How Reliable are Energy Audits? —Setting a Benchmark

by Karen Butterfield

It is common practice to obtain a second medical opinion before electing for major surgery. Should one obtain a second opinion before operating on a poorly weatherized house?

Although millions of dollars are spent each year retrofitting houses to save energy, no one in the U.S. has taken the time to analyze the recommendations of different auditors. Recently, however, a group of European researchers completed such a comparison, and the results are startling. Different auditors are likely to provide significantly different recommendations on the same house, as well as savings estimates that vary by fifty percent or more.[1]

The group's members work at the largest of the Joint Research Centers (JRCs) operated by the European Community. This center has an international staff and is situated at Ispra in Northern Italy.

The JRC team set out to discover whether expensive audits justify their extra cost by providing better accuracy and better advice (see box on error). To do this they invited four audit firms (from three different countries) to conduct audits on the same set of buildings. The firms were all experienced in auditing the types of buildings chosen and knew that they were taking part in a comparison of audit techniques.

The four firms supplied the JRC team with their working data at each stage of the audits. The JRC group then compared the audits produced by the four firms with each other, as well as with a much more detailed "benchmark" audit conducted by the JRC researchers.

The Audits

The JRC team chose three different types of buildings for the benchmark study. These buildings—a single-family, two-level row house, a primary school, and a six-apartment complex—represent the range of complexity likely to be encountered by auditors.

The companies performing the audits used the following methods:

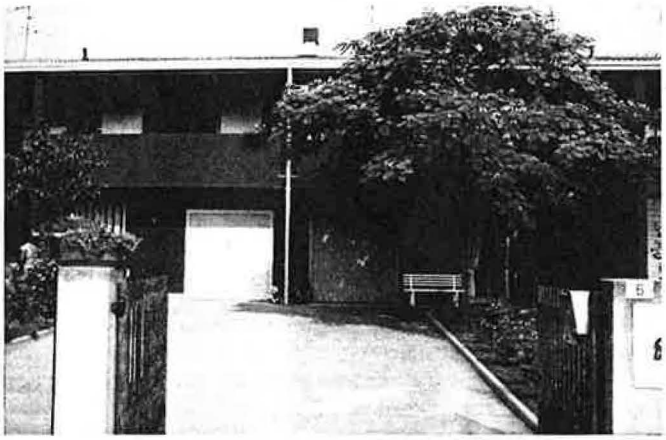
- **Company #1** relied on a walk-through audit. They did not use any instruments. They collected data only during the site visit and from building plans. They used a static simulation model. These methods produced recommendations with the fewest working hours and lowest cost.
- **Company #2** carefully evaluated heating system performance. They used a small data logger to obtain the "building energy signature."[2] They used the logger and reference values plus building plan data to compute energy consumption. Also, the energy signature information was used to determine whether the heating plant was oversized and to pinpoint incorrect control settings.

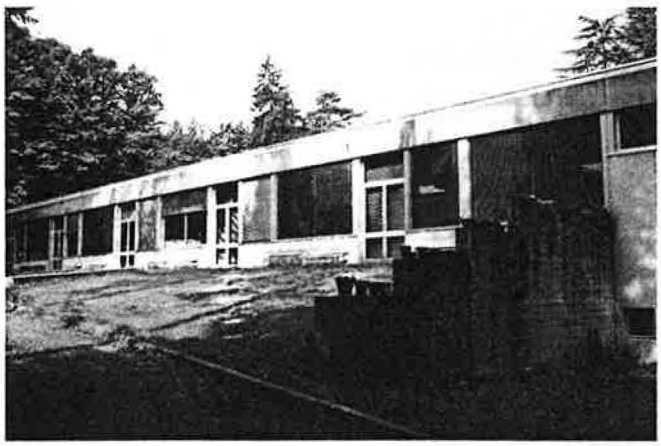
Sources of Error

Errors can occur in any of three stages of the audit: collecting data, using a thermal simulation model, and setting forth recommendations for the homeowner. The most serious disagreement in this benchmark experiment occurred during the first and final stages of the audits. Since the firms all used different simulation models, it did not surprise the scientists that the results varied so widely. In fact, when the various sets of data were run on the one single model, the results were much closer.

