Costs	$/kW	included	included	included	included	included
Total Capital Cost [1]	$/kW	$2,800 – $2,950	$1,750 – $2,950	$1,600 – $2,250	$1,100 – $900	$1,100 – $900
Fixed O&M	$/kW-yr	$14.00 – $25.00	$15.00 – $20.00	$12.00 – $16.00	$12.00 – $9.00	$12.00 – $9.00
Variable O&M	$/MWh	—	—	—	—	—
Heat Rate	Btu/kWh	—	—	—	—	—
Capacity Factor	%	19% – 13%	25% – 20%	25% – 15%	32% – 21%	34% – 23%
Fuel Price	$/MMBtu	—	—	—	—	—
Construction Time	Months	3	3	4 – 6	9	9
Facility Life	Years	25	25	30	30	30
Levelized Cost of Energy	$/MWh	$151 – $242	$75 – $154	$64 – $148	$36 – $44	$32 – $42

Source: Lazard estimates.
(1) Includes capitalized financing costs during construction for generation types with over 24 months construction time.
(2) Left column represents the assumptions used to calculate the low end LCOE for single-axis tracking. Right column represents the assumptions used to calculate the high end LCOE for fixed-tilt design.

Levelized Cost of Energy—Key Assumptions (cont'd)

	Units	Solar Thermal Tower with Storage (2)			Geothermal			Wind—Onshore			Wind—Offshore		
Net Facility Output	MW	110	–	150	20	–	50		150		210	–	385
EPC Cost	$/kW	$7,950	–	$5,250	$3,450	–	$5,750	$1,100	–	$1,500	$2,350	–	$3,550
Capital Cost During Construction	$/kW	$1,150	–	$750	$500	–	$850		—			—	
Other Owner's Costs	$/kW		included			included			included			included	
Total Capital Cost (1)	$/kW	$9,100	–	$6,000	$3,950	–	$6,600	$1,100	–	$1,500	$2,350	–	$3,550
Fixed O&M	$/kW-yr	$75.00	–	$80.00	$0.00	–	$0.00	$28.00	–	$36.50	$80.00	–	$110.00
Variable O&M	$/MWh		—		$24.00	–	$34.00		—			—	
Heat Rate	Btu/kWh		—			—			—			—	
Capacity Factor	%	68%	–	39%	90%	–	85%	55%	–	38%	55%	–	45%
Fuel Price	$/MMBtu		—			—			—			—	
Construction Time	Months		36			36			12			12	
Facility Life	Years		35			25			20			20	
Levelized Cost of Energy	$/MWh	$126	–	$156	$69	–	$112	$28	–	$54	$64	–	$115

Source: Lazard estimates.
(1) Includes capitalized financing costs during construction for generation types with over 24 months construction time.
(2) Left column represents the assumptions used to calculate the low end LCOE, representing a project with 18 hours of storage capacity. Right column represents the assumptions used to calculate the high end LCOE, representing a project with eight hours of storage.

Levelized Cost of Energy—Key Assumptions (cont'd)

	Units	Gas Peaking			Nuclear			Coal			Gas Combined Cycle		
Net Facility Output	MW	240	–	50		2,200			600			550	
EPC Cost	$/kW	$650	–	$900	$5,400	–	$9,600	$2,400	–	$4,900	$650	–	$1,200
Capital Cost During Construction	$/kW		—			—			—			—	
Other Owner's Costs	$/kW		included		$1,500	–	$2,650	$600	–	$1,300	$50	–	$100
Total Capital Cost (1)	$/kW	$700	–	$950	$6,900	–	$12,200	$3,000	–	$6,250	$700	–	$1,300
Fixed O&M	$/kW-yr	$5.50	–	$20.75	$108.50	–	$133.00	$40.75	–	$81.75	$11.00	–	$13.50
Variable O&M	$/MWh	$4.75	–	$6.25	$3.50	–	$4.25	$2.75	–	$5.00	$3.00	–	$3.75
Heat Rate	Btu/kWh	9,804	–	8,000	10,450	–	10,450	8,750	–	12,000	6,133	–	6,900
Capacity Factor	%		10%		91%	–	90%	83%	–	66%	70%	–	55%
Fuel Price	$/MMBtu	$3.45	–	$3.45	$0.85	–	$0.85	$1.45	–	$1.45	$3.45	–	$3.45
Construction Time	Months	12	–	18	69	–	69	60	–	66	24	–	24
Facility Life	Years		20			40			40			20	
Levelized Cost of Energy	$/MWh	$150	–	$199	$118	–	$192	$66	–	$152	$44	–	$68

Source: Lazard estimates.
(1) Includes capitalized financing costs during construction for generation types with over 24 months construction time.

Summary Considerations

Lazard has conducted this analysis comparing the LCOE for various conventional and renewable energy generation technologies in order to understand which renewable energy generation technologies may be cost-competitive with conventional generation technologies, either now or in the future, and under various operating assumptions. We find that renewable energy technologies are complementary to conventional generation technologies, and believe that their use will be increasingly prevalent for a variety of reasons, including to mitigate the environmental and social consequences of various conventional generation technologies, RPS requirements, carbon regulations, continually improving economics as underlying technologies improve and production volumes increase, and supportive regulatory frameworks in certain regions.

In this analysis, Lazard's approach was to determine the LCOE, on a $/MWh basis, that would provide an after-tax IRR to equity holders equal to an assumed cost of equity capital. Certain assumptions (e.g., required debt and equity returns, capital structure, etc.) were identical for all technologies in order to isolate the effects of key differentiated inputs such as investment costs, capacity factors, operating costs, fuel costs (where relevant) and other important metrics. These inputs were originally developed with a leading consulting and engineering firm to the Power & Energy Industry, augmented with Lazard's commercial knowledge where relevant. This analysis (as well as previous versions) has benefited from additional input from a wide variety of Industry participants and is informed by Lazard's many client interactions on this topic.

Lazard has not manipulated the cost of capital or capital structure for various technologies, as the goal of this analysis is to compare the current levelized cost of various generation technologies, rather than the benefits of financial engineering. The results contained herein would be altered by different assumptions regarding capital structure (e.g., increased use of leverage) or the cost of capital (e.g., a willingness to accept lower returns than those assumed herein).

Key sensitivities examined included fuel costs and tax subsidies. Other factors would also have a potentially significant effect on the results contained herein, but have not been examined in the scope of this current analysis. These additional factors, among others, could include: capacity value vs. energy value; network upgrades, transmission, congestion or other integration-related costs; significant permitting or other development costs, unless otherwise noted; and costs of complying with various environmental regulations (e.g., carbon emissions offsets or emissions control systems). This analysis also does not address potential social and environmental externalities, including, for example, the social costs and rate consequences for those who cannot afford distributed generation solutions, as well as the long-term residual and societal consequences of various conventional generation technologies that are difficult to measure (e.g., nuclear waste disposal, airborne pollutants, greenhouse gases, etc.).