PAPER 7

HOUSE DOCTORS PROGRAM – RETROFITS ON EXISTING BUILDINGS

D.T. HARRJE, G.S. DUTT
Princeton University
USA

HOUSE DOCTORS PROGRAM - RETROFITS ON EXISTING BUILDINGS

David T. Harrje
Gautam S. Dutt
Princeton University, Princeton, N.J., USA

ABSTRACT

The needs, history, procedures, and past case studies for the house doctor approach are outlined. This program of individualized instrumented energy audits and retrofits has reached a stage in development where steadily increasing numbers of house doctors are envisioned for the years immediately ahead.

INTRODUCTION - THE NEED FOR DOCTORING HOUSES

In countries around the world, one question that is being asked more and more often is: What changes can I make in my home so that energy consumption will be reduced? The answer is often given in the form of lists of energy saving measures, but how many "solutions" apply to the home in question? We believe the question demands a customized solution -- one tailored for the particular house. The most common response to this question is a paper and pencil energy audit of the house. Such audits do not rely on any measurements of key variables that influence energy use. Our experiments have shown that an energy audit based on computation alone would miss some of the most effective energy conserving measures. Princeton University's House Doctor approach is based on an instrumented energy audit and leads to the identification of all the major energy defects in the house. The procedure generally includes a partial retrofit along with the instrumented audit.

The energy savings program is conducted by a house doctor team, which in our definition, is a well-trained two or three person crew to handle energy analysis and retrofitting. The house doctors use a carefully selected kit of instruments to speed their house diagnoses of energy loss. The end result is a prescription for appropriate retrofit measures that partly takes place during the visit of the team. Although a given house may call for a change in procedures to meet certain particular needs, there is a recommended approach that will be described.

HISTORY OF THE APPROACH

The beginnings of the house doctor approach may be traced to the Twin Rivers Project.[1] In a series of residential energy studies that extended over a period of more than six years, a number of experiments were conducted. The first experiment concentrated on three side-by-side townhouses instrumented to provide almost 200 channels of energy data. The object was to understand, in great detail, the way in which the occupants in these townhouses used energy. A complete weather history from a dedicated weather station nearby was a critical aspect of the study. The instrumentation continuously located in the house was supplemented by other portable measuring devices. Infrared scanning equipment was a principal tool. Other portable instrumentation included hand-held temperature probes to measure a variety of air, water and surface temperatures, and hot wire anemometers to measure air flow in the warm air heat distribution system. An automatic air infiltration measurement device developed during this period was used extensively. The benefits derived from the detailed energy data were numerous, but the added information obtained from the portable instruments also proved to be significant.[2]

As the second series of experiments began, data logging was reduced to 12-channel tape recorders in more than 30 townhouses earmarked for retrofitting. Similar recorders were placed in ten homes heated and cooled with heat pumps. The use of auxiliary measurement techniques steadily increased during this experiment. The addition of the "Blower Door" pressurization device allowed the tightness of several Twin Rivers townhouses to be compared, and greatly expanded the versatility of infrared scanning.[3,4]

The realization at that point in the research was that if larger numbers of houses were to be analyzed, emphasis on inexpensive portable instrumentation and streamlined analysis procedures were absolutely necessary.

THE PROCEDURE

The procedure that has been used in the house doctor approach begins with an external examination of the structure, sizing the house, and cataloguing its important features.[5,6] The team makes use of simple measurement techniques and photography. The objective is to measure the size of dwelling and to photographically record the exterior details of the structure. These photographs include a clearly marked measuring stick so that measurements of windows and other features from the photographs are possible. The outside measurements allow a plan to be sketched accurately at the site. Using carbon sheets, multiple copies are produced so that a separate copy can be dedicated to the problems found on each floor of the house.

During the preliminary portion of the visit any energy problems encountered by the homeowners are also noted; cold rooms, localized draftiness, inadequate insulation, poor windows, etc. The final item is a room-by-room survey to determine how well the temperature is balanced and whether the thermostat(s) is functioning properly. A multiple setback clock thermostat may be installed by the house doctor so that temperatures can be programmed over the full 24-hour day (this includes daytime setback when appropriate). Setting the temperature back 1 degree C reduces space heating consumption by 7% in the average U.S. climate. Somewhat less than a third of this would be saved by an 8 hour night-time only setback. For residents not currently setting their temperature back at night (but would do so if a clock thermostat were available) these thermostats would be very cost effective.

