Forecasting Wind Energy Costs and Cost Drivers

The Views of the World's Leading Experts

Brief Summary of Survey Results

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https://emp.lbl.gov/iea-wind-expert-survey

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IEA Wind Survey of 163 of the World's Foremost Wind Experts, Focused on Cost and Technology Trends

What

Expert survey to gain insight on possible magnitude of future wind energy cost reductions, sources of reductions, and enabling conditions needed to realize continued innovation and lower costs

Covering onshore, fixed-bottom offshore, and floating offshore wind applications

Why

Inform policy & planning, R&D, and industry investment & strategy development while also improving treatment of wind in energy-sector planning models

Complement other tools for evaluating cost reduction, including learning curves, engineering assessments, other ways to synthesize expert knowledge

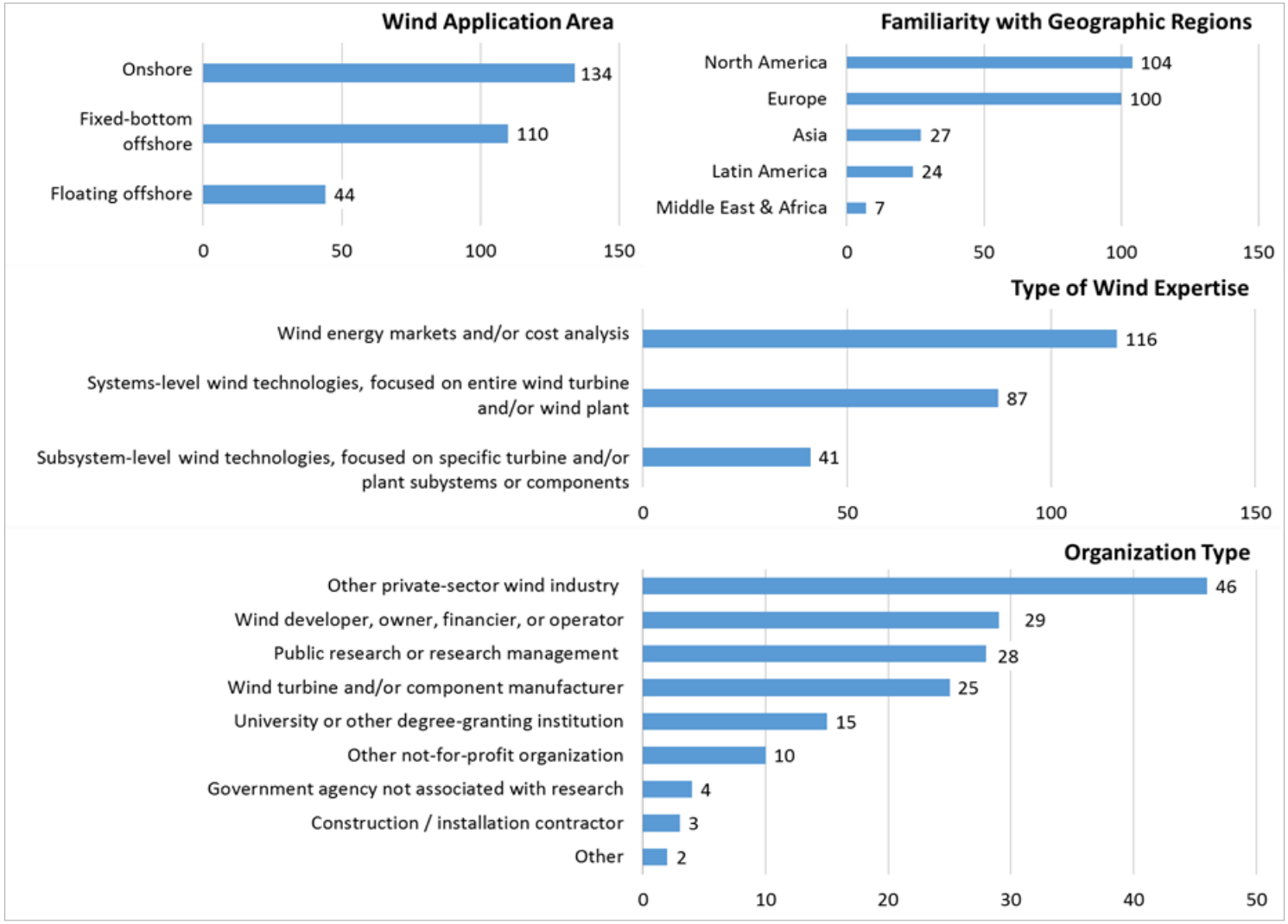
Who

Largest single expert elicitation ever performed on an energy technology in terms of expert participation: 163 of the world's foremost wind energy experts

Led by LBNL and NREL, under auspices of IEA Wind Task 26 on "Cost of Wind Energy," and with numerous critical advisers throughout

