THERMABILT
ENERGY EFFICIENT RESIDENTIAL CONSTRUCTION RESEARCH, DEMONSTRATION AND TECHNOLOGY TRANSFER

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ABSTRACT

Thermabilt is Washington State's component of the Bonneville Power Administration-funded Residential Standards Demonstration Program (RSDP). Under this program, 228 single family homes and 148 units in 19 multi-family buildings were constructed in Washington State during 1984 to high levels of energy efficiency corresponding to the Northwest Power Planning Council's Model Conservation Standards (MCS).

Thermabilt had multiple objectives: Technology transfer — training what heretofore were primarily conventional builders in the methods of very energy efficient construction; Demonstration -- broadly demonstrating very energy efficient construction to the shelter industry (builders, sub-trades, suppliers, realtors, appraisers, lenders) and the general public; and Research -- determining the incremental costs and energy savings associated with very energy efficient construction. Despite these multiple and often conflicting objectives, tight timelines and a highly charged political atmosphere, Thermabilt was largely successful. The major objectives were satisfied. The success of the program played a pivotal role in the adoption of a significantly more efficient energy code by the Washington State Legislature. One of the nation's largest and highest quality body of data on the cost and performance of very energy efficient homes has been developed. Moreover, valuable lessons were learned in the areas of training, construction, technical assistance and marketing. This paper provides an overview of Thermabilt, its major accomplishments and the key lessons learned.

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BACKGROUND

Thermabilt and the RSDP had their origins in the passage in 1980 of the Pacific Northwest Electric Power Planning and Conservation Act. This milestone legislation established the Northwest Power Planning Council, made up of appointees of the governors of each of the Northwest States — Washington, Oregon, Idaho and Montana. It charged the Power Council with developing a 20 year power plan to guide the actions of the federal Bonneville Power Administration (BPA). As part of that plan, the Council was to establish Model Conservation Standards for new buildings which were to capture "...**all** the power savings which are cost-effective for the region and economically feasible for consumers..." (Section 4(f)(1), PL 96-501,emphasis added). To back up the standards, the Council was authorized to recommend a 10 to 50 percent surcharge on BPA wholesale rates to utilities serving jurisdictions which do not enforce them.

In responding to that mandate, the Council devised standards which, of necessity, marked a significant departure from current construction practice. Satisfying the standards now involves such measures as: triple glazed or double glazed low emissivity glass windows with wood or thermally-improved metal frames; wall R values of 19, 24 or more; R-38 ceilings; R-19 or R-30 under floors; insulated doors; and most controversial, air tight construction (intended to achieve 0.1 air changes per hour (ACH) natural ventilation) along with heat recovery ventilation systems.

The MCS were controversial from the moment they were published in draft. Several homebuilder organizations ultimately sued the Power Council alleging, among other things, that the MCS were neither cost-effective nor economically feasible (that suit was recently rejected by the Ninth Circuit). Substantively, homebuilder representatives argued that the costs for conservation measures used by the Power Council were generally too low and the predicted energy savings too great. The Council's cost estimates were derived from surveys of Northwest builders and building material suppliers. The energy savings were estimated using the SUNDAY computer simulation[1]. The arguments of the Homebuilder Associations were attractive to some outside the industry.

The Council remained steadfast in its backing of the MCS, calling for a January 1, 1986 deadline for implementation of the MCS in code by state and local governments. It was clear, however, that if resistance to the MCS was to be overcome, the MCS would have to be demonstrated on a much larger scale than had been accomplished to date by the existing small cadre of "super-insulated" builders in the region. Accordingly, in the Council's first Plan, adopted in April of 1983, BPA was called upon to sponsor a "sample demonstration of houses built to the model standards".[2] While the action plan called for a "demonstration", there was also clearly a research component. The action plan called for collecting data on a statistically valid sample of single family homes (initially 1000). The data collected would involve triple meter monitoring of energy use (space heat, water heat and total consumption), occupant characteristics, infiltration and indoor air quality. Similar data would be collected in a control group of current practice homes. Given the reality of the relatively small number of builders in the region with experience in MCS level construction, it was clear there would have to be a substantial technology transfer component to the program as well.

