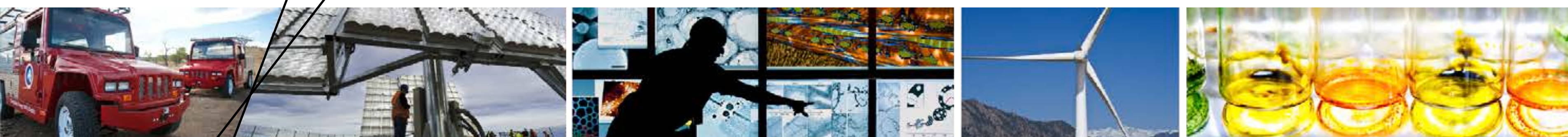
Wind Power Project Repowering: History, Economics, and Demand



Wind Exchange Webinar

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Presentation Overview

1. <u>Background</u> – Concepts and Context
2. <u>Status</u> – U.S. and Globally
3. <u>Economics</u> – Conceptual and 'Actual' Plants
4. <u>Future Demand</u> – Expectations for the 2020s
5. <u>Key Takeaways</u> – Summary of Findings

Background

- **Repowering can be defined in two ways:**
  - Full repowering: complete dismantling and replacement of turbine equipment at an existing project site
  - Partial repowering: replacing selected turbine or plant components to extend the life of a given facility at some cost that is less than full repowering; may also trigger fewer legal hurdles

- **Repowering offers various opportunities:**
  - Increased project productivity
  - Improved grid support and interactions
  - Better utilization of high-value resource areas
  - Reduced visual impacts (fewer turbines per overall capacity)
  - Potentially, reduced avian and wildlife impacts

- **Repowering first emerged in the early 1990s in the California and Danish wind power markets and was followed by the Dutch and German markets in the 1990s and 2000s**

Status

- **Denmark:**
  - Typically repowers 10s to 100s of MW per year
  - Has historically provided repowering incentives that are in addition to feed-in-tariffs
  - Cited constraints include: capital requirements of new projects, shifts in ownership models away from the community, limited economic value
- **Germany:**
  - Observed to have the largest potential market for repowering, estimated at approximately 6 GW
  - Typically repowers 10s to 100s of MW per year
  - Has historically provided repowering incentives that are in addition to feed-in-tariffs
  - Cited constraints include setbacks, turbine height restrictions, and limited economic value
- **U.S.**
  - 1980s and 1990s vintage technology in California represents the primary current opportunity for repowering in the U.S. (~2 GW), but has been limited by the 'California Fix' among other policy and regulatory factors
- **To date, repowering has tended to be Full Repowering**

Economics: Phase 1 Analysis

- Develop representative plants for four specific points in time: 1999, 2003, 2008, 2012
- Quantify and compare the financial impacts of *Full Repowering* and *Developing an Adjacent Greenfield Site*
- Quantify and compare the financial impacts of *Partial Repowering, Full Repowering* and *Developing an Adjacent Greenfield Site*, for the 2003 conceptual plant in 2025

Conceptual Plant Technology, Cost, and Performance Parameters

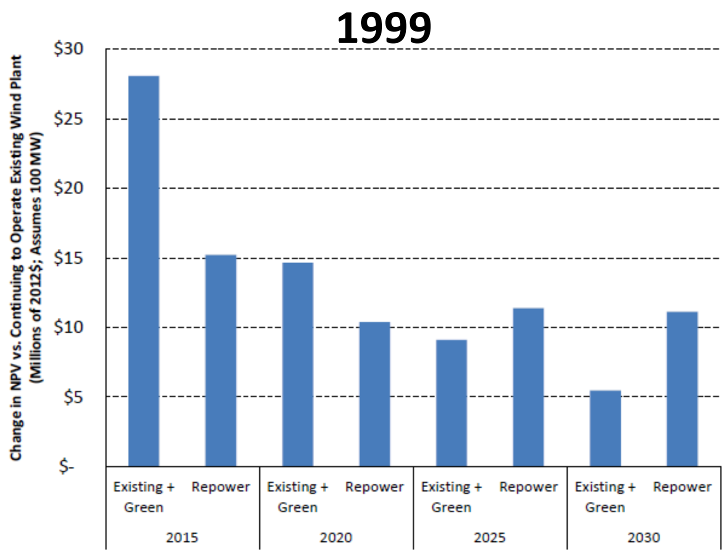
Year Commissioned	Turbine Rating (MW)	Hub Height (m)	Rotor Diameter (m)
1999	0.7	56	48
2003	1.2	66	64
2008	1.7	79	79
2012	2.1	85	95