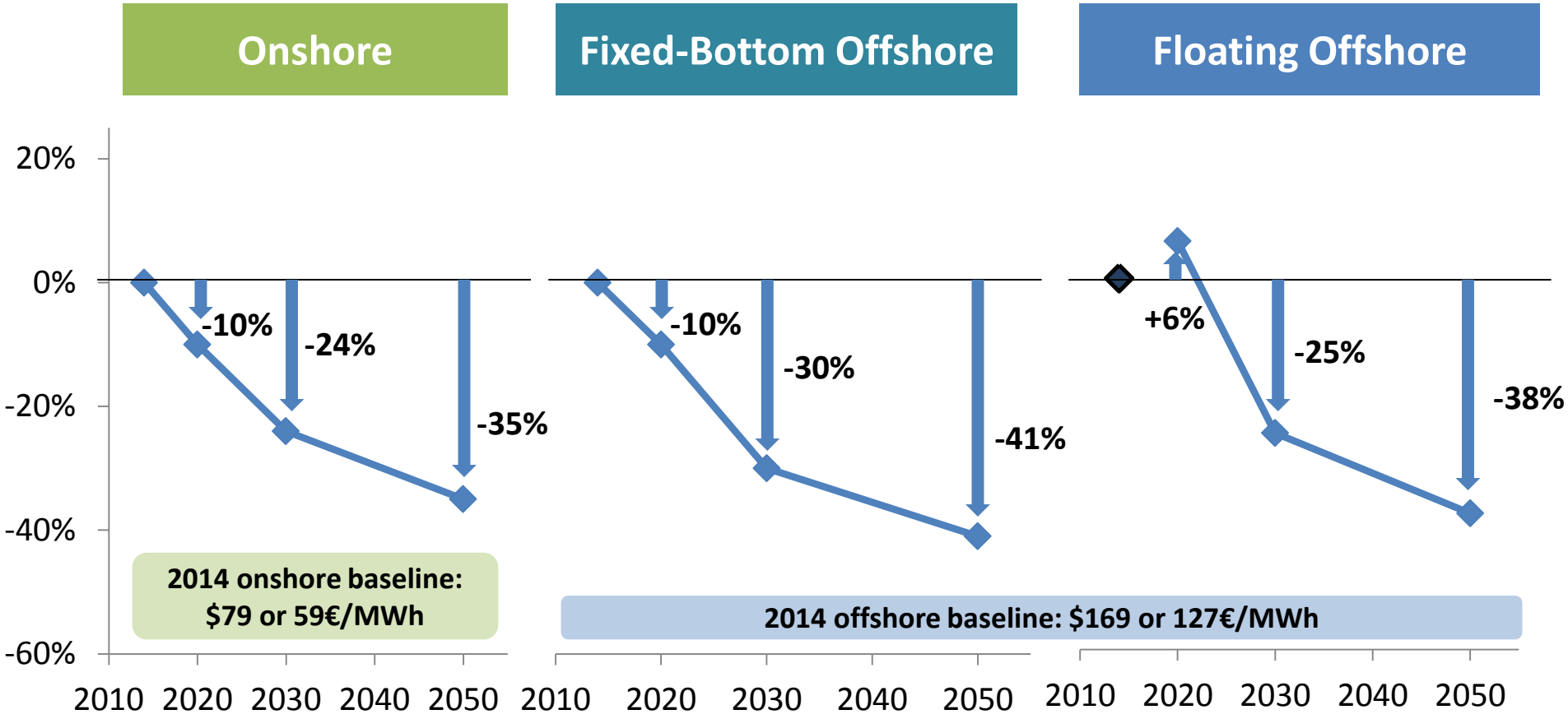
Survey focus was primarily on changes in levelized cost of energy (LCOE) from 2014 to 2020, 2030, and 2050 under low/median/high scenarios, and on build-up of LCOE in 2014 & 2030; LCOE excludes any subsidies and excludes grid interconnection costs outside plant boundary

Diverse Set of 163 Survey Participants (34% response rate), Including 22 from Leading-Expert Group (52%)



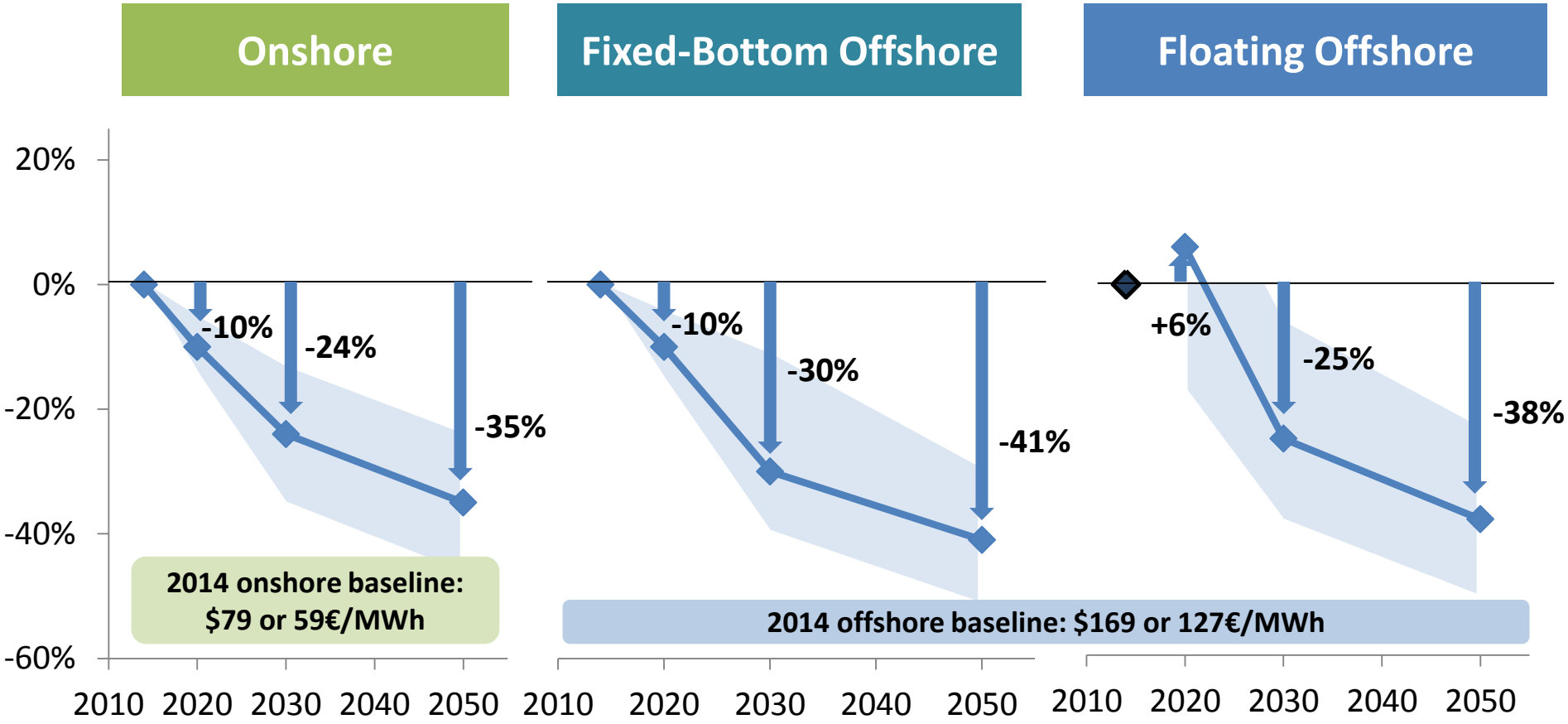
Smaller group of 22 “leading experts” pre-identified as uniquely-qualified

