DESIGN ASSISTANCE FOR NEW COMMERCIAL BUILDINGS: CASE STUDY EVALUATION

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The Washington State Energy Office conducted the Design Assistance for New Commercial Buildings Program from October, 1986 until June, 1989. The program continues to be operated by the region's utilities as Energy Smart Design. The purpose of the program is to promote energy efficient new commercial construction. Energy experts analyze building designs from an energy use standpoint, and recommend cost-effective energy efficiency measures. The building owner then decides which measures, if any, to install.

One of the fundamental questions posed by this program was whether developers/owners would install energy efficiency improvements based on the recommendations of energy experts. By participating in the program, it was hoped that developers/owners and the design community would increase their knowledge about building energy efficiency. A bottom-line measure of program results is the energy efficiency of the completed buildings. This paper examines these program goals using the results from a recently completed case study evaluation. Information is also drawn from two previous program evaluations.

The case study evaluation of 10 early Design Assistance Program participants showed the program delivered cost-effective energy conservation. Participants responded favorably to the simple nature of the program. However, the program had only a small impact on the energy efficiency of many of the case study buildings. The energy performance of the buildings tended to be less than expected. Design Assistance was too limited in scope to consistently produce energy efficient buildings. A more flexible program with a broader range of services is recommended.

INTRODUCTION

The Washington State Energy Office (Energy Office) conducted the Design Assistance for New Commercial Buildings Program (Design Assistance) for the Bonneville Power Administration from October 1986 until June 1989. Design Assistance was a pilot program intended to encourage energy-efficient building design. It continues today as the Energy Smart Design program and is operated by the Northwest region's utilities. Energy Smart Design is a key component of the Bonneville Power Administration's conservation efforts in new commercial buildings.

The Energy Office has conducted a series of evaluations of the Design Assistance Program. These include a process evaluation, a mid-stream phone evaluation, and a recently completed case study evaluation. This paper focuses on the results of the case study evaluation, with particular emphasis on the selection of energy efficiency improvements, program educational benefits, and the energy performance of the buildings.

PROGRAM DESCRIPTION

The Design Assistance Program matched commercial developers/owners and their design teams with energy consultants who are experts in building energy efficiency and analysis. The consultants met with the design teams early in the design process and discussed various energy efficiency improvements that could be made in the building design. The energy efficiency improvements were analyzed by the consultants using computer models. Based on the results of the modeling, the consultant recommended cost-effective energy efficiency improvements to the design team and the developer/owner. The design team and developer/owner then decided which of the recommendations, if any, to install. They were under no obligation to install any of the energy efficiency improvements; however, they were asked to seriously consider them.

It was hoped that the owners or developers would choose to incorporate the energy efficiency recommendations into their buildings without additional financial incentives. Another program goal was to educate developers/owners and the design community about building energy efficiency.

The program provided no financial incentives to cover the costs of the efficiency improvements. It did pay for the services provided by the energy consultants.

PAST EVALUATIONS

A series of three evaluations were done for the Design Assistance Program. The recently completed case studies are the last of this series. The first was a process evaluation of the first-year participants. Later, a mid-stream evaluation was conducted. This evaluation consisted of telephone calls to project participants to determine which recommended energy efficiency improvements were made.

Process Evaluation

The process evaluation of the 21 first-year participants was completed in mid-1988 (Dethman 1988; Kilpatrick and Dethman 1988). This evaluation showed a high level of satisfaction from program participants and indicated the program had influenced their behavior. Key findings included:

- 77% of participants said the program influenced them to seriously consider energy strategies or to take action
- 94% of participants said the program would affect how they did business in the future
- 81% of participants said the program increased their knowledge about energy-efficient design
- 69% of participants were very satisfied with the program; 28% were somewhat satisfied

The participants noted that the program provided them with the "hard numbers" they needed to make decisions and support existing hunches. Reasons for the high level of satisfaction included the precision of the information and recommendations, the professional quality of the consultant services, and the streamlined, low red tape approach taken by the program.

Mid-Stream Evaluation

Follow-up telephone interviews were made to participants in the Spring and late Summer of 1989 to identify which of the recommended energy efficiency improvements were installed in the buildings. This information was combined with data from the original technical studies for each project to produce a summary of results for the program (Washington State Energy Office 1989).

There were 48 participants in Design Assistance (Table 1). Due to time constraints, 10 of the participants received limited consulting services from the program. For the 38 participants that received full Design Assistance services, 26 installed one or more efficiency improvements. No efficiency improvements were made in nine of the projects due to building delay, cancellation, or recommendations made too late in the design process to be implemented.