The next priority is to determine the leakiness of the building envelope. A Blower Door, a large calibrated multispeed fan system, is installed in an exterior doorway and the house is pressurized.[2-7] The amount of flow required to pressurize (or depressurize) the house over a range of pressure levels is recorded. This test not only indicates the amount of leakage, but rates the house with others as to tightness. Should the house be sufficiently tight (at Princeton we have set six air changes per hour at 50 Pascal as the temporary criterion) further leak sealing is not necessary. However, this degree of tightness is rarely found.

Leak site detection begins with the attic. A slightly pressurized house means that a greater than normal amount of air is forced through a variety of attic floor leakage sites. These leaks are detected by scanning the attic floor with portable infrared equipment. Even with insulation in place, the leaks are readily visible using the infrared technique. "Bypasses" from interior walls, plumbing stacks, electrical fixtures and wiring holes are just a few of the leaks that are detected.[7,8] Often there are large energy loss sites due to lowered (soffit) ceilings, whole house fan openings, special piping or ducting chases, etc. These sites present leakage levels that demand immediate attention. Large openings are sealed with a plastic sheet placed over the leak and under the insulation. Smaller openings are sealed with foam, compressed fiberglass, caulking or tape. The access to the attic is often a major leak site and requires weatherstripping or perhaps an insulated sealing cover to cure the problem. Any sealing improvements can be measured while the Blower Door instrumentation is in place. In this way the house doctor knows that progress is being made - the patient is improving.

Next the house is depressurized by reversing the Blower Door fan. Under these conditions ceiling leakage can be double checked from the inside. Now we are dealing with cooler surface areas (under heating season conditions) inadequate insulation and the presence of leaks are identified by cool patterns across the interior surfaces. The infrared viewer is used to survey all the interior surfaces of the house. Interior walls receive equal attention in this survey. Piping and wiring through the internal walls often are the cause of major leakage paths from the living space or basement to the attic. This condition results in characteristic cool stripes extending from floor-to-ceiling and indicate high priority sites for retrofitting. Soffit ceilings appear as cool areas in need of an attic seal. The floor is also scanned in the internal surface check. Often leakage along the floor-wall joint is a major source of air infiltration together with the electrical outlets. The latter leaks may be cured using closed-cell plastic gaskets as a retrofit measure. Transparent caulking on the joints along floor edges and around windows can prove to be very worthwhile. This tightening process typically yields 10-35% improvement in reduced air infiltration.

Having catalogued problems in the building envelope due to air leakage and insulation shortcomings, attention is next turned to the heating system. Both oil and gas fired systems have shown marked improvements through tune-up. Remember a 5% improvement on a heating system with a 70% seasonal performance translates into a more than 7% overall gain. The house doctor should use the best measuring equipment available for these tests. Direct readout of performance is helpful so that the tests, and adjustment if necessary, may be done in approximately 15 minutes. This can prove to be the conservation measure with the fastest payback. Since this check takes place after the Blower Door testing, the house has cooled down insuring reasonably long burner operation times.

Last, but not least, in the checklist for the house doctor is the inspection of major appliances. Generally additional insulation on the outside of gas and electric water heaters have a relatively short payback period. The hot water temperature should be set as low as possible to meet household needs. This setback can save as much as upgrading the insulation. Where needed, flow limiting devices should be employed in showers and sinks. The refrigerator may require some additional monitoring if questions arise as to its performance. We have developed a simple meter that provides such data by monitoring over a 24 hour period.[6] This meter measures the cumulative energy consumption and avoids the problem created by on and off cycles of the compressor, fans and other components.

FOUR HOUSES UNDER STUDY

The experience with townhouses, condominiums and single family detached houses built during the 1970's at Twin Rivers was revealing but that experience left many questions unanswered. Measurements of older homes, where a variety of style and vintage questions were relevant, was the next step.[9] The techniques of the house doctor approach were employed.