Expectations for Significant LCOE Reduction: Median "Best Guess" Scenario, Median Respondent



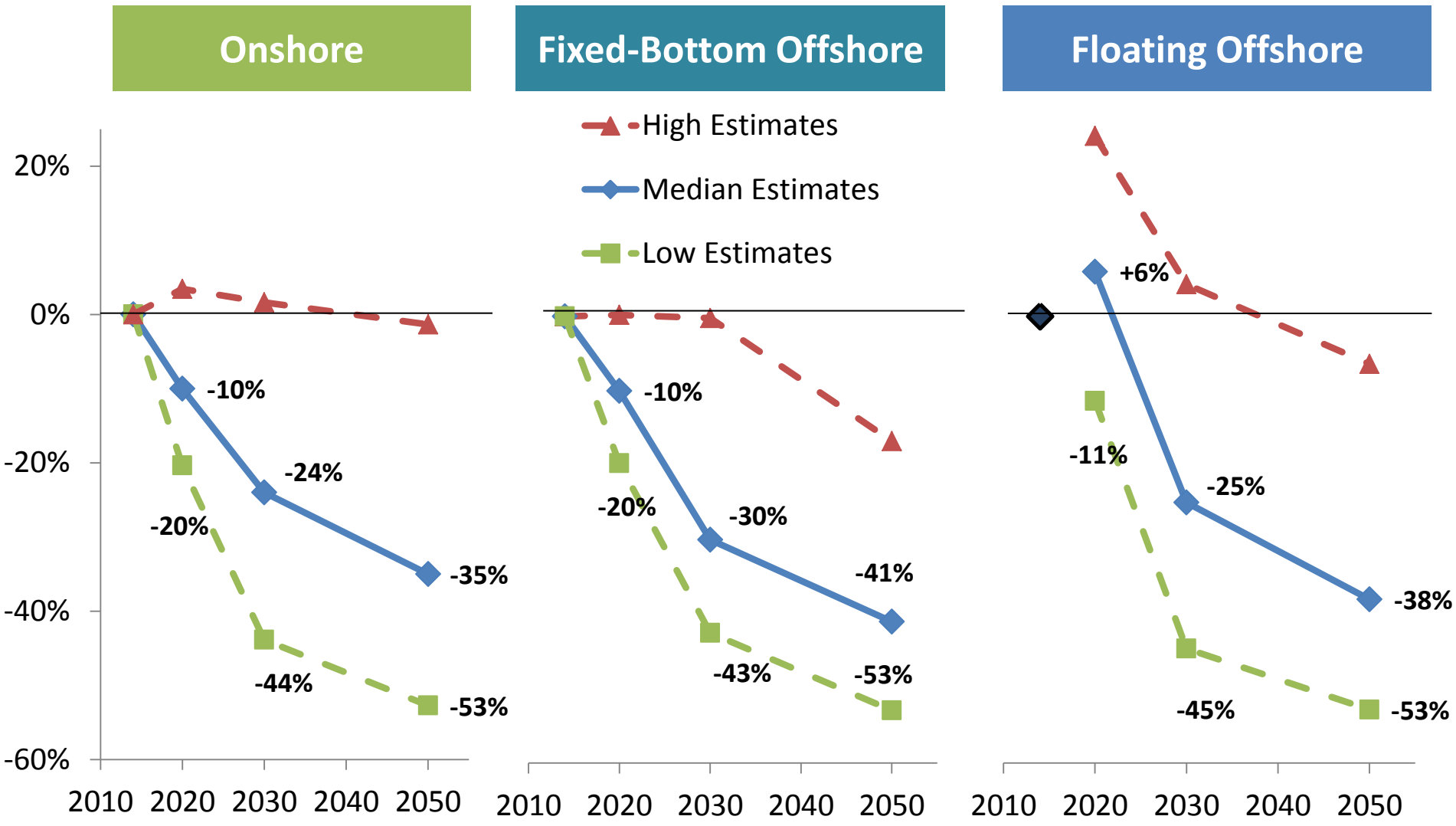
Lines/markers indicate the **median** expert response
For **floating,** change is shown relative to 2014 baseline for fixed-bottom
All dates are based on the year in which a new wind project is commissioned

Uncertainty Revealed When Reviewing Range of Expert Responses: Median "Best Guess" Scenario



Lines/markers indicate the **median** expert response
Shaded areas show the 25th to 75th percentile range of expert responses

Sizable Opportunity Space for LCOE Reductions (and Uncertainty) Illustrated by Low / High Scenario Results