In the summer of 1983, BPA turned to the energy agencies of Washington, Oregon, Idaho and Montana to carry out what by then was known as the Residential Standards

Demonstration Program, RSDP. The challenges facing BPA and the states were daunting. We had to: translate the MCS into workable specifications; develop training materials; recruit a large number of builders; provide training to the builders; try to alert manufacturers and suppliers to needs of the program; review builder designs and provide technical assistance to builders to bring designs into compliance with the standards; develop a system for tracking the incremental costs of construction; train inspectors in the MCS requirements and provide for timely inspections; devise marketing materials and a marketing plan; recruit control homes; and on and on. Moreover, this had to be accomplished in the context of a difficult political situation where some leaders of the homebuilding industry were antagonistic to the aims of the program. In Washington, we were under the time pressure of the need to bring information from the RSDP to bear on the deliberations to take place during the legislative session beginning in January of 1985. This would be the last session before the Council's 1986 surcharge deadline.

THE THERMABILT PROGRAM

The RSDP was carried out along similar lines in each of the Northwest states with some differences to account for state-specific conditions and preferences. The most obvious differences were the names. It was clear that "Residential Standards Demonstration Program" was bureaucratic jargon unsuited to marketing the program to builders or the products to homebuyers. BPA, however, was unable to come up with a name for its regional new residential construction marketing program in time for the launching of the RSDP. Consequently, the states came up with their own names. In Washington, the name chosen was "Thermabilt", a name which was intended to convey a sense of energy efficiency, warmth and quality construction.

Key to the planning of Thermabilt was the establishment of a Shelter industry advisory committee. This committee was composed of homebuilders of both the "conventional" and the "super-insulated" varieties, an insulation contractor, a realtor, a mortgage lender, an architect, a professional engineer and utility representatives. The membership included both friend and foe of the MCS — or at least a good number of skeptics. This helped us to understand the key industry issues and provided an indispensible reality check during the planning phase.

Thermabilt "hit the road" in January of 1984. Every one of the 17,000 registered contractors in the state of Washington was invited to briefings held in seven cities around the state. Almost 1,700 builders accepted the invitation. What we offered the builders were:

1. Training in the methods and materials of very energy efficient construction;
2. Limited marketing assistance (at the time, we did not appreciate how limited);
3. Cash incentives — $2 to $3 per square foot of floor space plus $800 for an air-to-air heat exchanger (AAHX) and $200 for the installation of metering equipment; and
4. A competitive edge — an opportunity to get the jump on their competitors in building very energy efficient homes.

What we were asking for in return was not trivial. Participating builders would have to:

1. Participate in intensive two day training sessions;
2. Develop house plans which would satisfy the MCS and have those plans approved by WSEO;
3. Keep careful track of their costs using a cost accounting system developed by the regional homebuilders association and report those costs to WSEO;
4. Build the houses as they said they would, clearing changes with Thermabilt staff; and
5. Submit their homes to additional "energy inspections" beyond those required by current codes.

These requirements proved to be too unattractive for many of the briefing attendees. None the less, over 1,000 (mostly builders) chose to attend one of the fourteen training sessions offered that spring. The training was the key technology transfer element of the program. Our assumption was that there is a good and a better way of doing everything. Time and money could be saved if builders learned the better ways right at the beginning.

To carry out this training, WSEO contracted with the Energy Business Association of Washington (EBA). EBA put together an impressive training team which included experienced energy efficient designers, a Washington builder with extensive superinsulated construction experience, and a member of the Canadian R-2000 training team. (R-2000 is Canada's highly successful national energy efficient home program) Experience and, in particular, the participation of at least one builder were essential to the training being credible to other builders. The curriculum and training materials developed by this team became the model for the region. The training team's efforts were effective and well-received. Ultimately, the EBA team trained over 1,800 shelter industry members (builders, code officials, realtors, etc.) during the first year.