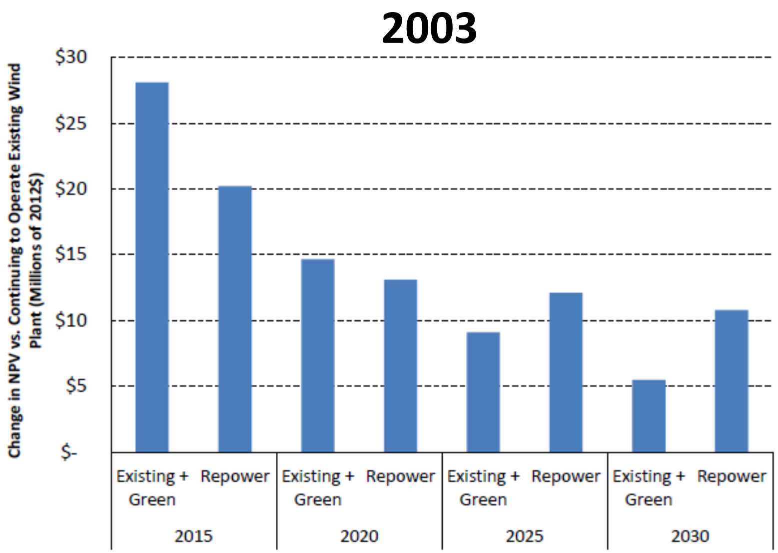
Source: Lantz et al., 2013

Plant Commission Date	Installed Capital Cost			Net Capacity Factor[b]			PPA Price[c]		Operations Expenditures (Year 1)	
	Greenfield 2012 $/kW	Repower 2012 $/kW	Partial Repower 2012 $/kW	Greenfield	Repower	Partial Repower	2012 $/MWh	PTC Available	Fixed 2012 $/kW-yr	Variable 2012 $/MWh
1999	1,672			28.1%			50	Yes	12.5	10.2
2003	1,402			29.8%			35	Yes	12.5	8.2
2008	1,998			33.7%			57	Yes	12.5	6.1
2012	1,890			35.6%			52	Yes	12.5	6.1
2015	1,862	1,769		41.0%	41.0%		63	No	12.5	6.1
2020	1,816	1,725		42.0%	42.0%		57	No	12.5	6.1
2025	1,770	1,681	1,504	43.0%	43.0%	37.2%	53	No	12.5	6.1
2030	1,712	1,626		43.0%	43.0%		51	No	12.5	6.1

[a] Historical data are derived from Wiser and Bolinger (2012); future data are derived from NREL cost projection analyses (e.g., Chapman et al. 2012; U.S. Department of Energy 2008), current industry trends, and semi-structured interviews with owner operators.