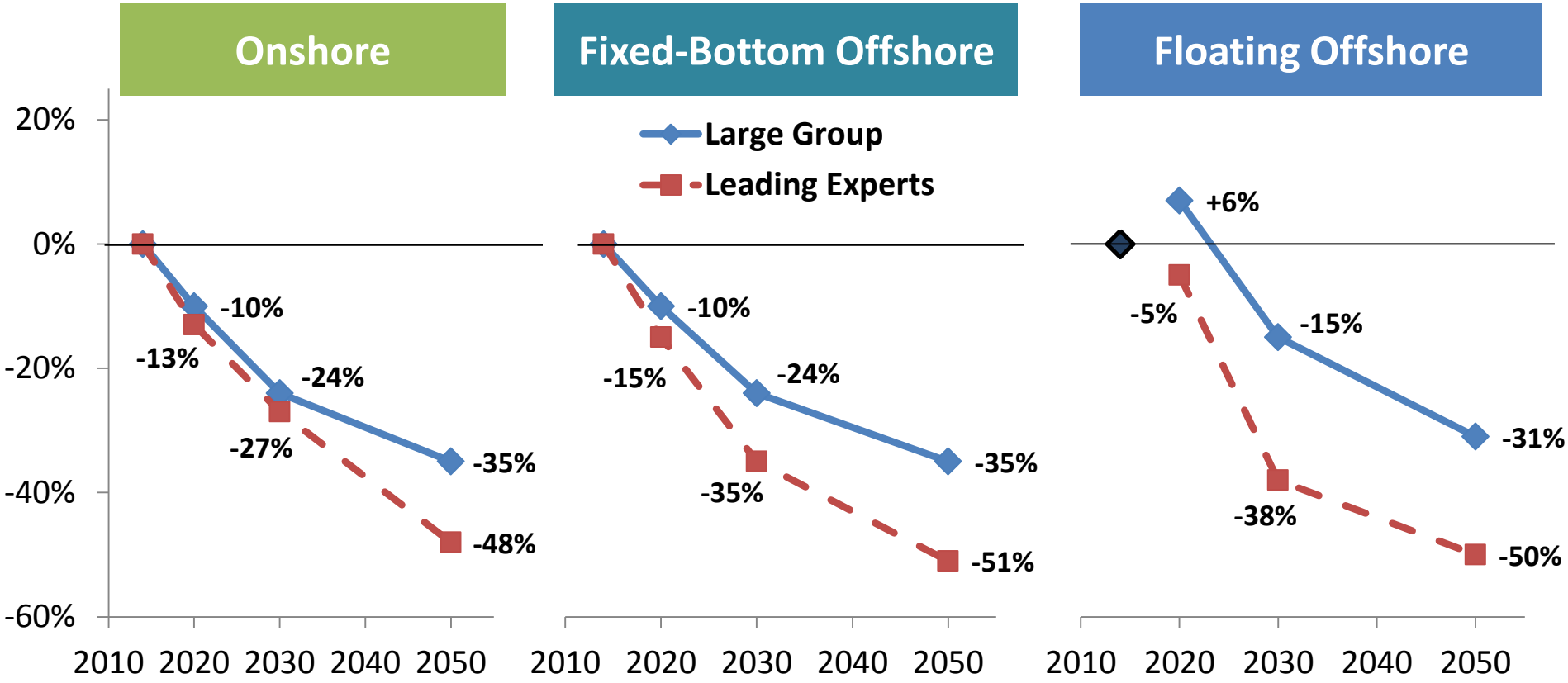
Managing Uncertainty and Aiming for Lower LCOE Is Partly Within the Control of Decision Makers

Asked respondents to rank broad drivers that might enable achieving low-scenario LCOE, separately for onshore and fixed-bottom offshore

	Wind technology, market, or other change	Percentage of experts ranking item "most important"	Mean Rating , Rating Distribution Ranking from **1**- most important to 5- least important	
Onshore Wind	Learning with market growth	33%	2.2	
	Research & development	32%	2.4	
	Increased competition & decreased risk	16%	2.5	
	Eased wind project & transmission siting	14%	3.2	
Offshore Wind	Learning with market growth	33%	2.2	
	Research & development	32%	2.3	
	Eased wind project & transmission siting	25%	2.3	
	Increased competition & decreased risk	5%	3.4	

Learning with market growth and **Research and development** are the two most-significant enablers for the low LCOE scenario

Smaller "Leading Experts" Group Expects Greater LCOE Reduction than Larger Survey Group: Median Scenario



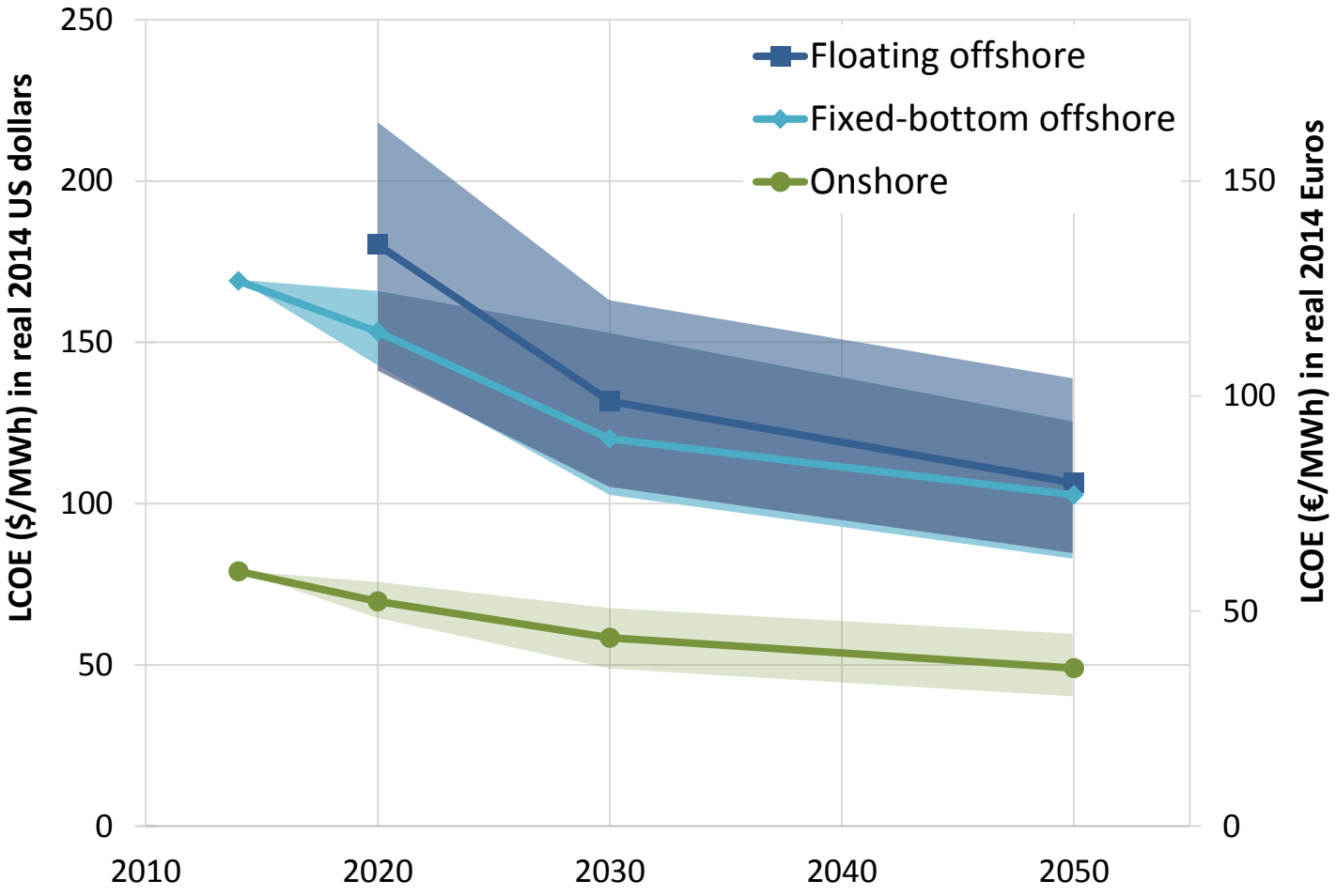
Leading experts (22) foresee greater LCOE reductions in comparison to larger group less those leading experts (141) in the **median scenario** (shown) as well as in the **low scenario**

