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Retrofit Conservation Alternatives for Standard Army Designs

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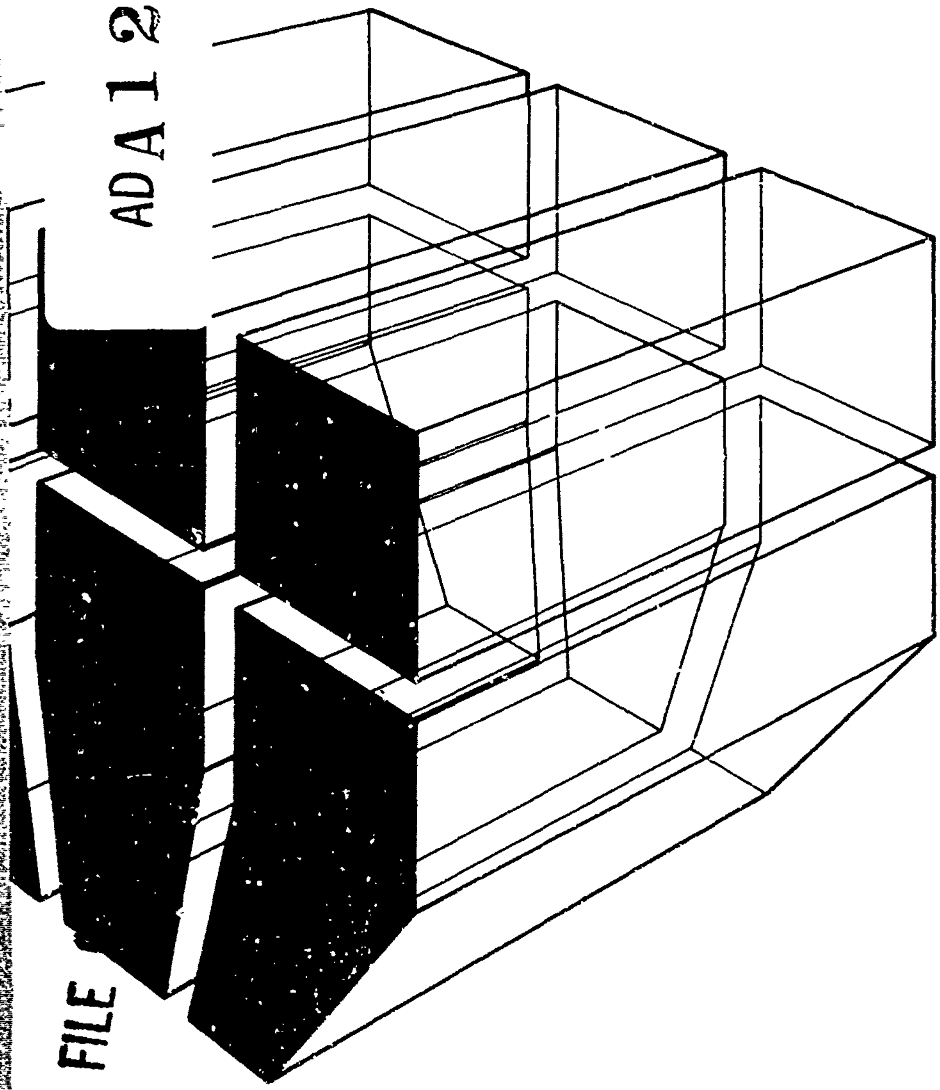
ANALYSIS OF ENERGY CONSERVATION ALTERNATIVES FOR STANDARD ARMY BUILDINGS



by
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This report describes energy conservation alternatives for five standard Army building design[illegible] [illegible]y surveying maps of major Army installations and using the Integrated [illegible]acilities System, the most popular designs were determined to be a two-company, rolling-pin-shaped barracks for enlisted personnel; a Type 64 barracks; a motor repair shop; a battalion headquarters and classroom building; and an enlisted personnel mess hall.

(Continued on next page)

BLOCK 20. (Continued)

The Building Loads Analysis and System Thermodynamics (BLAST) energy-analysis computer program was used to develop baseline energy consumption for each design based on the building descriptions and calibrated by comparison with the measured energy usage of similar buildings. Once the baseline was established, the BLAST program was used to study energy conservation alternatives (ECAs) which could be retrofit to the existing buildings. The ECAs included closing off air-handling units, adding storm windows, adding 2 in. (0.051 m) of exterior insulation to the walls, partially blocking the windows, adding roof insulation, putting up south overhangs, installing programmable thermostats, recovering heat from exhaust fans, installing temperature economizers, replacing lights, and installing partitions between areas of differing temperature.

The viability of the ECAs was decided using the Army's Energy Conservation Investment Program (ECIP) criteria. Through FY84, all retrofits must have a benefit-to-cost ratio of greater than 1 and have an energy-to-cost ratio greater than those values given in ECIP guidelines. As of FY85, the retrofits will be ranked based on Savings Investment Ratios (SIRs).

The results of combining the BLAST models with the ECIP guidelines to find desirable ECAs were sizeable predicted decreases in the energy consumption of the five buildings. Under both sets of guidelines, the average energy consumption could be decreased 32 and 40 percent for the rolling-pin-shaped barracks and the enlisted personnel mess hall, respectively. The three remaining buildings are also affected by the guideline changes: under the criteria in effect through FY84, ECIP projects for the Type 64 barracks, the motor repair shop, and the battalion headquarters could realize average energy reductions of 33, 33, and 48 percent, respectively. With the new guidelines, the decreases would be 41, 35, and 50 percent, respectively, since additional projects are justified based on SIR.

The total energy savings, if all suggested retrofits were undertaken, would be 1.79×10^6 MBtu/year (1.8×10^6 GJ/year) under the old guidelines. With the new guidelines, the energy savings would be 2.13×10^6 MBtu/year (2.2×10^6 GJ/year) for oil heating and 2.00×10^6 MBtu/year (2.1×10^6 GJ/year) for gas heating.

FOREWORD

This work was performed for the Assistant Chief of Engineers under Project 4A762781AT45, "Energy and Energy Conservation"; Task Area B, "Insulation and Conservation Strategy"; Work Unit 002, "Retrofit Conservation Alternatives for Standard Army Designs." Mr. B. Wasserman, DAEN-ZCF-U, was the Technical Monitor.

The work on the rolling-pin-shaped barracks and the Type 64 barracks was done by the Energy Systems (ES) Division of the U.S. Army Construction Engineering Research Laboratory (CERL). Mr. R. G. Donaghy is the Chief of CERL-ES. Appreciation is expressed to Mr. C. Mack of CERL for compiling the standard building data and to Mr. G. Brassington and Mr. J. C. Gaines of the staff of the Facilities Engineer and Mr. G. Bean and Mr. P. Motte of the Photography Laboratory at Fort Bragg, NC.

The evaluation of the motor repair shop, the battalion headquarters, and the enlisted personnel mess hall was done under contract by the Energy Applications group at GARD, the research and development subsidiary of GATX, where Mr. Robert Henninger and Mr. Ken Spalding were the Principal Investigators.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

TABLES

TABLES (Cont'd)

TABLES (Cont'd)

TABLES (Cont'd)

FIGURES

FIGURES (Cont'd)

ANALYSIS OF ENERGY CONSERVATION ALTERNATIVES
FOR STANDARD ARMY BUILDINGS

1 INTRODUCTION

Background

The dramatic increase in fuel prices in recent years has made the Army acutely aware that it is a large energy user. Because of the economic implications of high fuel costs, the Army has set stringent goals for reducing its FY85 facilities energy consumption by 20 percent from FY75, and by another 20 percent (a total of 40 percent) by the year 2000.[1] To meet these goals, new energy-conservative building designs and operation strategies must be developed and existing buildings must be examined to see how they can be retrofit to be more energy efficient.

The Energy Conservation Investment Program (ECIP) was established to achieve 12 percent of the 20 percent FY85 energy reduction goal.[2] Under the initial guidelines, the ECIP was designed to identify those retrofit projects with the largest energy savings to cost-of-retrofit ratio. To see whether a building retrofit can meet ECIP criteria, the energy savings and cost of the retrofit must be analyzed. To do this, an energy (MBtu) to retrofit construction cost ($1000) ratio (E/C) is calculated. If the E/C ratio is above the minimum for that fiscal year,[3] a DD Form 1391 is submitted for project approval.

Recently, new draft ECIP guidelines were issued. Beginning in FY85, the ECIP's main objective will be cost-effective, energy-conservative facility retrofit. With this emphasis, projects shall be ranked based on their greatest potential life-cycle cost payback, as indicated by a Savings-to-Investment Ratio (SIR).[4]

Each major Army installation has a large number of buildings, which, although the location and mission of each installation may differ, have the same function (e.g., barracks, motor repair shops, mess halls, battalion headquarters). Because of this, the Army has developed standard designs for these common buildings. Only slight modifications are made to these basic designs, depending on an installation's location and mission. Standard designs built in large numbers are prime candidates for ECIP analysis. If retrofits to these standard designs can be analyzed easily while accounting for differences in climatic region, the Army could quickly do an ECIP analysis on many buildings.

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1 E. C. Meyer, Army Energy Plan (Department of the Army [DA], 8 August 1980), pp 3-6 and 3-7.
2 David M. Crabtree, "Energy Conservation Investment Program (ECIP) Guidance," Letter to Army Commanders, 7 November 1977.
3 Crabtree, p 1.
4 Millard Carr, "Redrafted ECIP Guidance -- Action Memorandum," Memorandum for Defense Energy Policy Council (12 May 1982).

The most efficient way to provide the ECIP calculations needed for potential ECIP projects at installations around the country is to do a one-time analysis of standard designs for several climatic regions using a detailed energy analysis tool. Also, by following the approach described below, ECIP data for additional projects can be provided even if a building has already been modified to conserve energy.

Objective

The objective of this investigation was to (1) determine what cost-effective retrofit conservation options can be applied to five standard Army buildings that have been constructed in large numbers at major Army installations and (2) define, by example, the process of analyzing energy conservation options.

Approach

1. Survey major Army installations for standard building designs.

2. Select standard designs built in large numbers that have a potential for ECIP projects.

3. Group the locations of the standard designs by climatic region.

4. Determine which climatic zones should be studied and select a representative city and corresponding weather tape for each zone.

5. Obtain building plans and data for each of the standard designs studied.

6. Visit the site of the actual plans to confirm their accuracy.

7. Review the documentation and create input models (data files) to simulate the energy consumption of the standard (baseline) designs using the Building Loads Analysis and System Thermodynamics (BLAST) computer program.[5, 6]

8. Calibrate the baseline models to reflect measured annual energy budgets now being experienced for these types of buildings.

9. Cut the cost of running the computer program by reducing the detail of the BLAST models to the minimum amount needed for accurate results.

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[5] D. C. Hittle, The Building Loads Analysis and System Thermodynamics (BLAST) Program, Version 2.0, Users Manual, Vols I and II, Technical Report (TR) E-153/ADA072272 and ADA0722730 (U.S. Army Construction Engineering Research Laboratory [CERL], June 1979).

[6] D. Herron, G. Walton, and L. Lawrie, Building Loads Analysis and System Thermodynamics (BLAST) Program Users Manual — Volume I Supplement, Version 3.0, TR E-171/ADA099054 (CERL, March 1981).

10. Identify possible energy conservation alternatives (ECA) for each standard design, including a review of selected Energy Engineering Analysis Program (EEAP) studies. ECAs not previously identified in EEAPs should also be considered.

11. Minimize the number of runs by using preliminary analysis to reduce the number of ECAs to be considered. Create a plan for performing a parametric analysis which covers the range of investigation.

12. Estimate the cost to implement each ECA.

13. Perform a BLAST analysis for a given building and location using the baseline models and each individual retrofit option (installed separately).

14. Calculate the E/C and benefit/cost (B/C) ratios for each retrofit option.

15. Rank order the retrofit options having acceptable B/C ratios on the basis of decreasing E/C.

16. Perform additional BLAST analyses (as required) to account for any synergistic effects that may occur when implementing several ECAs as an ECIP project.

17. Recommend (by climatic region) the ECIP projects to be submitted for each standard design.

While some EEAP studies analyze one or more buildings of standard design, these studies are usually limited to only a few conservation alternatives. The approach taken to produce the results described in this report was to analyze each standard building design in much greater detail. This was done by using <u>one</u> analysis method (the BLAST computer program) to evaluate the energy savings potential of conservation alternatives. Once the BLAST input data were prepared for each building, it was relatively easy to change the data to consider conservation alternatives. This allowed energy savings estimates to be made for the conservation alternatives taken alone or in combination with other alternatives.

The impact of the order in which the alternatives could be implemented was also analyzed. For example, a building could be insulated before adding storm windows or storm windows could be installed first, followed by an insulation project. The cost and energy effectiveness as measured by the SIR and E/C ratio might be different for each of these ECAs, depending on which project is implemented first.

Scope

This report describes conservation alternatives for only these five standard Army buildings:

1. Two-company rolling-pin-shaped barracks for enlisted personnel.

2. Type 64 barracks.

3. Motor repair shop.

4. Battalion headquarters.

5. Enlisted personnel mess hall.

The buildings designs were assumed not to have had energy conservation retrofits. However, if they have been retrofit, the Facility Engineer can use the results of the parametric analysis presented in this report to determine whether the usefulness of proposed retrofits will be diminished by previous ECIP projects.

For each of the buildings, energy savings estimates are given for each conservation alternative for five different climatic zones (see Figure 1). Climatic data from the following cities were used to typify each climatic zone:

1. Colorado Springs, CO (Zone 1)

2. Columbia, MO (Zone 2)

3. Raleigh, NC (Zone 3)

4. Phoenix, AZ (Zone 4)

5. Fort Worth, TX (Zone 5).

Organization of Report

Chapter 2 describes each of the buildings analyzed in detail by BLAST. Chapter 3 describes baseline energy consumption estimates for each building in each climatic region. Chapter 4 describes the process of evaluating ECAs. Chapter 5 presents the results of these evaluations.

Mode of Technology Transfer

It is recommended that the results of this study be abstracted in an Engineer Technical Note.

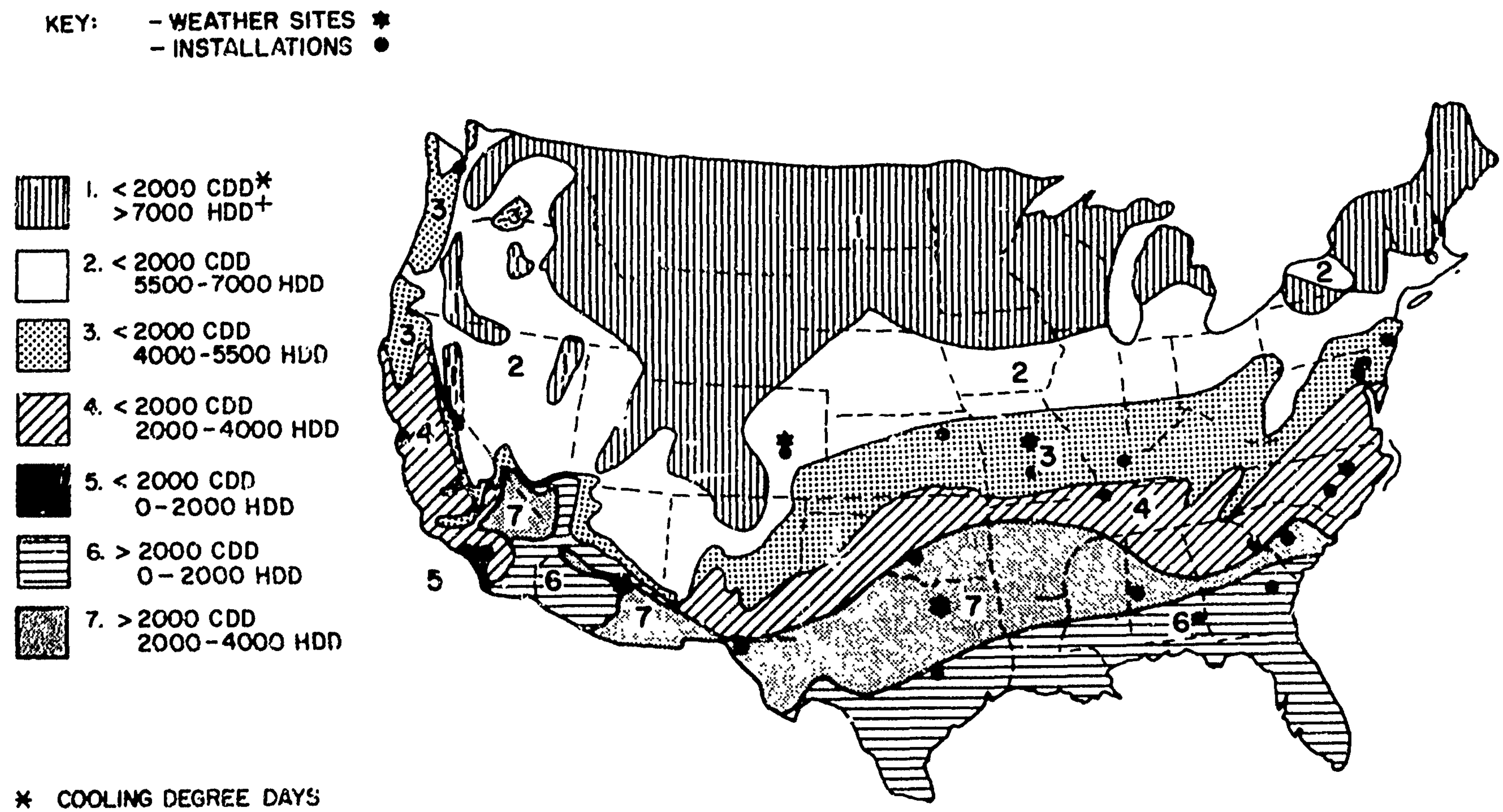

Figure 1. Climatic zones of the United States.

