WIND O&M

Tribal Commercial Energy Workshop

Sep 3, 2015

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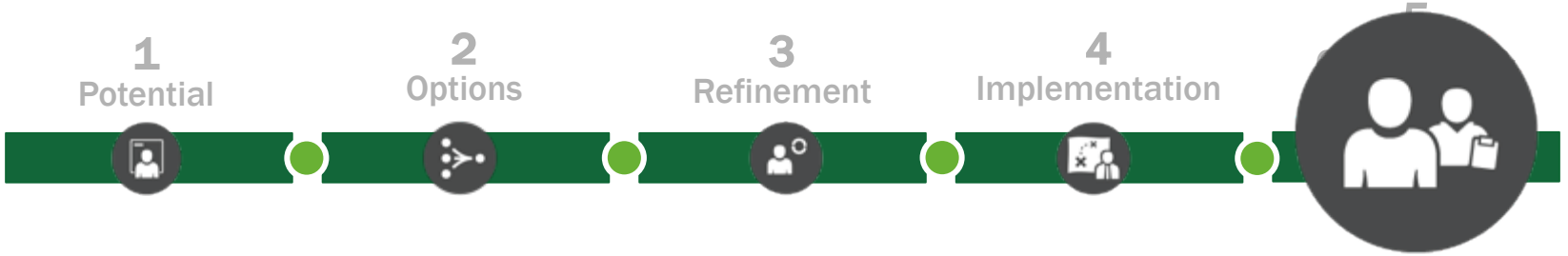
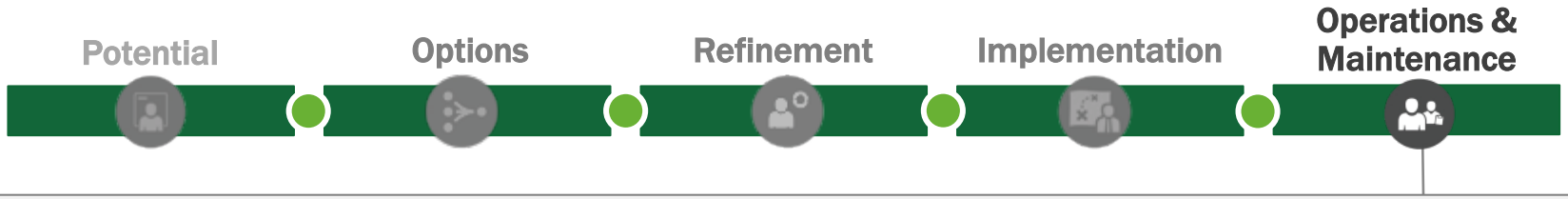
Presentation Agenda

- Where O&M Fits in the Project Process
- O&M Drivers (Why do O&M?)
- O&M Defined (O&M Categories)
- O&M Cost Trends
- Options for Conducting O&M
- Closing Thoughts

Project Development Process



Step 5: Operations & Maintenance



Purpose: Conduct or ensure ongoing operations and maintenance (O&M), including repair and replacement (R&R)*

Task:

- O&M Plan and Budget
- System performance
- Monitoring system
- O&M Contracts and agreements
- Warranties
- Production guarantees
- Buyout Options

Outputs:

- Ensure responsible party carries out O&M/R&R*
- Measuring and tracking success
- Correlate with business plan and strategic energy plan
- Contract compliance
- Reporting of generation
- Met or exceeded energy and financial performance

**Especially if owner – role of highest O&M risk*

Photo by Dennis Schroeder, NREL 26641

Drivers for Improved O&M

- Increase efficiency and energy delivery (kWh/kW)
- Decrease downtime (hours/year)
- Ensure safety and reduce risk
- Extend system lifetime
- Often required in financing and warranty

What's Included Under O&M?

