Decommissioning: Lessons Learned

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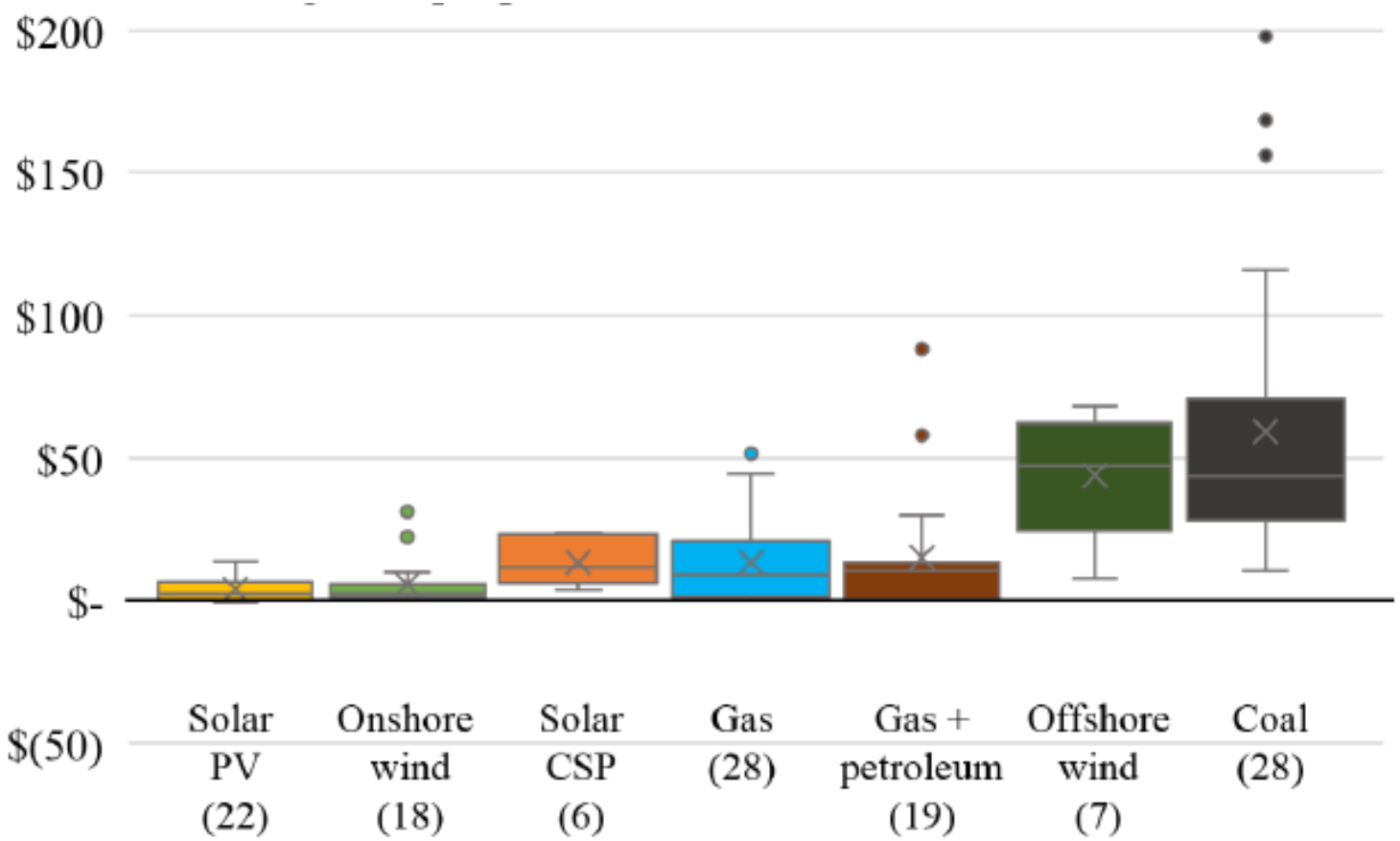
Unit type	Capacity of retirements (MW)	Number of units retired	Average age when retired	Average retired unit size (MW)
Coal	49,936	545	54	92
Natural gas (all)	42,513	995	38	43
Combined cycle	3,981	109	30	39
Combustion turbine	6,508	310	34	21
Combustion engine	307	204	37	2
Steam turbine	31,717	372	51	86
Petroleum liquids	14,677	1,054	38	14
Nuclear	4,188	5	35	838
Conventional hydro	1,281	174	70	8
Biomass	655	63	41	10
Onshore wind	565	37	15	15
Municipal solid waste	173	13	17	13
Solar PV	7	11	10	1
All other	1,106	396	40	12
Total	115,103	3,293	40	35