2 BUILDING DESCRIPTIONS

To find which standard building designs were built in the largest numbers, maps of major Army installations were examined to locate buildings of the same shape. Building numbers for buildings of the same shape were compared with the Integrated Facilities System (IFS) data base to identify buildings which were not of the same design. Table 1 gives the survey results.* The two-company rolling-pin-shaped barracks for enlisted personnel and the Type 64 barracks were built in the largest numbers: 257 and 399 buildings, respectively. Next came the motor repair shops (83 buildings), the battalion headquarters (93 buildings), and the enlisted personnel mess hall (103 buildings).

Rolling-Pin Barracks

The standard rolling-pin barracks was simulated as a three-story building with 40,698 sq ft (3781 m^2) of floor area. The exterior walls are 4 in. (0.102 m) of face brick, 2 in. (0.051 m) of air space, and 4 in. (0.102 m) of concrete block. There are 16,061 sq ft (1492 m^2) of exterior wall and 4399 sq ft (409 m^2) of single-pane glass. The ground floor is 4 in. (0.102 m) of stone, an air space, and 4 in. (0.102 m) of concrete. There is a built-up roof with 1/2-in. (0.013-m) stone, 3/8-in. (0.0095-m) felt and membrane, 2 in. (0.051 m) of dense insulation, and 4 in. (0.102 m) of concrete. The barracks houses 204 soldiers. The barracks has two-pipe fan coil units with through-wall outdoor air vents. Figure 2 is a line drawing of this barracks.

Type 64 Barracks

The standard Type 64 barracks was simulated as a three-story building with 31,122 sq ft (2891 m^2) of floor area. The adjoining mess hall or office space was not simulated. The exterior walls are 8 in. (0.204 m) of concrete block. There are 12,946 sq ft (1204 m^2) of exterior wall and 4965 sq ft (461 m^2) of single-pane glass. The 6-in. (0.15-m) concrete ground floor is over a crawl space. The roof is 1/2 in. (0.013 m) of stone, 2 in. (0.051 m) of insulation, 2 in. (0.051 m) of concrete, an air space, and acoustic tile. The barracks houses 152 soldiers. The building has two-pipe fan coil units with ventilation supplied through separate rooftop fans with reheat coils. Figure 3 is a line drawing of the barracks.

Motor Repair Shop

The motor repair shop (Figure 4) is a single-story rectangular structure with a floor area of 4800 sq ft (446 m^2) and a window area of 1278 sq ft (119 m^2). One end of the building has a fenced-in secured area for an office and tools and parts storage. A small restroom and a battery storage room also are located in this end. The rest of the building consists of high-bay vehicle

* Family housing was not considered in this survey.

Table 1

Standard Army Building Designs

Building Name	Number of Buildings	Most Common Drawing Number
Administration — Supply	90	30-14-03
Battalion Headquarters	93	30-02-44
Battalion Administration — Classroom	87	30-09-12
Battalion Administration — Classroom and Headquarters	40	30-09-03
Enlisted Personnel Mess	103	36-05-106
Type 64 Barracks	399	21-01-64
LBC&W Barracks	128	21-01-44
Motor Repair Shop	83	35-02-11
RGT/BDE Headquarters	27	30-02-66
Two Company, Rolling-Pin-Shaped Barracks for Enlisted Personnel	257	21-01-142
Type 121 Barracks	35	21-01-13

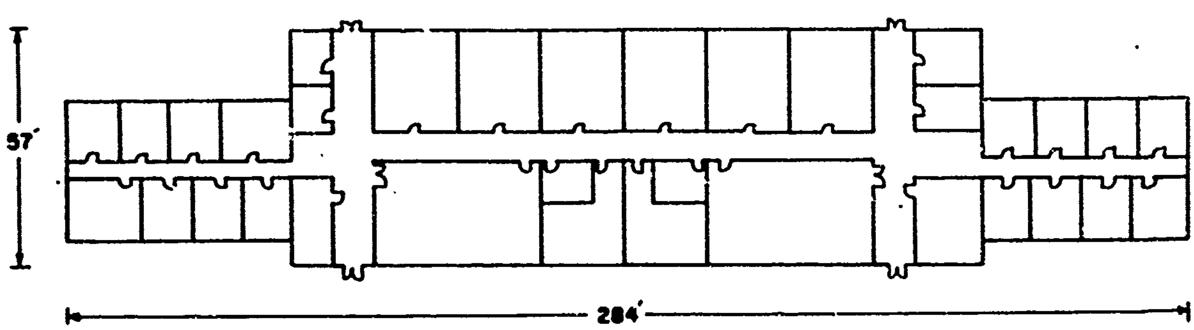

Figure 2. Line drawing of first floor of the two company, rolling-pin-shaped barracks for enlisted personnel.

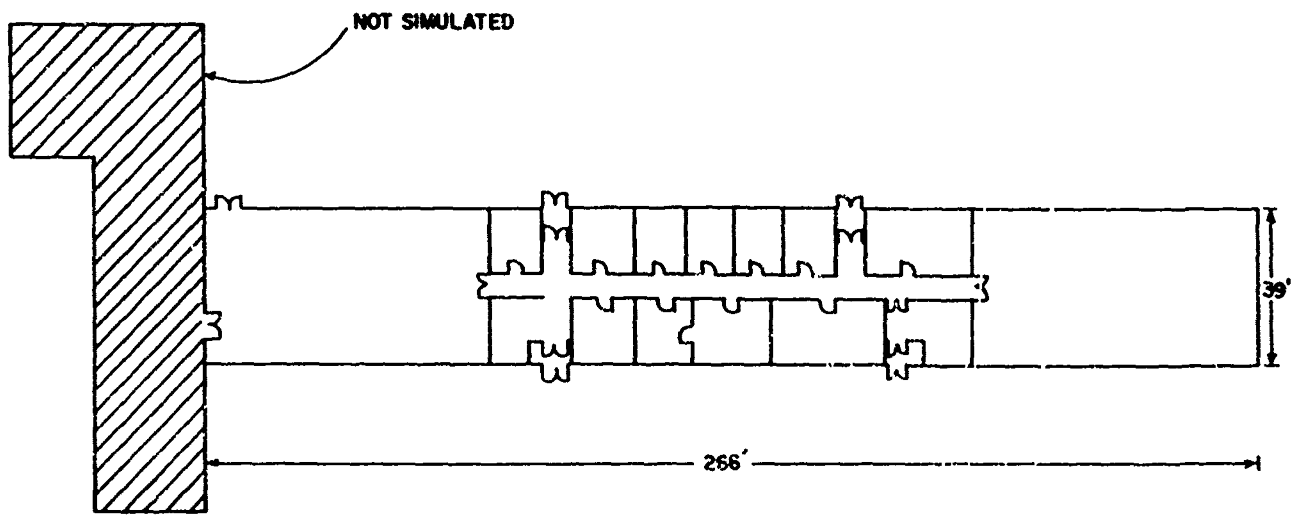

Figure 3. Line drawing of the first floor of the Type 64 barracks.

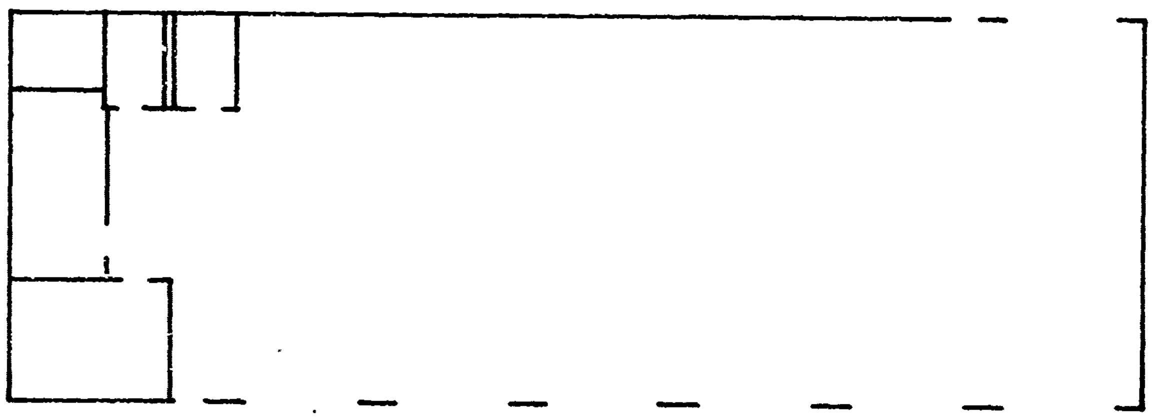

Figure 4. Motor repair shop floor plan.

work stations. Because of its minimal interior partitioning, the entire building is simulated as a single zone. Weekday and Saturday occupancy levels are assumed to be 10 and four people, respectively.

The vehicle repair area has walls made of 9-1/2-in. (0.231-m) reinforced concrete. The secured area walls are of 8-in. (0.24-m) reinforced concrete. Above and below the window units, the walls are made of 8-in. (0.204-m) hollow concrete masonry units. The interior finish is paint over the wall surface. The window units are a projecting type using single-sheet glass sections. The roof is a built-up roof laid over 1 in. (0.025 m) of rigid insulation supported by a concrete roof deck which has an average thickness of 3 in. (0.076 m). The vehicle room floor is a 6-in. (0.152-m) reinforced concrete slab-on-grade. The secured area floor is a 4-in. (0.102-m) reinforced concrete slab-on-grade.

The repair shop is heated by suspended steam unit heaters served from a central heating plant. These fans are simulated as one unit ventilator which provides no ventilation air. Two small steam radiators heat the restroom and battery storage room. Fresh air is brought in as infiltration. A small exhaust fan removes fumes from the battery storage room. This fan is assumed to run all year. There is no mechanical cooling available.

Battalion Headquarters

The battalion headquarters (Figure 5) is a small, single-story building with 2581 sq ft (240 m^2) of floor area and 456 sq ft (42.4 m^2) of window area. Because the building has no interior thermostat, the building is simulated as a single zone. Weekday occupancy is assumed to be 16 people. The building is unoccupied on weekends.

The wall construction is mainly 8-in. (0.204-m) hollow concrete masonry units. Sections of 12-in. (0.305-m) solid concrete blocks surround two large picture windows. The interior surface is paint over the exterior walls. All of the windows are single-sheet glass. The roof is a sandwich of built-up roofing, 1 in. (0.025 m) of rigid insulation, and 2-1/2 in. (0.064 m) of concrete deck. The floor is a 4-in. (0.102-m) reinforced concrete slab-on-grade.

The building environment is maintained by a hot-water baseboard radiation system. The supply water temperature is varied by an outdoor air thermostat. Hot water is supplied from a steam converter. Steam comes from a central heating plant. Winter ventilation is provided by infiltration. Roof ventilators supply summer ventilation. The system model chosen is a unit ventilator with no reheat capacity.

Enlisted Personnel Mess Hall

The enlisted personnel mess hall (Figure 6) is a one-story structure with an attic, kitchen, dining room, and a combined cloak room and entranceway. The maximum number of diners is assumed to be 100 people. The kitchen workers total 12. The total floor area is 10,620 sq ft (986 m^2).

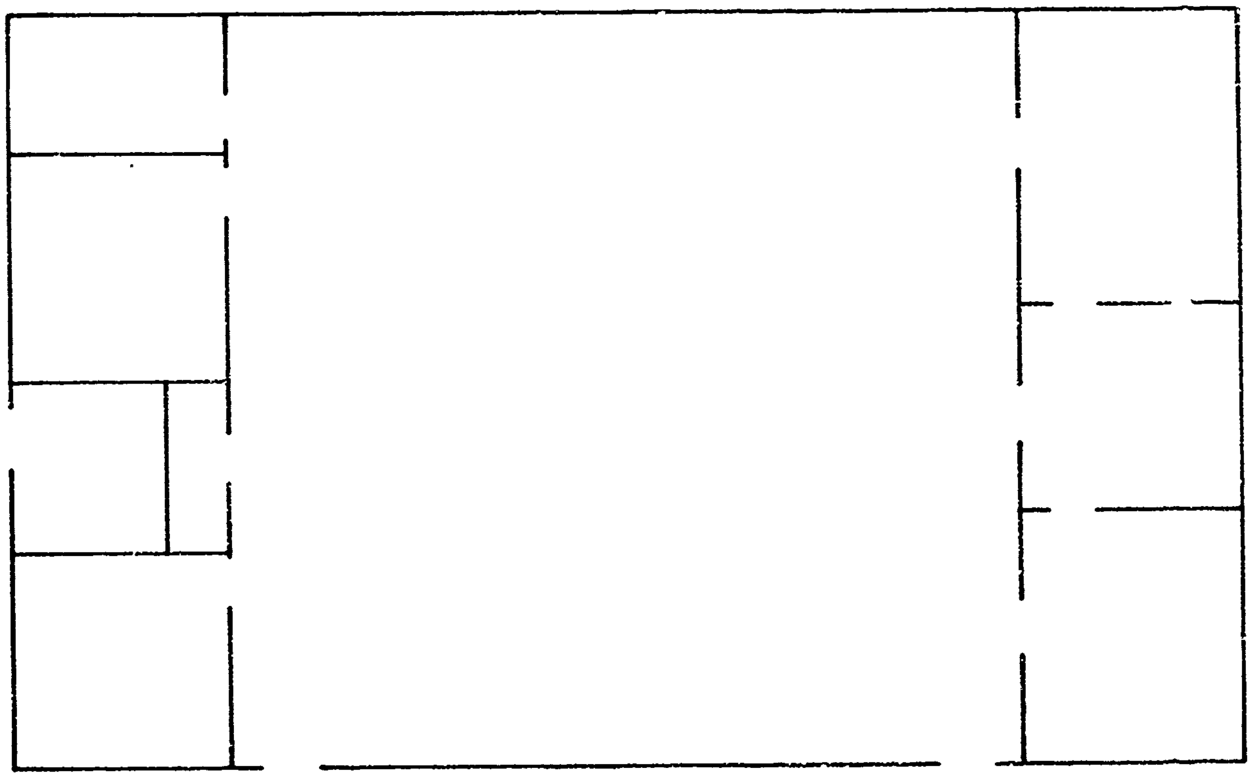

Figure 5. Battalion headquarters floor plan.