O&M is often narrowly interpreted as this (maintenance)…

- Preventive Maintenance
  - Scheduled and planned
  - Expenditure is budgeted
- Corrective Maintenance (repair) [Capital Replacement]
  - Unplanned or condition-based
  - Costs tend to increase over time
  - Must be timely and effective
  - Have sufficient funds available to cover cost of major component repair or replacement
- Monitoring
  - Metering for revenue
  - Alarms
  - Diagnostics
  - Condition Monitoring

But can also includes this

- Administration
  - Billing; accounting
  - Hiring subcontractors
  - Enforcement of warranties
  - Management of budget and reserves
- Insurance
  - General Liability
  - Property
  - Business Income (loss of profit)
  - Equipment Protection (from breakdown)
- Site Maintenance
  - Mowing around the tower base
  - Snow removal from turbine driveway
- Land Lease Costs

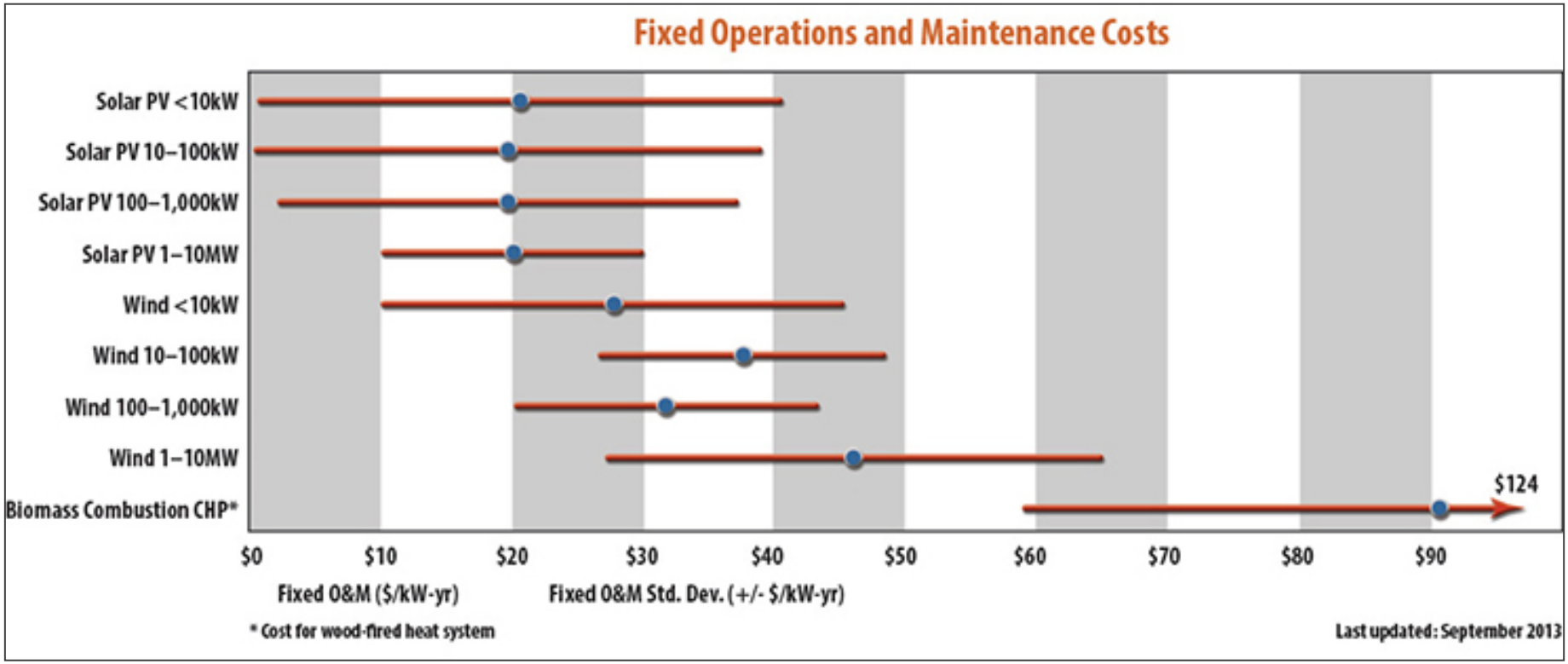
How Wind O&M Costs are Described/Modeled

- O&M costs typically expressed as:
  - $/kW/yr (capacity-based)
  - $/MWh/yr or $/kWh/yr (energy-based)
  - $/yr (simple, fixed)