The biggest shortcoming of the average audit may occur when an auditor fails to consider measures that are not standard for the area or that are less popular with the auditor. For example, window shading may be cost-effective for a particular house, but the auditor may not be familiar with available window products or may not know how to calculate the savings for this type of product. This is a particularly common problem with the computer audits performed in most residential programs in the U.S. The computer misses many potentially cost-effective measures because it is programmed with the fifteen or twenty most common items for that area. If the program is not capable of evaluating a wind break, then the auditor cannot even recommend one, even if it would be cost effective!

Karen Butterfield is a contributing editor to ***Home Energy.***





The buildings audited in the benchmark experiment (from upper left): a single-family two-story row house, a complex of apartment buildings connected to the same heating plant, and a primary school. Note the built-in window shades that reduce night-time heat loss in both the single- and multi-family buildings.

- **Company #3** sent a single expert who carried out a detailed audit in just under two days. The auditor inspected the inside and outside of the building envelope using an infrared camera with a hand-held viewer. The auditor also measured instantaneous burner efficiencies and used a static thermal simulation model.
- **Company #4** performed the most detailed audit, spending almost three days on site. A small team of professionals used an infra-red camera (Thermovision) to study the envelope. They also measured the instantaneous burner efficiencies. They used a dynamic thermal simulation model for the larger buildings and a static simulation for the house.

Starting on Common Ground

To ensure a common starting point for the evaluations, the JRC researchers gave each company the following information to use during the first step of the audit:

- climate data for the building's location;
- gas and electricity bills for the previous three years;
- building plans; and
- a list of materials and labor costs for various measures.

Despite the common starting point, the auditors estimates of building volume, envelope surface, and even degree-days quickly diverged. Part of the discrepancy may be attributed to conventions used in the different countries from which the firms came. Even larger variations appeared when ventilation rates and heat transmittances were taken into account (see figure 1).

During the second stage of the audits, the auditors calculated the heating loads using both dynamic and static thermal simulation models, as mentioned earlier. These models estimate seasonal heat losses and gains. Large variations were found in the data generated by the models, but even larger variations were found in quantities that had to be estimated by other means. The most important of these were solar gains and ventilation losses. Surprisingly, estimates of the overall heating system efficiencies were in relatively close agreement.

Finally, the JRC team compared the auditors' recommendations. Since the JRC team had determined the retrofit costs at the outset, differences in the cost-effectiveness of any single measure should have depended solely on differences in estimated energy savings. It turned out that the auditors agreed on only a few of the most common measures such as attic insulation, double-glazing, and improved heating system controls.

A number of potentially worthwhile measures were completely ignored in the final recommendations–even some that had been suggested by the auditors during their site visit. Table 1 lists the measures that the JRC team addressed in its control audit but that were neglected by the audit firms. The JRC team estimated that the forgotten items would generate additional savings of more than 50% for the school, 42% for the house, and 22% for the apartment complex.

Will the Real U-Value Please Step Forward?

The JRC researchers went to great pains to set up an accurate benchmark for comparing the measurements and calculations of the four companies. They ran

Measure	Building
Repair/install window- and door-closing devices	
Repair/install weatherstripping	
Close convective paths to and from stairs	apartment
Add reflective, insulating layer behind radiators	apartment
Insulate and seal roller blind cases	apartment
Close air gaps in the false ceiling	school
Replace broken glazing	school
Displace entrance doors to line of building	school
Rebalance heating distribution to building zones	
Break up air stratification with large roof fans	school
Install damper to close kitchen fan when off	school
Insulate garage doors	house
Close passageway at both ends	house
Close off balconies to improve insulation and create sun spaces	
Upgrade boiler and piping insulation	
Install thermostatic radiator valves in rooms exposed to sun	

Table 1. List of some energy conservation measures neglected by the audit companies.

each auditor's data on their own dynamic simulation model known as SPIEL.[3]

They found a 28-percent variation among the companies for all buildings. The JRC team then measured and calculated their own U-values and ventilation rates, and carefully estimated internal and solar gains. They used three methods to try to obtain reliable values for thermal transmittances (U-values). First, a heat flux meter was used to obtain U-values from measurements averaged over several days. U-values were also obtained from surface and air temperatures. Finally, they were calculated using book values for the U-value of each building component.

