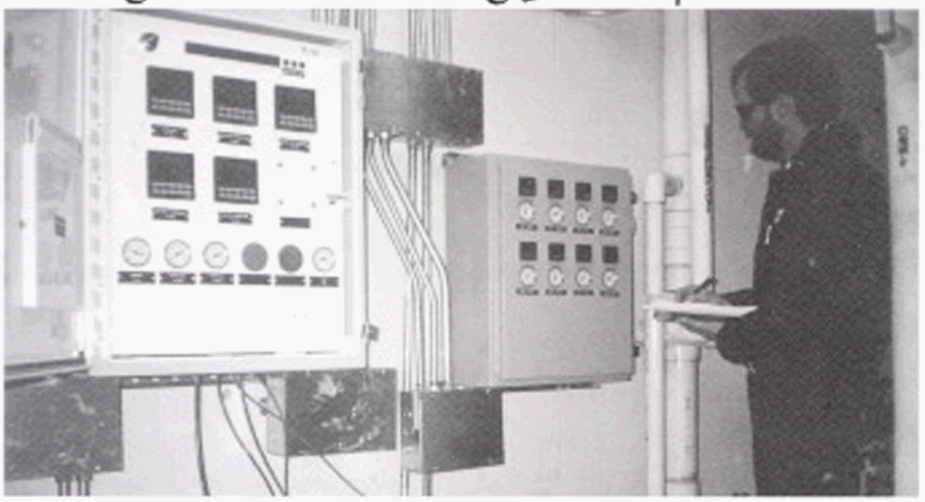
Energized
National Renewable Energy Laboratory
Buildings and Energy Systems Division

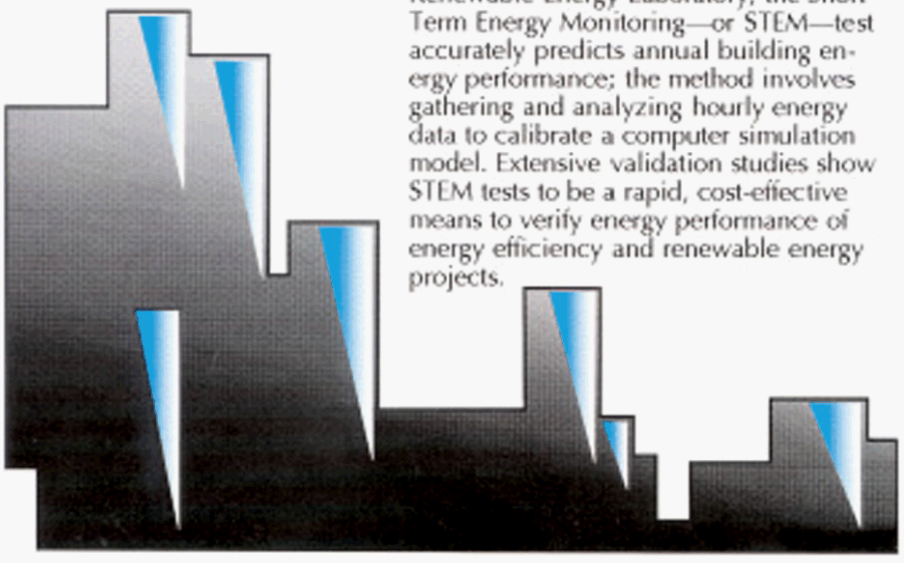
Short-Term Energy Monitoring: A Quick Way to Predict Long-Term Energy Performance



Researchers compare STEM data to data from a building's existing energy-monitoring system to validate test results.

A Proven Technique

Long-term building energy efficiency can now be determined from building data collected over a short period. Developed by the National Renewable Energy Laboratory, the Short-Term Energy Monitoring—or STEM—test accurately predicts annual building energy performance; the method involves gathering and analyzing hourly energy data to calibrate a computer simulation model. Extensive validation studies show STEM tests to be a rapid, cost-effective means to verify energy performance of energy efficiency and renewable energy projects.



Quick, Accurate, and Versatile

STEM testing is a quick and very accurate way to predict long-term energy performance such as annual heating requirements. Monitoring programs in residential and small commercial buildings have shown that STEM-predicted energy use differed from actual measured use by less than 5%. This method is thus a valid way to verify energy performance for third-party financing and utility rebate programs.