Economics: Conceptual Plants

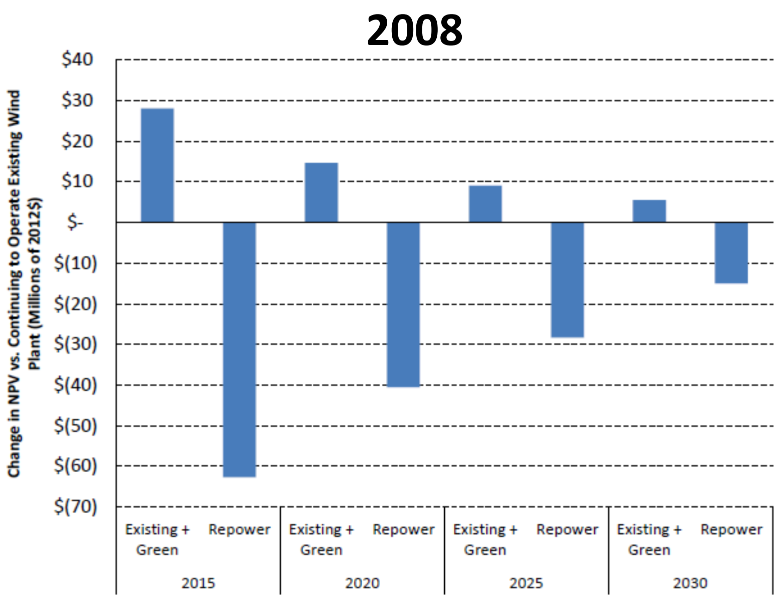


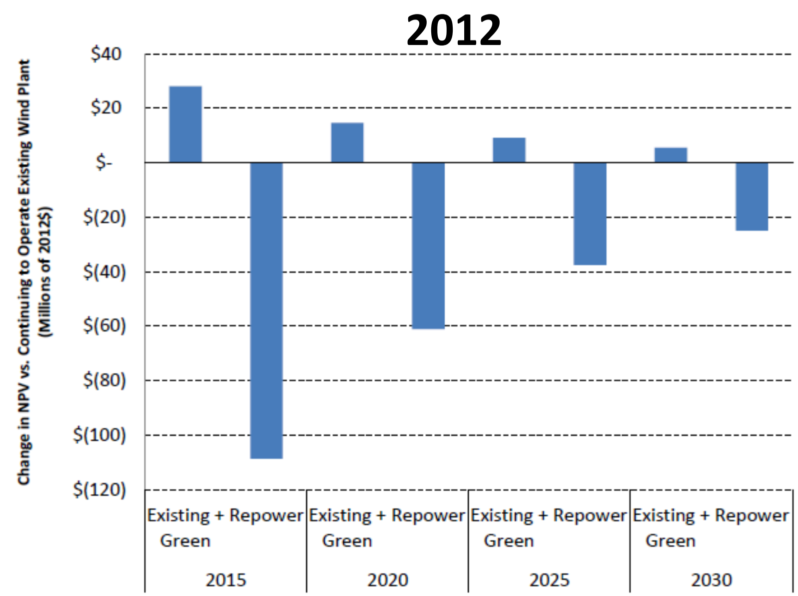


Source: Lantz et al., 2013; Note: data illustrate value gained or lost as a result of a specific investment decision; as each of these plants is modeled at an equivalent size, the change in plant-specific NPVs can be compared across time; however, caution is advised against any direct assessment of wind plant profitability or return on investment, as the overall magnitude of NPV is highly correlated to plant size

- **Wind power plants built in 1999 appear to be reasonably profitable after about 15 years of operations, but both repowering and developing an adjacent greenfield could add additional value**
- **After 20 years, the economics start to shift, with full repowering becoming more attractive than an adjacent greenfield sometime between 20 and 25 years of operation**
- **For the 2003 facility, analysis suggests that building an adjacent greenfield plant in 2015 and 2020 is also the preferred alternative; however, repowering appears to become financially attractive a bit sooner, between 16 and 21 years of operation (2020–2025)**
- **The shorter expected lifetime for the 2003 facility is a function of its lower estimated PPA price, which results in lower overall profitability and allows increasing operational costs to erode the value of these projects, earlier in their life**