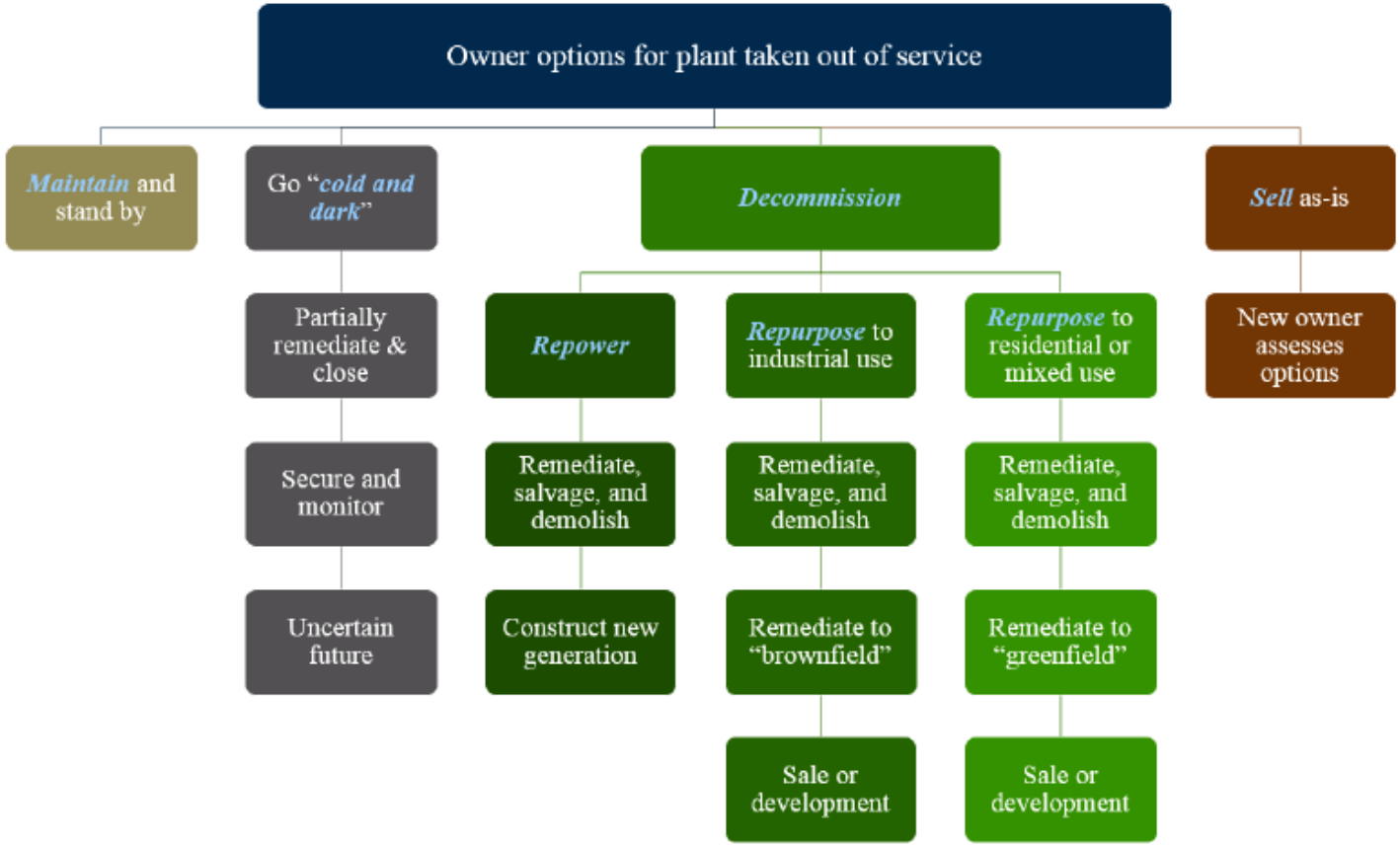
Source: Data from EIA (2016).