Prior energy records were collected from two ranch-style (single-storey) and two colonial-style (two-storey) homes. Wherever possible, an Energy Signature (a compilation of energy use plotted against outside temperature for the period) should be determined prior to a contemplated house visit.

Very evident from the house doctor visits to the four homes was that more than conventional retrofitting was necessary. Of particular interest was the amount of leakage in the band joist areas especially in the case of the two-storey houses. The use of depressurization and infrared scanning revealed these problems. The solution involved devising techniques to inject blown in insulation into these locations and make certain it would stay in place. Use of glue, cellulose, and a special spray nozzle were all part of this activity. Each of the houses received an attic insulation upgrading -- normally moving from 8 to 25 cm of equivalent mineral wool insulation (actually both fiberglass and cellulose blown in insulation were used). Basement band joists were upgraded through use of sealants, and 15 cm of fiberglass with vapor barrier. Crawl space walls were insulated as well. Electric outlets were gasketed; windows and doors were checked for leakage, and weather-stripped where economical; and other leakage sites, primarily in the ceiling, were treated with 0.15 mm plastic sheets, under the insulation. Each of the furnaces was checked with the highest gain being a 9% change due to increased steady-state performance in a modern oil burner.[6]

Certain of the houses required return visits to: monitor moisture problems in an underventilated attic where increased insulation had aggravated the situation; treat a local problem due to a missed envelope opening which was hidden by a bathtub; and vents blocked by insulation.

An appreciation for the saving potential of the house doctor approach can be gained from the Table.[10] The first house is the Twin Rivers townhouse that received extensive retrofit treatment.[1] The last three entries are three of the four older houses just discussed. As an aid in visualizing the consumption, all energy for heating has been converted to liters per year and savings expressed in cost of energy saved (Dollars per 1000 liters.)

TABLE RETROFIT COSTS AND ENERGY SAVINGS

House (Year of Construction)	Heating Fuel	Energy Use b) (liters per year)		Retrofit Cost ($) c)	Cost of Saved Energy d) ($/1000 liters)
		Before Retrofit	After Retrofit		
TR (1972)	gas	2207	522	3000	119
HS 11 (1957)	gas	1624	973	700	72
HS 21 (1973)	oil	3596	1703	1200	42
HS 22 (1963)	gas	3115	2290	1000	81

a) These data relate to four houses in New Jersey retrofitted by Princeton University's Center for Energy and Environmental Studies and local contractors.

b) Space heating energy use in equivalent fuel oil liters per year normalized to a standard year, based on a 10 year average of weather data.

c) Includes both materials cost and labor cost (computed at $100 per person-day).

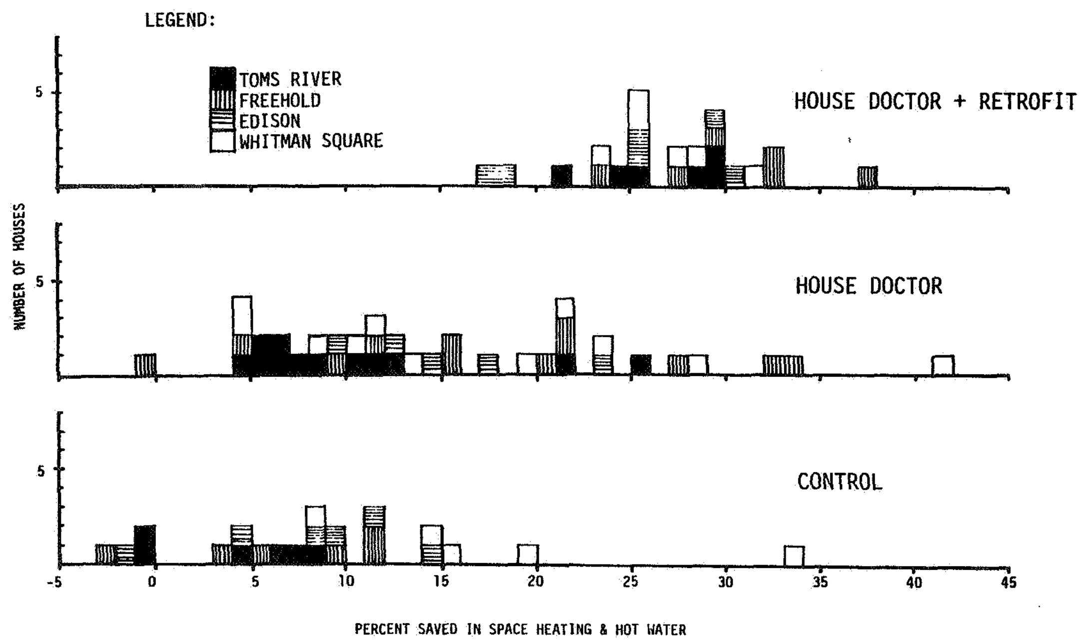
d) Cost of saved energy = $\frac{\text{cost of retrofit}}{\text{life cycle energy savings}}$; for these retrofits a 15 year life expectancy has been assumed.

