DEMONSTRATED COST AVOIDANCE THROUGH BUILDING ENERGY SIMULATIONS AND ECONOMIC ANALYSES

STEVEN P. KIMSEY, A.I.A.
ANDREW T. SMITH
Heery Energy Consultants, Inc. Atlanta Ga.

ABSTRACT - This paper discusses the effectiveness of energy cost avoidance consulting services for architects and engineers. Significant savings in both energy operating costs and construction costs are demonstrated through comparative analyses of alternative Energy Conservation Measures (ECM's). Case Studies applying the DOE-2 building energy simulation program, Summary (A micro-based post processor for DOE-2), and MECON (Micro-based ECONomic analysis program) are presented.

INTRODUCTION

Energy and economic analyses are playing an increasing role in building design services as designers and owners demand greater operating cost control. Computer-based comparative analyses can be an effective tool in identifying, in economic terms, the relative importance of energy conservation. The results of such analyses enable the architect and owner to make energy related design decisions more intelligently.

The benefits of comparative energy analyses to the client include:

- Lower energy operating costs than comparable facilities.
- Competitive returns on energy related capital investments.
- Enhanced interior environmental quality.
- Higher level of building systems control and overall operational efficiency.

The ASHRAE standard "Energy Conservation in New Building Design" recognizes the importance of computer-based analyses through the performance option to code compliance. Sophisticated computer simulations, such as DOE-2, provide the designer with the ability to develop a dynamic building model that can respond to design changes and evaluate energy efficiency. The computer analyses also provide the design team with engineering based information to support recommended energy conservation measures.

The following methodology and case studies represent energy consulting services provided to corporate clients. They illustrate insight and experience gained through applying computer tools in the building design industry.

COMPARATIVE ANALYSIS METHODOLOGY

Comparative energy analysis involves establishing a benchmark energy budget, based on the initial building program and recommended energy design criteria. Proposed Energy Conservation Measures (ECM's) are then evaluated in comparison to the benchmark. The building design is monitored throughout the design process to assure energy efficiency and to review the cost-effectiveness of proposed ECM's. Using the building program (including recommended energy criteria) and preliminary building concepts, the design team identifies opportunities for energy conservation in the architectural, mechanical and electrical systems. Energy and economic analyses of alternative design strategies are performed to determine the most cost-effective measures. Energy analyses are performed using the DOE-2 building simulation program. Economic analyses, based on the client's economic criteria and local utility rates, are performed using two microcomputer based programs described below.

DOE-2 is a public domain computer program which can be used to explore the energy characteristics of buildings and their associated heating, ventilating, and air conditioning (HVAC) systems. Incorporating mathematical models and utilizing hourly weather data, DOE-2 calculates the hour by hour performance and response of a building whose description has been provided by the designer.

Summary is a microcomputer based post processor for DOE-2. It incorporates local utility rate schedules and DOE-2 monthly kilowatt-hour and kilowatt demand output to calculate the cost of purchasing energy.

MECON uses the cost output from the Summary program, building component cost data, and client economic criteria to calculate comparative Life-Cycle Costs. Net present value, simple payback after tax, discounted payback after tax, internal rate of return before tax, and cash flow summaries are typical results of the program.

CASE STUDY ONE: NEW BUILDING

Project:	MILICO/FANS Office Development
Client:	Massachusetts Indemnity Life Insurance Co.
Location:	Gwinnett County, Georgia
Area:	151,740 Gross Square Feet
Design Completed:	1984

Building Description

The final design for the MILICO/FANS Office consists of two adjoining 2-story 75,000 GSF office buildings separated by a 2-story atrium entrance. Exterior walls are constructed of insulated precast concrete panels. The windows are 1 inch reflective thermopane in an anodized aluminum framing system. The typical interior lighting source is a parabolic fluorescent fixture. Packaged Variable Air Volume (VAV) rooftop units serve interior VAV boxes and perimeter Powered Induction Units (PIU's).

Economic Scenario

MILICO/FANS contracted with a developer at a fixed sum to build and lease the facility. Therefore expenditures for ECM's involved the reallocation of existing funds within the construction budget. ECM's that significantly reduced first cost as well as operating cost were desirable. A two year simple payback was established by the client.