Electricity Retirement Summary Statistics by Fuel Type 2000-2015



Sources: Onshore wind: (EDP Renewables 2006; Ripley-Westfield Wind LLC 2010; State of Vermont Public Service Board 2010a, b, 2011a, b; EDP Renewables 2015a, b; McCarthy 2015; Algonquin Power Co. 2016; Invenergy 2016; State of Minnesota ND). Solar PV and CSP: (CH2MHill 2010; US Bureau of Land Management 2010-2016; Belectric 2011; EMC Planning Group Inc. 2012; Maryland Solar 2013; Michael Brandman Associates 2013; Apple One LLC 2014; Birdseye Renewable Energy 2015; RBI Solar 2015; Cypress Creek Renewables 2016; New York State Energy Research and Development 2016). Offshore wind: (Deepwater Wind 2012; Kaiser & Snyder 2012a; Levitan & Associates 2016). Solar PV, petroleum, gas (various), gas and petroleum, and coal estimates in Florida: (Progress Energy Florida 2009; Florida Power and Light 2016) . Onshore wind, gas (various), and coal estimates in Colorado: (Burns & McDonnell 2014). Onshore wind, gas and petroleum, and coal estimates in Minnesota: (Xcel Energy 2015; Minnesota Power 2016).

Decommissioning Cost Estimates for Various Plants (2017$)



KEY DECISION – ULTIMATE USE OF SITE

Lessons from Oil and Gas

- Tens of thousands of abandoned oil and gas wells across America
- Examples of “orphaned” wells
  - Colorado
    - 244 known
    - 52 reclaimed
  - Wyoming
    - 6,300 known
    - 1,700 reclaimed


ERIC GAY/AP


DAVID MCNEW VIA GETTY IMAGES

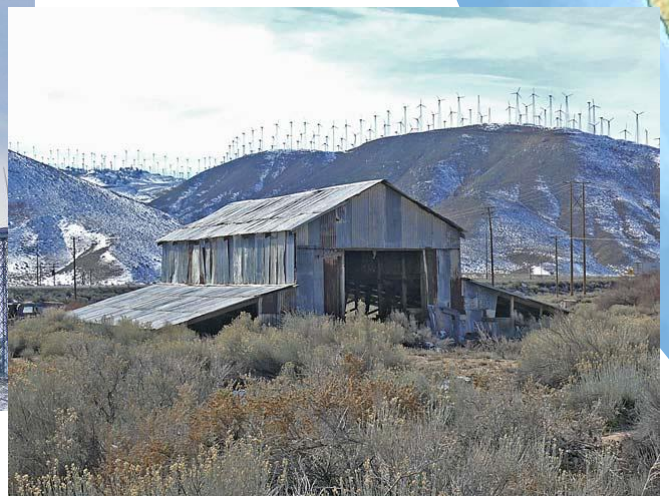
Lessons From Other Power Generation Industries

- Nuclear
  - Nuclear Regulatory Commission (NRC)
  - Reporting required every 2 years on fund
- Coal / Gas Plants
  - Utilities maintain decommissioning fund
  - Re-power with a different generation source
  - Many are left “cold and dark”