A wide range of facility types were represented among the buildings that installed measures (Table 2). Offices and schools were the most common types. There were a total of 112 efficiency improvements recommended in these buildings. Shell measures and lighting were the most common measures recommended (Table 3). Participants reported that 69 percent of the recommended

Table 1. Participants Served by Design Assistance

Limited Consulting Services	10
Building Canceled After Assistance	2
Building Delayed/Uncertain	3
Design Recommendations Too Late	4
One or More Measures Installed	26
Unable to Contact	3
Total	48

Table 2. Building Type

Building Type	Number (%)
Office	7(27%)
School	7(27%)
Medical	3(12%)
Retail	2(8%)
Light Industrial	2(8%)
Public	2(8%)
Residential	1(4%)
Bank	1(4%)
Motel	1(4%)

Table 3. Recommended Efficiency Improvements

Measure Type	Recommended Measures Number (%)	Percent Installed
Shell/Envelope	43(38%)	81
Lighting	35(31%)	51
HVAC	19(17%)	74
Controls	11(10%)	64
Domestic Hot Water	4(4%)	75

measures were installed. The shell/envelope measures had the highest acceptance level and the lighting measures the least. The building energy modeling by the Design Assistance consultants estimated a 15 percent reduction in building energy consumption from the installed energy efficiency improvements.

It is important to note that these results are based on follow-up telephone calls and energy estimates from the computer models. The case study site visits show that the energy efficiency improvements actually installed at the facilities are sometimes different and a number of on-site factors may be affecting the energy savings estimates.

CASE STUDY APPROACH

The case study evaluation of Design Assistance was initiated by the Energy Office in the summer of 1989 and completed in June 1990. Out of the 26 program participants who indicated installation of one or more energy efficiency improvements, 10 case studies were conducted. Early program participants were selected so there would be at least 1 year of building operation. The sample was intended to be representative of Design Assistance participants (Table 4). Most of the buildings are less than 50,000 square feet, owner-occupied, and located in western Washington (the more populous part of the state). Note that in one case no energy efficiency improvement was installed, even though the mid-stream evaluation indicated installation of one improvement.

Case study evaluation combines both process and impact evaluation. For each individual case study, a six-step process was conducted.

1. *Initial Contact/Request for Information:* Program participants were contacted and utility data were requested.
2. *Preparation for Site Visit:* At least a year of utility consumption data for electric energy, electric demand, and fuel (where applicable) were analyzed and the report and recommended measures for the project reviewed.
3. *Site Visit:* A site visit was made by Energy Office staff and the original energy consultant (except in two cases). The purpose of the visit was to identify which measures were actually installed and what changes from the original design (physical and operational) had occurred at the facility. A walk-through inspection of the facility was made and as-built facility plans reviewed. The building operator or manager was asked about the operation of the facility.
4. *As-Built Modeling:* Based on the information from the site visit, the consultant developed an as-built

Table 4. Characteristics of the Case Study Sample

Type	Size (ft^2)	Measures Recommended	Measures Installed	Occupancy Type	Location
Retail	76,500	4	3	Leased	East
School	80,580	5	4	Owner	West
School	50,050	4	1	Owner	West
Bank	4,800	5	3	Owner	West
Medical	31,720	4	0	Owner/Lease	East
Medical	39,600	2	2	Owner/Lease	West
Industrial	17,700	5	5	Leased	East
Office	36,300	4	2	Owner	West
Office	39,300	2	2	Leased	West
Office	18,200	6	3	Owner	West

computer model of the facility. This usually only required modification of the original Design Assistance computer model for the building. Energy savings for the installed efficiency improvements were reestimated using the as-built model.

5. *Interviews:* Energy Office staff interviewed project participants (design team, developer/owner, and energy consultant), the occupants of the building, and the building operator. Interviews covered selection/implementation of the efficiency improvements, educational benefits, building operation and energy management, and satisfaction with the building in general.

6. *Final Analysis:* The impacts of the program were estimated and important process issues identified for each case study.

ISSUES FOR DISCUSSION

To get a broad flavor of the results of the Design Assistance Case Study Evaluation, one would need to read each individual case study. Each of the projects evaluated provides a unique and interesting story. Generalizing the results can be difficult. The case studies are not a statistical analysis. However, the trends evident in the sample group indicate which issues are significant. Specific examples can be used to illustrate program successes and failures.