After the training, the reality of the program hit both the builders and the Thermabilt staff. Builders began submitting their home plans for WSEO approval so they could enter into contracts. About 200 builders took that step. After that, there was the necessity of getting financing; finding materials of which some suppliers had never heard; putting what had seemed clear in the training sessions into practice at the job site, and finding that perhaps it was not so clear; dealing with innumerable problems which were never thought of, let alone mentioned, during the training; getting the home approved by local building officials; getting attention from the local press; getting ignored by the local press; dealing with realtors who couldn't spell energy efficiency, appraisers who couldn't recognize it and value it, and lenders who did not care; trying to fathom what the cost accounting manual was really after; and fielding calls from Thermabilt staff asking whether they had met their contract milestones and what the builder really meant on his cost report form.

Despite these headaches, 133 single family and 11 multi-family builders persevered. The homes were built, the cost data was obtained, the thermal monitoring instrumentation was installed (although not in time for the entire 1984-85 heating season), the incentive payments were made, the homes sold and, now, the data has been and is being analyzed.

Who were these builders? According to a survey of the participants they are generally smaller builders (77% built 25 or fewer homes in the preceding 5 years). Most had little experience in building to the levels of energy efficiency required in Thermabilt. For example, 81 percent had not built homes with the kind of infiltration control measures required. Most were custom builders (83%) although some decided to build homes on spec for the program.[3] There were many different motivations for the builders who participated in Thermabilt. To a large extent, however, they can be characterized as innovators, looking for a competitive edge and a market niche through energy efficient construction.

THERMABILT – THE LESSONS LEARNED

In the course of the Thermabilt program many lessons were learned – some easy, some painful and all valuable. These lessons pertain to the technology transfer process, the construction of very energy efficient homes, the marketing of these homes, and, in general, the process of pushing new technologies and practices into the market. The lessons may be summarized, only somewhat facetiously, as follows:

1. There is no such thing as too much enthusiasm... except for sometimes. Or, sometimes "better" isn't "best."
2. Murphy is alive and well. What can go wrong will.
3. There's such a thing as "critical mass" in homebuilding too.
4. What you are really after is quality, quality, quality.
5. There is no such thing as too much marketing... except for sometimes.
6. You can't beat location, location, location... only nudge it.
7. Take your local appraiser and lending official to lunch.
8. Technology Transfer/Demonstration and Research aren't a perfect mix.

THERE'S NO SUCH THING AS TOO MUCH ENTHUSIASM... EXCEPT FOR SOMETIMES

One of the most important qualities Thermabilt had going for it was enthusiasm -- enthusiasm on the part of the staff, the training team, and most of the participating builders. In large measure, it was this enthusiasm that made it possible for Thermabilt to be carried out despite the obstacles. This enthusiasm, however, if not tempered with sufficient experience and judgement can have unanticipated consequences.

One example was the training. The training focused on the "better" ways of building very energy efficient homes – better in terms of achieving the highest degree of energy efficiency. There were several reasons for this. First, much of the knowledge base for such construction was the Canadian experience – an experience reflective of a very harsh climate. Second, there was a concern for insuring that the product, the houses, would perform well. This concern was reflected in the program specifications and in the training. Finally, there was a general lack of real data on the cost-effectiveness of specific approaches.

A concrete example is the use of advanced or raised trusses to achieve full depth of ceiling insulation all the way out to the walls instead of tapering the insulation to

accommodate to the slope of the roof line near the eaves. This may be better in terms of energy efficiency but is it the best way in terms of cost-effectiveness? In hindsight, the answer is no. But this is the approach the training emphasized and this is the approach many builders chose to use.