Equipment manufacturers sometimes expect less LCOE reduction, especially in near term for fixed-bottom offshore; respondents who only expressed knowledge of offshore wind (not also onshore) tend to be more aggressive on LCOE reduction

In Absolute Terms, Narrowing Gap Between Onshore & Offshore, and Fixed-Bottom & Floating: Median Scenario

LCOE reductions for floating offshore are expected to be especially sizable between 2020 and 2030

Greater uncertainty in offshore wind LCOE than in onshore LCOE



Lines/markers indicate the **median** expert response
Shaded areas show the 25th to 75th percentile range of expert responses

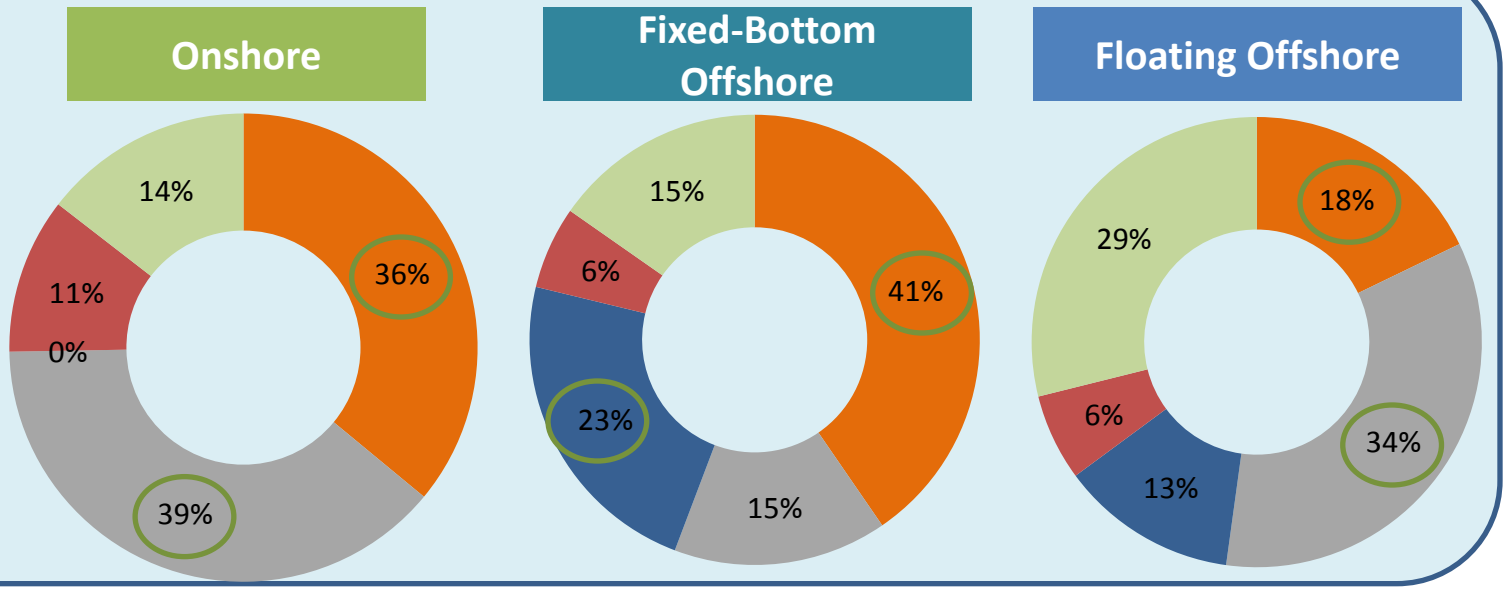
Note: Percentage changes from baseline are most broadly applicable approach to presenting findings (because each region & expert might have a different baseline value), but the relative absolute values of expert-specified LCOEs are also relevant

How Will We Get There? Factor-Contribution to Median LCOE Reductions, 2014 to 2030