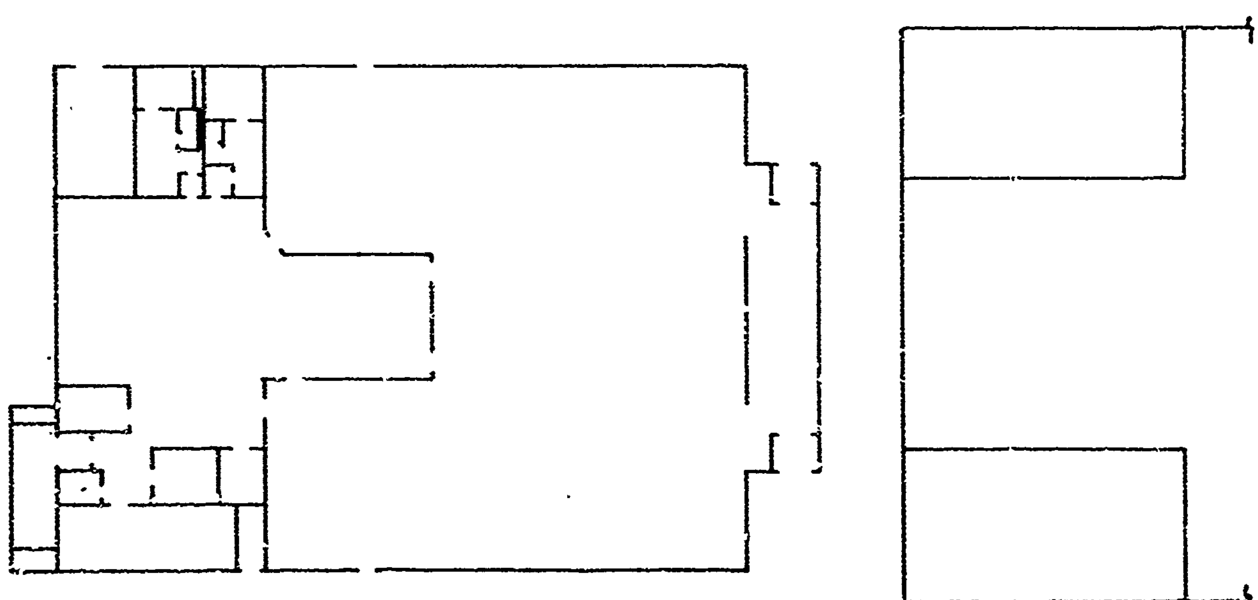

Figure 6. Enlisted personnel mess hall floor plan.

There are two major types of wall construction: one is 4 in. (0.102 m) of brick, a 2-in. (0.051-m) air gap, and a 6-in. (0.152-m) hollow glazed masonry unit; the second has an interior wall of 4-in. (0.102-m) brick instead of the glazed masonry unit. Interior walls are made of 8-in. (0.204-m) hollow glazed masonry units. The roof is built-up roofing over 1 in. (0.025 m) of rigid insulation supported by a metal roof deck. The attic is separated from the kitchen by a Keene's cement plaster ceiling and from the dining room by acoustical tile, both of which are covered with a 3-in. (0.076-m) batt insulation. The dining room floor is a 5-in. (0.127-m) concrete slab laid on the grade with a tile covering. The kitchen is separated from the crawl space by a 6-in. (0.152-m) concrete slab with a tile covering. The crawl space walls are 12-in. (0.305-m) reinforced concrete. The crawl space floor is dirt.

The cloak room is heated by the ceiling-hung fan-coil units. These are simulated as a unit ventilator. The dining room is both heated and cooled by two single-zone air handlers, simulated as one. There are also some hot water baseboard radiation convectors used to handle some skin loads. This was simulated in the Loads section of BLAST. The kitchen has two ceiling-hung unit heaters and baseboard convectors. These were summed together and simulated in the Loads portion as baseboard convectors. Two exhaust fans have separate make-up air heating units. These are simulated as a 100-percent outside air single-zone heating system which is controlled by a separate schedule.

Steam is supplied to all of the air heating units and the baseboard hot water converters from a central heating plant. Steam is also used to heat the domestic hot water and the dishwasher hot water booster. Chilled water for the air-conditioning units is supplied from a central chilled-water plant.

3 BASELINE ENERGY ANALYSIS

Baseline building models were developed in BLAST input format for the standard building designs described in Chapter 2. Each of the five baseline models was then simulated using BLAST for the five geographic locations under consideration. (Appendix A describes the BLAST program.)

If the BLAST building description did not respond the way the real building did, the analysis could be unrealistic. To avoid this, the BLAST building descriptions were calibrated to actual buildings by using the results of an earlier analysis of measured energy consumption.[7] Appendix B describes how the building descriptions used in BLAST were adjusted so the estimated baseline energy consumption corresponded to estimates based on field measurements. (Although detailed BLAST building descriptions were made of each building, some variables like infiltration had to be assumed.)

There was good correlation between BLAST predictions and measured performance for four of the five buildings. A large deviation occurred, however, for the enlisted personnel mess hall. When the BLAST simulation was adjusted to include a night-setback thermostat in the baseline model, the results were brought into the 95 percent prediction limit. This would seem to indicate that the mess halls where actual measurement data were collected may have already been retrofit with a night-setback control or had much of their electrical equipment shut off by occupants. In any case, the mess halls appeared to be operating more efficiently than originally designed.

Because of the large number of BLAST runs needed, the BLAST building descriptions were simplified to reduce the cost of the runs. The models were simplified as much as possible without sacrificing accuracy. The costs of running BLAST analyses for the rolling-pin and Type 64 barracks were reduced by factors of 6 and 3, respectively.

Tables 2 through 6 present the results of the baseline energy consumption analysis for the five buildings and five locations. To estimate the building energy requirements, air-handling systems were assumed to be served by a central plant with a boiler efficiency of 60 percent and a chiller coefficient of performance (COP) of 3.0. A power production efficiency of 30 percent was assumed. Hence the "System Heating" reported is the hot water or steam demanded annually by the building air-handling (heating) system divided by .6, the "System Cooling" is the annual building chilled water demand divided by .9 (which is the product of COP and power production efficiency) and the "Electricity" tabulations are the annual consumption for lights and fans or the annual fan power savings divided by .3. All tables use units of MBtu or millions of Btus.

7 B. J. Sliwinski, D. Leverenz, L. Windingland, and A. R. Mech, Fixed Facilities Energy Consumption — Data Analysis, Interim Report E-143/ADA066513 (CERL, February 1979).

Table 2

Annual Baseline Energy Consumption for the Rolling-Pin Barracks

	Colorado Springs		Columbia		Raleigh		Fort Worth		Phoenix	
	MBtu*	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%
System Heating	5572	67	4913	61	3322	51	2293	37	1118	19
System Cooling	278	3	721	9	778	12	1451	23	2148	38
Electricity	2447	30	2453	30	2453	37	2453	40	2473	43
Total Energy	8297	100	8087	100	6553	100	6197	100	5739	100

*Metric conversion: 1 MBtu = 1.055 GJ.
1 MBtu = 1×10^6 Btu.
1 GJ = 1×10^9 J.

Table 3

Annual Baseline Energy Consumption for the Type 64 Barracks

	Colorado Springs		Columbia		Raleigh		Fort Worth		Phoenix	
	MBtu*	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%
System Heating	4133	57	3493	45	2365	34	1655	25	815	14
System Cooling	922	12	1957	25	2327	33	2623	40	2917	49
Electricity	2260	31	2263	30	2263	33	2260	35	2263	37
Total Energy	7315	100	7713	100	6955	100	6538	100	5992	100

*Metric conversion: 1 MBtu = 1.055 GJ.
1 MBtu = 1×10^6 Btu.
1 GJ = 1×10^9 J.

Table 4

Annual Baseline Energy Consumption for the Motor Repair Shop

	Colorado Springs		Columbia		Raleigh		Fort Worth		Phoenix	
	MBtu	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%
Electricity	1004	36	950	37	897	46	842	54	777	69
System Heating	1799	64	1600	63	1053	54	725	46	349	31
Total Energy	2803	100	2550	100	1950	100	1567	100	1126	100

*Metric conversion: 1 MBtu = 1.055 GJ.
1 MBtu = 1 x 10^6 Btu.
1 GJ = 1 x 10^9 J.

Table 5

Annual Baseline Energy Consumption for the Battalion Headquarters

	Colorado Springs		Columbia		Raleigh		Fort Worth		Phoenix	
	MBtu*	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%
Electricity	220.4	27	222.2	33	223.5	41	225.7	52	228.3	65
System Heating	583.8	73	456.5	67	320.3	59	209.2	48	121.6	35
Total Energy	804.2	100	678.7	100	543.8	100	434.9	100	349.9	100

*Metric conversion: 1 MBtu = 1.055 GJ.
1 MBtu = 1 x 10^6 Btu.
1 GJ = 1 x 10^9 J.

Table 6

Annual Baseline Energy Consumption for Enlisted Personnel Mess Hall

	Colorado Springs		Columbia		Raleigh		Fort Worth		Phoenix	
	MBtu*	%	MBtu	%	MBtu	%	MBtu	%	MBtu	%
Electricity	2255	32	2234	36	2190	45	2162	51	2141	56
System Heating	4498	64	3600	58	2275	47	1471	35	885.5	23
System Cooling	314.1	4	397.1	6	404.7	8	595.1	14	825.6	21
Total	7067.1	100	6231.1	100	4869.7	100	4228.1	100	3852.1	100

*Metric conversion: 1 MBtu = 1.055 GJ.
1 MBtu = 1 x 10^6 Btu.
1 GJ = 1 x 10^9 J.

4 ENERGY CONSERVATION ALTERNATIVES

Retrofitting a building can involve not only envelope changes like adding insulation or storm windows, but also modifying the heating and cooling system and the building operation. BLAST can simulate such construction, system improvement, or building operation retrofits. During this investigation, several energy-conserving modifications applicable to the five buildings under study were identified from the engineering drawings for each standard design and from an analysis of each building's baseline energy usage.

Rolling-Pin Barracks

Possible retrofits to the rolling-pin barracks were identified first:

1. Reduce window area by one-third.

2. Add exterior insulation.

3. Add cavity wall insulation.

4. Add insulation to the ceiling.

5. Put reflective film on the windows.

6. Add storm windows.

7. Block the fan/coil unit's outside air vents.

Preliminary screening runs eliminated those retrofits that showed little promise of success. The remaining retrofits were analyzed by modifying the baseline BLAST building description and making a BLAST run with the modified description. The predicted energy consumption of the modified description was then compared with the baseline description's energy consumption.

The screening analysis was done by using year runs with a Columbia, MO, weather tape. The retrofits dropped from further consideration were:

1. Adding exterior insulation as opposed to using cavity wall insulation.

2. Adding insulation to the ceiling.

3. Putting reflective film on windows.

The exterior insulation was eliminated because it was only slightly better than cavity wall insulation and would be more expensive. Additional ceiling insulation decreased the energy consumption by only a minor amount. Since the building already had overhangs, putting film on the windows did not reduce energy consumption much. The following are detailed descriptions of the proposed retrofits for the rolling-pin barracks (Table 7 gives estimated costs for each proposed ECA):

1. Block outside air fan/coil vents. Block vents with 2 in. (0.051 m) of blueboard insulation, rubber sealant, and 1/8 in. (0.003 m) of aluminum plate. Reduce bathroom exhaust by 50 percent.

2. Cavity wall insulation. Fill the wall's 2-in. (0.051-m) cavity with R = 10 sq ft-hour-°F/Btu (1.84 m^2-°C/W) sprayed-in insulation.

3. Add storm windows. Add storm windows made of 1/8-in. (0.003-m) thick glass. Assume that infiltration is reduced 20 percent by adding storm windows.

4. Block one-third of the windows. Block the windows with a 1/16-in. (0.002-m) thick metal panel, 1.5 in. (0.038 m) of urethane, and a 1/16-in. (0.002-m) thick metal panel. Assume that infiltration is reduced by 7 percent.

Type 64 Barracks

A different approach was taken to identify retrofits for the Type 64 barracks. With the insight gained from the study of retrofits for the rolling-pin barracks, it was decided not to do a screening analysis for the Type 64 barracks.

The following are detailed descriptions of the retrofits for the Type 64 barracks (Table 8 gives cost estimates for each proposed ECA):

1. Close off rooftop AHUs. Disconnect the AHUs and use metal sheeting to block the AHUs' intake and exit ducts and the ducts to the barracks. Reduce the bathroom exhaust by 30 percent.

2. Add storm windows. Add storm windows made of 1/8-in. (0.003-m) thick glass. Assume that infiltration is reduced by 20 percent.

3. Add 2 in. (0.051 m) exterior insulation. Add 2 in. (0.051 m) of polystyrene with a stucco finish to the outside of the exterior wall.

4. Block two-thirds of the windows. Block the windows with a 1/16-in. (0.002-m) thick metal panel, 1.5 in. (0.038 m) of urethane, and a 1/16-in. (0.002-m) thick metal panel. Assume that infiltration is reduced by 13 percent.

5. Block two-thirds of the windows and add exterior insulation. Block the windows by using polystyrene with a stucco finish so the blocked windows are flush with the wall's exterior insulation. Assume that infiltration is reduced by 13 percent.

6. Add 8 in. (0.204 m) of ceiling insulation. Put 8 in. (0.204 m) of fiberglass insulation with an overall R = 32 sq ft-hr-°F/Btu (5.8 m^2-°C/W) above the top floor's ceiling.

7. Put up south overhangs. Put up a 2.5-ft (0.76-m) wide overhang that extends over the windows.

Table 7

Retrofit Construction Costs for the Rolling-Pin Barracks

ECA	Estimated Implementation Cost ($)*
Block outside air fan/coil vents	1,121
Add cavity wall insulation	12,848
Add storm windows	19,800
Block one-third of the windows	21,990

*Estimated for FY84 project year.

Table 8

Retrofit Construction Costs for the Type 64 Barracks

ECA	Estimated Implementation Cost ($)*
Close off AHUs	520
Add storm windows	22,500
Add storm windows while blocking two-thirds of the windows	7,650
Add 2 in. (0.51 m) of exterior insulation	52,000
Block two-thirds of the windows	49,500
Block two-thirds of the windows while adding 2 in. (0.51 m) of exterior insulation	16,500
Add 8 in. (0.204 m) of roof insulation	10,000
Put up south overhangs	11,200
Put up south overhangs while blocking two-thirds of the windows	3,710

*Estimated for FY84 project year.

Motor Repair Shop

The following ECAs were identified for the motor repair shop (Table 9 gives cost estimates for each proposed ECA):

1. Install night-setback thermostats. Replace existing single set-point thermostats with night-setback thermostats to maintain 55°F (13°C) during unoccupied periods.

2. Insulate walls. Install fiberglass batt insulation on the interior side of the exterior walls and finish the interior with fire-resistant gypsum wallboard.

3. Insulate roof. Replace the existing roof covering with rigid extruded polystyrene insulation covered by asphalt roofing materials.

4. Cover windows. Install a prefabricated insulating metal panel over the top half of the existing windows.

5. Install door seals. Weatherstrip the vehicle doors with neoprene gaskets.

6. Replace lights. Replace 54 fluorescent fixtures in the high-bay vehicle repair area with 10 to 250 W metal halide fixtures.

7. Install interior partition. Erect an insulating partition to separate the vehicle repair area from the office/tool storage area to maintain 60°F (16°C) in the vehicle repair area and 68°F (20°C) in the office/tool storage area during occupied periods.

Battalion Headquarters

The following ECAs were identified for the battalion headquarters (Table 10 gives cost estimates for the proposed ECAs):

1. Timeclock hot water pump. Install a 7-day, 24-hour timeclock in the hot water circulating pump control circuit to allow for shutdown during unoccupied periods.

2. Repipe baseboard and install night-setback thermostats. Convert the perimeter heating system from a single-pipe, series circuit to a dual-pipe, parallel circuit. Replace exterior thermostats with interior night-setback thermostats.