The training certainly interacted with the characteristics of the builders. Most are naturally innovative, problem-solving types. Thermabilt was an opportunity for them to try new ideas and the incentive payments removed some of the risk for them in doing so. Consequently, when presented with a "better" way in training, they wanted to try it. Moreover, if some was good, more was probably better. So the insulation levels used were frequently greater than was necessary to meet the minimum requirements of the program.

The same enthusiasm and lack of adequate information afflicted the Thermabilt staff. Consequently, when, in reviewing designs, they should have been talking builders into more cost-effective levels and approaches, they weren't. The net result of all this was that many Thermabilt homes were built to higher, more costly and less cost-effective levels of efficiency than was necessary to satisfy the MCS.

The benefit of this was a richer, more varied data set. This experience has improved subsequent training and design review activities so that the emphasis is on cost-effectiveness. Still, things would have been better if Thermabilt's enthusiasm could have been tempered with more experience from the beginning.

MURPHY IS ALIVE AND WELL

It would seem to be axiomatic that when introducing new techniques, materials and equipment to builders with little or no previous experience with them, mistakes will be made. Thermabilt demonstrated this amply.

Some of the mistakes are relatively harmless and fairly humorous in retrospect. For example, the builder who used a propane heater in a closed house to dry out the mud on his sheetrock job learned two things. First, the exhaust of a propane heater contains a lot of water vapor. Second, the vapor barrier in the ceiling worked. This was demonstrated by the fact that when he returned to the house after an all night "drying" session, he found the sheetrock from the ceiling all over the floor and far from dry.

Other mistakes could be more serious. For example, inexperience in sizing and laying out the duct runs for an AAHX could result in inadequate flow rates and imbalances in the system.[4] The consequences could be odor and moisture problems and, in situations where pollutant sources are present, even health risks for the occupants.

What was remarkable about Thermabilt was all the problem solving and mistake mending being done by the builders and staff. When mistakes were found, efforts were and continue to be made to correct them. The best problem solvers are invariably the builders themselves. We held reunions of the Thermabuilders after the completion of the construction phase of the program. The exchange of information on the mistakes made, the problems encountered and the solutions which were developed was an important part of the technology transfer process.

THERE'S SUCH A THING AS CRITICAL MASS IN HOMEBUILDING, TOO

It is one thing to introduce the building community to new materials and practices. It is quite another to assume that the builder will be able to find those materials when they need them. Overall, 42 percent of the Thermabilt builders reported difficulty in finding some of the materials. Problems were concentrated in the AAHXs (13%), caulking and sealant products (17%), and vapor barrier tape (15%).[5] Anecdotes always stick with one better than statistics. The story of the builder who drove from Spokane to Seattle to find vapor barrier tape is now one of the legends of the Thermabilt experience. What applied to materials also applied to services — like subcontractors experienced with the requirements of super-insulated, tight construction and sheet metal contractors with experience in installation of AAHXs.

Of course, the corollary of materials and services which are difficult to find is materials and services which are relatively costly because they are essentially specialty items. We have termed this situation a lack of critical mass. During Thermabilt there was not a critical mass of contractors building to MCS levels of efficiency. As a consequence, there was little incentive to stock the necessary materials or provide the necessary services and price them competitively. At present, we have no hard data to prove the effect of this lack of critical mass. We believe, however, that many of the costs incurred by Thermabilt builders were high compared to what one would expect in a mature market. We are looking forward to getting cost data from the City of Tacoma which has adopted the MCS in code. In this local setting where a sizeable number of builders are building to the MCS routinely, we expect that we should see the effect of achieving critical mass.