Coupled with this accuracy is the power and versatility of STEM to isolate the effects of individual components that influence energy use. STEM tests conducted before and after adding insulation, window shading, or performing a furnace tune-up give precise information on how the changes affect a building's thermal and energy-consumption characteristics. Unlike traditional methods, which require constant conditions throughout the testing period, STEM is run during realistic conditions when all inputs are changing naturally.

Nuts and Bolts of STEM

A STEM test is a 3-day sequence where researchers record various heat-flow-related data in a building. By analyzing the recorded data with a special mathematical technique that calculates building-specific adjustment factors, STEM identifies four key building characteristics: building-load coefficient, effective building thermal mass, effective solar gain, and heating efficiency. The method relies on a data-acquisition system—a portable computer programmed to turn test equipment on and off, scan data channels, and compute hourly averages from recorded data.

First, anomalous air leakage is identified by pressurizing the building or by using tracer gas, and the effect of air flow on energy use is estimated. Next, inside temperatures are held constant by several portable electric heaters individually

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Side by Side and Inside Out

NREL and All American Modular (Arlington, Texas) have used STEM testing to study structural differences of two 12-ft by 44-ft modular office buildings. One unit used conventional wood-frame construction with insulation batts; the other used a newer foam-core construction technique involving structural insulated panels (SIPs).

NREL ran STEM tests on each building to see if the structural differences affected energy use. Energy performance results from testing under constantly changing outdoor conditions were compared to results from indoor testing when the modular buildings were moved into a controlled-environment warehouse.

An important measure of energy efficiency is the *building-load coefficient*—the heat required to maintain a one-degree temperature difference between the inside and outside of a building. Tests indicated a load coefficient for the SIP unit of 150 Btu per hour, compared to 240 Btu per hour for the conventional wood unit. These values mean that the SIP unit is more energy efficient than the conventional unit, requiring 40% less heating to keep the same inside temperature.

The two modular units being STEM-tested under actual outdoor conditions. Inset shows a unit being moved into warehouse for indoor testing under controlled conditions.

switched on and off by the data-acquisition computer from sundown on the first day through midnight on the second night, when all heating is cut off for the cool-down test. Temperatures are again held steady by the electric heaters through the third day until midnight. Then, to determine heating-system efficiency, operation is transferred to the regular heating system controlled by the building's thermostat.

A Solid Track Record

NREL has established the practicality of the STEM technique in short-term tests on 40 houses from California to Colorado to Virginia. NREL also did an extended series of short-term tests in one house—with one STEM test every 10 days for a 5-month period. Each test supplied an independent measure of adjustment factors and estimated performance during the period. The variation in calculated adjustment factors led to an expected accuracy exceeding 95% in predicting long-term energy performance. And model-related error based on actual long-term performance was less than 1%.

Other validation tests of STEM have involved checking energy-use differences in side-by-side houses with identical designs but slightly different construction, measuring the efficiency of retrofit furnaces in place, evaluating the effectiveness of various ventilation and shading cooling strategies, and determining savings from window retrofits (see box above).

Expanding STEM's Uses

STEM testing works well with residential and smaller commercial buildings. But the technique is being expanded to larger commercial buildings such as offices with complex heating, ventilating, and air-conditioning (HVAC) systems.

Furthermore, a STEM-calibrated house can be used to test energy products and construction designs. STEM can give building designers and energy auditors valuable data on the efficiency and effectiveness of furnaces, cooling systems, ventilation and shading strategies, occupant characteristics, fireplaces, and thermal storage strategies. NREL hopes to extend the STEM method's success to include issues of multizone behavior, complex infiltration and airflow patterns, and more complex HVAC systems.

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The National Renewable Energy Laboratory (NREL)

NREL is the nation's premier renewable energy and energy efficiency laboratory. Located in Golden, Colorado, NREL is part of the U.S. Department of Energy's family of national laboratories. More than 735 staff members conduct or support research at NREL; this staff is augmented by 150 visiting scientists from industry and academia. Founded in 1977 as the Solar Energy Research Institute, NREL develops renewable energy technologies to heat and cool buildings; increase efficiency in industry; light homes and offices; power cars and trucks; produce plastics, clothing, and chemicals; clean our water; and destroy toxic wastes.

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