3. Insulate walls. Install fiberglass batt insulation on the interior side of the exterior walls. Finish the interior with gypsum wallboard.

4. Insulate roof. Replace the existing roof covering with a rigid extruded polystyrene insulation covered by asphalt roofing materials.

5. Install storm windows. Install removable storm windows on the interior of the existing windows.

Table 9

Retrofit Construction Costs for the Motor Repair Shop

ECA	Estimated Implementation Cost ($)*
Install night-setback thermostats	240
Insulate walls	3,170
Insulate roof	17,800
Cover top half of windows with metal panels	2,650
Install vehicle door seals	1,560
Replace fluorescent lighting with HID lighting	3,620
Install interior partition	990

*Estimated for FY84 project year.

Table 10

Retrofit Construction Costs for the Battalion Headquarters

ECA	Estimated Implementation Cost ($)*
Install timeclock on hot water circulating pump	260
Repipe baseboard and install night-setback thermostats	2,250
Insulate walls	1,390
Insulate roof	9,550
Install storm windows	2,490
Add vestibules	1,050
Timeclock electric domestic hot water heater	260

*Estimated for FY84 project year.

6. Add vestibules. Add small exterior vestibules to the entrances.

7. Timeclock electric domestic hot water heater. Install a 7-day, 24-hour timeclock to the electric domestic hot water heater circuit to allow for shutdown during unoccupied periods.

Enlisted Personnel Mess Hall

The following ECAs were identified for the enlisted personnel mess hall (Table 11 gives estimated costs for the proposed ECAs):

1. Night setback. Replace existing single set-point thermostats with night-setback thermostats to maintain 55°F (13°C) during unoccupied periods.

2. Timeclock. Replace existing thermostats with a 7-day, 24-hour programmable dual set-point thermostat.

3. Insulate walls. Add blown-in insulation to the existing exterior wall air cavity.

4. Cover one-half of the windows. Install a prefabricated insulating metal panel over the top half of the dining room windows.

5. Replace lights. Replace existing dining room and foyer incandescent lighting with fluorescent lighting.*

6. Temperature economizers. Install temperature economizers on the dining room air-conditioning units.

7. Heat recovery of exhaust air. Install heat recovery glycol loops and coils to the kitchen exhaust systems to preheat outdoor makeup air.

8. Variable air volume. Install a variable-speed drive and associated controls to the existing dining room air-conditioning units.

* The change to fluorescent fixtures may entail a change in chromatic content of the lighting. Because color rendition of food is an important consideration in the lighting design, proper color should be assured before implementing this retrofit.

Table 11

Retrofit Construction Costs for the Enlisted Personnel Mess Hall

ECA	Estimated Implementation Cost ($)*
Install night-setback thermostats	630
Install 24-hour, dual set-point programmable thermostats	770
Insulate walls	10,770
Cover top half of dining room windows with insulated metal panels	4,100
Replace incandescent lights with fluorescent lights	3,170
Install temperature economizers	6,400
Install heat recovery on kitchen exhaust systems	31,610
Convert single zone air-conditioning systems to variable air volume systems	3,520

*Estimated for FY84 project year.

5 RESULTS OF ECA ANALYSIS

The ECIP analysis requires that the effect of each retrofit be considered individually, even if it is combined with another retrofit. If a retrofit is very successful, it should be taken as a new baseline and other retrofits compared with it.

During this study, all of each building's retrofits were run for each weather tape. For FY84 ECIP projects, the minimum acceptable E/C ratio was $\geq$ 13, and the average acceptable E/C ratio was $\geq$ 30.[8] For FY85, the acceptable SIR was >1 for both individual retrofits and entire projects.[9]

The new guidelines had no noticeable effect on the results for the rolling-pin or Type 64 barracks; their SIRs were the same as the B/C ratios. For the other three buildings, however, the guideline changes affected the results enough so the SIRs had to be recorded separately.

The baseline consumption and the retrofits for each rolling-pin barracks location are given in Tables 12 through 16. The ECIP analyses are shown in Figures 7 through 11. These tables and figures indicate that blocking the outside air vents of the fan/coil units was a successful retrofit at all locations. This is because when the fan/coil units are on, they no longer have to heat or cool the outside air to room temperature. Infiltration still introduces enough outside air to keep the air fresh, but in reduced amounts. Adding cavity wall insulation also met the minimum E/C ratio at all locations. Both the fan/coil vent and cavity insulation retrofits worked best in colder zones, where the indoor-to-outdoor temperature difference can be large. Adding storm windows to reduce heat loss or gain and to lessen infiltration was also successful in all climatic zones.*

The baseline consumption and the retrofits for the Type 64 barracks in each climatic zone are given in Tables 17 through 21. The results of the ECIP analyses are shown in Figures 12 through 16. Closing off the rooftop AHUs was successful in every climatic zone. The rooftop AHUs took in outside air and heated or cooled it to 70°F (20°C). The air was being heated or cooled even when the buildings were comfortable and needed no heating or cooling. Adding storm windows was the only other retrofit that met the minimum ECIP criteria.

Because installing automatic night-setback thermostats has become common practice, a new baseline with this ECA was established for the motor repair shop, the battalion headquarters, and the enlisted personnel mess hall. All other ECAs were then compared with this second baseline. ECA effectiveness was determined by the E/C and B/C ratios. If an ECA proved very effective (E/C > 100), then it was used to establish succeeding baselines. The procedure for calculating the E/C, B/C, and simple paybacks is described in Appendix C.

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8 DAEN-ZCF-U, Message No. 2917Z, "Energy Conservation Investment Program (ECIP) Guidance," 12 December 1980.

9 Millard Carr, p 1.

* The addition of storm windows requires the fans to run more often albeit with smaller loads. This negligible increase in fan electricity does not affect the retrofit's overall desirability.

Table 12

ECA Simulation Summary -- Energy Savings for the Rolling-Pin Barracks, Colorado Springs, CO

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
						Oil	Gas	Oil	Gas
A1 Block Fan/Coils	1178	16	3	1197	804	211	91	213	93
New Baseline = A1									
B1 Insulate Walls	983	6	3	992	58	15	6	15	6
B2 Add Storm Windows	1147	-16	-3	1128	43	12	5	12	5
B3 Block Windows	355	24	0	359	12	3	1.3	3	1.3
New Baseline = B1									
C1 Add Storm Windows	1173	-16	-3	1154	44	12	5	15	5
New Baseline = C1									
D1 Block Windows	-18	34	3	19	1	0	0	0	0

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 13

ECA Simulation Summary -- Energy Savings for the Rolling-Pin Barracks, Columbia, MO

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
						Oil	Gas	Oil	Gas
A1 Block Fan/Coils	755	34	0	789	532	137	60	138	61
New Baseline = A1									
B1 Insulate Walls	790	50	3	843	49	12	5	12	5
B2 Add Storm Windows	1013	8	0	1021	39	10	4	10	4
B3 Block Windows	322	67	3	392	13	3	1.4	3	1.4
New Baseline = B1									
C1 Add Storm Windows	1060	3	-3	1060	40	11	4	11	4
New Baseline = C1									
D1 Block Windows	13	71	3	87	3	0.3	0.2	0.3	0.2

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 14

ECA Simulation Summary — Energy Savings for the Rolling-Pin Barracks, Raleigh, NC

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	E/C		SIR	
						Oil	Gas	Oil	Gas
A1 Block Fan/Coils	633	20	0	653	440	114	49	115	50
New Baseline = A1									
B1 Insulate Walls	585	30	3	618	37	9	4	9	4
B2 Add Storm Windows	715	-3	0	712	27	7	3	7	3
B3 Block Windows	215	69	3	287	10	2	1.0	2	1.0
New Baseline = B1									
C1 Add Storm Windows	728	-7	0	721	28	7	3	7	3
New Baseline = C1									
D1 Block Windows	-5	77	3	75	2	0.1	0.2	0.1	0.2

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 15

ECA Simulation Summary -- Energy Savings for the Rolling-Pin Barracks, Fort Worth, TX

Conservation Retrofit Option	Energy Heating (MBtu*)	System Cooling (MBtu)	System Electricity (MBtu)	Energy (MBtu)	E/C	Total B/C		SIR	
						Oil	Gas	Oil	Gas
A1 Block Fan/Coils	448	102	3	553	371	86	40	86	40
New Baseline = A1									
B1 Insulate Walls	415	123	3	541	32	7	3	7	3
B2 Add Storm Windows	536	91	-3	624	24	6	3	6	3
B3 Block Windows	153	117	3	273	9	2	0.9	2	0.9
New Baseline = B1									
C1 Add Storm Windows	535	93	-3	625	24	6	3	6	3
New Baseline = C1									
D1 Block Windows	8	97	3	108	3	0.2	0.2	0.2	0.2

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 16

ECA Simulation Summary — Energy Savings for the Rolling-Pin Barracks, Phoenix, AZ

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
						Oil	Gas	Oil	Gas
A1 Block Fan/Coils	392	202	7	601	401	82	42	81	41
New Baseline = A1									
B1 Insulate Walls	197	248	3	448	26	4	2	4	2
B2 Add Storm Windows	170	148	-7	311	15	3	1.5	3	1.5
B3 Block Windows	62	167	3	232	8	1.0	0.7	1.0	0.7
New Baseline = B1									
C1 Add Storm Windows	243	157	-7	393	15	3	1.5	3	1.5
New Baseline = C1									
D1 Block Windows	-10	132	7	129	4	0.2	0.3	0.2	0.3

*Metric conversion: 1 MBtu = 1.055 GJ.

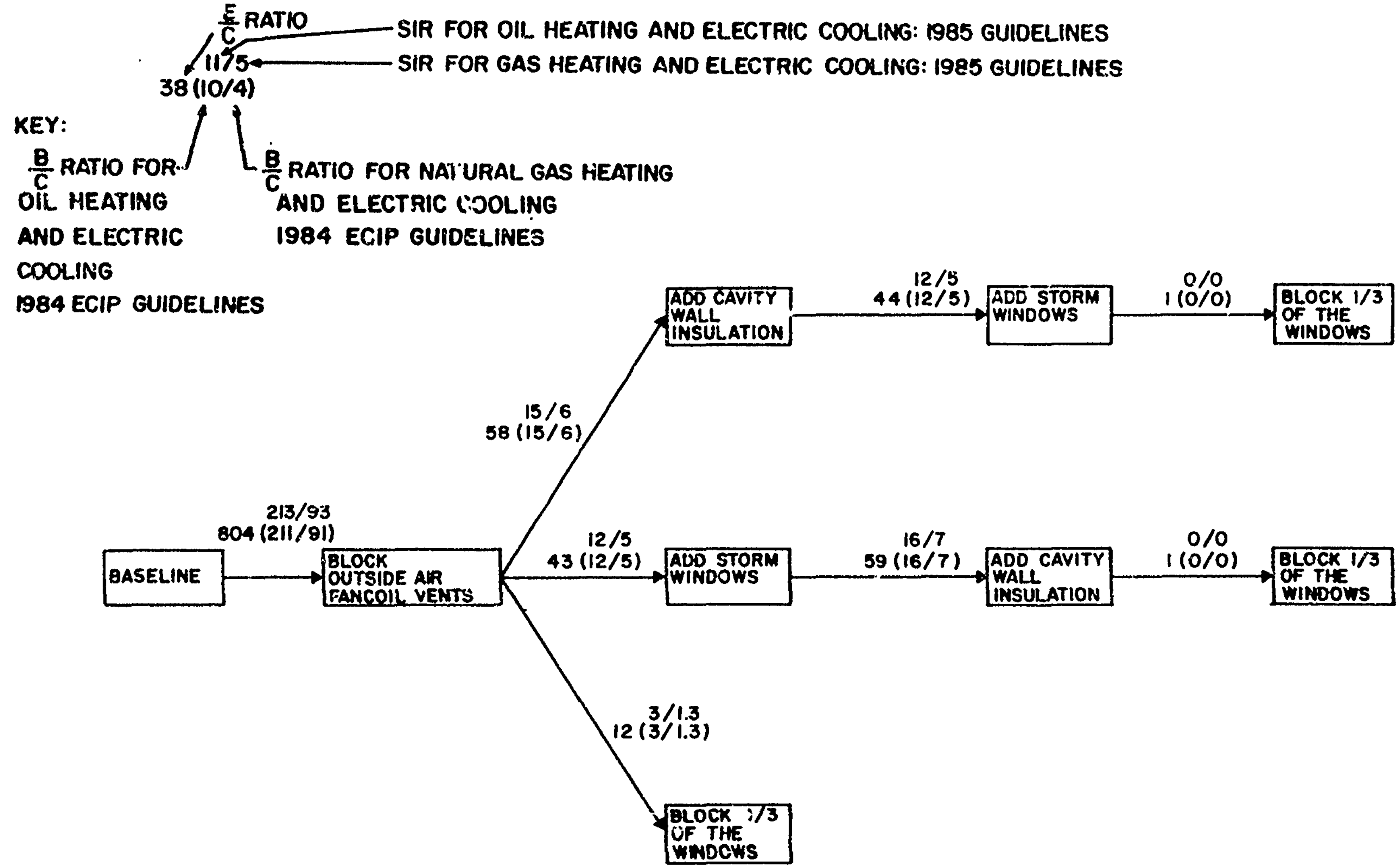

Figure 7. ECIP analysis for the rolling-pin barracks, Colorado Springs, CO.

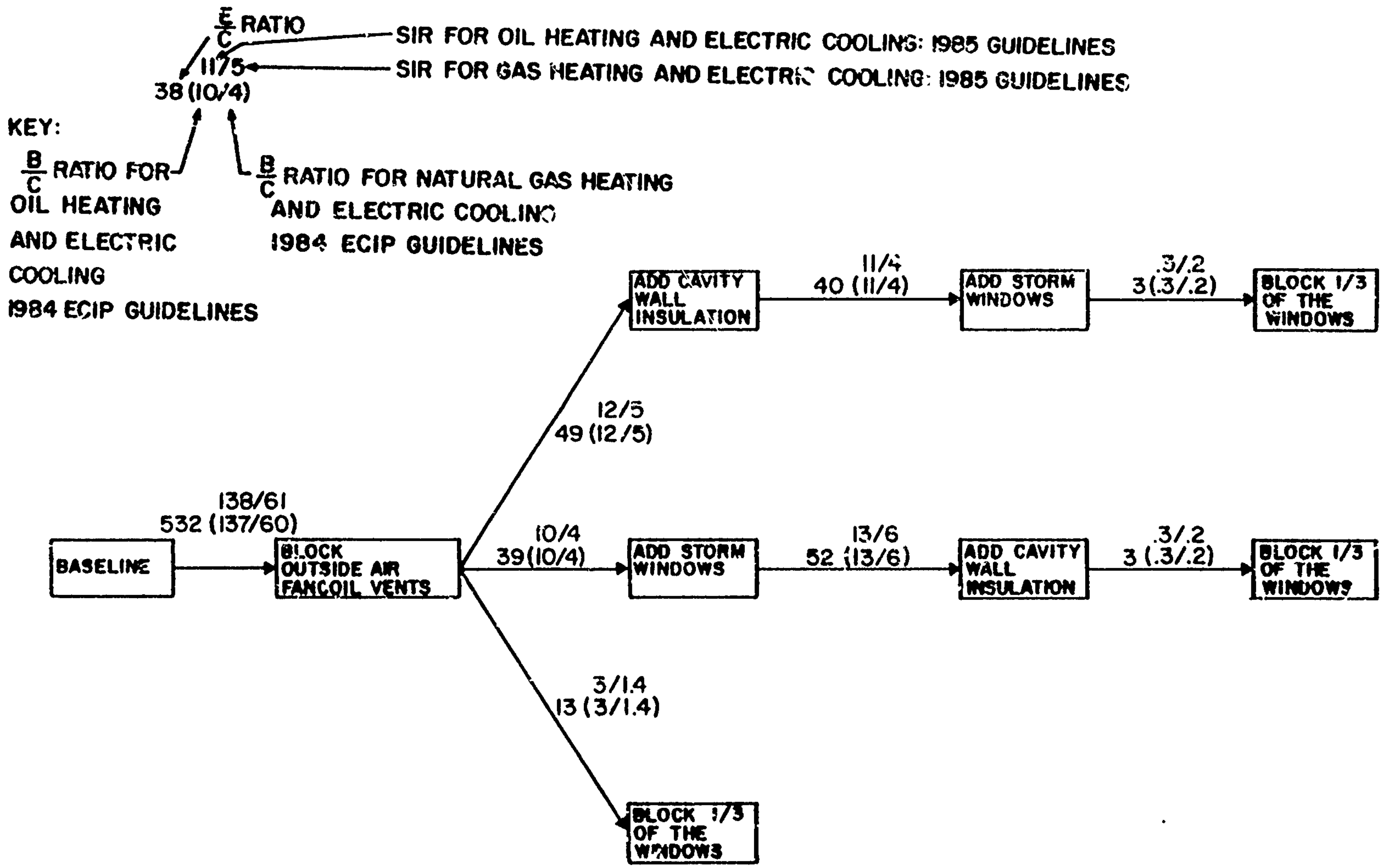

Figure 8. ECIP analysis for the rolling-pin barracks, Columbia, MO.