	Onshore	Fixed-Bottom Offshore	Floating Offshore
Absolute Change in five factors from 2014 to 2030 in median scenario	**Capacity Factor: +10%**(=39%) **Project life: +10%** (=24.5 yrs)	**Capacity Factor: +4%** (=47%) **Project life: +15%** (=23 yrs)	**Capacity Factor: +9%** (=49%) **Project life: +25%** (=25 yrs)
	CapEx: -12% (=1539$/kW) **OpEx: -9%** (=53$/kW-yr) **WACC: 0%** (=8%)	**CapEx: -14%** (=4,000$/kW) **OpEx: -9%** (=105$/kW-yr) **WACC: -10%** (=9%)	**CapEx: -5%** (=4,400$/kW) **OpEx: -8%** (=105$/kW-yr) **WACC: -5%** (=9.5%)

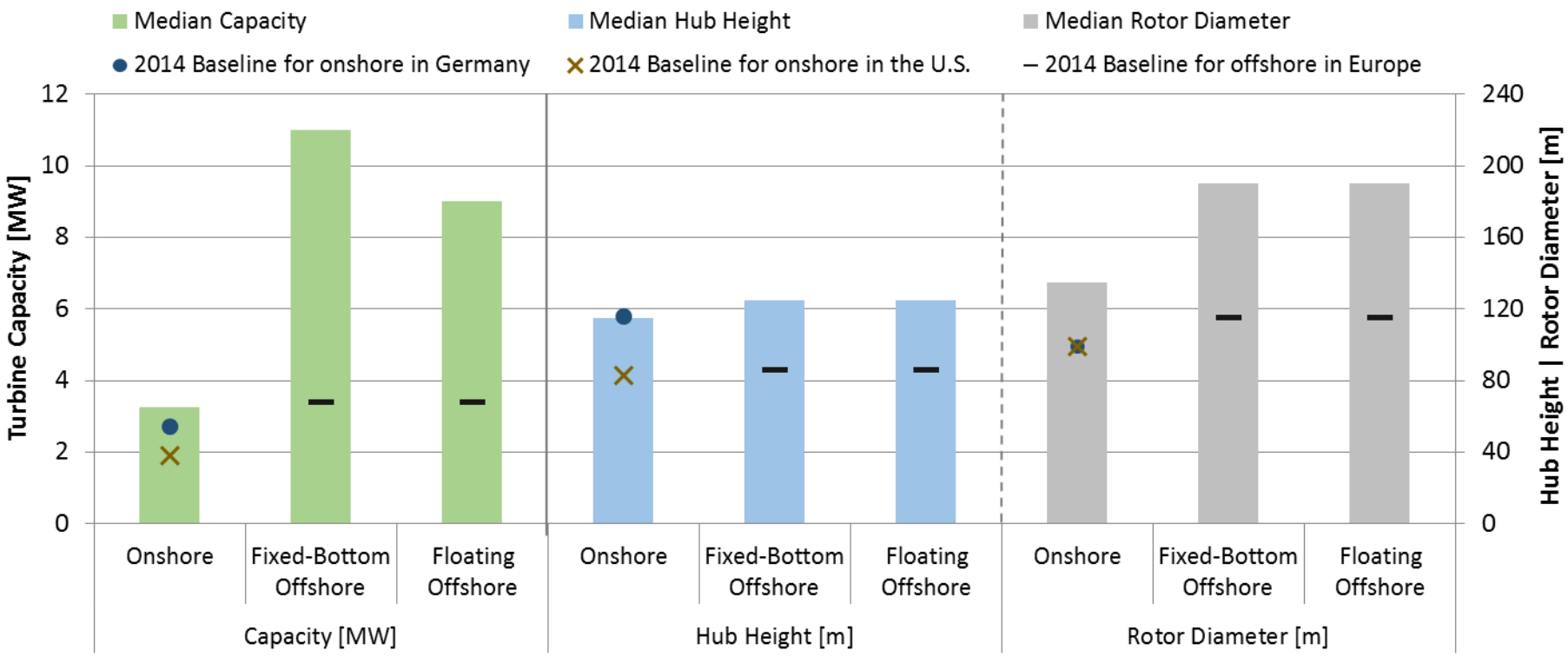
Relative Impact of five factor changes from 2014 to 2030 in median scenario on LCOE reduction

- CapEx
- Capacity Factor
- Financing Cost
- OpEx
- Project Life



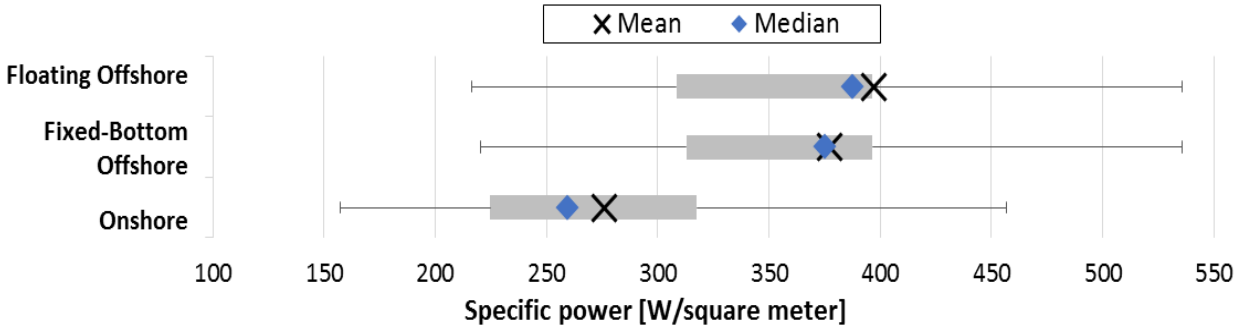
For **floating offshore wind,** change and impact are shown relative to 2014 baseline for fixed-bottom

CapEx & Capacity Factor Improvements Driven in Part by Growth in Turbine Size: Median Turbine Stats in 2030



Offshore: emphasis on increased capacity to reduce CapEx, with specific power at current levels

Onshore: scaling in capacity, height, rotors, with decline in specific power globally, to reduce CapEx, increase capacity factors