Energy Services Provided

Energy design consulting services were provided from Schematic Design through Design Development. The energy related goals were:

- To achieve a cost-effective level of energy conservation in the building design.
- To ensure a high quality occupant environment to support personnel productivity.

Comparative Analyses

A number of Energy Conservation Measures (ECM's) for reducing energy operating costs of the proposed facility were evaluated. Table 1 summarizes the comparative analyses results for the major ECM's identified for the project. The initial proposed design included several energy conservation features established in the programming phase such as additional insulation and an efficient VAV air distribution system. The ECM's shown in Table 1,

TABLE 1:
COMPARATIVE ANALYSES RESULTS

ECM Descriptions	DOE-2 Simulation Parameters
1. Efficient Light Fixtures - Energy efficient parabolic fixtures compared to standard fixtures.	Adjusted lighting watts per sq.ft. Demand, consumption and cooling load reductions resulted (36 tons).
2. Efficient Lamps and Ballasts - Energy efficient lamps and ballasts compared to standard lamps and ballasts.	Adjusted lighting watts per sq.ft. Demand, consumption and cooling load reductions resulted (22 tons).
3. Reflective Glazing - Reflective glazing compared to tinted glazing.	Adjusted glass conductance and shading coefficient. Demand, consumption and cooling load reductions resulted (20 tons).
4. Electric Meter Totalization - One meter for two tenants in comparison to two meters.	Utility cost calculated based on one meter versus two separate meters, using DOE-2 output.
5. Additional Roof Insulation - Increase roof insulation from R-10 to R-20.	Adjusted roof U-value and description. Nominal savings.
6. Centrifugal Chiller - Central plant with centrifugal chiller compared to multiple DX cooling units.	Revised cooling system plant description to centrifugal chiller. Demand, and consumption reductions resulted.
7. HVAC EMS - Incorporate an HVAC Energy Management System (EMS).	Estimated effect on schedules for tighter control of building systems.

were evaluated for greater energy and cost reductions. The initial design was estimated to use 48,550 Btu's/GSF/Year (excluding office equipment) and $156,179 or $1.03/GSf /Year. The final energy design was estimated to use 33,290 Btu's/GSF/Year and $87,050 or $0.57/GSF/Year.

Modelling Techniques

The MILICO/FANS building design presented several modelling problems. The two-story atrium, to be modelled accurately, needed to consider stratification within the large volume. The space was divided into two zones vertically and the upper zone assigned a higher temperature. Defining the walls bordering the atrium as air-walls, and then changing the air-wall to single pane and double pane glazing, allowed the evaluation of alternate atrium/building interface strategies. Powered Induction Units (PIU's) are not a system option currently available in the DOE-2 program. The PIU heating coils were simulated as thermostatically controlled baseboard and the PIU fans as exhaust fans (series flow).

Definitions:

DOE-2 Simulation Parameters - Adjustments to the computer model to simulate the ECM.

Additional First Cost - Cost above standard or base component.

First Cost Savings - Deferred construction cost due to ECM.

Net Additional First Cost - Developer added cost due to ECM above original contract.

Annual Energy Cost Savings - Energy operating cost saved due to ECM.

Simple Payback - Ratio of Net Additional First Cost to Annual Energy Cost Savings.

Internal Rate of Return - Rate of return using a 10 year lease period, 4 % inflation and 6% energy escalation, indicating investment potential.

Implemented - Yes = ECM selected by client.

ECM	Additional First Cost	First Cost Savings	Net Additional First Cost	Annual Energy Cost Savings	Simple Payback (Years)	Internal Rate of Return	Implemented (Yes/No)
1.	$ 32,400	$ 54,054	$ 0	$ 27,475	< 1	> 1000	Yes
2.	$ 32,400	$ 33,033	$ 0	$ 15,525	< 1	> 1000	Yes
3.	$ 39,420	$ 30,030	$ 0	$ 810	< 1	> 1000	Yes
4.	$ 0	$ 0	$ 0	$ 3,600	< 1	> 1000	Yes
5.	$ 69,797	$ 0	$ 69,797	$ 119	> 25	0	No
6.	$100,000	$ 0	$100,000	$ 18,108	4.6	21	No
7.	$110,000	$ 49,500	$ 60,500	$ 8,756	6.9	16	Yes