Photo: Bill Dickinson/Flickr

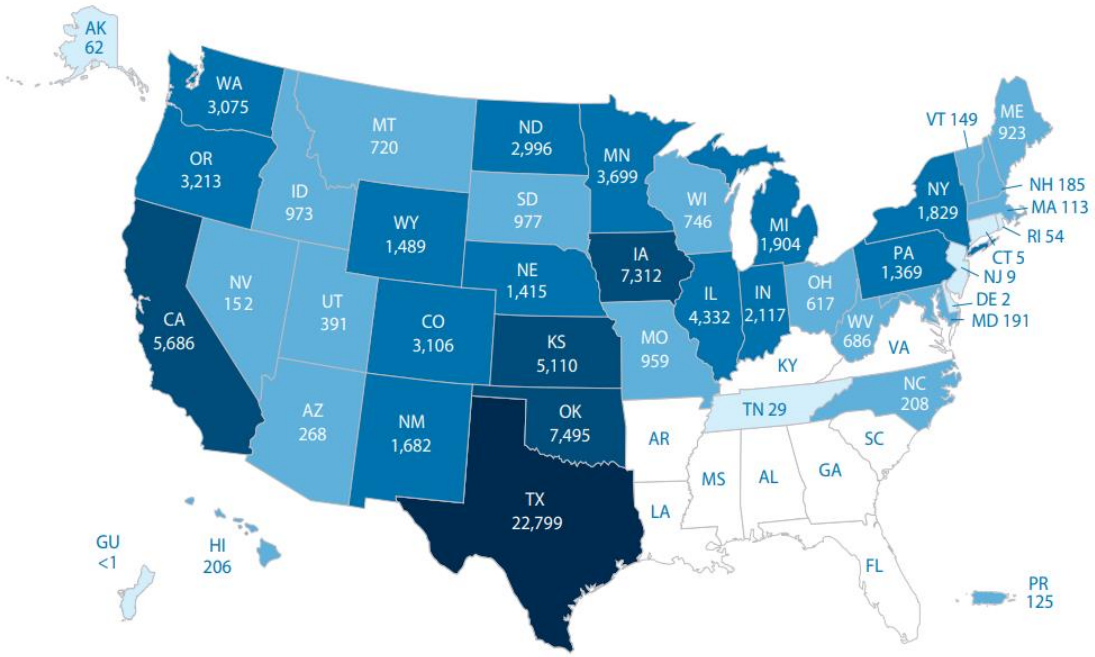
Problem Definition

- Abandoned wind farms in Hawaii
- 4,500 abandoned turbines in California
  - Altamont Pass
  - San Gorgonio Pass
  - Tehachapi



Magnitude of the Problem

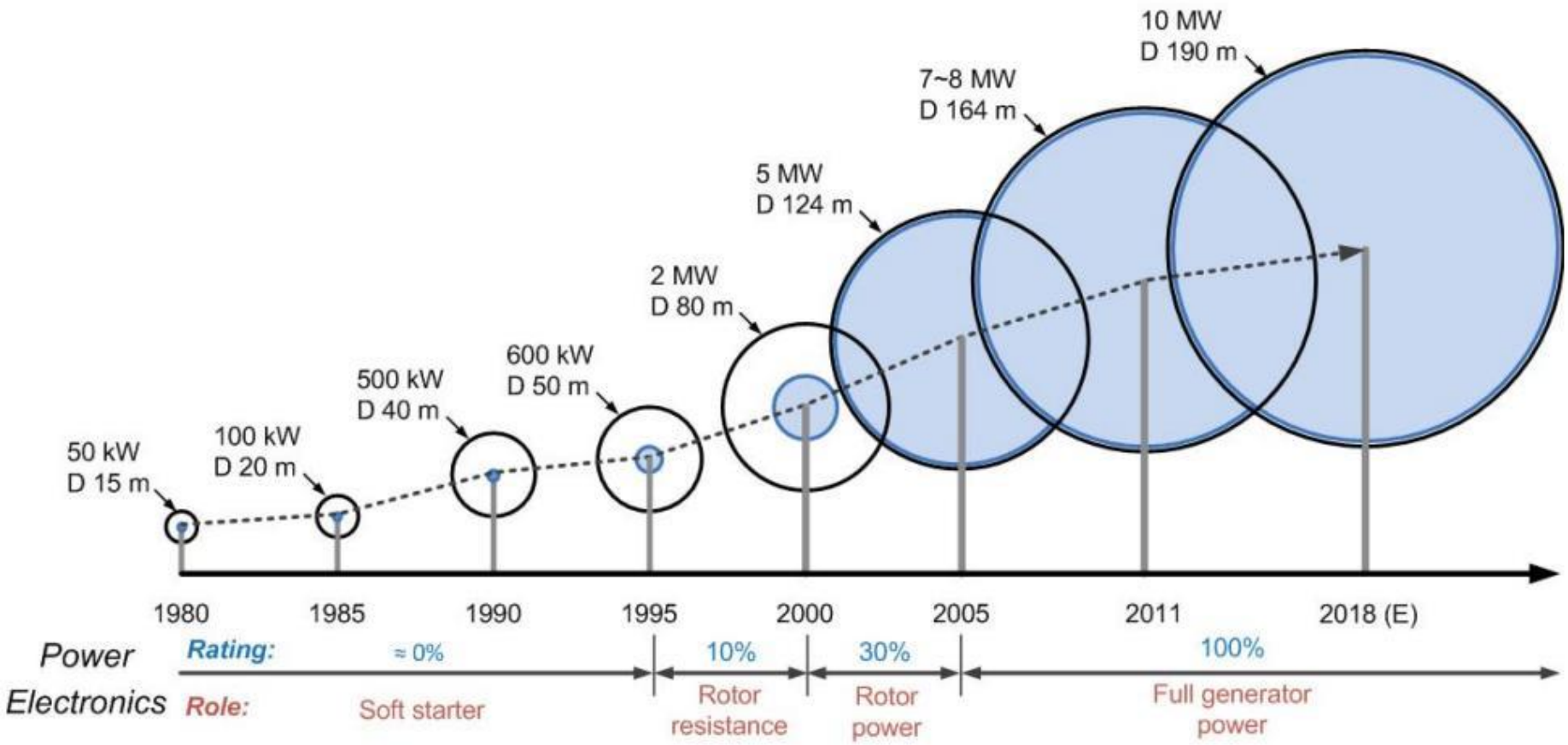
- Second wind boom – previously unimaginable scale
- Assuming standard service life of 20 years
  - Between 2017 and 2030
  - 29,000 wind turbines will reach the end of useful life
- Options:
  - Decommission – conservatively, per turbine cost $25K
  - Re-power