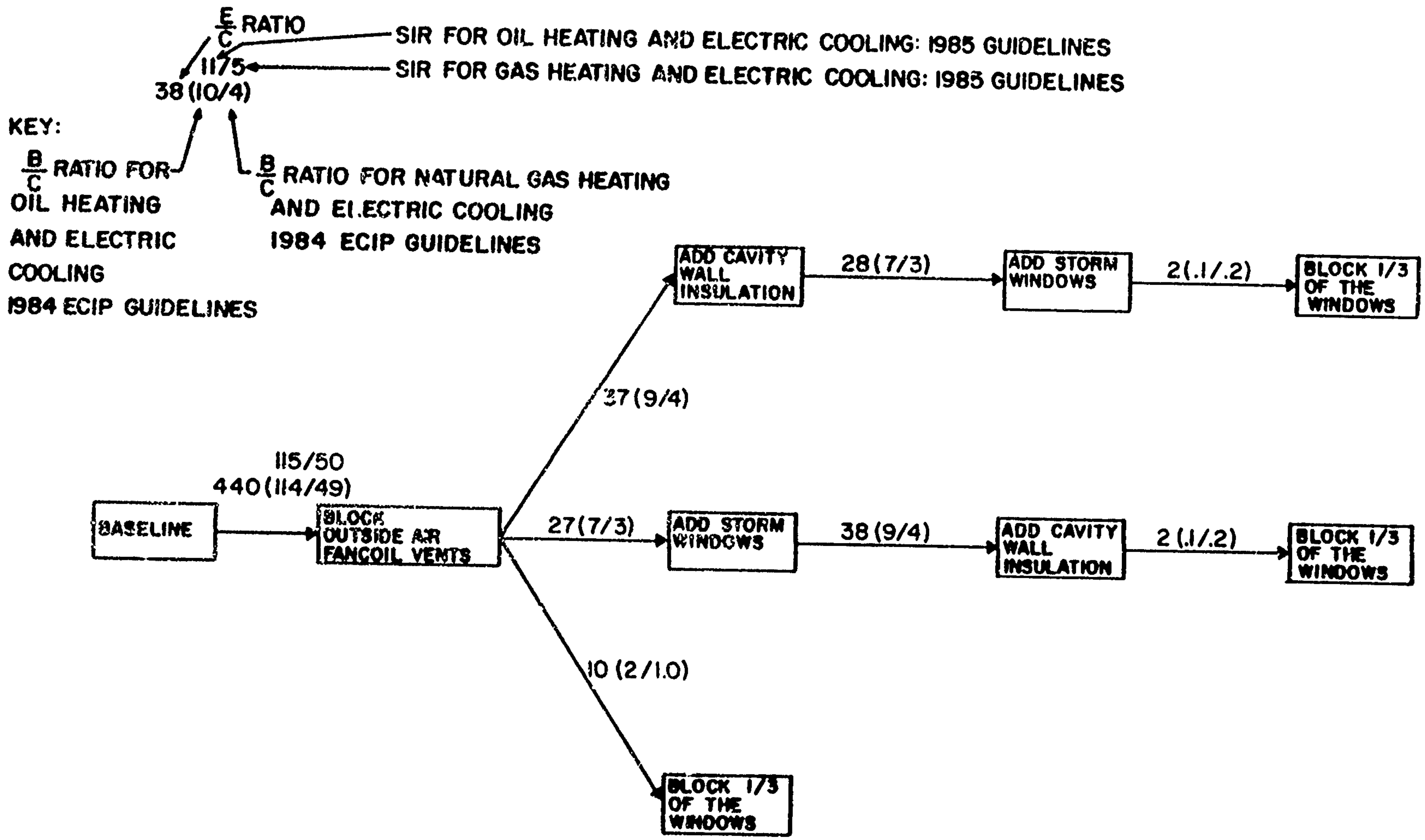

Figure 9. ECIP analysis for the rolling-pin barracks, Raleigh, NC.

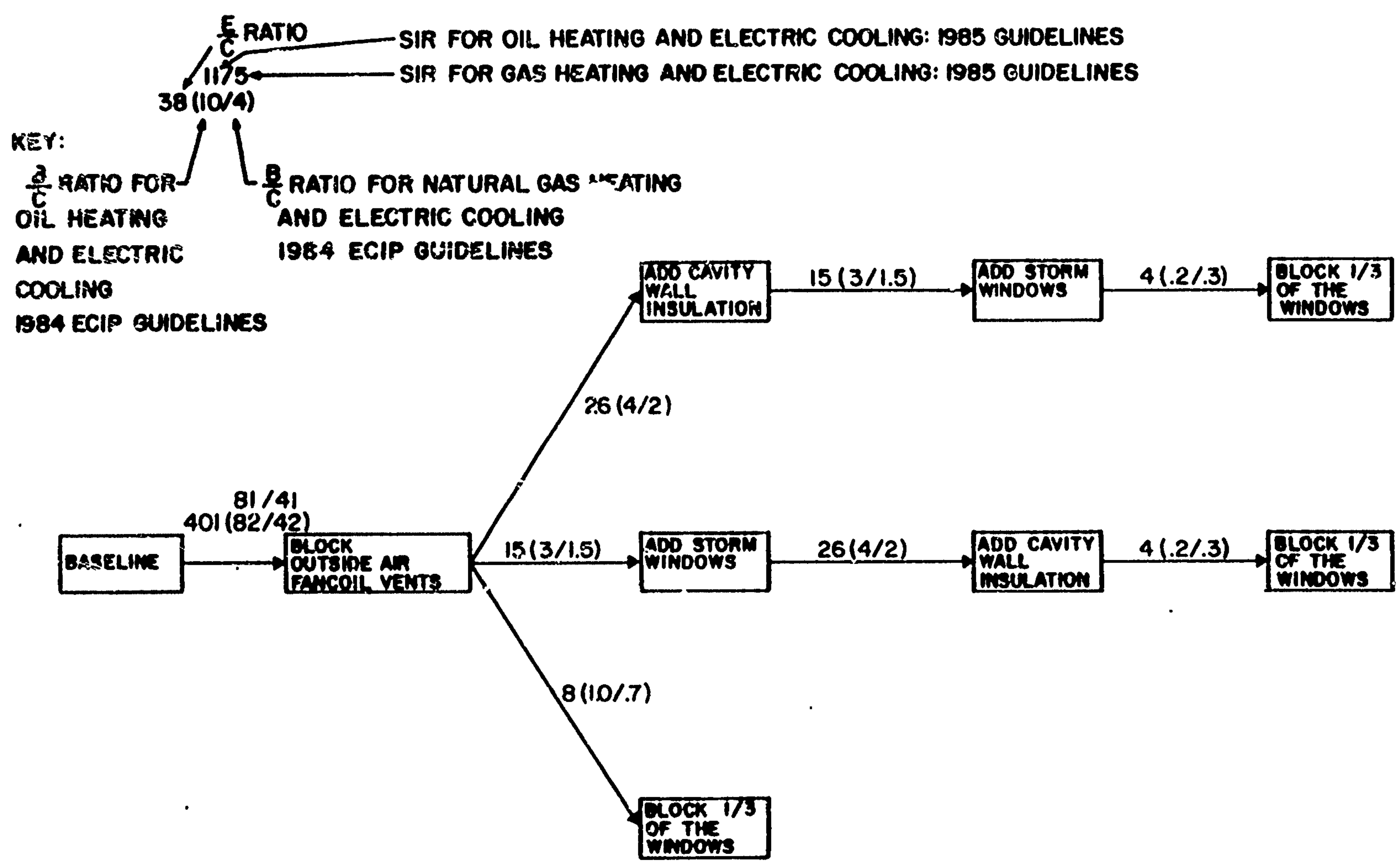

Figure 10. ECIP analysis for the rolling-pin barracks, Fort Worth, TX.

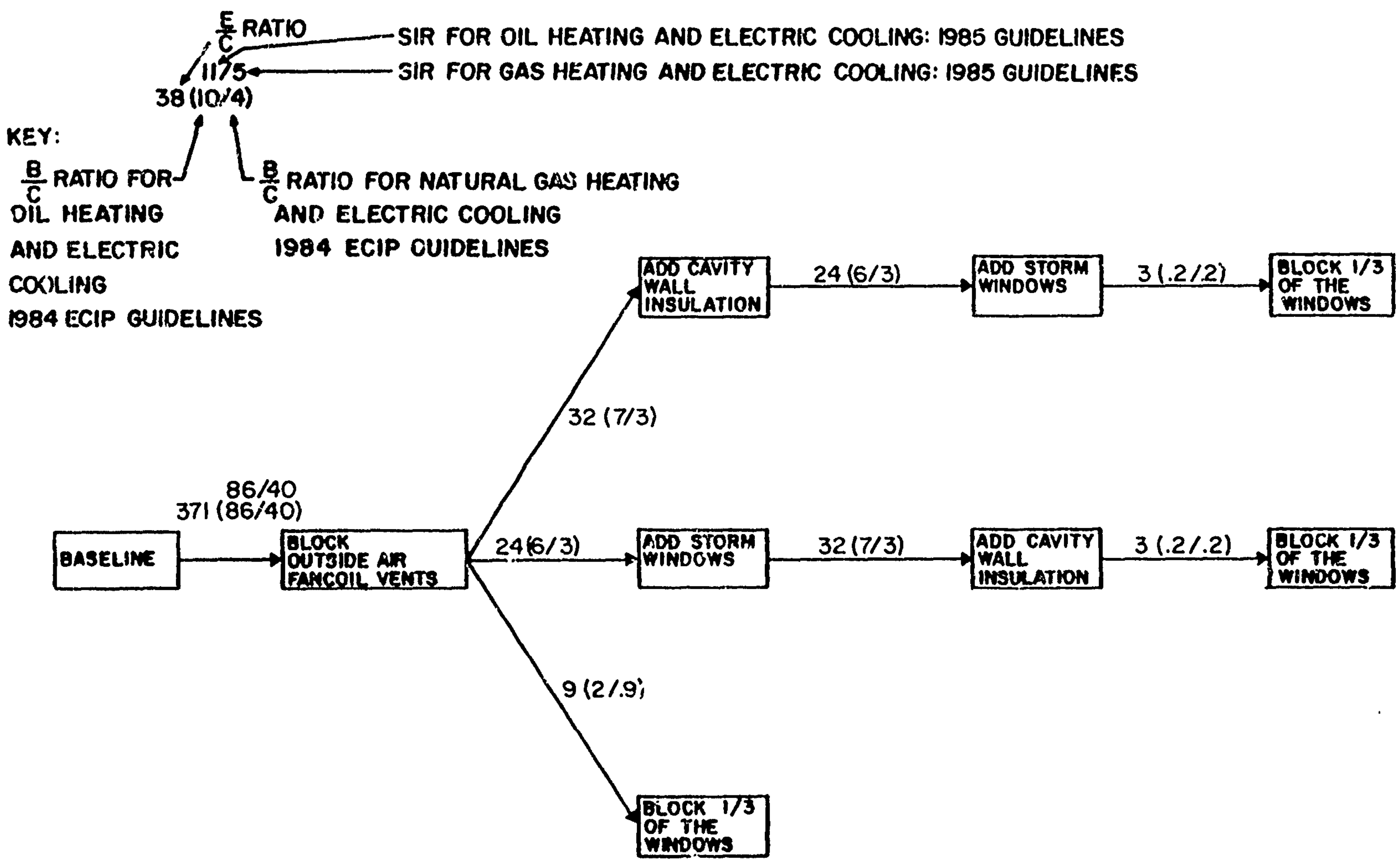

Figure 11. ECIP analysis for the rolling-pin barracks, Phoenix, AZ.

Table 17

ECA Simulation Summary — Energy Savings for the Type 64 Barracks, Colorado Springs, CO

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	E/C		SIR	
						Oil	Gas	Oil	Gas
A1 Disconnect Roof AHUs	510	604	180	1294	1618	271	157	264	150
New Baseline = A1									
B1 Add Storm Windows	1131	-9	3	1125	38	10	4	10	4
B2 Add Exterior Insulation	800	0	0	800	12	3	1.3	3	1.3
B3 Block of Windows	633	110	13	756	11	3	1.2	3	1.2
B4 Add Roof Insulation	143	4	0	147	11	3	1.2	3	1.2
B5 South Overhangs	-205	60	13	-132	-10	-3	-1	-3	-1
New Baseline = B1									
C1 Exterior Insulation	775	-2	3	776	11	3	1.2	3	1.2
C2 Block Windows	-135	122	10	-3	0	0	0	0	0
New Baseline = B2									
D1 Block Windows	717	116	20	853	38	9	4	9	4
New Baseline = B3									
E1 South Overhangs	-88	21	10	-57	-14	-4	-2	-4	-2
New Baseline = C1									
F1 Block Windows	8	126	10	144	6	0	0.5	0	0.5
New Baseline = D1									
G1 Add Roof Insulation	172	7	0	179	13	3	2	3	2
G2 South Overhangs	-88	23	13	-52	-13	-4	-2	-4	-2
New Baseline = G1									
H1 South Overhangs	-88	-21	13	-96	-13	-4	-2	-4	-2

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 18

ECA Simulation Summary — Energy Savings for the Type 64 Barracks, Columbia, MO

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
						Oil	Gas	Oil	Gas
A1 Disconnect Roof AHUs	140	1226	180	1546	1981	205	175	186	156
New Baseline = A1									
B1 Add Storm Windows	903	39	3	945	32	8	4	8	4
B2 Add Exterior Insulation	622	29	3	654	9	2	1.0	2	1.0
B3 Block of Windows	587	214	13	814	12	3	1.2	3	1.2
B4 Add Roof Insulation	130	10	3	143	10	3	1.1	3	1.1
B5 South Overhangs	-130	73	10	-47	-4	-2	0	-2	0
New Baseline = B1									
C1 Exterior Insulation	647	27	10	684	10	2	1.0	2	1.0
C2 Block Windows	-12	192	13	193	3	0	0	0	0
New Baseline = B2									
D1 Block Windows	663	437	13	1113	41	9	4	9	4
New Baseline = B3									
E1 South Overhangs	-57	26	10	-21	-6	-3	-1	-3	-1
New Baseline = C1									
F1 Block Windows	52	210	13	275	12	1.4	1.0	1.4	1.0
New Baseline = D1									
G1 Add Roof Insulation	152	17	0	169	13	3	1.4	3	1.4
G2 South Overhangs	-57	28	10	-19	-6	-2	-1	-2	-1
New Baseline = G1									
H1 South Overhangs	-57	27	10	-20	-6	-2	-1	-2	-1

