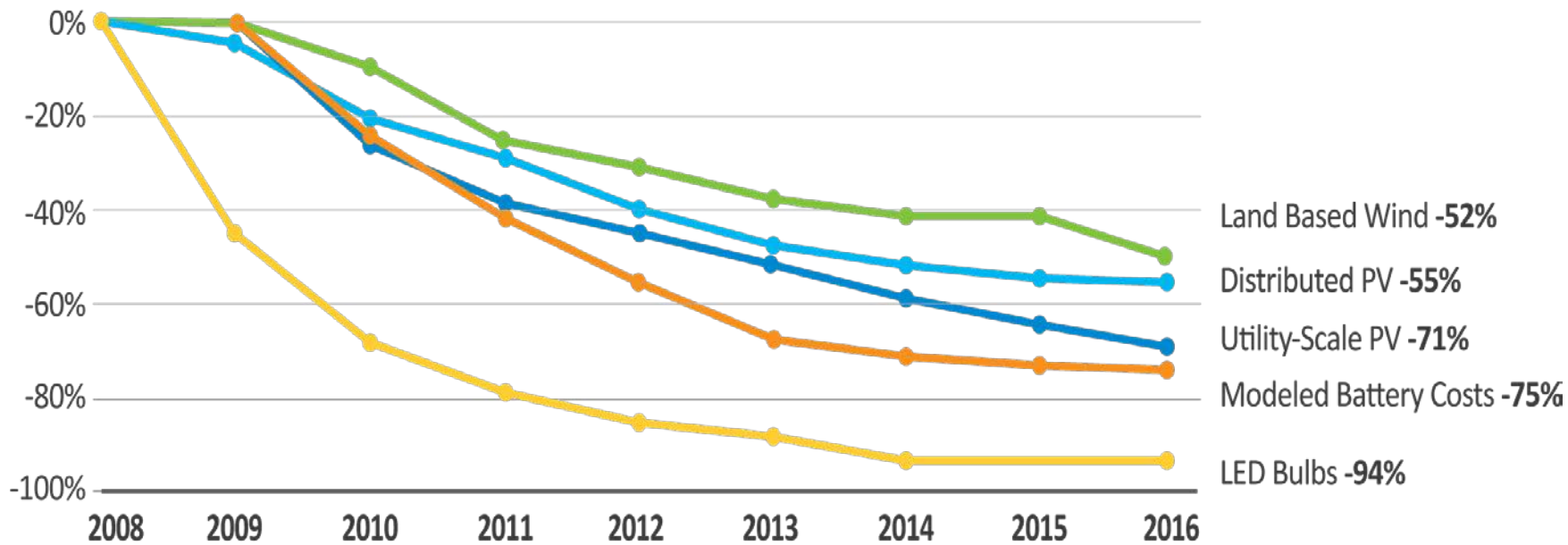




*Falling Renewable Electricity
Cost and the Impact on Grid
Operations*

Dr. Martin Keller, Director, NREL



Falling Costs of Renewables

Renewable energy technologies will be cost competitive with fossil fuels by 2020.

RFP Responses by Technology							
EIA	Generation Technology					Price Range	Pricing Units
	Coal					72 - 100	\$/MWh
	Natural Gas Combustion Turbine					59 - 120	\$/MWh
	Natural Gas Combined Cycle					30 - 35	\$/MWh
	Nuclear					63	\$/MWh
Xcel Bids		# of Bids	Bid MW	# of Projects	Project MW	Median Bid Price or Equivalent	Pricing Units
	Wind	96	42,278	42	17,380	18.10	\$/MWh
	Wind and Solar	5	2,612	4	2,162	19.90	\$/MWh
	Wind and Battery Storage	11	5,700	8	5,097	21.00	\$/MWh
	Solar (PV)	152	29,710	75	13,435	29.50	\$/MWh
	Wind and Solar and Battery Storage	7	4,048	7	4,048	30.60	\$/MWh
	Solar (PV) with Battery Storage	87	16,725	59	10,813	36.00	\$/MWh