STATEWIDE/NATIONWIDE

During the winter of 1979/1980 the four gas utilities of the State of New Jersey, in a model collaborative project with Princeton University, began a statewide experiment to conduct a large scale test of the house doctor concept.[11] The utility house doctor teams were trained at Princeton and received further field training at six housing sites. The experimental research plan involved 18 house modules which provided: six controls, six house doctor visits, and six houses that received major retrofitting following the house doctor visit. Energy signature data generally required R square fits better than 0.95 to qualify a house for consideration in the program. Since time did not permit the collection of preretrofit data, house/occupants that were not following a well-prescribed energy use pattern were excluded. As in the case of Twin Rivers housing (and a number of other housing sites where detailed measurements have been taken) there was again a more than two-to-one variation in gas use in the houses of each of these groups of nearly identical houses.[12]

The data from this experiment have answered many questions but have posed new questions as well.

First the questions of training. The basis for training house doctors has been established, the conclusion has been that a minimum of five days of classroom and planned activities followed by a comparable field experience can satisfy the training needs. The savings due to both the house doctor and the visit plus retrofit have been documented as shown in the Figure. A subset of these data point out that improvements are evident as the team experience grows.



HISTOGRAM OF PERCENT ENERGY SAVED IN MRE, 4 MODULES, FIRST HALF 80 - 81 WINTER

Some of the new questions that have arisen include the lack of benefit from the thermostat installation. Post retrofit interviews have revealed that the setback thermostats are only being used by those occupants that previously used manual setback. The interaction of the house doctor with occupant must include training and encouragement in the use of control systems. Another question deals with extreme outlying data points. In a period of rapidly rising fuel prices some of the homeowners are achieving major savings in their energy use, (10 percent reduction in gas use for the utility as a whole), the previous major change of this type was seen in the 73 - 74 period.

The house doctor activities of the utilities within the state involving some 130 houses have been mirrored in other regions throughout the country, e.g. Minnesota, New York, Tennessee and California. Full results of energy savings and costs are currently being analysed.

THE MARKET PLACE

The realization that a house doctors approach is needed and that the time has come is evident from recent events. The program at Princeton has received much publicity in the past but recent coverage[13] has brought a virtual deluge of requests from prospective house doctors throughout the United States and many from other countries as well. Last year the level of interest was far lower.

A variety of groups in North America have come to the conclusion that the house doctor or similar technique is the way to approach home energy retrofitting. In the last few months many of these groups are moving to franchise the methods that have been developed. Unfortunately mixed in with the dedicated energy savers are groups that have only monetary gains in mind, offering inferior instruction and/or equipment of marginal value. Some have also become quite specialized, perhaps too specialized, in that they are concerned only with envelope tightening, neglecting furnace efficiency, and insulation questions. Others have become regionalized dealing with the specific problems of regional housing, this regional approach may be necessary in many instances.

