Motivated by rising energy prices, global climate change, escalating demand for electricity and global energy supply uncertainties, the U.S. government has established an ambitious goal of generating 80% of its electricity supply from clean, renewable sources by 2035. Wind energy is poised to play a prominent role in achieving this goal as it is estimated that 20% of the total domestic electricity supply can be reliably generated by land-based and offshore wind turbines by 2030. However, the cost of producing wind energy remains a significant barrier with operating and maintenance costs contributing as much as 20 to 47.5% of the total cost of energy. Given the urgent need for clean, renewable energy sources, and the widespread appeal of wind energy as a viable alternative, it is imperative to develop effective techniques to reduce the total cost of wind energy in general, and the operating and maintenance costs in particular.

In this talk, I will present a framework within which real-time, condition-based data can be exploited to optimally time the replacement of critical wind turbine components. First, we develop hybrid analytical-statistical tools to estimate the current health of the component and approximate the expected time at which it will fail by observing a surrogate signal of degradation. The signal is assumed to evolve as a switching diffusion process, and its parameters are estimated via a novel Markov chain Monte Carlo procedure. Next, I will address the problem of optimally replacing a critical component that resides in a partially-observable environment. Two models are formulated using a partially-observed Markov decision process (POMDP) framework. The first model ignores the cost of turbine downtime, while the second includes this cost explicitly. For both models, it is shown that a threshold replacement policy is optimal with respect to the cumulative level of component degradation. Moreover, these thresholds depend on the decision maker’s assessment of the environmental conditions. Time permitting, I will present a third model that considers cases in which the environment is partially observed and degradation measurements are uncertain. It will be shown that a threshold policy is also optimal for this challenging scenario. Several numerical examples will illustrate the main results and the value of including environmental observations in the wind energy setting.