WHAT YOU'RE REALLY AFTER IS QUALITY

One of the most important lessons of the Thermabilt program is the importance of quality to energy efficient construction. We do not mean quality as in ceramic tiles or hard wood floors. What we mean is quality as in attention to fit and detail. This is most clearly an issue in reducing random air infiltration. The fact that a builder is installing a supposedly continuous vapor barrier and is supposed to be carefully caulking and sealing doesn't guarantee low infiltration. This is borne out by the results of blower door testing done after the completion of construction. While the majority of Thermabilt builders achieved tight construction, there were some participants that did not. To some extent this can be explained by the fact that some designs are much more difficult to seal than are others. More likely, however, the explanation is attention to quality.

The proof of the importance of this factor will be found in the thermal monitoring data. We are analyzing the thermal data with this in mind.

THERE IS NO SUCH THING AS TOO MUCH MARKETING ...EXCEPT FOR SOMETIMES

The biggest failure of the Thermabilt program was marketing — not because our marketing efforts were ineffective, they were simply inadequate given the limited budget. At the start of the program, we had anticipated being able to ride the coat tails of BPA's regional residential construction marketing program — which ultimately turned

out to be Super Good Cents. It was this effort on which we counted to build overall consumer awareness of the benefits of energy efficient housing.

Unfortunately, the launching of Super Good Cents took too long to benefit the RSDP. Consequently, we were on our own. We did enter into a lot of marketing activities — a brochure was produced for the use of builders and realtors, yard signs were printed, ad copy was produced and used in cooperative advertisements, and numerous open houses were held with a fair degree of press attention. We engaged the services of an advertising agency, resulting in a very professional approach to the marketing problem. None the less, the overall consumer awareness, which, in a TV oriented society seems to require TV exposure, was not there.

Now the "Except for sometimes" part. A key lesson is that when marketing energy efficient homes, don't allow yourself to get carried away. It's easy to let the advertising types sell you on slogans which can get you into trouble. For example, "Watch your energy bills fade away," the headline for the Thermabilt poster. This is enticing but not wholly accurate. In fact, the energy efficient home can't be built and the marketing materials cannot be written carefully enough that a homeowner can't make the house use more energy than he or she thinks it should.

In the first place, the homeowner typically does not distinguish between heating and the overall utility bill. Thermabilt did not address anything but heating energy efficiency. And if you say a home is going to use less energy than a conventional home, the homeowners will expect it to. This is despite the fact they are comparing it to a home which is half as large, located in a warmer area, and not equipped with half the energy consuming appliances as the new "energy efficient" home. Finally, the homeowners confuses energy use with the size of the utility bill. If you say the energy efficient home will use less energy, they will expect the utility bill to be less too. This is despite the fact that the new home is in a different utility area with rates three times greater than those to which they are accustomed.

There are several lessons in all this. First, build your marketing approach on a base of overall consumer awareness — a base which the Super Good Cents advertising is now building effectively in the Northwest. Second, be very careful what you claim. The tension between conveying the benefits of energy efficient construction and the complexities of the performance of such homes results in a very fine line which must be walked. Finally, be prepared with the inevitable misunderstandings in straightforward, factual ways.

YOU CAN'T BEAT LOCATION, LOCATION, LOCATION... ONLY NUDGE IT

While we're talking about marketing, let's be realistic about the role energy efficiency plays in the home buying decision. There is survey research which indicates that energy efficiency is a major consideration in the mind of the buyer. It probably is, but it is only one major consideration among many.

Energy efficiency is a valued attribute. We in the energy community have been trying to sell it on the basis of rational and, to the layperson, largely incomprehensible economics. We should also be focusing on the amenity values -quiet, draft-free warmth and comfort. But we must remember that energy efficiency is only one attribute.

Homebuyers are willing to pay a reasonable amount for energy efficiency in a house which also meets their other criteria, e.g., location, schools, number of bathrooms and so on. Energy efficiency, marketed correctly, can be a competitive edge. But homebuyers won't buy a dog, even an energy efficient dog.