CASE STUDY TWO: EXISTING BUILDING

Project:	600 West Peachtree Tower
Client:	Jaymont Properties, Inc.
Location:	Atlanta, Georgia
Area:	436,673 Gross Square Feet
ign Completed:	1984

Building Description

The 600 West Peachtree Tower consists of an existing 29-story office building to be renovated and modernized. The building includes tenant office spaces, a ground floor bank, several computer floors, a cafeteria floor, and various supporting areas. The exterior envelope is marble faced precast concrete with integrated vertical windows. The typical interior light source is a 3-foot by 3-foot fluorescent fixture. Two central air-handling units serve interior Constant Volume Reheat (CVR) and perimeter VAV Reheat/Baseboard on each floor.

Economic Scenario

This project involved the renovation and modernization of the existing building to provide features that reduced building operating costs. The reduced costs would be passed on to leased tenants through competitive rental rates. A simple payback of two years for ECM's was established by the client.

Energy Services Provided

A comprehensive engineering analysis for the 600 West Peachtree Tower renovation and modernization project was performed. The primary goals were:

- To determine cost-effective renovation and modernization alternatives within the constraints of the client's budgeted program; considering construction, energy and other operating costs.
- To evaluate the operational status of the existing building electrical, lighting and HVAC systems.

TABLE 2:
COMPARATIVE ANALYSES RESULTS

ECM Descriptions	DOE-2 Simulation Parameters
1. New Efficient Light Fixtures - Replace existing 3 x 3 fixtures with 2 x 4 parabolic.	Adjusted lighting watts per sq. ft. Demand, consumption and cooling load reductions resulted.
2. Retrofit VAV System - Upgrade existing interior Constant Volume Reheat (CVR) and Perimeter VAV Reheat to all VAV/Baseboard.	Revised system description.
3. Retrofit VAV/PIU System - Upgrade existing interior CVR and perimeter VAVR to VAV/PIU.	Revised system description.
4. Retrofit CVR/PIU System - Retain existing interior CVR and upgrade perimeter VAVR to PIU.	Revised system description.
5. New Waterside Economizer - Retrofit existing chilled water system to allow for direct cooling from cooling towers.	Revised plant description.
6. Driveline Modification - Retrofit existing chiller with new driveline and compressor for higher efficiency.	Revised chiller performance curves.
7. Attenuator Removal - Remove return air sound attenuators.	Revised return air static pressure.
8. New Single Electric Meter - Replace existing two separate meters with one. Add one 4160/480 transformer.	Recalculated utility cost based on one meter using DOE-2 output.
9. New Eddy Current Clutch - Replace inlet vane guide fan control on central AHU's with Eddy Current Control.	Revised AHU fan performance curves.

Comparative Analyses

A major task of the modernization program was the development of ECM's to reduce energy operating costs. The principal tool used to evaluate proposed measures was the DOE-2 energy simulation program, along with the cost analyses programs. A detailed computer model of the existing building and systems was developed and used to evaluate proposed ECM's. Table 2 summarizes the comparative analyses results for the major ECM's identified for the project. The existing design was estimated to use 99,515 Btu's/GSF/Year and $654,302 or $1.50/GSf /Year. The retrofit energy design was estimated to use 75,785 Btu's/GSF/Year and $475,039 or $1.09/GSF/Year.

Modelling Techniques

Extensive effort was put into visiting the existing 600 West Peachtree Tower and verifying actual building information for the DOE-2 input. Occupancy and office equipment schedules were developed by monitoring building activities. A detailed lighting and office equipment inventory was taken. Numerous DOE-2 simulations were necessary to fine tune the model to match building utility bills from the previous year. The PIU heating coils were modelled as thermostatically controlled baseboard and the PIU fans as outdoor-reset baseboard (parallel flow).

Definitions

Installation Cost - Cost of ECM retrofit. For new applications this includes the cost differential to standard systems.

Annual Energy Cost Savings - Energy operating cost saved due to ECM.

Simple Payback - Ratio of Net Additional First Cost to Annual Energy Cost Savings.

Implemented - Yes = ECM selected by client.