Although the JRC team used the three methods, they believe that none of them is entirely satisfactory for commercial audits. For example, the heat flux meter is dependent on weather conditions, a fact that limits its applicability. Performing the measurements was time consuming and would be prohibitively expensive for a private company.

Measurements of surface and air temperatures are subject to the errors inherent in measuring small temperature differences. Calculating U-values from these temperature differences requires the use of standard values for the surface resistances which may not be appropriate for the particular conditions. However, this method appeared to be able to distinguish insulated from uninsulated elements. It was also quick and cheap and may be improved with better values for the surface resistances.

Calculating U-values from the composition of the elements is fine in theory. The problem is determining the composition. The typical house may be constructed with a wide range of materials having different resistances. There may or may not be a cavity, and if there is one, it may or may not contain insulation. In cases where a brick wall is involved, customers tend to be opposed to drilling a hole to find out whether the wall is insulated.

The JRC recommends further research on measurement techniques as well as the development of international standards for thermal transmittance values of materials.

The wide variation in ventilation rates was probably due to the fact that one company derived the rate from their dynamic simulation model. The other three companies estimated ventilation rates in a range of 0.5 to 0.8 air changes per hour (ACH), based on the standard value for the types of buildings. The JRC tracer-gas measurements

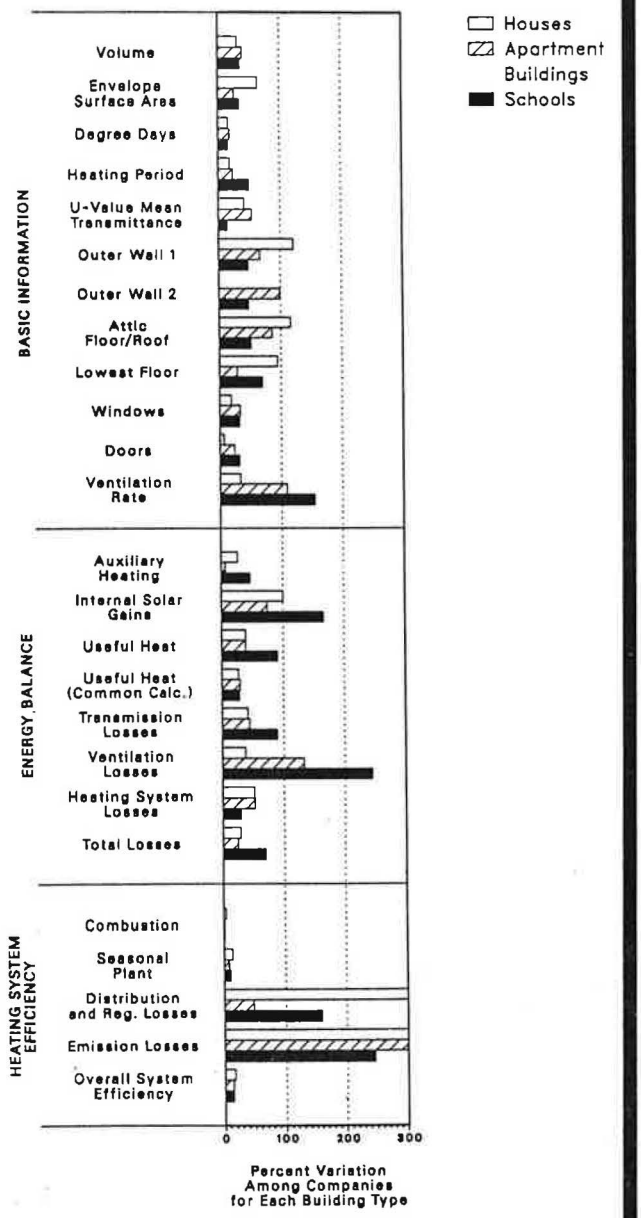


Figure 1. Comparing audit measurements and results. The horizontal bars show the variation among the four audit companies for three sets of audit results: the basic data and measurements collected during the audit, the companies' calculations of energy balance, and the companies' esimates of heating system efficiency. In general, the variation is greatest for audit results of the school building.

were 1.0 ACH for the stairwells in the apartments and between 0.4 and 0.5 ACH for heated spaces.

A High-Tech or Low-Cost Solution?

What does the JRC study say about the business of energy auditing? The JRC researchers found that there is little correlation between cost and quality. Even the use of high-tech equipment such as the infra-red viewer did not produce significantly better recommendations, despite the advantage such a device has for detecting the presence of defects such as thermal bridges. The infra-red study seems to have been ignored by the operator running the simulation model that produced the final recommendation. Clearly, audits should be optimized for the particular building type, and expensive, high-tech equipment should be used only when the extra cost and time can

If the only tool you have is a hammer, every problem looks like a nail.

be justified by the savings. The results from such equipment must then be integrated into the final analysis.