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 19

ECA Simulation Summary — Energy Savings for the Type 64 Barracks, Raleigh, NC

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C Oil	B/C Gas	SIR Oil	SIR Gas
A1 Disconnect Roof AHUs	225	1539	183	1947	2559	277	227	254	204
New Baseline = A1									
B1 Add Storm Windows	620	31	0	651	22	6	2	6	2
B2 Add Exterior Insulation	457	26	0	483	7	2	0.7	2	0.7
B3 Block of Windows	370	217	10	587	9	2	0.9	2	0.9
B4 Add Roof Insulation	95	12	0	107	8	2	0.8	2	0.8
B5 South Overhang	-108	70	10	-28	-2	-2	0	-2	0
New Baseline = B1									
C1 Exterior Insulation	467	23	3	493	7	2	0.7	2	0.7
C2 Block Windows	-42	199	10	167	2	0	0	0	0
New Baseline = B2									
D1 Block Windows	423	234	13	670	30	6	3	6	3
New Baseline = B3									
E1 South Overhangs	-48	26	7	-15	-5	-2	-0.6	-2	-0.6
New Baseline = C1									
F1 Block Windows	8	219	13	240	10	0.9	0.8	0.9	0.8
New Baseline = D1									
G1 Add Roof Insulation	110	17	3	130	10	2	1.0	2	1.0
G2 South Overhangs	-48	27	10	-11	-4	-2	-1	-2	-1
New Baseline = G1									
H1 South Overhangs	-48	27	10	-11	-4	-2	-0.6	-2	-0.6

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 20

ECA Simulation Summary — Energy Savings for the Type 64 Barracks, Fort Worth, TX

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
						Oil	Gas	Oil	Gas
A1 Disconnect Roof AHUs	168	1318	180	1666	2156	228	191	208	171
New Baseline = A1									
B1 Add Storm Windows	460	126	0	586	20	4	2	4	2
B2 Add Exterior Insulation	327	84	0	411	6	1.3	0.6	1.3	0.6
B3 Block of Windows	278	327	10	615	9	2	0.9	2	0.9
B4 Add Roof Insulation	63	26	0	89	7	1.4	0.7	1.4	0.7
B5 South Overhangs	-78	71	10	3	0	-1	0	-1	0
New Baseline = B1									
C1 Exterior Insulation	327	89	0	416	6	1.3	0.6	1.3	0.6
C2 Block Windows	-25	248	13	236	3	0	0	0	0
New Baseline = B2									
D1 Block Windows	317	357	17	691	31	5	3	5	3
New Baseline = B3									
E1 South Overhangs	-43	26	10	-7	-4	-2	0	-2	0
New Baseline = C1									
F1 Block Windows	13	274	17	304	13	1.2	1.1	1.2	1.1
New Baseline = D1									
G1 Add Roof Insulation	73	33	0	106	8	2	0.8	2	0.8
G2 South Overhangs	-43	26	13	-4	-4	-2	0	-2	0
New Baseline = G1									
H1 South Overhangs	-42	27	13	-2	-3	-2	0	-2	0

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 21

ECA Simulation Summary -- Energy Savings for the Type 64 Barracks, Phoenix, AZ

Energy Conservation Retrofit Option	System Heating (MBtu*)	System Cooling (MBtu)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
						Oil	Gas	Oil	Gas
A1 Disconnect Roof AHUs	203	992	163	1358	1734	201	156	186	141
New Baseline = A1									
B1 Add Storm Windows	227	202	3	432	14	2	1.4	2	1.4
B2 Add Exterior Insulation	170	180	3	353	5	0.8	0	0.8	0
B3 Block of Windows	135	498	10	643	10	1.1	0.8	1.1	0.8
B4 Add Roof Insulation	27	50	3	80	6	0.8	0	0.8	0
B5 South Overhangs	-37	159	10	132	8	0	0.6	0	0.6
New Baseline = B1									
C1 Exterior Insulation	160	192	3	355	5	0.8	0	0.8	0
C2 Block Windows	-15	370	7	362	5	0	0	0	0
New Baseline = B2									
D1 Block Windows	150	543	13	706	32	4	3	4	3
New Baseline = B3									
E1 South Overhangs	-25	54	10	39	6	0	0	0	0
New Baseline = C1									
F1 Block Windows	7	408	13	428	19	2	2	2	2
New Baseline = D1									
G1 Add Roof Insulation	32	64	3	99	7	1.0	0.6	1.0	0.6
G2 South Overhangs	-27	56	20	49	6	0	0	0	0
New Baseline = G1									
H1 South Overhangs	-23	57	20	54	7	0	0	0	0

*Metric conversion: 1 MBtu = 1.055 GJ.

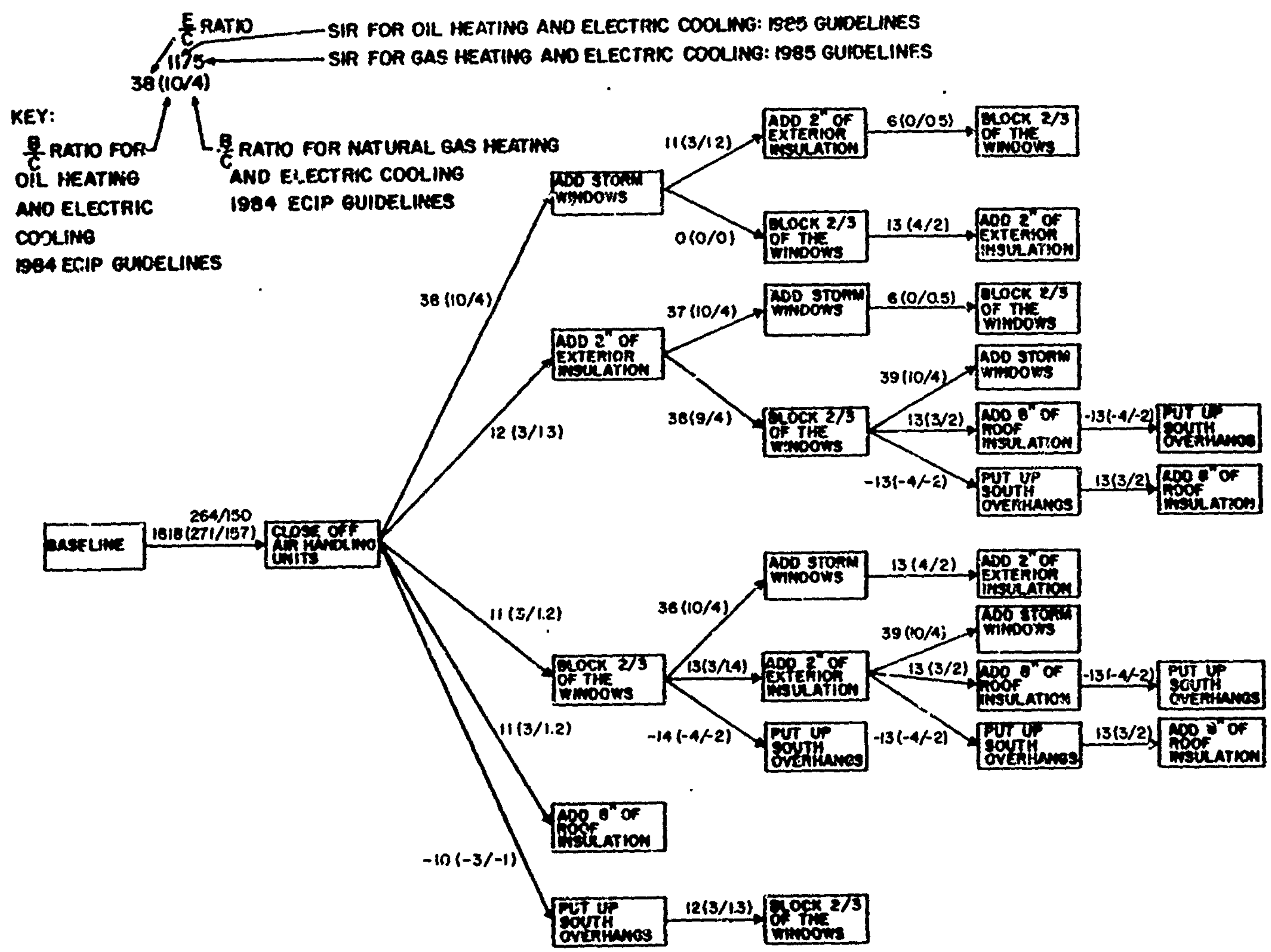

Figure 12. ECIP analysis for the Type 64 barracks, Colorado Springs, CO.

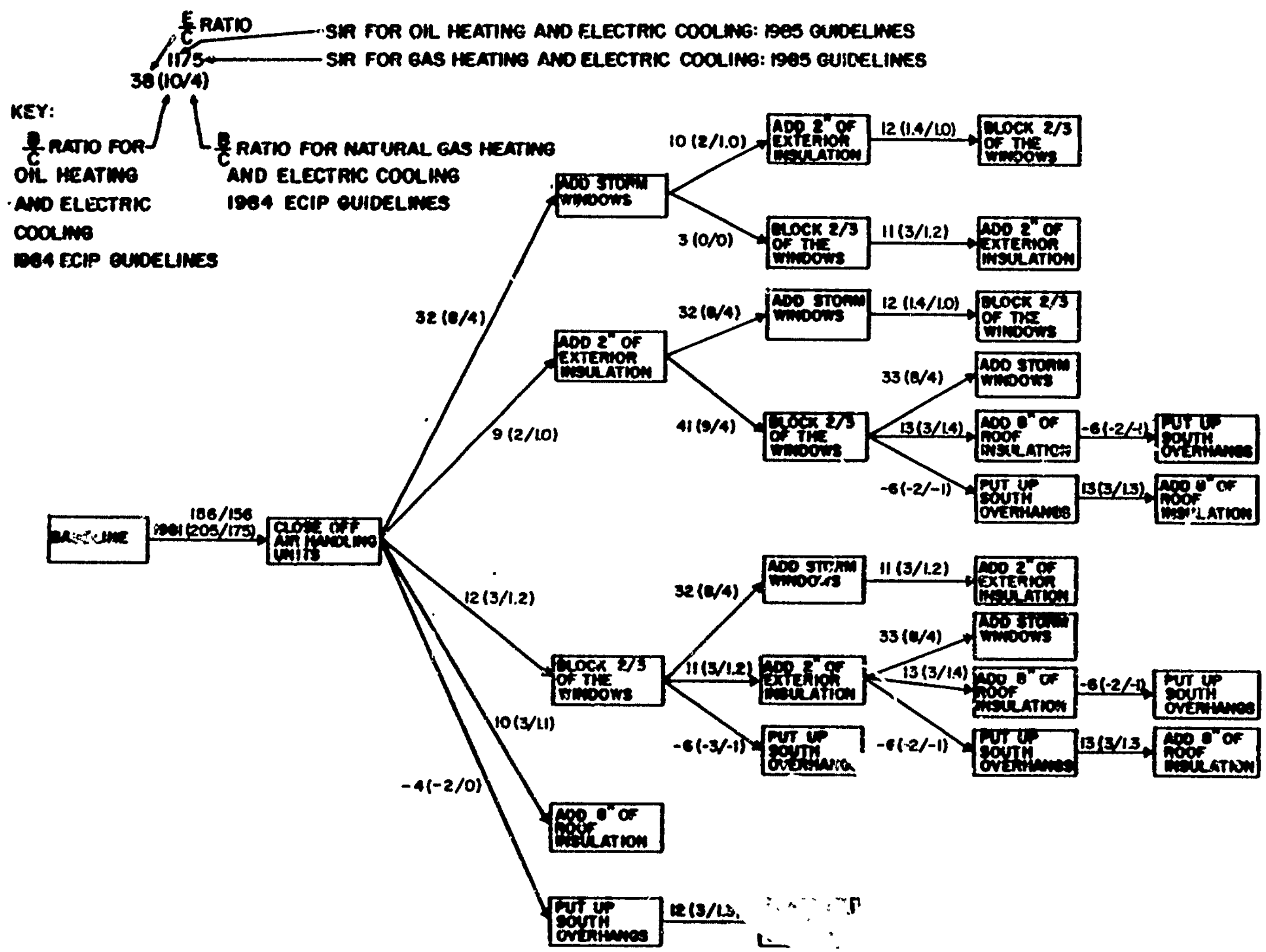

Figure 13. ECIP analysis for the Type 64 barracks, Columbia, MO.

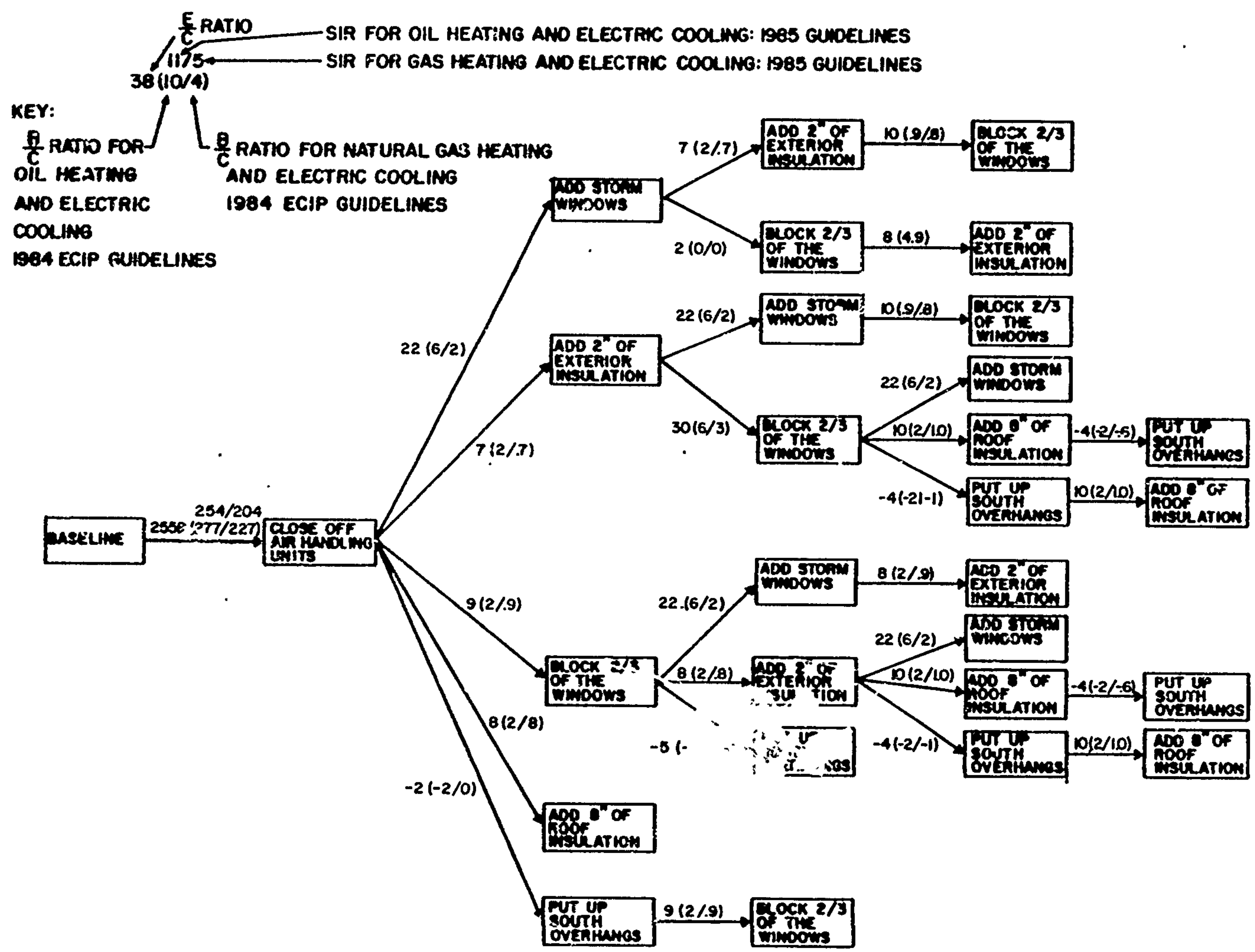

Figure 14. ECIP analysis for the Type 64 barracks, Raleigh, NC.