ECM	Installation Cost	Annual Energy Savings	Simple Payback (Years)	Implemented (Yes/No)	Comments
1.	$159,375	$ 18,644	8.55	Yes	ECM 1 applied to existing building model.
2.	$254,600	$ 86,417	2.90	Yes	ECM 1 and 2 combined in simulation.
3.	$462,100	$ 96,055	4.80	No	ECM 1 and 3 combined in simulation.
4.	$397,500	$ 89,829	4.40	No	ECM 1 and 4 combined in simulation.
5.	$695,092	$172,586	4.00	No	ECM 1, 2 and 5 combined in simulation.
6.	$721,866	$177,919	4.10	Yes	ECM 1, 2 and 6 combined in simulation.
7.	$ 2,400	$ 1,344	1.80	Yes	ECM 7 applied to existing building model.
8.	$299,600	$101,286	3.00	Yes	ECM 1, 2 and 8 combined in simulation.
9.	$302,600	$147,773	2.00	Yes	ECM 1, 2 and 9 combined in simulation.

FIGURE 1

EXAMPLE SUMMARY OUTPUT

CHILLER VERSUS DX COMPARISON

UTILITY COST ANALYSIS SUMMARY

Project: MILICO/FANS — File Name: BAS201
Location: GWINNETT CO. GA. — Analysis Date 09/17/84
Run Description: 1.5/DX/TG/RF10/SL

	ELECTRICITY			GAS		TOTAL
MONTH	MONTHLY CNSMPTN (KWH)	BILLING DEMAND (KW)	MONTHLY COST ($)	MONTHLY CONSUMPT'N (THERMS)	MONTHLY COST ($)	TOTAL COST ($)
JAN	241929	1101	19055.64	0.00	0.00	19055.64
FEB	211407	1101	17838.97	0.00	0.00	17838.97
MAR	245976	1101	19171.52	0.00	0.00	19171.52
APR	286932	1101	20344.16	0.00	0.00	20344.16
MAY	306999	1101	20918.70	0.00	0.00	20918.70
JUN	311221	1135	21309.46	0.00	0.00	21309.46
JUL	341771	1159	22368.56	0.00	0.00	22368.56
AUG	341888	1146	22274.52	0.00	0.00	22274.52
SEP	302990	1152	21205.51	0.00	0.00	21205.51
OCT	282052	1101	20204.43	0.00	0.00	20204.43
NOV	236698	1101	18905.89	0.00	0.00	18905.89
DEC	242905	1101	19083.61	0.00	0.00	19083.61
ANNUAL	3352768		242680.96	0.00	0.00	242680.96

Project: MILICO/FANS — File Name: CHL201
Location: GWINNETT CO. GA. — Analysis Date 09/17/84
Run Description: 1.5/CHLR/TG/RF10/SL

	ELECTRICITY			GAS		TOTAL
MONTH	MONTHLY CNSMPTN (KWH)	BILLING DEMAND (KW)	MONTHLY COST ($)	MONTHLY CONSUMPT'N (THERMS)	MONTHLY COST ($)	TOTAL COST ($)
JAN	257566	967	18345.12	0.00	0.00	18345.12
FEB	225567	967	17428.95	0.00	0.00	17428.95
MAR	251002	967	18157.20	0.00	0.00	18157.20
APR	268469	967	18657.31	0.00	0.00	18657.31
MAY	281071	967	19018.11	0.00	0.00	19018.11
JUN	276710	987	19112.29	0.00	0.00	19112.29
JUL	301957	1018	20124.16	0.00	0.00	20124.16
AUG	301106	989	19837.99	0.00	0.00	19837.99
SEP	271729	1015	19235.65	0.00	0.00	19235.65
OCT	268782	967	18666.27	0.00	0.00	18666.27
NOV	237966	967	17783.95	0.00	0.00	17783.95
DEC	252705	967	18205.95	0.00	0.00	18205.95
ANNUAL	3194630		224572.95	0.00	0.00	224572.95

NOTES:

1. ENERGY CONSUMPTION AND PEAK DEMAND QUANTITIES OBTAINED FROM DOE 2.1B OUTPUT REPORT PS-B.
2. ELECTRIC RATE SCHEDULE BASED ON LATEST AVAILABLE DATA FROM GEORGIA POWER RATE SCHEDULE PL-6, JANUARY 1984.