Sources: Xcel Energy and EIA

Rising Demand for Renewables

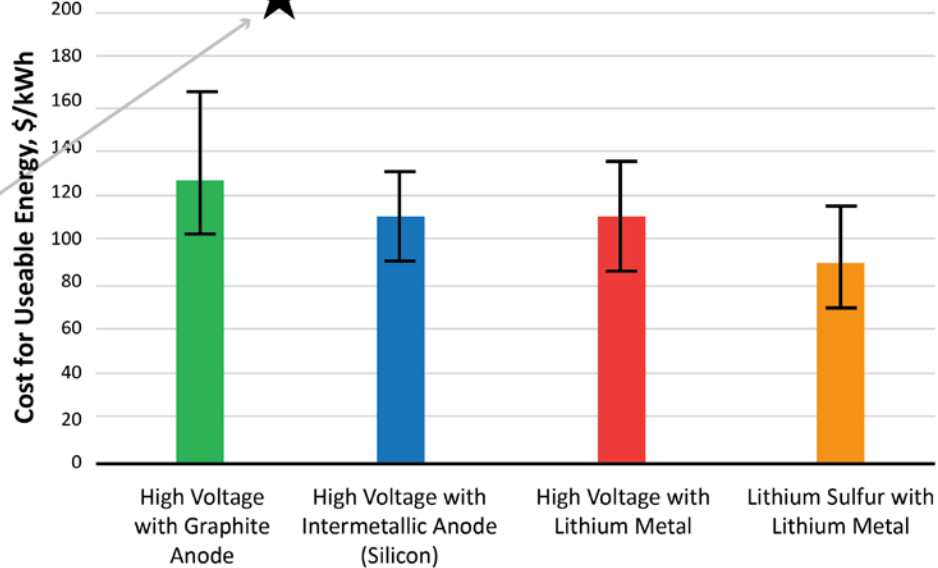
In 2013, Xcel Energy received 55 bids from energy developers for renewable projects.

Projected Cost for a 100kWh Total 80kW Battery Pack

These are the best case projections (all chemistry problems solved, performance is not limiting, high volume manufacturing) and do not include extreme fast charge capability

Status

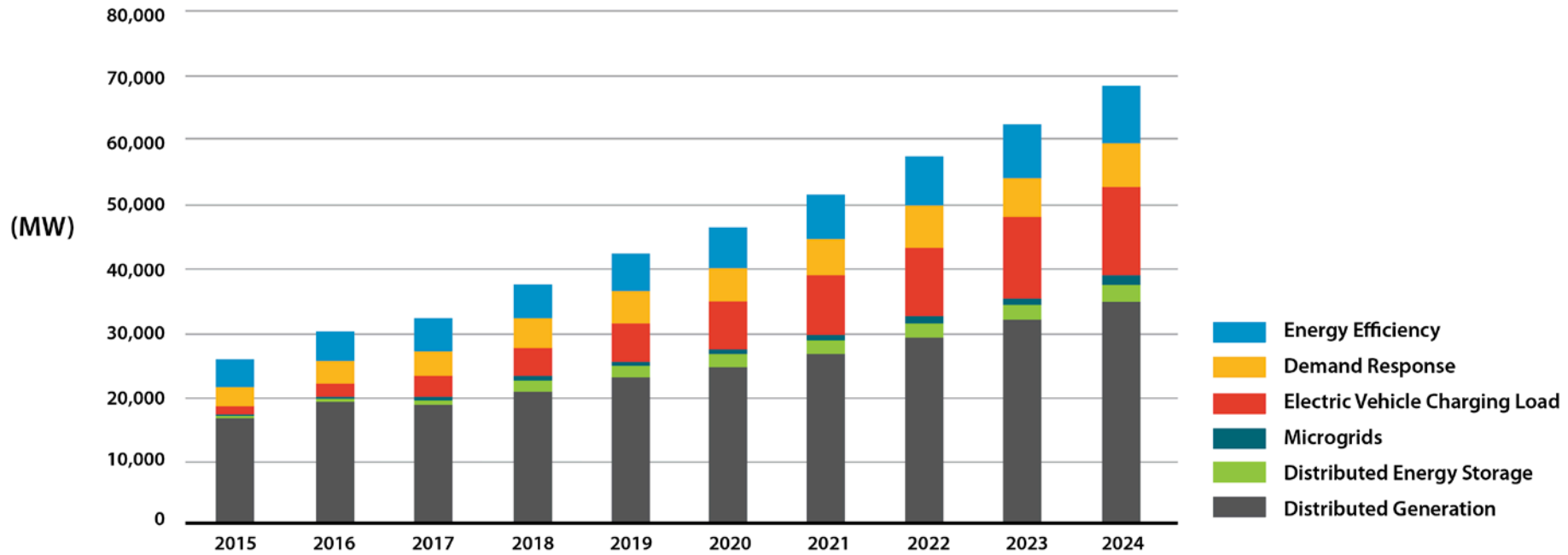
DOE R&D has lowered the cost of EV battery packs to \$219/kWh; ~80% reduction since 2008



Source: DOE, Office of Energy Efficiency and Renewable Energy, *Batteries and Electrification R&D Overview*, June 2018