Drivers for LCOE Reduction by 2030 Are Diverse: It's Not Just Turbine Size

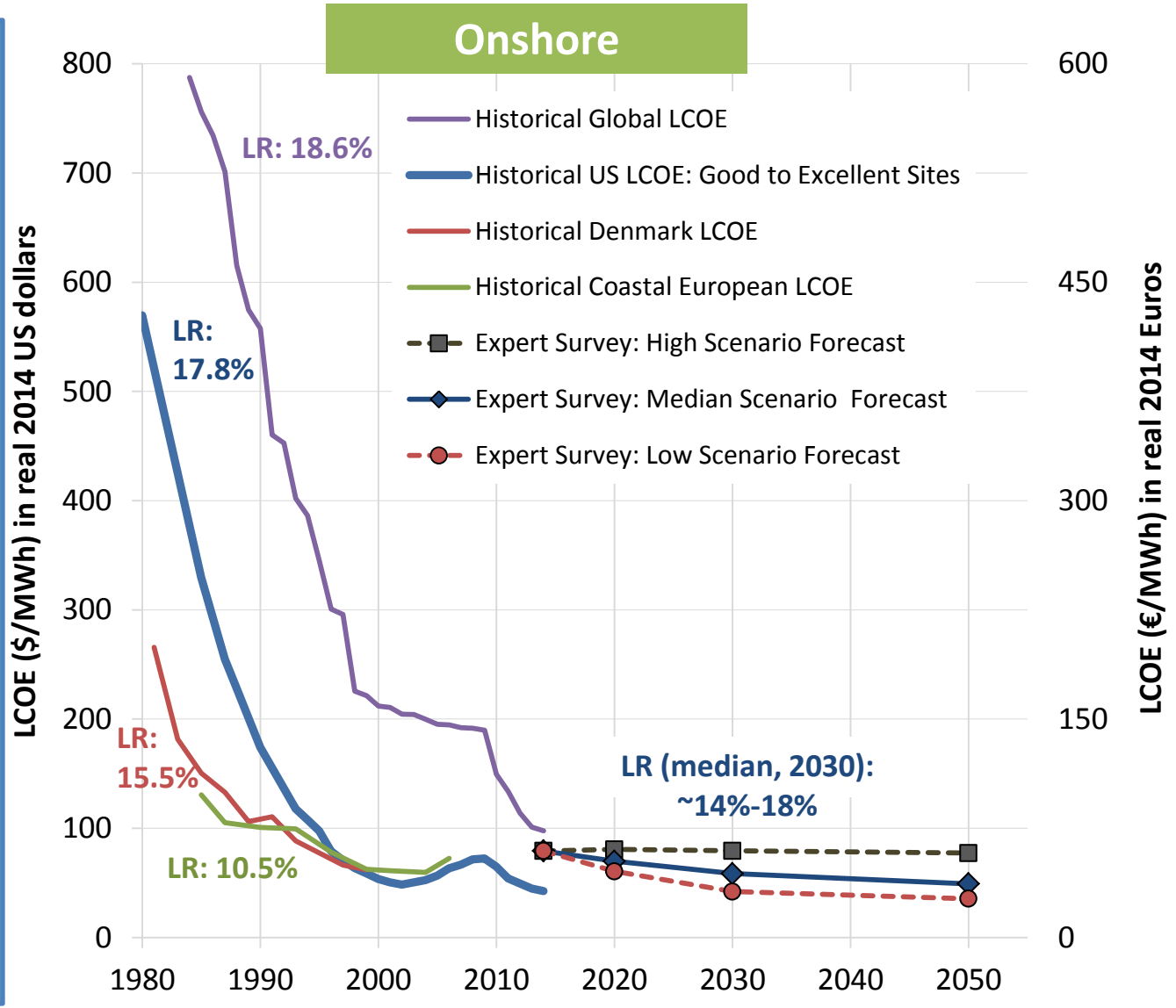
Survey asked about expected impact of 28 different technology, market, and other changes on LCOE reductions by 2030; Table shows top 5 responses for each turbine application

	Wind technology, market, or other change	% of Experts rating "Large expected impact"	Rating Distribution 3- large impact 2- medium impact 1- small impact 0- no impact
Onshore	Increased rotor diameter such that specific power declines	58%	
	Rotor design advancements	45%	
	Increased tower height	33%	
	Reduced financing costs and project contingencies	32%	
	Improved component durability and reliability	31%	
Fixed-Bottom Offshore	Increased turbine capacity and rotor diameter (thereby maintaining specific power)	55%	
	Foundation and support structure design advancements	53%	
	Reduced financing costs and project contingencies	49%	
	Economies of scale through increased project size	48%	
	Improved component durability and reliability	48%	
Floating Offshore	Foundation and support structure design advancements	80%	
	Installation process efficiencies	78%	
	Foundation/support structure manufacturing standardization, efficiencies, and volume	68%	
	Economies of scale through increased project size	65%	
	Installation and transportation equipment advancements	63%	