FIGURE 2

EXAMPLE SUMMARY ENERGY AND ECONOMIC OUTPUT

CHILLER VERSUS DX COMPARISON

BUILDING ENERGY PERFORMANCE SUMMARY

Project:	MILICO/FANS	File Name:	MILICO
Location:	GWINNETT CO. GA.	Analysis Date:	09/17/84
Alternate Study:	DX vs CHILLER	1.5 EQUIP	

RUN NAME	DESCRIPTION	TOTAL ENERGY	HEATING ENERGY	COOLING ENERGY	AUXILIARY ENERGY	LIGHTING ENERGY	EQUPMNT ENERGY	SUMMER DEMAND (Kw)	WINTER DEMAND (Kw)
		(All Units in BTUs per Gross Square Foot)							
BAS201	1.5/DX/TG/RF10/SL	75,440	1,010	14,310	5,920	25,510	26,890	1159	1148
CHL201	1.5/CHLR/TG/RF10/SL	71,880	1,010	9,620	7,050	25,510	26,890	1018	999

NOTES:

1. Domestic Hot Water Energy Consumption is 1300 BTUs per Gross Square Foot.
2. Vertical Transportation Energy Consumption is 490 BTUs per Gross Square Foot.

ECONOMIC ANALYSIS FOR : MILICO/FANS
GWINNETT CO. GA.

NET PRESENT VALUE	=	$29967
SIMPLE PAYBACK AFTER TAX	=	4.6 YRS
DISCOUNTED PAYBACK AFTER TAX	=	7.3 YRS
INTERNAL RATE OF RETURN BEFORE TAX	=	21.29 %

CASH FLOW SUMMARY

YEAR	(1) UNDISCOUNTED ANNUAL ENERGY COST SAVINGS $	(2) UNDISCOUNTED NET ANNUAL COST SAVINGS $	(3) DISCOUNT RATE=15.00% NET ANNUAL COST SAVINGS $	(4) DISCOUNTED CASH FLOW WHICH EQUALS FIRST COST $
		-100000	-100000	-100000
1	18108	18108	15746	14929
2	19919	19919	15061	13539
3	21911	21911	14407	12279
4	24102	24102	13780	11136
5	26512	26512	13181	10099
6	29163	29163	12608	9159
7	32079	32079	12060	8306
8	35287	35287	11536	7533
9	38816	38816	11034	6831
10	42698	42698	10554	6195
TOTAL	288595	288595	129967	

CONCLUSIONS

The interface of the energy consultant with the other design team members can greatly influence the acceptance of proposed ECM's. The development of the lationship should emphasize the team approach in .ich the energy consultant provides needed information for decision making at the critical points within the design process. Design experience and creativity are needed to develop innovative concepts. A planned approach will enhance the design teams ability to incorporate effective energy conservation strategies.

The usefulness of energy and economic comparative analyses is directly related to the accuracy of the input data and understanding of the computer model. The following guidelines should be observed to assure that useful energy and economic information is developed:

DOE-2

- For new buildings obtain the latest drawings and specifications.
- For existing buildings use actual field measured data when possible.
- Use specific product information; performance curves, efficiencies, etc. when available rather than default values.
- Verify that default values are appropriate for each alternative, and compare default values to current engineering practice.
- Understand how each input data is used by the computer model.
- Document and review with the design and client all assumptions made.
- Develop standard procedures for checking output.

Utility Calculations

- Obtain the most recent utility rate schedule from the local utility company. Include any applicable fuel cost adjustments and local/state taxes.
- Verify computer calculations with known utility bills and hand calculations.

Economic Calculations

- Obtain client's economic criteria and review all assumptions.
- Verify computer calculations with known case studies and hand calculations.

Economic indicators for proposed Energy Conservation Measures, developed using computer-based comparative analyses, were presented for two case studies. Significant energy operating cost savings as well as construction cost savings were achieved through a planned energy evaluation process including the use of computer analyses. The analyses provided useful economic guidelines for implementing energy saving building concepts. The incorporation of many of the cost-effective measures into the building designs, demonstrates the useful application of computer simulations as a design tool.

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