TAKE YOUR LOCAL APPRAISER AND LENDING OFFICIAL TO LUNCH

A major barrier to energy efficient housing encountered in the Thermabilt program was the lending industry. It could also be a major help. At a minimum, the appraisers and lenders must be convinced to recognize the extra value in an energy efficient home and reflect that in the valuation of the home and the amount they are willing to loan. Without this, builders of energy efficient homes will have difficulty in selling these homes for what they are worth.

At best, lending institutions can recognize that lower energy bills mean greater disposable income and, therefore, greater ability to make the mortgage payments. They can and should be willing to adjust their debt/income ratios to reflect this, thereby qualifying more potential homebuyers for loans. The federal mortgage agencies, Fanny Mae and Freddy Mac, currently allow this.

Thermabilt may be the key to effecting these changes. Lenders are skeptical of the claims of energy savings of very efficient homes. They all seem to be from Missouri and want to be shown. Soon the thermal monitoring data from Thermabilt and the rest of RSDP should be able to show them.

TECHNOLOGY TRANSFER/DEMONSTRATION AND RESEARCH AREN'T A PERFECT MIX

The RSDP had the multiple objectives of technology transfer, demonstration and research. In retrospect, it seems clear that the latter objective was compromised by the first two. Several of the problems have been mentioned in preceding paragraphs. The following summarizes these important points with respect to the cost data obtained from Thermabilt:

1. The majority of the participating builders (and their subtrades) were putting new methods and materials into practice for the first time. Experience with learning curves would suggest these initial homes would have significantly higher costs than those produced later.
2. The markets for much of the materials and equipment required were immature. These items (e.g., air-to-air heat exchangers, vapor barrier materials, some kinds of insulation, thermally improved windows) were not routinely produced or stocked. Consequently, it can be expected that premium prices were often paid.
3. As a result of the relatively low level of understanding of very energy efficient construction which existed at the time, most designs were not cost-optimized, i.e., the most cost-effective ways of achieving a given level of thermal integrity were often not employed. In fact, the RSDP specifications did not require or even encourage cost optimization.

4. As a result of the enthusiasm of many builders to try new methods, many of the homes were over-built, i.e., exceeded the efficiency levels required for the MCS prescriptive paths (although frequently not from an energy budget standpoint).
5. The fact that the builders were paid a substantial cash incentive may have reduced the desire of many builders to control costs closely.
6. The participating builders may not have been representative of the building industry. Few large builders participated. One can argue with equal assurance that this led to higher than average or less than average costs.
7. The cost data were collected in terms of the incremental cost to construct to the MCS. This required the builder to estimate what his costs would have been for a current practice house he wasn't building. The impact of this on the accuracy of the incremental cost is unknown. The data cannot be used at all to estimate overall (rather than incremental) costs.

Although it is impossible to say with complete confidence, it seems probable that the above factors in combination would lead to incremental construction costs which are greater than one would expect when the building industry has reached "steady-state" with respect to MCS construction.

Although the deficiencies are probably less severe, there are some concerns about the thermal data. Aside from difficulties encountered with the instrumentation and data collection systems, the concerns are:

1. The fact that many of the demonstration homes were "over-built" may result in data which is not representative of "steady-state" construction practices.
2. The "first time" factor with techniques like air-tight construction and AAHXs may result in performance which is not representative of steady state.
3. The control group of homes and homeowners were self-selected. The participating homeowners may have chosen to participate either to get the monitoring incentive or because they were energy enthusiasts curious about how their homes and lifestyles affect energy use.
4. The demonstration homeowners were similarly self-selected. Did they choose to buy such a home because of their energy enthusiasm and, if so, what effect might that have on their consumption? Does the fact that they were relatively affluent persons buying during a period of near historic high interest rates influence their behavior in ways that affect energy use?
5. Uncertainties about AAHX performance (flow rates, hours and levels of operation, efficiency) and overall ventilation rates (combined natural and mechanical) make it difficult to assess the impact of ventilation on energy use.