The following discussion focuses on three issues that are important parts of the program: 1) selection of energy efficiency improvements, 2) long-term educational benefits, and 3) building energy efficiency.

Selection of Energy Efficiency Improvements

Economic factors are often identified as very important in the decision to invest in energy efficiency improvements. However, the participants in the case study sample used a wide range of decisionmaking criteria including economics. One participant characterized their selection process as a "common sense approach."

Efficiency improvements with short paybacks did not have a higher level of installation than those with longer paybacks (Table 5). Recommendations with more than a 10-year payback were accepted.

One explanation is provided by examining the types of efficiency improvements that were installed in the buildings (Table 6). Envelope improvements tended to have longer paybacks. They also had the highest level of acceptance in the case study sample. Insulation improvements are low risk. They do not require additional maintenance and are invisible to building occupants.

In contrast, glazing reduction was suggested in one building and rejected. Even though this recommendation would have reduced both energy cost and initial cost, the building owners wanted the windows. In another project, electric heat pumps

Table 5. Range of Paybacks for Energy Efficiency Improvements

Range (years)	Number of Occurrences Recommended	Installed
0-2	15	10
3-5	8	5
6-10	9	6
10+	9	4

Table 6. Energy Efficiency Improvements by Measure Type

Measure Type	Number of Occurrences Recommended	Installed
Envelope	8	8
Glazing	8	2
Lights	13	7
Controls	2	0
HVAC	8	6
DHW	2	2
Total	41	25

with less than a 2-year payback were rejected in favor of packaged roof-top units with gas heating. Previous maintenance and operating problems with heat pumps and success with gas units caused the building developer to choose gas. Octron (T-8) fluorescent fixtures were rejected at one of the school projects because of apparent supply problems. Instead of choosing energy efficient fixtures as a replacement, the district selected standard four-tube fixtures because they preferred this type of lighting and the resulting classroom lighting levels were higher. The power requirement was also about 30 percent greater.

It is clear that a number of factors affected the decisions leading to which efficiency improvements were selected. Although economic factors were usually considered, personnel preference, building aesthetics, and past experiences all contributed to the decision.

Long-Term Educational Benefits

One of the goals of Design Assistance was to educate participants regarding energy efficient building design. To check this goal, the degree of innovation resulting from the program was examined. Also, participant responses about what they learned were reviewed.

We identified energy efficiency improvements from the case study projects that were innovative (Table 7). This required some subjective judgment because what is considered innovative to some may not be innovative to others. We defined innovative measures in this way: they push the learning curve in the design community and they go beyond common building design practice in the Northwest.

The innovative measures in Table 7 represent about 40 percent of all the measures recommended. About half of these measures were actually installed. Measures that were not considered innovative were commonly found levels of envelope insulation, high-efficiency fluorescent fixtures, optimum start and demand controls, and common HVAC systems.

It would appear that Design Assistance pushed the learning curve in the design community. However, some of the projects were more innovative than others. Four of the innovative measures noted in Table 5 were for one project. Most of the other projects had just one innovative measure, while two did not have any. The potential for innovation in some of the buildings was somewhat limited due to the simple nature of the facility or restrictions established by the design team. Design Assistance did not provide any incentives for innovation, which may have limited the amount of risk designers were willing to take.

Did the participants learn anything from the program? The participants said the experience of being involved in Design Assistance was beneficial. However, it was much more difficult to pin them down on specific things that they learned or how they had applied what they learned. A one-time experience may not be sufficient to cause a change toward more efficient design practice.

Table 7. Innovative Energy Efficiency Improvements

Measure Type	Innovative Improvement (Number of Recommendations)
Envelope	Improved Steel Wall Insulation: Steel stud wall, R-19 Batt between studs, R-4 rigid insulation across studs on inside of wall(1)
Glazing	Low E Double Pane Glazing(4), Glazing Reduction(3)
Lights	Octron (T-8) Fluorescent Fixtures with Electronic Ballasts(4), Daylighting (1)
Controls	none
HVAC	Evaporative Cooling System(1), Variable Speed Drive (1)
DHW	Tankless Hot Water Heater(2)

Several of the design team participants indicated that Design Assistance confirmed energy efficiency improvements they usually recommend. Others said they were already pretty knowledgeable about building energy efficiency and did not learn anything from Design Assistance. In one case, the designteam even questioned the validity of the analysis produced by the Design Assistance consultant.