In reality, O&M costs are generally a mix of fixed, per-kW, & per kWh costs

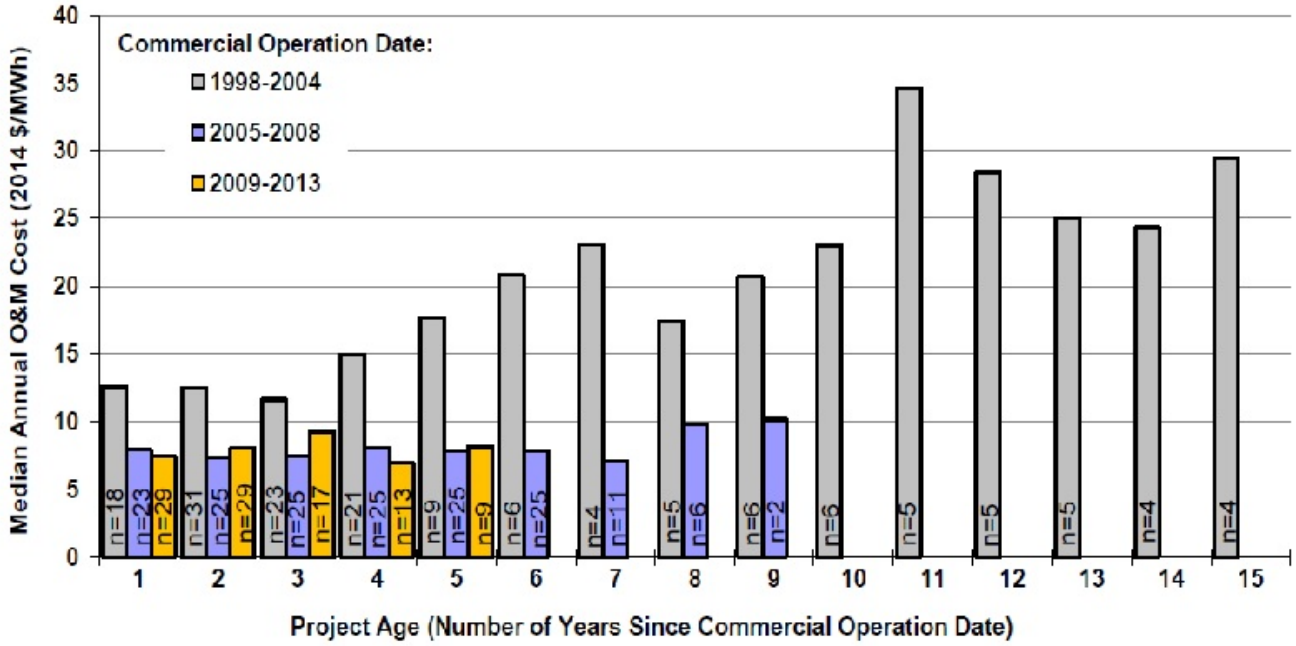
Kumeyaay Wind Power Project on the Campo Reservation. Photo by Robert Gough

O&M Costs for Renewable Energy Technologies



http://www.nrel.gov/analysis/tech_cost_om_dg.html

Operations and Maintenance Costs Varied By Project Age and Commercial Operations Date