American Wind Energy Association | U.S. Wind Industry First Quarter 2018 Market Report | AWEA Member Version

CURRENT STATUS

- U.S. wind boom
  - 1980-1986 – 1st boom added 1,265 MW installed capacity
  - 2002-2012 – 57,519 MW
  - Through 1st quarter 2018 – 89,379 MW
  - More than 54,000 wind turbines
  - 41 states plus Guam and Puerto Rico



EVOLUTION OF WIND TURBINE SIZE

Frede Blaabjerg and Ke Ma "Future on Power Electronics for Wind Turbine Systems" IEEE Journal of Emerging and Selected Topics in Power Electronics, Vol. 1, No. 3, September 2013

Decommissioning Process

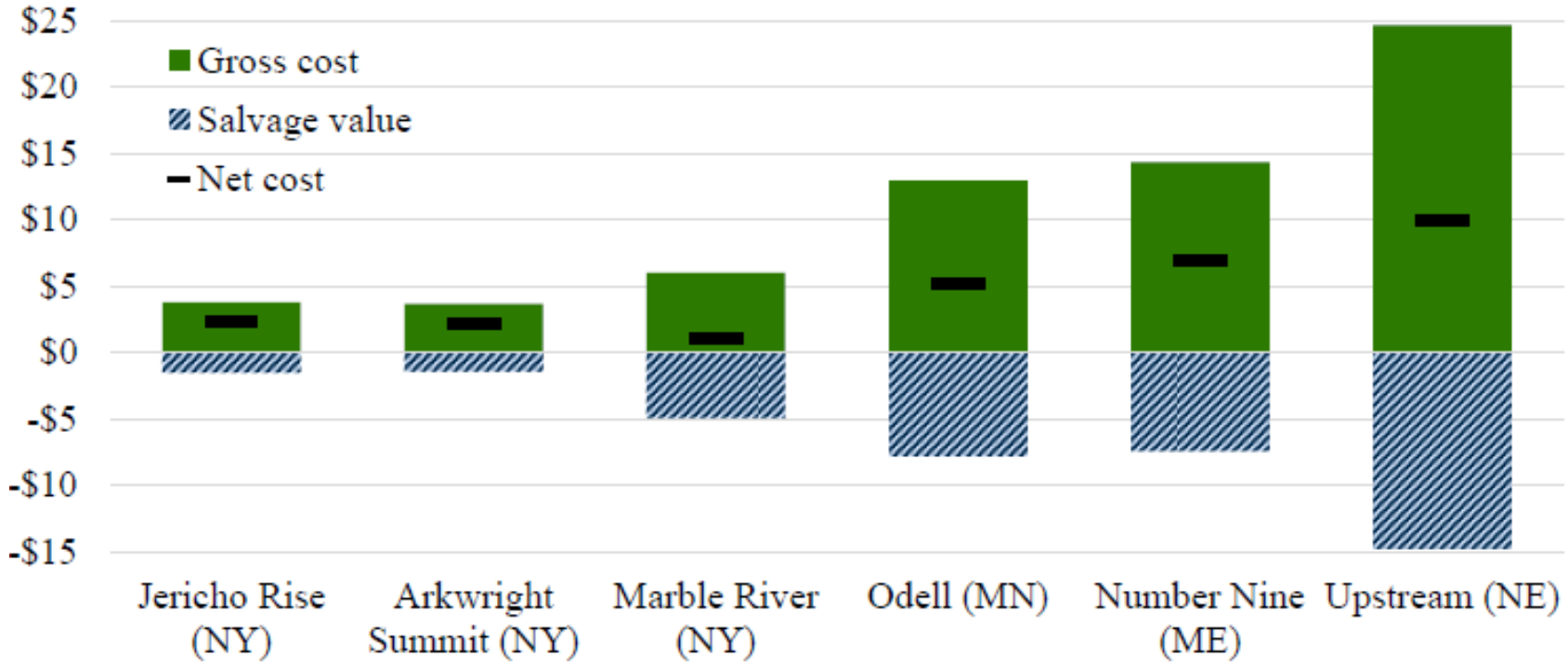
- New ecosystem established during life of wind farm
- On-site separation of modules
- Foundations – aboveground and sub-grade
- Substation / transmission
- Infrastructure support