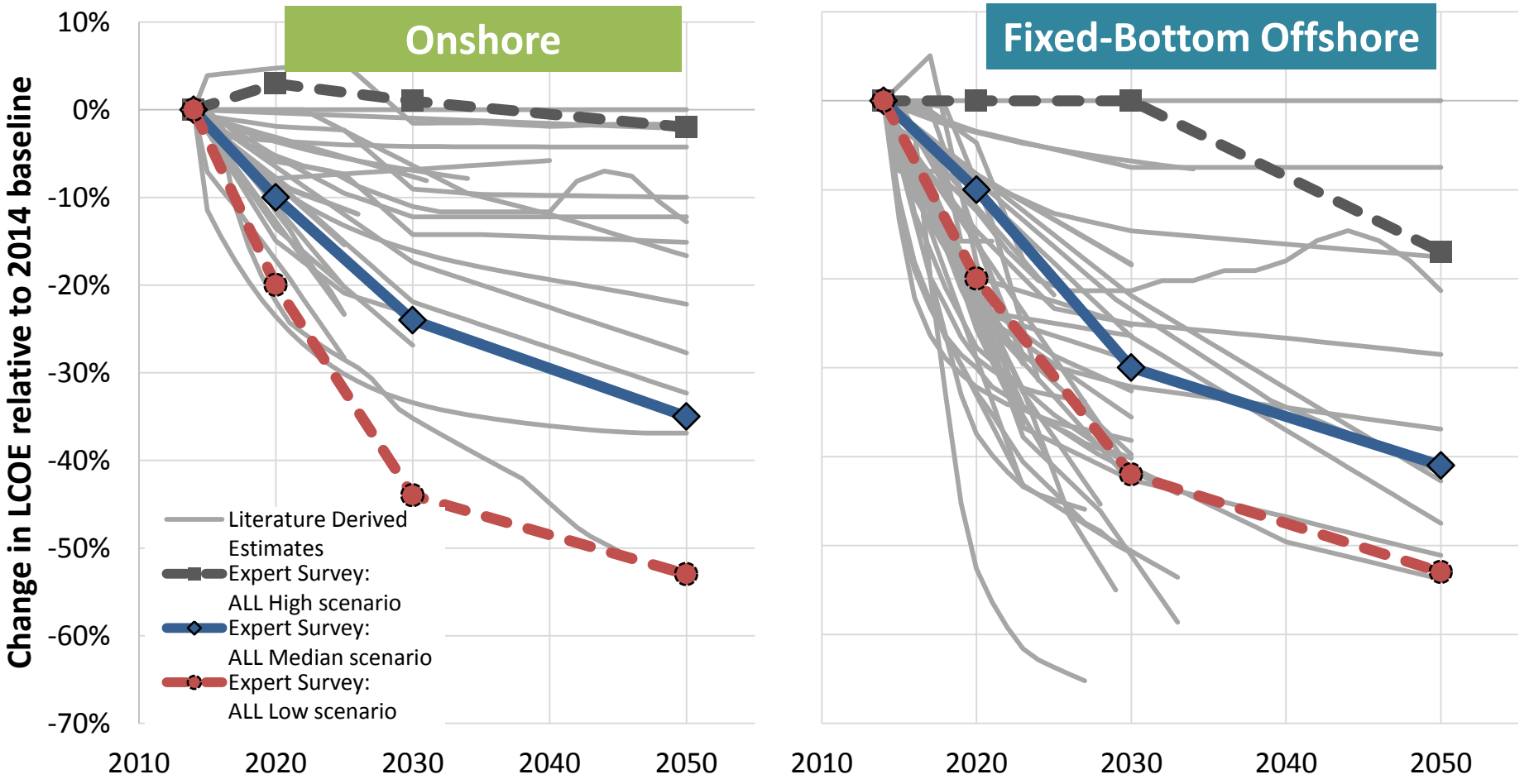
Implicit Learning Rates for Onshore Wind from Expert Survey Broadly Consistent with Historical Observations

Implicit onshore learning rate for the Median Scenario in 2030 (14-18%) in same range as historical LCOE-based learning

For offshore wind, experts either anticipate lower offshore-only learning relative to onshore (8%), or expect learning spillovers from onshore to offshore (leading to learning rates of 16%-20%)

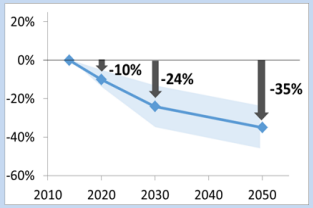
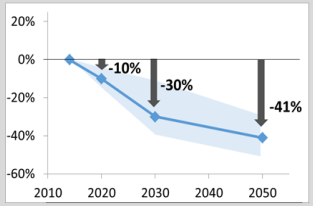
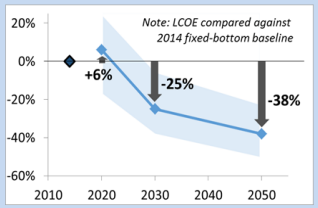


Experts Generally More Optimistic for Onshore Wind than Other LCOE Forecasts, but More Cautious for Offshore



- Previous slide suggests historical LCOE-based learning may be good guide for future, but most learning estimates have instead been based on CapEx, with lower onshore learning rates of 6%-9%
- If used to forecast costs, LCOE-based learning should be applied given multiple pathways to LCOE reduction; use of CapEx learning may explain relative conservatism of other onshore wind forecasts

Summary and Contact Information

	ONSHORE (LAND-BASED)	FIXED-BOTTOM OFFSHORE	FLOATING OFFSHORE
LEVELIZED COST OF ENERGY (median estimates for median scenario & 1st-3rd quartile range)			
DRIVERS FOR COST REDUCTION IN 2030 (median estimates; median scenario)	Capacity factor: +10% Project life: +10% CapEx: -12% OpEx: -9% WACC: no Δ	Capacity factor: +4% Project life: +15% CapEx: -14% OpEx: -9% WACC: -10%	Capacity factor: +9% Project life: +25% CapEx: -5% OpEx: -8% WACC: -5%
TURBINE SIZE IN 2030 (typical projects)	 3.25 MW 115 m hub height 135 m rotor diameter	 11 MW 125 m hub height 190 m rotor diameter	 9 MW 125 m hub height 190 m rotor diameter
TOP-FIVE IMPACT CATEGORIES	• Larger rotors, reduced specific power • Rotor design advancements • Taller towers • Reduced financing costs • Component durability / reliability	• Larger turbine capacity • Foundation / support structure design • Reduced financing costs • Economies of scale via project size • Component durability / reliability	• Foundation / support structure design • Installation process efficiencies • Foundation / support manufacturing • Economies of scale via project size • Installation / transport equipment

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For the full report on the survey results and a complete slide deck, see:
https://emp.lbl.gov/iea-wind-expert-survey