The above concerns are by no means intended to suggest that the data from Thermabilt and the rest of the RSDP are not useful. It does suggest that the data must be carefully interpreted. These data remain, however, one of the largest and most detailed sets of data on the cost and performance of very energy efficient housing in the nation if not the world. The information already derived from these data and that yet to be derived form the basis for advancing the understanding of residential energy performance and improving future building practice.

THERMABILT'S ACCOMPLISHMENTS

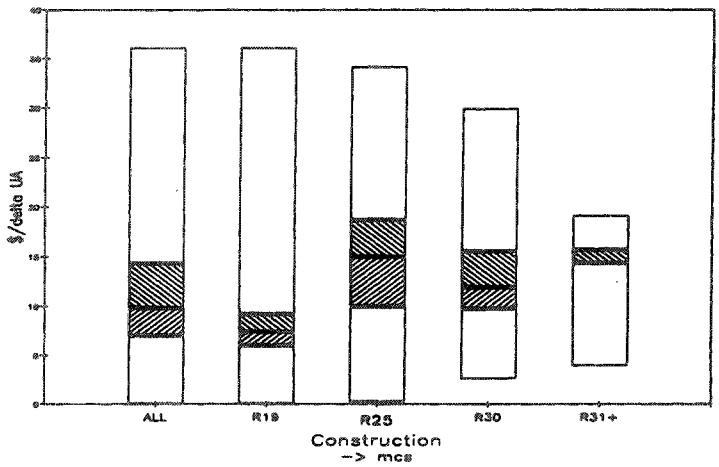
It is easy to focus on Thermabilt's problems and deficiencies. To do so exclusively, however is to ignore the program's very real accomplishments. In retrospect, the technology transfer and demonstration were, overall, immensely successful. Well over two hundred quality energy efficient homes were built, sold and occupied. Problems were certainly encountered but, for the most part were successfully overcome. The building industry in Washington was introduced to very energy efficient construction practices on a scale which exceeded previous levels by at least an order of magnitude. The same is true of the home buying public. As a consequence, materials, equipment and practices which were generally unheard of before Thermabilt are now familiar if not commonplace.

The positive impact of Thermabilt on participating builders is indicated by their future plans and expectations. Over 75 percent are building or are planning on building more homes to the MCS/Thermabilt/Super Good Cents levels of energy efficiency. Approximately 70 percent think the program has attracted other builders to this kind of construction. This is borne out by the tremendous demand for training. Since Thermabilt, almost 3,000 Washington builders and building officials have attended WSEO-sponsored training (including some repeats). Additional builders have attended training sessions offered independently. Finally, over 90 percent of the builders think they will be able to build to these levels of efficiency for less in the future.[6]

The Thermabilt experience has also made a substantial contribution to improving the cost-effectiveness of energy efficient construction because of the feedback on subsequent technology transfer efforts. In analyzing the Thermabilt cost data, we took pains to look not only at the cost of particular measures and approaches but at the relative cost-effectiveness as well. This was done by calculating the cost per unit change in the thermal transmittance of a component ($/delta UA).

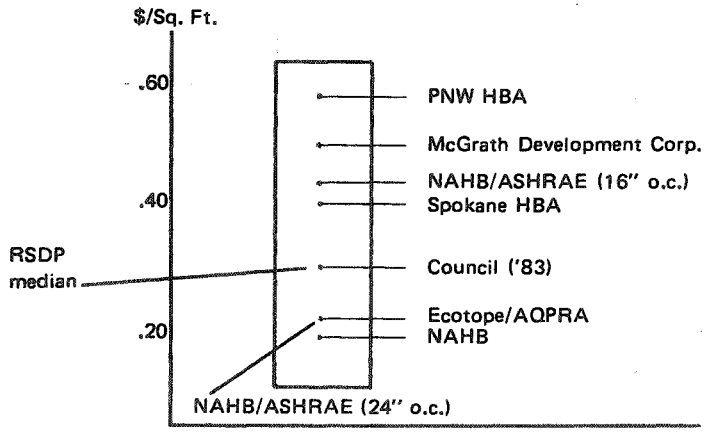
The results of this analysis for a relatively simple component, insulating the under floor areas of crawl spaces, is shown on Figure 1.[7] This chart clearly shows that once the decision has been made to use deeper floor joists (beyond 2" x 8"), it is relatively more cost-effective to go to higher levels of insulation, e.g., R-30 instead of R-25.

