Overview

Facility managers and building owners can quantify the variety of benefits from rooftop unit (RTU) replacements by validating energy and cost savings and other improvements through measurement and verification (M&V) methods. Various M&V methods are helpful in estimating the payback and justifying future projects and understanding water efficiencies, emissions reductions, maintenance costs and savings, indoor environmental quality (IEQ) improvements, and occupant satisfaction.

M&V is instrumental in justifying investment in and verifying the performance of RTU replacement and retrofit projects. Image from iStock 39026772

Measuring and Verifying RTU Energy Performance

M&V for RTUs (and space conditioning systems in general) requires more effort and care than other energy systems because RTU operation and energy consumption are highly variable. Energy savings are easier to verify for systems that are relatively constant or controlled by a schedule (for example, lighting or plug and process loads) where energy consumption can be accurately estimated based on power levels and hours of operation. However, the energy performance of RTUs varies continuously based on component efficiency, space conditions, occupancy, weather, building envelope, and interactions with other loads in the space.

Facility managers can verify energy savings based on simple observations of performance or based on the results of detailed and controlled measurements. Table 1 describes four levels of M&V appropriate for heating, ventilating, and air conditioning (HVAC) projects; provides insight into when they should be applied; and lists resources relevant to application.

Regardless of the approach or level of effort, M&V requires some basic steps, which are defined in Table 2 along with comments on how to apply them. These are suggested approaches, and will likely require some modifications and iterations between steps depending on the scope of the project.

Table 1. Levels of M&V for HVAC Projects

Level	Methodology	Comments	Examples
Simple (Facility Manager)	Savings based on proxies of energy consumption such as EER/SEER/IEER or savings from comparable projects	Predictive approach, not based on measurements; least effort but greatest uncertainty	Uniform Methods Project (NREL 2013)
Mid-level (Facility Manager and Engineering Consultant)	Savings estimated from regression equations based on short-term measurements	Most common approach; difficult to establish a baseline	NBI 2012, IPMVP Options A&B (EVO 2012), FEMP M&V Guidelines, Options A&B (DOE 2008), Performance Measurement Protocols (ASHRAE 2012)
Detailed (Engineering Consultant)	Continuous monitoring of performance (before and after, side-by-side, or alternating operation)	Accurate, long term, and resource intensive	IPMVP Option C (EVO 2012), FEMP M&V Guidelines, Option C (DOE 2008), Performance Measurement Protocols (ASHRAE 2012)
Detailed with Simulations (Engineering Consultant)	Similar to the Detailed approach but includes calibrated whole-building energy simulations	More accurate and resource intensive than the detailed approach; simulations are used to extrapolate results to an entire year or to other buildings and locations	IPMVP Option D (EVO 2012), FEMP M&V Guidelines, Option D (DOE 2008), Performance Measurement Protocols (ASHRAE 2012)

Example: Mid-level M&V for RTU Replacement

Objectives:

- Estimate the annual cooling energy and cost savings for an RTU replacement
- Observe the impact on IEQ

Performance Metrics:

- Annual RTU cooling and ventilation energy savings
- Annual RTU cooling and ventilation energy cost savings
- Observed IEQ including temperature, relative humidity, carbon dioxide level, and noise

Data Requirements:

- At least two weeks of before and after data:
  - Hourly RTU energy use and outdoor air temperature
  - Hours of operation
  - Indoor air temperature and relative humidity
  - IEQ
- Observed and/or verified information:
  - Same thermostat control and set points for before and after operation
  - Same ventilation strategy unless RTU replacement provides additional recognized ventilation efficiency strategies, such as demand controlled ventilation
  - IEQ

Analysis Methods:

- Develop regression models to estimate RTU energy consumption for cooling and ventilation as a function of outdoor air temperature for the baseline and replacement cases.

Table 2. Steps to Measurement and Verification

No.	Step	Description	Comments
1	Define the objectives	Define the questions that need to be answered with M&V	Very important step because it defines the purpose and extent of the project.
2	Assemble a team and define roles and responsibilities	The team size and technical expertise needed will depend on the project objectives	May be one person, an internal team, or include an outside contractor.
3	Define the M&V plan –scope, metrics, data, baseline, analysis methods	Starting with the objectives, define the scope and boundaries, metrics used to determine performance, data requirements, baseline definition, how the data will be acquired, analysis methods, and preliminary approach to uncertainty	This is the hardest and most important step. A well-defined plan will save time and effort later and will lead to a successful project.
4	Take measurements	Install monitoring equipment if necessary and collect data	Data are likely acquired from many sources and care should to be taken to ensure compatibility. Data should be continuously checked for gaps and errors.
5	Evaluate performance	Continuous review and analysis of performance data. Final analysis, adjustments, comparison, and uncertainty analysis	Continuous or periodic data analysis will help identify problems early and provide input to optimize performance
6	Draw conclusions and report results	Develop conclusions about performance, state uncertainty, and report results with recommendations	Communicating the results and the recommendations of project performance and the M&V process should guide future projects

References

ASHRAE (2012). *Performance Measurement Protocols for Commercial Buildings: Best Practices Guide*. Atlanta, GA: ASHRAE.

DOE (2008). *M&V Guidelines: Measurement and Verification for Federal Energy Projects Version 3.0*. Washington, DC: U.S. Department of Energy. eere.energy.gov/femp/pdfs/mv_guidelines.pdf.

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NBI (2012). *Standard Protocol for Measurement of Fan and Cooling Savings from Commercial Sector Packaged Rooftop and Split System HVAC Units*, Draft, Vancouver, WA: New Buildings Institute.

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