Economics: Conceptual Plants





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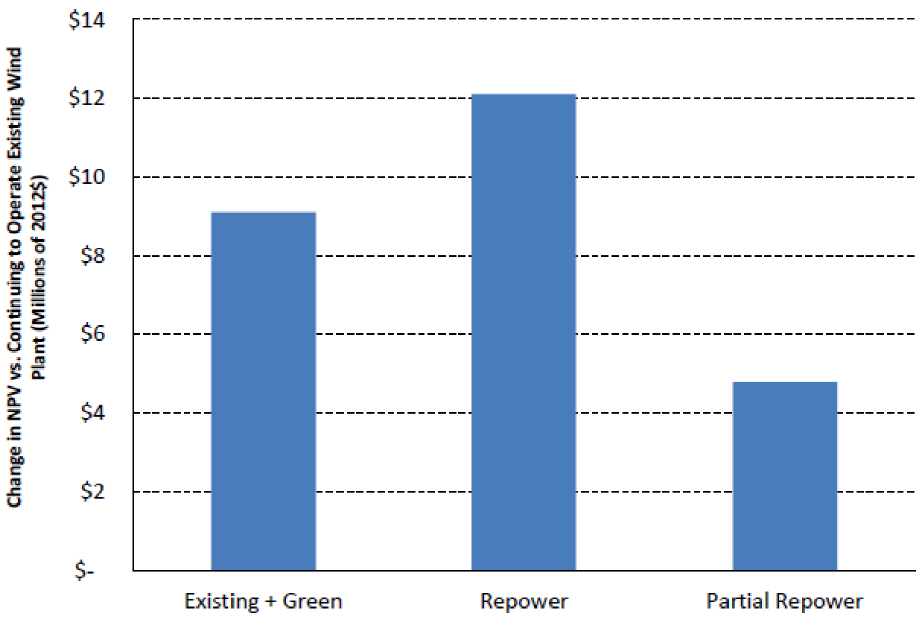
- **Full repowering results in a reduction in the NPV of future after-tax cash flows, through 2030, for these more recent projects**

- **This effect is in part the result of historically high PPAs signed in 2008, but also results from the assumed declines in pricing that are expected as future technology advancements and cost reductions are realized**

- **Based on these results, more recent projects could ultimately delay repowering investments until 25 years of operation or beyond**

Economics: Partial Repowering 2003 Plant

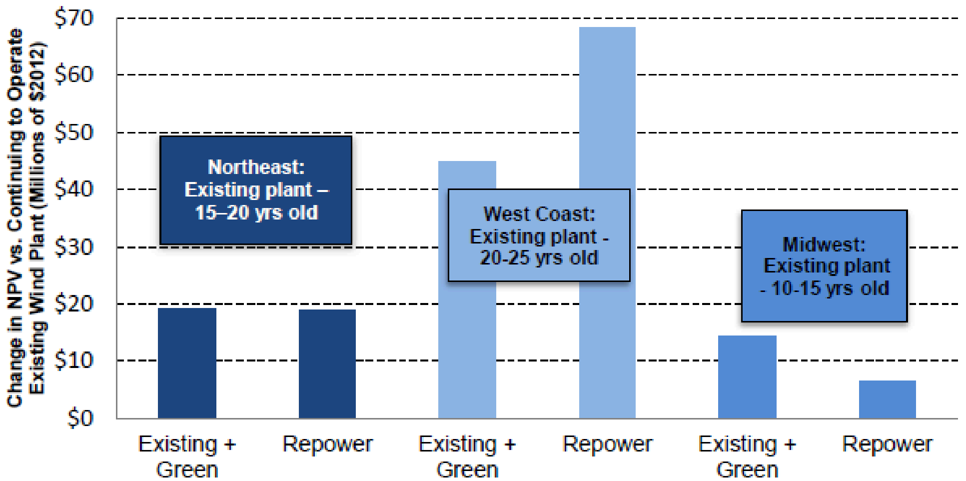
- **Analysis of partial repowering assumes:**
  - Replacement of rotor and drivetrain
  - Increase in NCF from 30% to 37%
  - 15% cost reduction relative to a green field (~10% relative to repowering)
  - Construction in 2025
- **From these premises, the benefits of partial repowering come in well below that of developing an adjacent greenfield and full repowering**
- **Partial repowering solutions that can be realized at lower cost, would likely prove more viable**