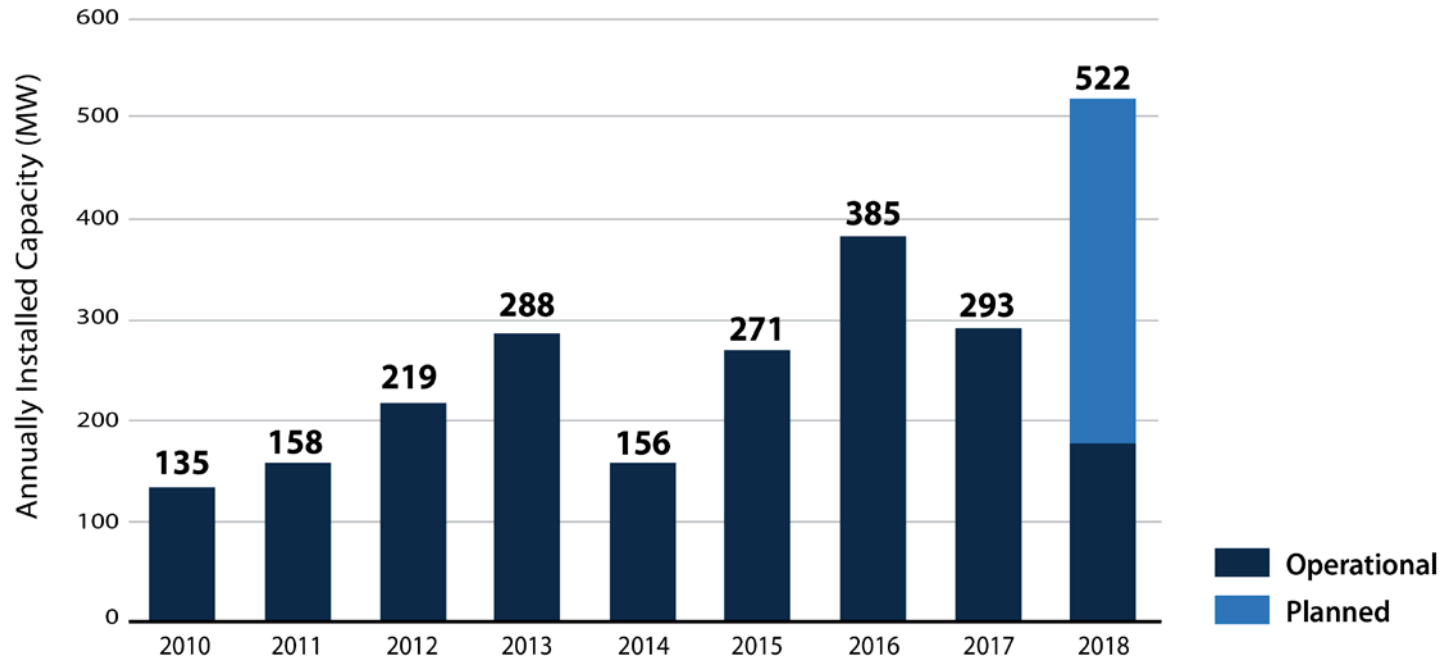
Declining Storage Costs

DOE estimates the time frame for these cost projections as about 2026 - 2028.



Source: Federal Energy Regulatory Commission, Staff Report, Docket No. AD18-10-000, February 2018

Increasing Distributed Energy Resources Capacity



Source: GTM Research, U.S. Microgrid Tracker Q2 2018

Annually Commissioned Microgrid Capacity

2010 – 2018

Microgrids Enhance Resiliency

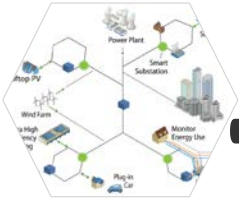
- Collaborating with SDG&E to expand the Borrego Springs microgrid;
- Providing expertise on system operations, power flow and control; and
- Helping reduce outages and boost resiliency for SDG&E customers.



Creating Autonomous Energy Systems

Applications

Power Grids



Transportation



Buildings



Wind Plants



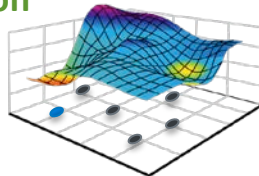
Common Problems:

- Real-time controls and optimization
- Hundreds to millions of control points
- Asynchronous data and communications
- Multi-domain systems (complex) and stochastic systems (variable renewables, consumer/occupant behavior)

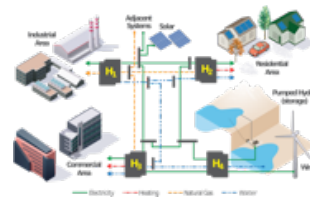
Nonlinear Control



Optimization



Complex Systems



Big Data Analytics