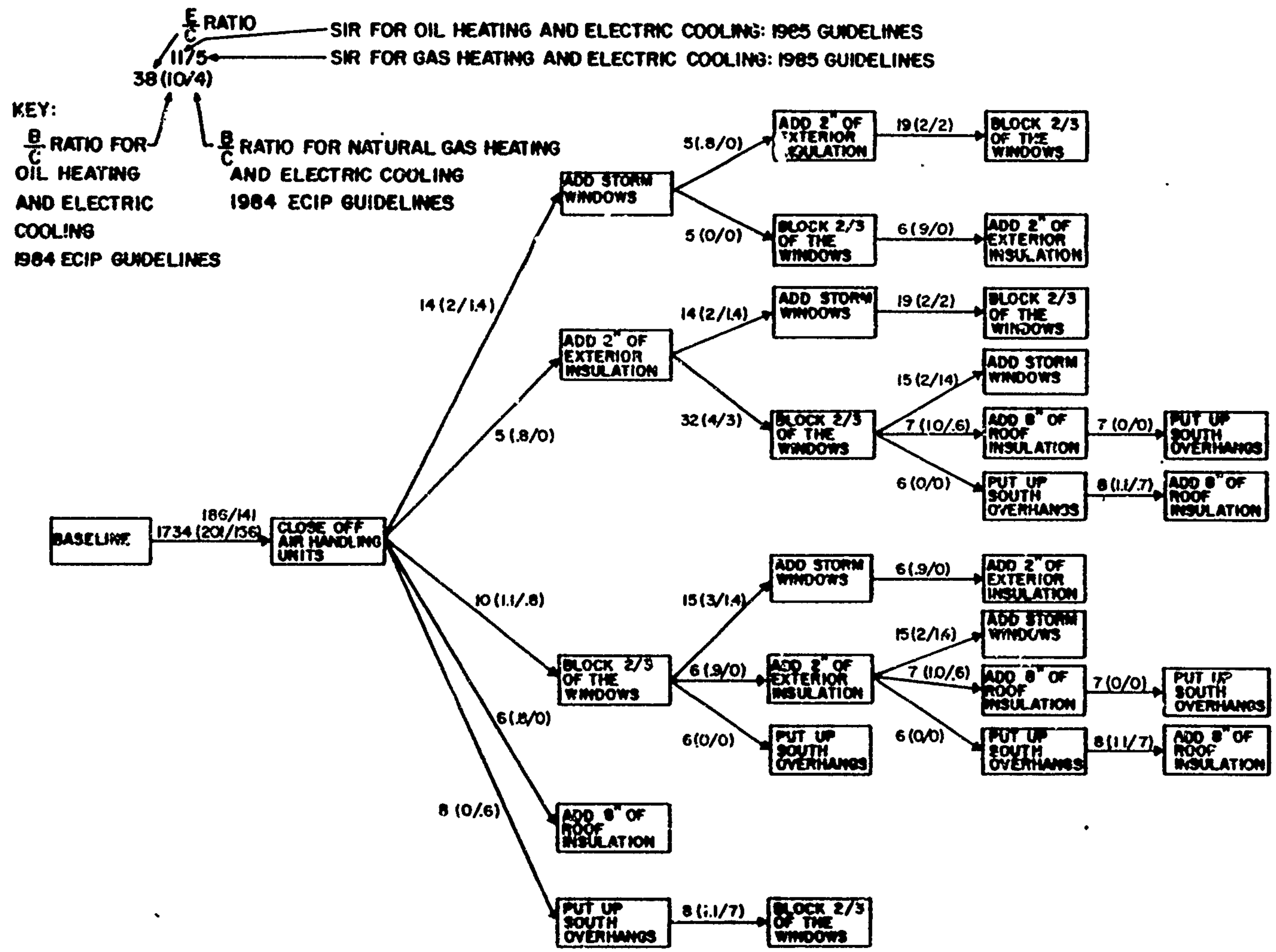

Figure 15. ECIP analysis for the Type 64 barracks, Fort Worth, TX.

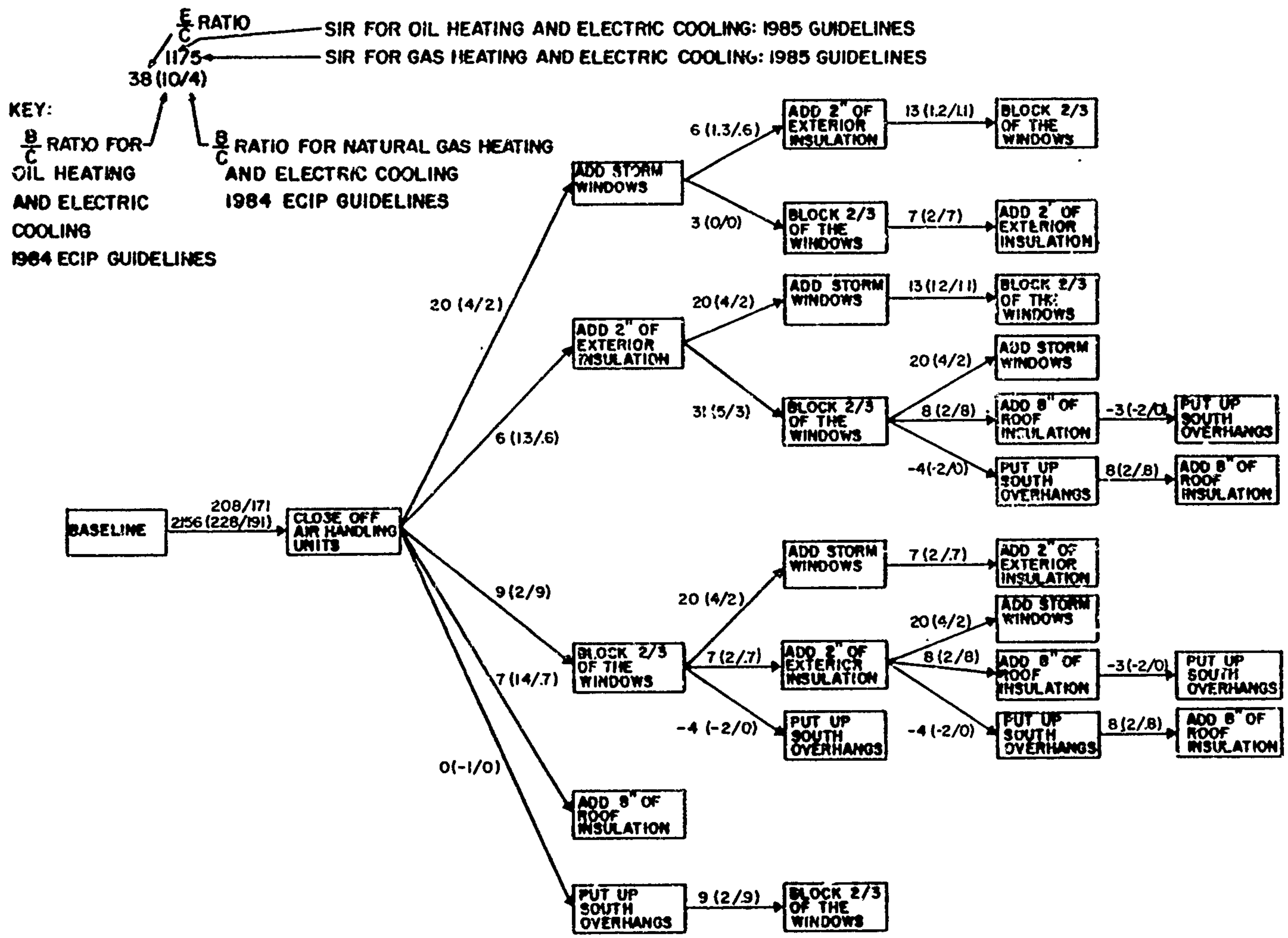

Figure 16. ECIP analysis for the Type 64 barracks, Phoenix, AZ.

Since heating energy is a large part of the total energy consumption for the motor repair shop and battalion headquarters, their initial ECA tests were done using weather data from the coldest region: Colorado Springs. ECAs which were ineffective in this climate were eliminated from further consideration, since they would do no better in warmer climates.

For the motor repair shop, the ECAs which did not meet the ECIP criteria in Colorado Springs were (1) insulating the roof and (2) replacing lights. The expense of a new roof covering overwhelmed the energy saved. Replacing lights saved the least energy of all the ECAs. In contrast, the ECAs of installing vehicle door seals and partitioning the interior had very high E/C ratios and were used in subsequent climates to establish a third and fourth baseline. Tables 22 through 26 summarize the results of the ECA simulations for the motor repair shop. Figures 17 through 21 show the ECIP analyses. The only ECA successful at all locations was internal partitioning. This ECA allows lower building temperatures in part of a building during unoccupied periods. Installing door seals was not effective in the hottest climate (Phoenix), where reducing infiltration is not critical. Insulating the walls worked best in the colder climates. Reducing the window area by one-half proved disappointing; it barely met the criteria at Colorado Springs and was quickly dropped from consideration.

Tables 27 through 31 list the results for the battalion headquarters. Figures 22 through 26 show the ECIP analyses. Since this building used a baseboard heating system with the hot water temperature controlled by outside temperature, no room temperature controls were used. One ECA considered for this building was to shut down the circulating pump during unoccupied periods. When it was simulated, it was found to be very cost effective because of its low implementation cost. The type of heater system control used, however, did not respond to the actual building heating demand. As a result, making additional building modifications like adding insulation only caused overheating and did not save any energy. The first concern, therefore, was to bring the heating system under the control of the space. The ECA for repiping and installing thermostats did this and was used to establish a second baseline. This particular ECA proved to be the only other one which met ECIP criteria at all locations. Insulating the walls was effective only for the three coldest climates. None of the other ECAs could meet the criteria.

Tables 32 through 36 list the enlisted personnel mess hall results. Figures 27 through 31 show the ECIP analyses. Since the programmable thermostats saved more energy than the regular night-setback thermostats, they were chosen as the second baseline. They were also the ECA of choice where night-setback thermostats already existed. Two ECAs (replacing the lights and installing temperature economizers) appear promising in all the regions. Replacing incandescent lighting fixtures with fluorescent ones becomes progressively more attractive as the climate changes from coldest to hottest. The heating penalty from using cooler bulbs decreases from 36 to 1 percent of the energy savings. In contrast, the temperature economizer option becomes less attractive as it spends more of its time in the "minimum stop" position caused by the longer cooling season. In Region 3 (Raleigh) and succeeding warmer climates, replacing the lights becomes the recommended second alternative instead of installing a temperature economizer. In the hottest region (Phoenix), the temperature economizer has a B/C ratio <1 where natural gas is the source of heating energy. The B/C ratio for replacing lights is >1. In the two coldest regions (Colorado Springs and Columbia), covering the upper half of the dining room windows meets the ECIP criteria. Pouring insulation into the wall air gap is a marginal project for the coldest region. Because it is not cost effective in the other regions, it is recommended only when all other alternatives have been completed and only in the coldest regions.

An interesting option is the conversion of the existing dining room, single-zone air-conditioning units to variable air volume units. Three kinds of variable air volume operation were simulated: (1) a fixed set-point cold deck with a fixed amount of outside air, (2) a fixed set-point cold deck with a temperature economizer, and (3) a zone-controlled cold deck with a temperature economizer. The latter operation is one of the most energy efficient. However, it should be designed to replace, not retrofit, existing systems. Trying to implement this type of operation by adding only a fan control, without any corresponding changes in the ductwork or diffusers, can cause severe problems such as poor air distribution and complete loss of humidity control. The results indicate that the fixed set-point variable air volume operation will usually use more energy than the existing system because of the constant cooling and heating required.

The fixed set-point with a temperature economizer meets ECIP criteria in the colder regions when installed as a single unit. However, most of its savings are attributed to the economizer. When the fan control is added after the economizer, the option is no longer feasible.

The zone-controlled variable air volume proved to be the only one that consistently saved energy. However, it is recommended only where humidity control is not critical and where cooling energy is a substantial part of the building's energy usage (e.g., at Phoenix). It should be used only after all other feasible alternatives have been installed.

Several simplifying assumptions had to be made to stimulate the heat-recovery ECA. The performance of the desired arrangement, a run-around loop, was highly dependent on the outside air conditions. However, the BLAST program does not model this technique. Although BLAST was modified to create a simple model of this technique, this option is not strongly recommended, although the results indicated that exhaust-air heat recovery has good potential for energy savings and should be seriously considered for the colder regions.

If a building has already been retrofit, Figures 7 through 31 can be used to see if more ECIP projects can be used to meet the ECIP criteria minimums. For example, if a Type 64 barracks in climatic zone 2 has closed off the AHUs and blocked two-thirds of the windows, adding storm windows would satisfy the ECIP minimums.

ECIP projects which do not meet the ECIP minimums may still be useful if they reduce energy consumption or maintenance, or improve aesthetics. For example, exterior insulation cannot be justified on ECIP criteria alone (even though it saves a lot of energy) because of its cost. However, it reduces building maintenance and improves building appearance.

Tables 37 through 41 summarize the ECIP ratios for both the old and new guidelines for each building at each location. These results indicate which ECIP projects should be recommended. The projects recommended using the criteria in use through FY84 (an E/C ratio > 17 and a B/C ratio > 1) are listed in Tables 42 through 46. The projects recommended using the criteria beginning with FY85 (an SIR of > 1) are listed in Tables 47 through 51. (Key for Tables 37 through 51: L1 = Colorado Springs, CO; L2 = Columbia, MO; L3 = Raleigh, NC; L4 = Fort Worth, TX; L5 = Phoenix, AZ.)

Using the criteria in effect through FY84, the following energy consumption reduction estimates were realized:

1. The average energy usage of a rolling pin barracks decreased by 32 percent from 172 to 117 kBtu/sq ft/year (543 to 368 kWh/m^2/year).

2. The average Type 64 barracks energy usage decreased by 33 percent, from 222 to 148 kBtu/sq ft/year (699 to 466 kWh/m^2/year).

3. The average energy consumption of the motor repair shop decreased by 33 percent, from 417 to 281 kBtu/sq ft/year (1313 to 885 kWh/m^2/year).

4. The battalion headquarter's energy usage decreased by 48 percent, from 218 to 113 kBtu/sq ft/year (686 to 356 kWh/m^2/year).

5. The energy consumption of the enlisted personnel mess hall decreased 40 percent, from 492 to 295 kBtu/sq ft/year (1550 to 929 kWh/m^2/year).

Beginning with FY85, the implementation of the recommended projects could result in the following reductions:

1. Modifying the motor repair shop could reduce energy consumption by 35 percent, from 417 to 272 kBtu/sq ft/year (1314 to 857 kWh/m^2/year).

2. Retrofitting the battalion headquarters could reduce the energy consumption by 50 percent, from 218 to 109 kBtu/sq ft/year (687 to 344 kWh/m^2/year).

3. Retrofits to the Type 64 barracks cut energy consumption by 41 percent, from 222 to 131 kBtu/sq ft/year (699 to 413 kWh/m^2/year).

The recommended changes to the enlisted personnel mess hall and the rolling-pin barracks under the new criteria are the same as those suggested under the old criteria.

These predicted energy savings do not have to be repeated for individual ECIP projects unless an individual building is markedly different from the standard design. Thus, cost analyses should be reviewed for local variations. If the costs are correct, the entire ECIP analysis can be taken directly from this report. A sample ECIP economic analysis is given in Appendices D through F. These appendices use the energy savings and cost information given in this report. They describe how to fill out an ECIP economic analysis using this report.