Source: Lantz et al., 2013; Note: data illustrate value gained or lost as a result of a specific investment decision; as each of these plants is modeled at an equivalent size, the change in plant-specific NPVs can be compared across time; however, caution is advised against any direct assessment of wind plant profitability or return on investment, as the overall magnitude of NPV is highly correlated to plant size

Economics: Case Study Analysis

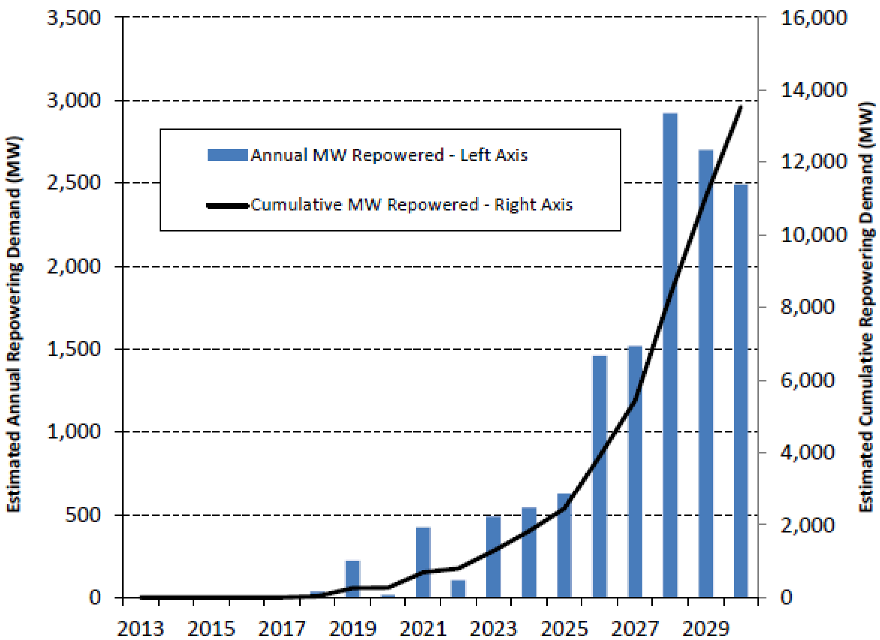
- Case studies were developed for plants in the Northeast, on the West Coast, and in the upper Midwest
- With the exception of the West Coast plant repowering, at the present time, does not appear to be overly compelling
- These results are consistent with decisions made on the ground and the results of the prior conceptual analysis
- Age and estimated project financials are the primary variables affecting these results
- An assumed lower capacity factor for the greenfield investment option on the West Coast also supports repowering relative to other regions where high quality resources remain available



Source: Lantz et al., 2013; Note: Comparing the NPV across the three case studies is not appropriate. The absolute magnitude of the NPV is highly correlated with the size of the wind plant, as larger wind plants require higher levels of investment. Within each case study, it was always assumed that both greenfield and repowering decisions would be of the same size (i.e., same rated capacity) and thus can be fairly compared.

Future Equipment Demand

- **Supply chain demand can be approximated based on calculated lifetimes**
- **Estimates assume:**
  - 25% of existing facilities repower at 20 years
  - 50% repower at 25 years of operation
  - Remaining 25% of the existing fleet are assumed to continue to operate after 25 years or to be decommissioned
- **By in large U.S. repowering activity can be expected to remain rather modest until the mid- to late-2020s, achieving cumulative levels of 14 GW by 2030**
- **Repowering demand could be expected to remain strong after 2030, based on the assumed lifetimes applied here as well as recent and projected average installation levels**



Source: Lantz et al., 2013; Note: Results assume 1 MW of existing capacity is replaced by 1 MW of repowered capacity .