In the project where four innovative measures were identified, the Design Assistance consultant and the design team indicated they learned a lot about these technologies. However, the design engineer noted there was a time cost for this learning experience. He said they lost money and could not afford to spend as much time on future projects without some form of reimbursement. Several other participants indicated they did not have time to absorb all the information produced by the Design Assistance consultant.

Some program participants did identify actions they had taken as a result of what they learned in Design Assistance. One commented they were now installing R-19 wall insulation and tankless hot water heaters in all their projects. A building owner said the program heightened their energy conservation awareness enough to pursue energy efficiency improvements in several other existing buildings. One of the consultants noted that the interaction the program promoted between the different design professionals had caused his firm to use this model for all their projects. As projects are started, all the designers/engineers are brought together for a brainstorming session and initial coordination.

Building Energy Efficiency

The bottom line measurement of the success of Design Assistance is the impact the program had on the energy efficiency of the resulting buildings. This can be examined in several ways. First, the original energy savings estimates can be compared to savings estimates for the actual building. Second, the energy consumption of the buildings can be compared to other new commercial buildings in the region.

Actual energy savings were not directly measured in any of these buildings. As part of the case studies, the consultants developed computer models for the buildings as they were actually constructed and occupied. The energy savings for the installed energy conservation measures were re-estimated with these as-built computer models. Although these energy savings are only estimates, they do give a more accurate indication of savings than the original Design Assistance models developed when the buildings were only in the design stage.

Table 8 presents estimated and actual energy use data and savings estimates for the case study buildings. Actual Energy Use Intensity (EUI) is

Table 8. Energy Use for the Case Study Buildings

	Actual[2] EUI[1]	Predicted[3] EUI	As-Built[4] EUI	% Energy Reduction[5] Predicted Electric	As-built Electric
Retail	95	76	89	6	10
School	100	41	57	1	-1
School	47	21	44	4	1
Bank	56	84	55	8	23
Medical	96	96	95	0	0
Medical	84	50	81	15	6
Industrial	69	64	60	14	6
Office	91	82	89	7	13
Office	65	43	67	14	22
Office	68	35	76	9	5

[1]EUI = Energy Use Intensity (kBtu/ft^2/year)
[2]Based on actual utility data
[3]Based on the original Design Assistance computer model
[4]Based on the as-built computer model
[5]Electric only. All but three of the buildings are all-electric

based on utility records for the latest year of consumption. Predicted EUI is from the original Design Assistance analysis. The as-built EUI is based on the as-built model developed by the consultants for the case studies. The estimated reduction in electric energy consumption for the original and as-built models is compared to show the impact of the savings estimates on total building consumption.

Many of the buildings are using significantly more energy than initially predicted by the original Design Assistance model. Generally, models are used to predict energy savings and not absolute building energy consumption. However, when the difference in absolute consumption is as great as shown in Table 8 for many of the cases, the accuracy of the predicted savings is questionable.

The level of impact of Design Assistance on the total energy consumption in these buildings was fairly small. The predicted percent reduction in electric consumption was less than 10 percent for most of the buildings and several buildings showed almost no reduction.

There are some significant differences between the predicted and as-built energy savings for some of the buildings. In half the cases, the as-built energy savings estimate (in kWh) differs by more than a factor of two from the original predicted savings.A number of factors limit the energy efficiency of these buildings and the accuracy of the original energy performance predictions. These include operation and control of the facility, changes in building design and use after the Design Assistance consulting, difficulties in modeling a building that does not exist, and the very limited impact of the program in some of the buildings.

Control and operation of these facilities seem to be major factors impacting energy consumption. In many cases, the buildings are not being operated in an optimum fashion.

At one of the schools, the building schedules had not been entered into the controller, so the building was operating several hours longer than necessary. School holidays had not been scheduled. Several areas of the building were used primarily in the evenings, yet these spaces were scheduled with the rest of the building, even though the capability existed to schedule them separately. An override timer was used in the evening. The control system in this building is fairly sophisticated, yet it was not set to operate the building in an optimum fashion.

In another case, the energy management control system was described as not very user friendly by the only person in the building who knew how to operate it. As a result, many of the occupants would override the system and set it to manual mode, particularly during non-business hours. The next day the building operator would discover the building had been in manual mode all night.

It often takes several years to work out the bugs in a building and get it performing optimally. This is particularly true of learning how to operate a control system because these buildings have only been in operation for 1 to 2 years, their performance may improve over time.

There were changes in the building designs after the Design Assistance modeling was conducted. In some cases this resulted in a less efficient building. It was also common to have greater levels of occupancy and higher equipment loads in the buildings than was originally predicted by the modelers. For example, a pasta manufacturer occupies a significant amount of space in the light industrial building. The processing energy load from this operation was not included in the original modeling.