Note: Sample size is limited

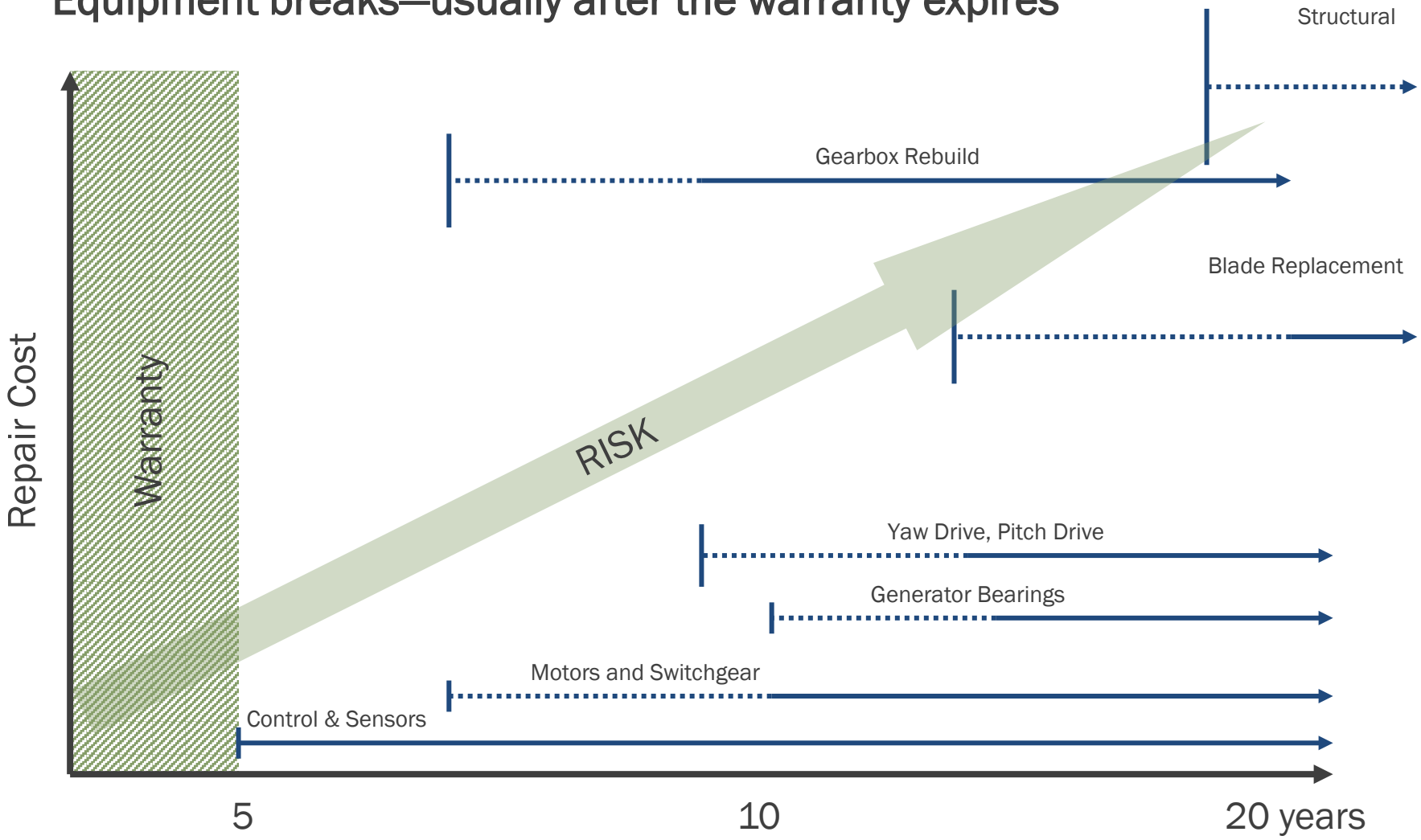
O&M reported in figure does not include all operating costs: Statements from public companies with large U.S. wind asset bases report total operating costs in 2014 for projects built in the 2000s of ~$21-25/MWh

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Source: 2014 Wind Technologies Market Report

Major Components at Risk

Equipment breaks—usually after the warranty expires



Source: Chris Walford: GEC (now DNV GL)

O&M Options & Lifecycle

<table>
<tr><td colspan="3">Timeline (Years)  </td></tr>
<tr><td>0-2</td><td>3-5</td><td>End of warrantee – life of project</td></tr>
<tr><td rowspan="3">Typical Warrantee Period</td><td rowspan="3">Typical Extended Warrantee Period (optional)</td><td>Original Equipment Maker (OEM)</td></tr>
<tr><td>Third Party O&M Vender</td></tr>
<tr><td>In-house</td></tr>
<tr><td colspan="3">Notes
• Warrantee terms alter over time depending upon market conditions
• Recommended practice is to conduct an inspection prior to end of warrantee period to identify any incipient problems that can be fixed under the warrantee.</td></tr>
</table>

Closing Thoughts

- O&M may not be as sexy as project development and construction. However!!!!!, the O&M phase provides many opportunities to earn, save, or lose, a lot of money
- O&M considerations should be an important consideration in turbine selection (turbine quality, cost & availability of maintenance services).
- Ensure funds are available from the project beginning to cover cost of major repairs (R&R fund).
- Develop an O&M plan as part of the overall project plan
- Unit O&M costs likely to be higher for small (< 10 MW) projects
- Industry-recommended best practices exist for all aspects of wind turbine maintenance. Study & understand them.
- Generally, the annual O&M costs increase over the life of the turbine, especially in later years of 20- to 25-year useful life

Questions?