Decommissioning Gone Wrong

- Kamaoa Wind Farm
  - Developed in 1987
  - South Point of Hawaii's Big Island
  - Purchased in 2004;
  - Turbines taken out of service in 2006
- Removed in 2012
  - Cost = $1M
  - Salvage value only $300,000

Costs

- Cost estimate of at least $725M
- Does not include 11,000 already abandoned
- Does not include recently installed turbines
- Costs continue to accumulate
- Current capacity goals: installation of approximately 126,500 new turbines over next 20 year



Sources: (EDP Renewables 2006, 2015a, b; Algonquin Power Co. 2016; Invenergy 2016; Patriot Renewables ND). *Note*: This figure highlights the importance of salvage value for the net costs of decommissioning wind plants, with salvage values estimated to recover more than half the costs of decommissioning in some cases.

Decommissioning Cost Estimates for Onshore Wind (Millions)

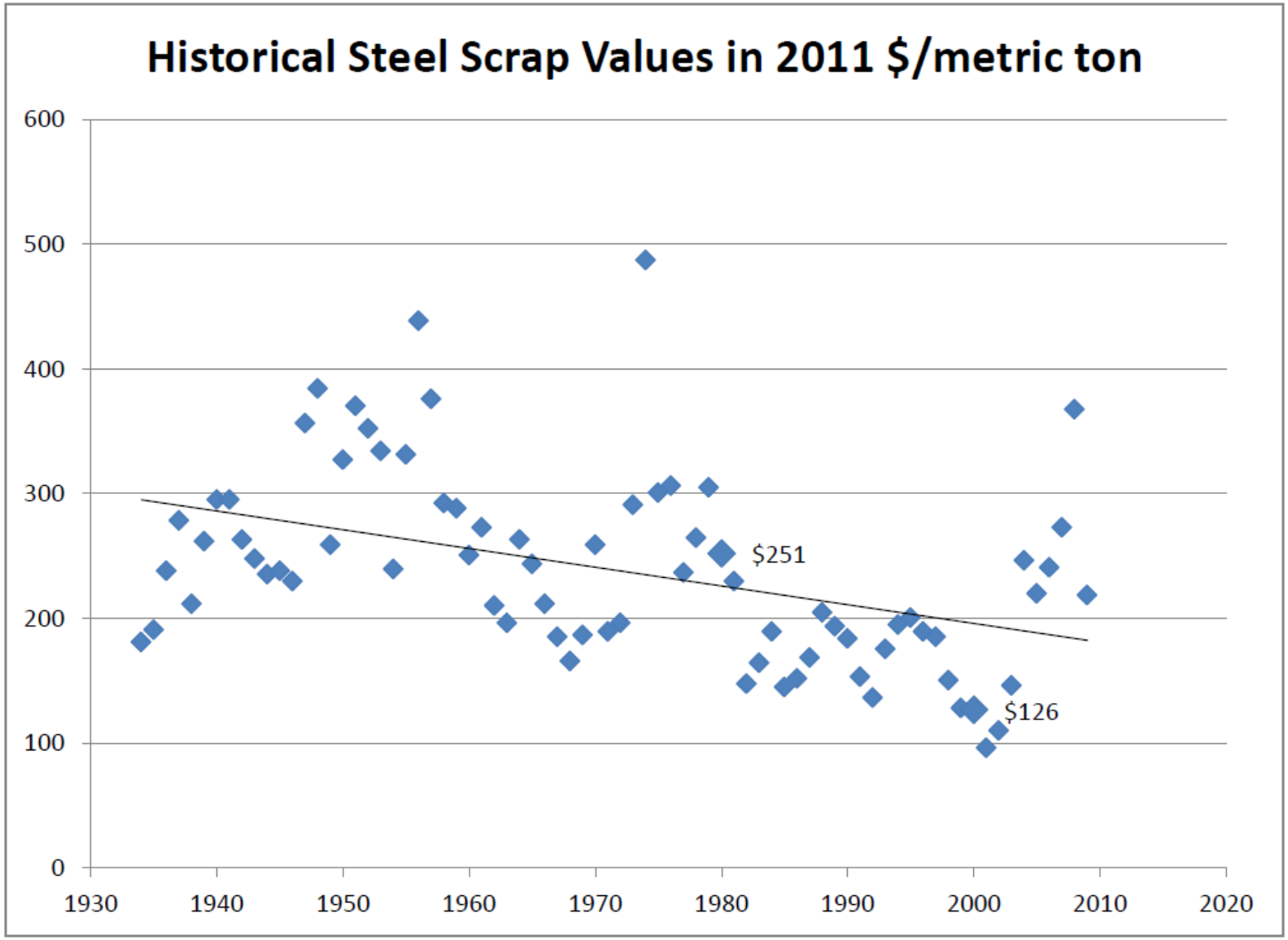
Variability of Cost Estimates

- Differences in turbines, locations, timelines
- Very little public data
- Assumption that salvage value will cover decommissioning

PROJECT EXAMPLE	COST / TURBINE	SALVAGE	NET SURPLUS
Hancock Wind Farm – 2014	$139,335	$84,047	($55,308)
Canton Mountain Wind Project - 2013	$128,000	$79,729	($48,271)
Record Hill Wind Project - 2012	$148,600	$133,658	($34,942)
Spruce Mountain Wind Project – 2012	$117,000	$90,268	($26,732)
Rollins Wind Project - 2012	$651,725	$631,875	($19,850)

Cost Variability (cont.)

- Salvage values
- Decommissioning of high-value, low-cost components
  - Turbine components
  - Electrical wiring
- Incentivizes partial decommissioning


Historical Steel Scrap Values in 2011 $/metric ton
600
500
400
300
200
100
0
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
$251
$126

Regulatory Oversight

- No overarching federal regulations
- State regulation – 3 categories
  - Require decommissioning, but not financial assurances
    - California, North Dakota
  - Law-of-the-Lease States – no requirement
    - Texas, Iowa, Colorado, Kansas, Massachusetts, Michigan, Montana, New Mexico
  - Require operators to prove fiscal responsibility
    - Contribute to a fund or post a bond
    - Oklahoma, Oregon, Indiana
- Municipal / county-level regulation

Private vs. Public Lands

- Key: surety of availability of funds
  - Escrow account
  - Bond decommissioning costs
  - Set aside funds from energy sales
- Federal agencies with renewable facility decommissioning rules
  - DOI
  - FERC
  - BLM

Moving Forward

- To support regulatory oversight
  - Effective statutes with financial commitments
  - Regulation on a state-wide basis
  - Allocation of decommissioning responsibility
  - Clear definition of triggering events

THANK YOU!