Also, one must consider what degree of accuracy can be expected of a computer model of a building in the early stages of design. There are many factors about the building that are unknown. Information about tenant characteristics is often limited. Many design features can be changed as the design proceeds to later stages. Finally, the as-built facility may not operate as it was designed.

The level of predicted energy savings in most of these buildings is small. Low levels of energy savings are generally more difficult to predict accurately because they are very sensitive to the assumptions made in creating the building computer model. Even minor changes in actual building operation can have significant impacts on small energy savings estimates.

Even though the impact of the program was small, it does appear cost effective. The average as-built electric savings per case were about 61,000 kWh/year. Considering program costs and estimated incremental costs of the conservation measures (excluding natural gas measures) to the buildingowner/developer, the cost per kWh saved was about 3 cents/kWh, which is a little less than two thirds the regional cost-effective limit for conservation. However, it is clear from Table 8 that some cases were much more cost effective than others.

These savings estimates are probably overstated because they assume the program caused the installation of the energy efficiency improvements. However, some of the participants indicated they would have installed some of the recommended energy efficiency improvements even without Design Assistance. Estimating savings in new buildings is difficult because it is hard to determine how the building would have been constructed if there was no conservation program.

An alternative method to evaluate the energy performance of the Design Assistance buildings is to compare their energy use with other new commercial buildings in the region. Table 9 shows the actual EUI (from utility records) for the Design Assistance buildings and a comparable EUI for commercial buildings in the Pacific Northwest. The comparable EUI is derived from information in the most recent Northwest Power Plan Supplement (Northwest Power Planning Council 1989). Data are for current practice buildings except for one of the offices and one of the schools, which were remodeled existing facilities. Instead of a single number, a range is shown, since a building's EUI is very dependent on the activities that occur in the facility.

The actual energy consumption for all the buildings is similar to the energy use for current practice buildings. Four of the buildings exceed the comparable range. One is slightly below the comparable

Table 9. Comparable Energy Use for Northwest Commercial Buildings

	Actual[2] EUI[1]	Comparable[3] EUI
Retail	95	61-75
School	100	74-90
School	47	37-45
Bank	56	61-75
Medical	99	80-96
Medical	84	80-96
Industrial	69	63-77
Office	91	83-101
Office	65	65-79
Office	68	65-79

[1]EUI = Energy Use Intensity (kBtu/ft^2/year)
[2]Based on actual utility data
[3](Northwest Power Planning Council 1989): Values represent current practice (1980 construction) except for the first school and office.

range, while several others are toward the lower end of the range. None of the Design Assistance cases is notably energy efficient relative to the comparable buildings.

CONCLUSIONS

Based on the case studies, it appears Design Assistance delivered cost-effective energy conservation. Participants reacted favorably to the simple nature of the program and the experience they gained.However, the program had limited impact on the efficiency of the buildings. None of the case study buildings is notably energy efficient. The case studies show that providing the client with economic information on energy efficiency improvements early in the building design is not sufficient to ensure building energy efficiency. The accuracy of the original Design Assistance energy savings predictions was poor. This was due to the difficulties of accurately modeling a building that is in some stage of design.

The Northwest region is moving from a period of energy surplus to energy acquisition. Commercial conservation programs will need to deliver higher levels of cost-effective conservation. With this in mind, the following recommendations for future programs for new commercial buildings are suggested:

1. The program needs to be more flexible and targeted to the specific needs of the client. A broader range of design services are needed. Computer modeling is not necessary for all buildings. For example, quality design guides and a design assistance hot line might be more appropriate for simple buildings.
2. Services need to be available throughout the design process. Important decisions are made in all phases of the building design. Design teams need to be encouraged to take responsibility for the efficiency of their buildings.
3. Some form of builder operator training and building commissioning need to be provided. A well-designed building does not automatically operate efficiently. Additional follow-up may be necessary to ensure long-term energy efficiency.
4. Some form of incentives both to the designers and building owners/developers may be required if the program wants all cost-effective energy efficiency improvements to be installed in the building.

When considering these recommendations, it is important to remember that one of the things participants liked about the Design Assistance Program was that it was simple, with minimal red tape. Future programs should avoid the temptation to add lots of program steps with many different checks to ensure the building is saving energy. The program can not force people to be energy efficient. Instead, it must show them that energy efficiency is in their best interest.

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