PHASE 5: OPERATIONS AND MAINTENANCE

Following Phase 3 and 4 project development and construction, the operations phase of energy systems is the time during which the benefits of most energy projects will be realized. Operations and maintenance (O&M) allows full use of the project assets and minimal impact from outages or unavailability. Because the equipment significantly impacts O&M budget requirements, project owners should work closely with vendors and manufacturers to shape O&M budgets, schedules, and employee training.

Phase 5 Describes:

- ☐ 5.1 Energy Efficiency Monitoring and Verification
- ☐ 5.2 End of Warranty Assessment
- ☐ 5.3 Condition Monitoring Equipment and Predictive Maintenance

An O&M strategy must describe in clear terms and metrics how the equipment should normally be used and the expected performance from normal use, both of the equipment and any larger system that directly incorporates that equipment. It should also describe personnel activities, including training, and responsibilities for maintaining and repairing equipment to meet key performance indicators, as well as provide for the exchange of O&M information between operational and managerial staff. The RACI diagrams referenced in Phase 3 can also be useful for O&M strategies.

O&M involves recordkeeping to document state of equipment and any remedial action anticipated/needed/taken. As such, a comprehensive O&M strategy can be an integral part of compliance with any applicable environmental or other regulation relevant to the performance and operation of the equipment, and is sometimes required by law. Beyond regulatory reporting requirements, consistent information collection facilitates component replacement or planned outage requests, warranty claims, and documenting success. It is also critical to energy efficiency projects, such as energy savings performance contracts (ESPCs), to demonstrate energy savings.

5.1 Energy Efficiency Monitoring and Verification

Efficiency monitoring and verification (EM&V) documents the level of energy use reductions from equipment installations and behavior changes. Calculating the energy savings attributable to efficiency programs can be complex, and should be tailored to meet the data requirements in question. At a program level, EM&V provides the experiential data needed to shape future programs and understand the role of energy efficiency in load and revenue forecasting. For utilities including energy efficiency services into their business model, EM&V can provide the data needed for sales and marketing. The needs of the program administrator will shape the EM&V approach needed to gather the appropriate data.

For Energy Savings Performance Contracts (ESPCs), a project structure where an energy services company is paid for service and equipment delivery from savings that would have been spent on EM&V is critical to project success. An ESPC relies on an accurate baseline of energy use before services are provided in order to calculate the money saved. Savings are calculated based on a mix of stipulated savings, for weather or equipment replacements, and post-installation measurements at the component, system, or meter level.

5.2 End of Warranty Assessment

As equipment warranties come to a close, a project owner should conduct an end of warranty assessment to determine whether any corrective action is needed from the equipment supplier. Given the importance of the end of warranty assessment, the owner should ensure that staff and any contractor support are trained and capable of collecting and analyzing the appropriate information.

Typical Components Identified in the End of Warranty Assessment

Foundation	Cables	Blade bearing	Roads
Tower structure	Bedplate	Generator	Substation equipment
Blades	Gearbox	Generator slip ring	Transformers
Converter	Pitch systems	Yaw system	

Source: DOE 2011

5.3 Condition Monitoring Equipment and Predictive Maintenance

For infrastructure and other critical equipment, condition monitoring and predictive maintenance may protect these large investments better than other approaches to O&M. Condition monitoring sensors can collect information on performance indicators and analyze discrepancies from specification in order to facilitate maintenance before service disruptions or other failures occur.

For the wind industry, a major component of post-warranty operations expenditures is unscheduled maintenance, indicating that honoring a maintenance schedule and using condition monitoring can help reduce costs. (Industrial control systems, such as linking to a supervisory control and data acquisition system, may also be appropriate, depending on the equipment and its role in the energy system.)

5.4 Phase 5 Resources

Information Resources

A comprehensive O&M strategy should include plans regarding the monitoring and maintenance of equipment, personnel activities, and compliance and reporting requirements. *Photo by Joe Verrengia, NREL 16996*

Information Resources for Phase 5

These information resources and useful links are illustrative, not comprehensive.

A Retrocommissioning Guide for Building Owners (U.S. Environmental Protection Agency 2009). This guide covers the business case for retrocommissioning and describes the process step-by-step, including key strategies for success.

Building Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency (U.S. Department of Energy [DOE] 2010). This guide provides energy managers with information and actions aimed at achieving these savings and benefits.

Commissioning for Federal Facilities (DOE 2006). This guide describes operations and maintenance (O&M) aspects of building commissioning and quality assurance.

Energy Efficiency Program Impact Evaluation Guide (DOE 2012). This guide describes the common terminology, structures, and approaches used for determining energy and demand savings, avoided emissions, and other non-energy benefits.

ESPC Life of Contract Plan: Documents Management and Checklist for Energy Savings Performance Contracts (State of Hawai'i 2012). This planning aid provides helpful guidance on effective energy efficiency retrofit project management.

Establishing an In-House Wind Maintenance Program (National Renewable Energy Laboratory 2011). This report discusses components of wind O&M plans.

Field Inspection Guidelines for PV Systems (Interstate Renewable Energy Council 2010). This guide provides a basic knowledge of how to inspect a photovoltaic system so that a field inspector can take this framework and develop the experience necessary to perform these inspections quickly and thoroughly.

Hounsfield Wind Farm Operations and Management Plan (Upstate NY Power Corp 2009). This is an example of a real-world O&M plan for a wind farm.

Introduction to Measurement & Verification (DOE 2007). This publication provides an overview of why and how measurement and verification is conducted.

Model Energy Savings Performance Contract Attachment 1 (Energy Services Coalition 2011). This model contract provides insight into the structure and content of an ESPC agreement, including monitoring and verification.

Planning and Reporting for Operations & Maintenance in Federal Energy Saving Performance Contracts (DOE 2007). These guidelines describe the O&M on planning and reporting in energy savings performance contracts.

PV System Operations and Maintenance Fundamentals (SolarABCs 2013). This report includes practical guidelines for PV system maintenance and options for inspection practices for grounded PV systems.

Reviewing Measurement & Verification Plans for Federal ESPC Projects (DOE 2007). These guidelines provide a framework for implementing uniform and consistent reviews of measurement and verification (M&V) plans for Federal ESPC projects

The **Maryland System Development Lifecycle website** (*http://doit.maryland.gov/SDLC/Hardware/Pages/Phase09Single.aspx*) provides a framework on reducing project failure, and provides an example of how to develop an O&M policy for an organization.