Key Takeaways

- **In the U.S., projects that continue to operate in the black after 20 years generally have little incentive to repower, relative to investing in new greenfield sites**

- **The balance tends to tip towards repowering sometime between 20 and 25 years of operations, but may be even later for more recent plants, depending on future operations costs**

- **Partial repowering that only results in modest cost savings relative to full repowering can be expected have minimal impact on the market**

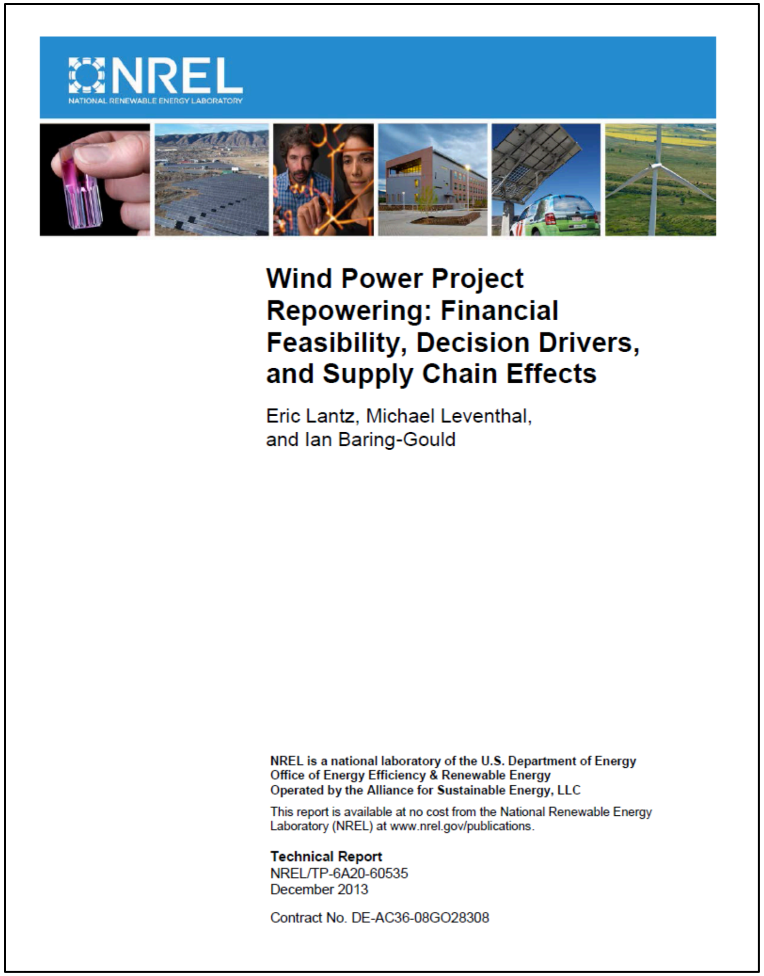
- **Repowering demand outside of California is not likely to have a noticeable impact until the mid- to late 2020s, but assuming healthy levels of wind installations into the future could ultimately constitute a large portion of the U.S. wind industry**

- **A number of variables could alter these conclusions and include:**
  - <u>Technology advancement</u>
  - <u>Wind resource quality</u>, for new greenfield plants
  - <u>Prices paid for wind generation</u>, now and in the future
  - <u>Operations expenditures</u> escalation rates (and plant performance generally)
  - <u>Cost savings</u> achieved by repowering, relative to greenfield development

Additional Information and Contact Details

- **For additional reading, the full report and associated references can be found here: http://www.nrel.gov/docs/fy14osti/60535.pdf**

- **For specific questions email: eric.lantz@nrel.gov**



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Wind Power Project Repowering: Financial Feasibility, Decision Drivers, and Supply Chain Effects

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