Two conclusions are apparent from the JRC study. First, there should be more collective study to improve and standardize measurement techniques. Second, auditing schemes should be expanded to include a wider variety of cost-effective measures. This variety will encourage a more detailed audit that can be tailored to the peculiarities of each building.

The JRC research has direct implications for those of us in the energy auditing and research business in the U.S. One course of action would include periodically calibrating auditors on "standard" houses to compare recommendations and projected savings. Managers could then assess the variation and identify problem areas. To our knowledge, this sort of auditor calibration has never been attempted in the U.S.

Epilogue

The doctor who recommends and performs treatment on a patient schedules a follow-up visit to make sure things are going as planned and to make further recommendations if necessary. How often does the auditor go back to the site of the audit to find out how her recommendations are working?

The JRC team did go back. They had suggested that the director of the school install time switches and thermostats to control the heating plant (it often ran 24 hours a day because its controls were inoperative). Initially the recommendation was heeded; however, when the JRC team returned, they found that the janitor had removed all the little red pegs from the clocks because they kept turning the heating plant off! It turned out that the janitor's own flat (he lived in the building) had a separate heating system that he had to pay for. He found that he could save his own money by keeping the school warm and letting the extra heat warm his apartment. He also used the school's cafeteria for a laundry drying area on rainy days! Thus, he had good reasons for keeping the school's heating system on when it was not needed by the school.

The janitor explained the deactivation of the time switches by saying that they did not allow the building enough time for the building to warm up before the start of school. This may have been true, since the start-up time is hard to estimate. However, no one had told him how to reset the clock according to the outside temperature.

There are two morals to the story. Return to the scene of the audit to see how the recommendations are faring. Make sure, also, that the operators of the new system know to use it properly. ■

Endnotes

1. Helcke, G.A., F. Conti, B. Daniotti, and R. Peckham. "The Ispra Benchmark Experiment to Compare Existing Building Energy Auditing Schemes." Commission of the European Communities, Joint Research Center, Ispra Establishment, 21020 Ispra, (Varese), Italy. Paper presented at the Third International Congress on Building Energy Management, Lausanne, Switzerland, 1987. *Home Energy* thanks the authors and JRC for their assistance in preparing this article.
2. The energy signature of a house is made up of three unique variables, alpha, beta and tau, that characterize the energy use of that house. See "Prism: a Tool for Tracking Retrofit Savings," *EA&R*, Nov/Dec '87.
3. SPIEL is part of a building design package called SCRIBE, which is available from ECOTECH, 45 Harefield Rd., Sheffield S11 8NU, England. Tel: 742/680982.