THE FUTURE

In the United States and Canada there is considerable activity taking place in house doctoring. In New Jersey, a thousand house experiment to test new financing for house doctoring and other conservation measures is imminent. Judging from recent media pronouncements the groups now active in house doctoring activities are numbered in the tens, but predictions in the near future are for a thousand crews.[14]

One of the big questions is certification. Federal or State certification could greatly assist the program in making certain that high standards are followed in any house doctor activities. No such certification appears to be close at hand, at least in the United States.

ACKNOWLEDGMENTS

The authors wish to acknowledge the sponsorship of the U.S. Department of Energy, Buildings Division for this research under Contract No. EE-S-02-4288. The support and encouragement of Howard Ross, Program Technical Monitor is especially appreciated. We also wish to acknowledge the contributions to the House Doctors Program from other members of the Buildings Group in the Center for Energy and Environmental Studies, namely, Kenneth Gadsby, Michael Lavine, Greg Linteris, and Robert Socolow.

REFERENCES

1. Saving Energy in the Home -- Princeton's Experiments at Twin Rivers Ed. Socolow, R.H., Ballinger, Cambridge, MA, 1978, Also appeared as the entire issue of Energy and Buildings, Vol. 1, No. 3, April 1978.

2. Harrje, D.T., Persily, A.K. and Linteris, G.T., "Instruments and Techniques in Home Energy Analysis" Proceedings of the Energy Audit Workshop sponsored by the IEA Energy Conservation in Buildings and Community Systems Annex III, Elsinore, Denmark, April 1981.

3. Blomsterberg, A.K., and Harrje, D.T., "Evaluating Air Infiltration Energy Losses," ASHRAE Journal Vol. 21, No. 5, (May 1979) pp 25-32 and as "Approaches to Air Infiltration Energy Losses in Buildings" ASHRAE Transactions 1979, Vol. 85, Part 1.

4. Harrje, D.T., Dutt, G.S., and Gadsby, K.J., "Isolating the Building Thermal Envelope". Thermal Infrared Sensing Applied to Energy Conservation in Building Envelopes (Thermosense III). Proc. Soc. Photo-Opt Instr. Engr. 254, 1981, pp 50-56.

5. Harrje, D.T. "The House Doctor Approach," Proceedings of the NBS-CSA Conference on Optimal Weatherization, Washington D.C., December 1980.

6. Harrje, D.T., and Cooper, J.B., Instrumenting Energy Audits, Princeton University, Center for Energy and Environmental Studies Rpt. No. 91, July 1979 (103 pages).

7. Harrje, D.T., Dutt, G.S., Beyea J. "Locating and Eliminating Obscure but Major Energy Losses in Residential Housing," ASHRAE Transactions, Vol. 85, Part II, 1979.

8. Dutt, G.S. and Beyea, J., "Hidden Heat Losses in Attics - Their Detection and Reduction," Princeton University Center for Environmental Studies Report No. 77, May 1979.

9. Socolow, R.H., Harrje D.T., Nall, D., Rouse, R.E., and Sinden, F.W., "Style and Vintage as Determinants of Energy - Costly Faults in U.S. Residential Housing", Energy Conservation in the Built Environment CIB Proceedings of the Second International Symposium, Danish Building Research Institute, Copenhagen 1979, Session 1, pp 135-144.

10. Dutt, G.S., "If Home Energy Saving is Such a Good Idea, Why Don't More People do it?" in Home Remedies: A Guidebook for Residential Retrofit (Ed. Wilson, T.) Mid Atlantic Solar Energy Association) Philadelphia, PA, 1981.

11. Dutt, G.S., Harrje, D.T. and Socolow, R.H., "The Modular Retrofit Experiment (MRE) - Research Plan", Princeton University Center for Energy and Environmental Studies, Working Paper 50, 1980.

12. Socolow, R.H., Dutt, G.S., and Lavine, M.L. "Preliminary Results of the Modular Retrofit Experiment: Tests of the House Doctor Concept by New Jersey's Gas Utilities," International Conference on Energy Resources and Conservation Related to Built Environment, Miami Beach, Florida, 1980.

13. "A Visit From House Doctors" National Geographic, Special Report on Energy, Feb. 1981.

14. "The Franchising Boom" a chart compiled by Naddaff and Senne VR Business Brokers, Needham Mass., Chicago Tribune 1981.