



Operate & Maintain

Operate and maintain energy systems, assets, and programs

Phase 5

The operations and maintenance (O&M) phase of an energy transition is when the benefits of most energy projects will be realized.

O&M allows full use of project assets and supports resilience by minimizing impact from disruptions and outages. 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.

An O&M strategy must describe—in clear terms and with metrics—the normal use of equipment and any larger system that incorporates that equipment as well as expected performance from normal use.

The strategy should also describe personnel activities, including training requirements and responsibilities for maintaining and repairing equipment, not only to meet key performance indicators but also to enable the exchange of O&M information between operational and managerial staff. The responsible, accountable, consulted, informed (RACI) diagrams referenced in Phase 3 can also be useful for O&M strategies.

O&M involves record keeping to document equipment conditions and any remedial action anticipated/needed/taken. As such, a comprehensive O&M strategy can be an integral part of compliance with applicable environmental or other regulations 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 documentation of renewable energy project success. It is also critical to energy efficiency projects, such as energy savings performance contracts (ESPCs), to demonstrate energy savings.

Phase 5 describes how to:

- ☐ 5.1 Monitor and verify system and program performance
 - ☐ 5.2 Conduct end-of-warranty assessments
 - ☐ 5.3 Monitor equipment condition and perform predictive maintenance
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5.1 Monitor and Verify System and Program Performance

Monitoring and verification (M&V) documents energy use reductions resulting from technology installations and behavior changes. Calculating the energy savings attributable to energy efficiency programs can be complex and should be tailored to meet data requirements for project monitoring needs.

At a program level, M&V provides the experiential data needed to shape future programs and understand the role of energy efficiency in load and revenue forecasting. For utilities that incorporate energy efficiency services into their business models, efficiency monitoring and verification (EM&V) can provide the data needed for sales and marketing. The needs of the program administrator will shape the approach to gathering the appropriate data.

For ESPCs, structuring the project so the energy services company (ESC) is paid for service and equipment delivery from avoided cost savings resulting from energy efficiency upgrades is critical to project success.

An ESPC relies on establishing an accurate baseline of energy use to calculate the cost savings resulting from the ESC's services. 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 Conduct End-of-Warranty Assessments

As equipment warranties expire, a project owner should conduct an end-of-warranty assessment to determine whether any corrective action is needed from the supplier. Given the importance of the end-of-warranty assessment, the owner should ensure that staff and contractors 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 Monitor Equipment Condition and Perform Predictive Maintenance

For infrastructure and other critical equipment, condition monitoring and predictive maintenance may offer better protection for these large investments than other approaches to O&M. Condition monitoring sensors can collect information on performance indicators and analyze discrepancies from specifications 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 Tools and Resources

Case Study

Monitoring and Evaluation of Bermuda's First Battery Highlights Savings and Informs Next Energy Transition Steps

In 2019, Bermuda's electric utility, BELCO, installed a 10 MW-/5.5-MWh battery energy storage system. The system's main use is providing reserve capacity to the Bermuda electricity grid, resulting in cost savings driven by direct fuel savings as well as maintenance cost savings. BELCO now maintains the battery while gathering data about its performance and monitoring its operation.

What common challenge or need did the project address?

Bermuda's utility, BELCO, needed to both ensure its first battery energy storage system (BESS) performed optimally and demonstrate the value of the project by monitoring and verifying cost savings and emissions reductions.

Why is this a common challenge for communities pursuing energy transitions?

When communities implement energy projects and leave them to operate without monitoring and verification while focusing resources elsewhere, they risk leaving potential savings unrealized and missing insights that could inform future projects.

How did the community address this challenge or need?

BELCO dedicated resources to monitoring the performance of its battery system, not only to ensure it was operating as expected but also to document its impacts on the electricity system and inform future projects and steps in Bermuda's energy transition.

What key decisions were integral to this project?

Key steps and decisions in the process included:

- Determining what metrics and information to collect on the ongoing performance of the battery
- Ensuring resources are dedicated to continually monitoring the battery's performance and documenting its impact on the utility's technical and financial operation.



Ongoing monitoring of battery energy storage system performance helps Bermuda chart its course to a clean, resilient energy future. *Photo from BELCO*

"The BESS continues to be a success story for BELCO. The simple use-case of offsetting mechanical spinning reserve has allowed the operational staff to become familiar with the opportunities energy storage technology can offer as well as allowing internal maintenance staff to gain experience in maintaining these systems. We are looking forward to developing use-cases for future energy storage projects."

—Stephanie Simons, Senior Engineer, Bermuda Electric Light Company

Who decided on this course of action and why?

The leadership team at BELCO decided to continually monitor system performance to collect metrics that demonstrate system value, gather data to inform future projects in Bermuda, and share information that can benefit other communities considering battery energy storage projects.

What key takeaways or lessons learned might benefit other communities?

Operating the BESS as a spinning reserve asset enables BELCO to avoid turning on additional diesel generators to provide system reserves while keeping the units that are running near their optimal performance settings.

Documenting the system's operation has highlighted significant benefits for BELCO and Bermuda, including:

- Realizing approximately \$2.7 million in energy cost savings
- Offsetting 15,000 barrels of fossil fuel use
- Avoiding more than 5,500 tonnes of CO₂e emissions.

Dedicating resources to monitor and evaluate system performance enabled BELCO to quantify the value of its first battery storage project while collecting insights to inform future projects. As Bermuda continues its clean energy transition, future battery projects may provide different values or meet different needs.

By completing this first battery project and carefully monitoring its performance, BELCO is gaining key experience with energy storage that helps pave the way for future projects in Bermuda. Bermuda's experience may prove useful to other communities as they implement Phase 5.

Resources

Monitor and Verify System and Program Performance

Energy Efficiency Program Impact Evaluation Guide—DOE guide to common terminology, structures, and approaches used for determining energy and demand savings, avoided emissions, and other nonenergy benefits of energy efficiency programs.

Reviewing Measurement & Verification Plans for Federal ESPC Projects—A DOE framework for implementing uniform and consistent reviews of M&V plans for federal ESPC projects.

Monitor Equipment Condition and Perform Predictive Maintenance

Building Operations & Maintenance Best Practices: A Guide to Achieving Operational Efficiency—DOE O&M guidance for energy managers, including information and suggested actions for achieving savings and benefits from building energy system upgrades.

Installation, Operation, and Maintenance Strategies to Reduce the Cost of Offshore Wind Energy—A National Renewable Energy Laboratory (NREL) technical report that provides a basis for evaluating cost-saving installation, operation, and maintenance strategies and technologies.

The Maryland System Development Life Cycle—Maryland Department of Information Technology framework for reducing project failure, including an example of how to develop an O&M policy for an organization.

Planning and Reporting for Operations & Maintenance in Federal Energy Saving Performance Contracts—ESPC project development guidelines for allocating O&M and repair and replacement (R&R) responsibilities and establishing O&M reporting requirements. The goal is to minimize disagreements over O&M and R&R, and to help ensure savings persist during performance period.

PV System Operations and Maintenance Fundamentals—Practical guidelines for solar photovoltaic (PV) system maintenance and options for inspection practices for grounded PV systems.



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*