Figure 1. Crawlspaces — $/Delta UA by Pairs



The Thermabilt data have also confirmed much of the Northwest Power Planning Council's cost data and pointed the direction for future development. For most components, the Council's original cost estimates agree very well with median Thermabilt/RSDP costs. For example, Figure 2 compares the several estimates of the incremental of going from an R-11 to an R-19 wall with the median RSDP cost.[8] As can be seen, the RSDP median falls right on top of the Council estimate.

Figure 2. Incremental Cost
Wall Insulation: R-11 to R-19



Where this is not true is those measures for which the building industry has the least experience, i.e., the infiltration control measures and AAHXs. In these instances, the RSDP median costs are well above the Council's estimates. This is hardly surprising in that it is these measures which represent the most significant departure from current practice. We can expect some improvement in these costs with experience and the development of competitive markets for these items and skills. The data also point out the need for further development in this area. For example, the air-tight drywall approach (ADA) is an example of a less costly way of achieving tight construction. This as well as other promising ventilation approaches and construction techniques are being investigated in BPA's Residential Construction Demonstration Project, currently being carried out by WSEO and the other Northwest state energy agencies.

Thermabilt also played a major role in the adoption in 1985 by the Washington State Legislature of legislation of a new, considerably more efficient state energy code. The Thermabilt experience allowed us to do two things. First, it allowed us to bring credible, real world cost data to bear on the political deliberations. Second, it allowed us to bring credible, real world builders into the political process. Testimony from these builders, who had and were building to high levels of energy efficiency, was much more effective than any data a bureaucrat could cite. The result was legislative direction for the establishment of an energy code which would achieve approximately 60 percent of the savings anticipated for the MCS. That code went into effect in April of this year.

Finally, one of the major benefits of Thermabilt is just now coming into play. The Thermabilt/RSDP thermal data provide an almost unprecedented opportunity to compare the performance of very energy efficient homes with their conventional counterparts. Moreover, because of the detailed information we have on the characteristics of the

Thermabilt homes, we have an unprecedented opportunity to explain the performance we observe. We look forward to disseminating the results of this analysis at future conferences.

In conclusion, Thermabilt was a success. Although there were numerous problems and difficulties, the programs objectives were met and the groundwork laid for better energy efficient construction in the future.

References

1 SUNDAY 2.0. Ecotope Inc., 2812 E. Madison, Seattle WA 98112.

2 Action Item 2.1. "1983 Northwest Conservation and Electric Power Plan." Northwest Power Planning Council, April, 1983, p. 10-10.

3 Johnson, Mark E. "Builders Exit Survey Report for the Residential Standards Demonstration Program." Bonneville Power Administration, Office of Conservation, February, 1986, pp. 6, 7.

4 Lubliner, Michael; Kingrey, Bill; and Byers, Richard. "Experience with Air-To-Air Heat Exchangers in the Residential Standards Demonstration Program in Washington State." Paper to be presented at the ACEEE 1986 Summer Conference.

5 Johnson, op. cit., p. 12.

6 Johnson, op. cit., p. 32.

7 Douglass, John et al. "Energy Conservation in New Residential Construction: Construction Cost Analysis from the Thermabilt Program in Washington State." Washington State Energy Office, May, 1986.

8 Eckman, Tom. Northwest Power Planning Council. Personal communication.