Table 22

ECA Simulation Summary -- Energy Savings for the Motor Repair Shop, Colorado Springs, CO

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Night Setback	499.7	6.5	506.1	1682	208	91	367	182
New Baseline = A1								
B1 Insulate Walls	152.8	0.7	153.5	38	7	3	13	6
B2 Insulate Roof	74.2	0.3	74.5	3	<1	<1	1	<1
B3 Cover Windows	54.5	0.3	54.8	16	3	1	6	2
B4 Install Door Seals	225.3	2.0	227.4	116	14	6	10	5
B5 Replace Lights	-16.3	56.8	40.4	9	1	2	<1	1
B6 Partition	150.8	4.1	154.9	125	23	10	42	19
New Baseline = B6								
C1 Install Door Seals	193.0	0.0	193.0	99	12	5	8	4
New Baseline = C1								
D1 Insulate Walls	129.5	0.0	129.5	32	6	3	11	5
D2 Cover Windows	49.3	0.0	49.3	14	3	1	5	2
New Baseline = D1								
E1 Cover Windows	56.0	0.0	56.0	16	3	1	6	3

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 23

ECA Simulation Summary — Energy Savings for the Motor Repair Shop, Columbia, MO

Energy Conservation Retrofit Option	System Heating (MBtu)*	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Night Setback	443.2	7.1	450.3	1497	185	81	162	326
New Baseline = A1 B1 Insulate Walls	151.0	3.1	154.1	124	23	10	42	19
New Baseline = B1 C1 Install Door Seals	189.8	0.0	189.8	97	12	5	8	4
New Baseline = C1 D1 Insulate Walls	106.8	0.0	106.8	26	5	2	9	4
New Baseline = D1 E1 Cover Windows	47.5	0.0	47.5	14	3	1	5	2

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 24

ECA Simulation Summary -- Energy Savings for the Motor Repair Shop, Raleigh, NC

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Night Setback	360.2	8.2	368.3	1224	151	67	266	133
New Baseline = A1 B1 Partition	139.5	4.1	143.6	116	22	10	39	17
New Baseline = B1 C1 Install Door Seals	107.8	0.0	107.8	55	6	3	5	2
New Baseline = C1 D1 Insulate Walls	60.3	0.3	60.6	15	3	1	5	2
New Baseline = D1 E1 Cover Windows	25.5	0.0	25.5	8	1	<1	3	1

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 25

ECA Simulation Summary -- Energy Savings for the Motor Repair Shop, Fort Worth, TX

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Night Setback	281.3	8.2	289.5	962	119	53	208	105
New Baseline = A1 B1 Partition	106.7	3.1	109.7	88	16	7	30	13
New Baseline = B1 C1 Install Door Seals	68.8	0.7	69.5	36	4	2	3	2
New Baseline = C1 D1 Insulate Walls	37.0	0.3	37.3	9	2	<1	3	1

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 26

ECA Simulation Summary -- Energy Savings for the Motor Repair Shop, Phoenix, AZ

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Night Setback	172.0	1.4	173.4	576	71	31	126	62
New Baseline = A1 B1 Partition	59.8	2.0	61.8	50	9	4	17	8

*Metric conversion: 1 MBtu = 1.055 GJ.

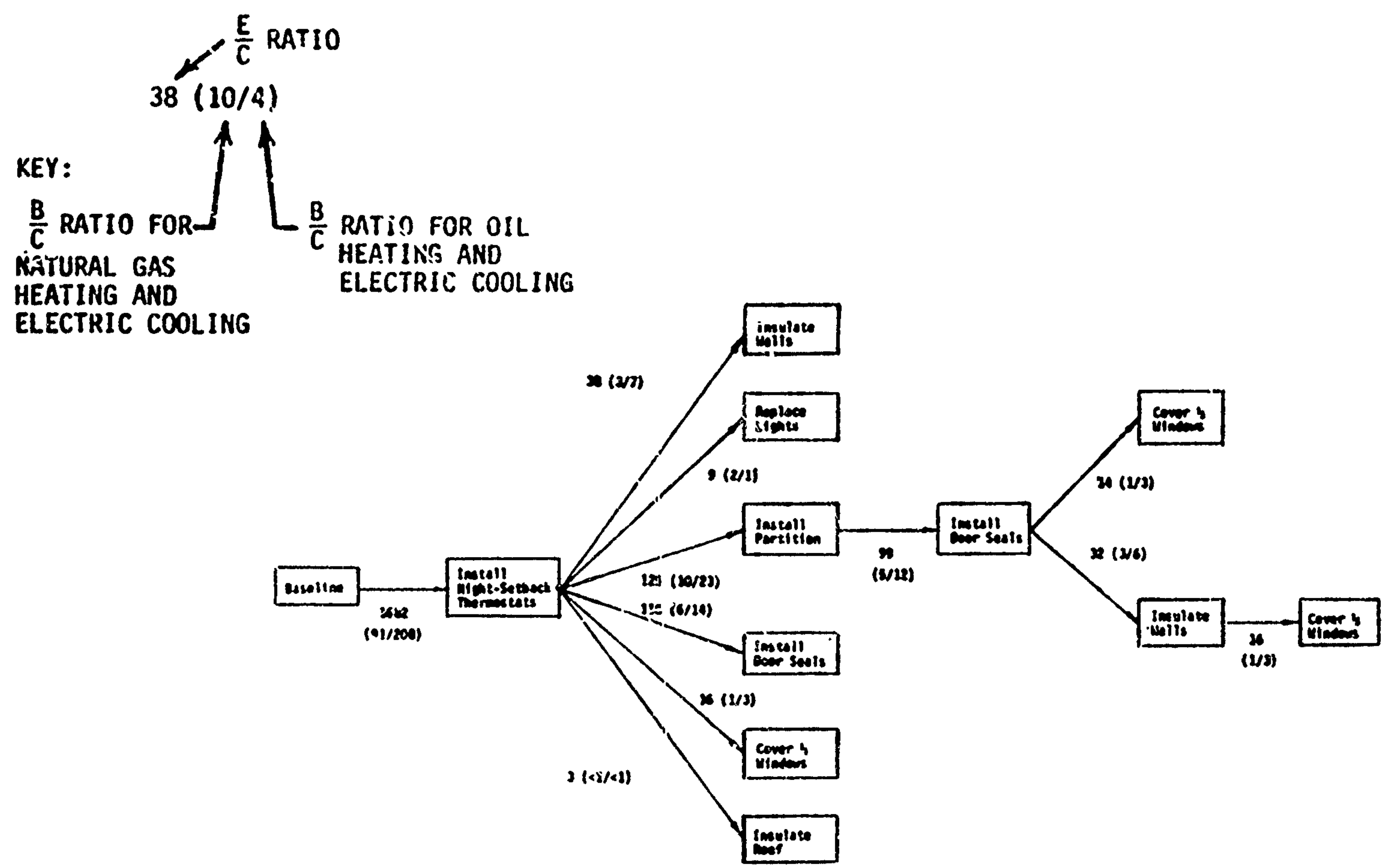

Figure 17. ECIP analysis for the motor repair shop, Colorado Springs, CO.

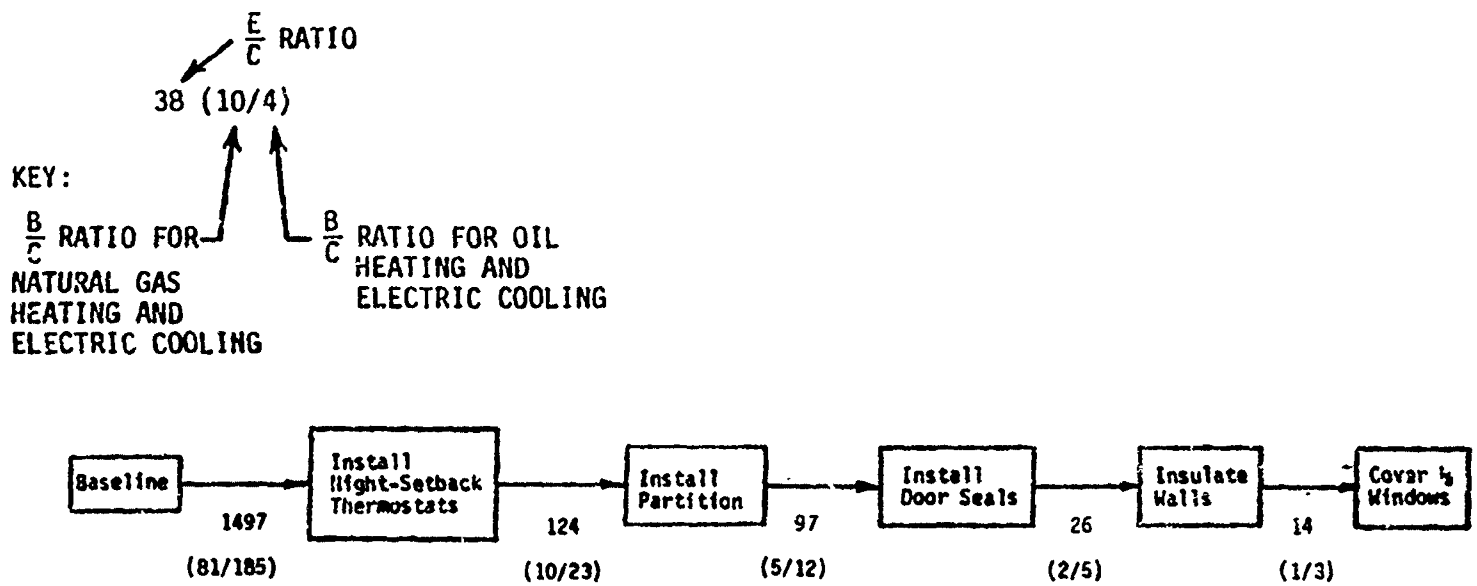

Figure 18. ECIP analysis for the motor repair shop, Columbia, MO.

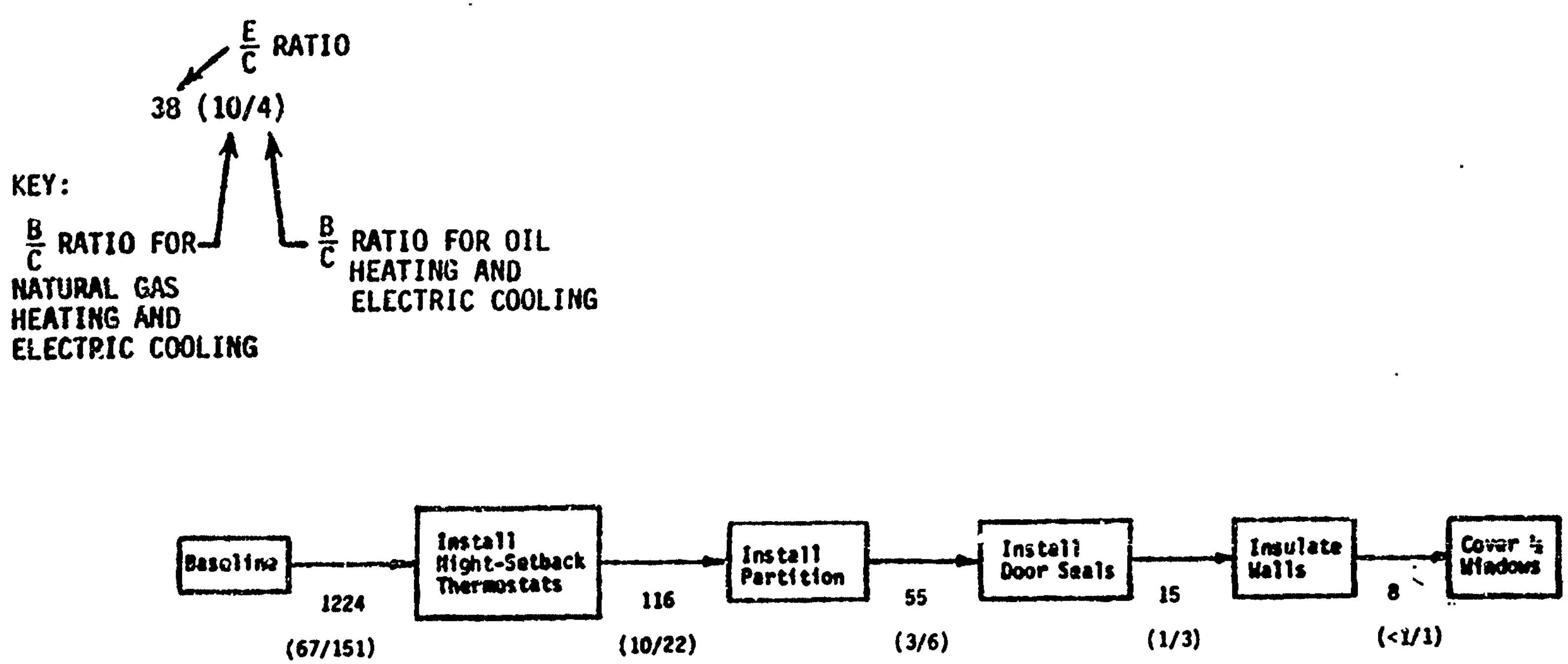

Figure 19. ECIP analysis for the motor repair shop, Raleigh, NC.

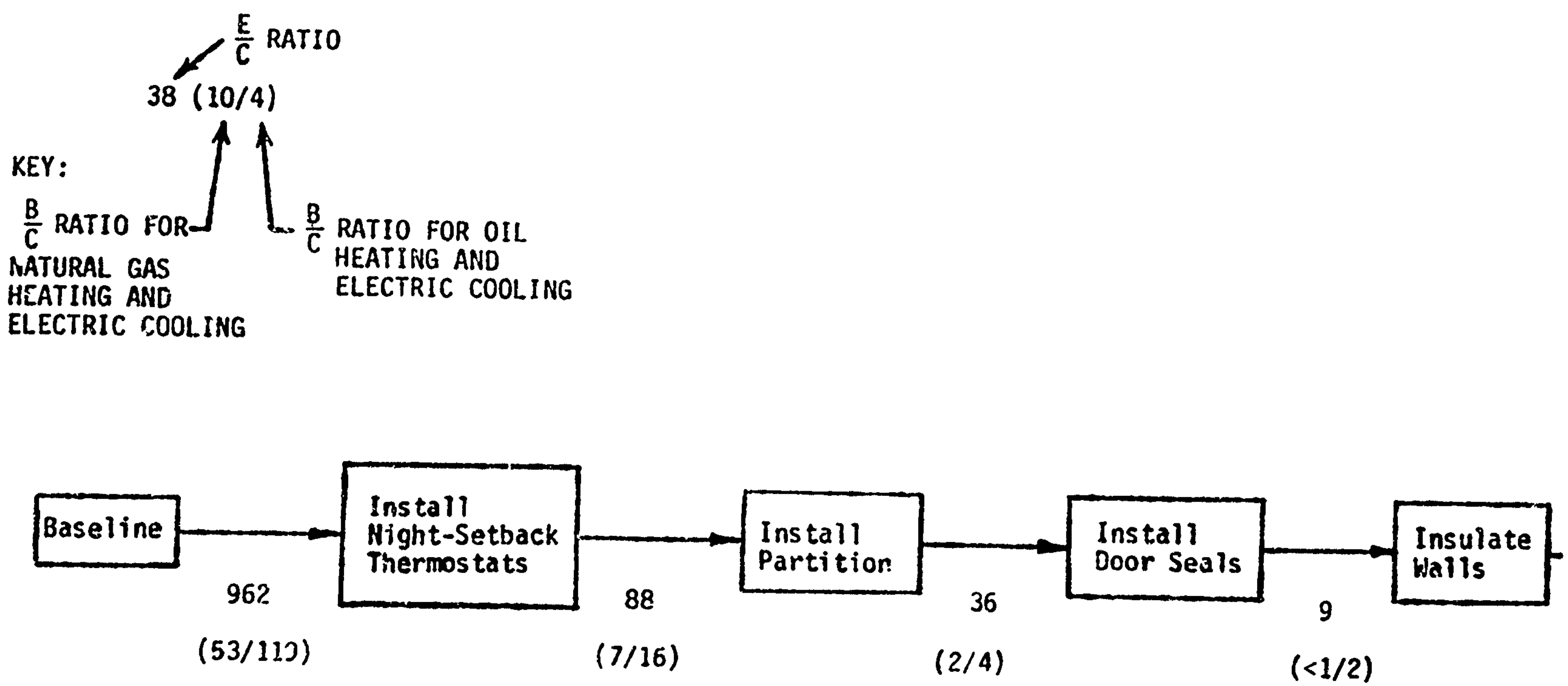

Figure 20. ECIP analysis for the motor repair shop, Fort Worth, TX.

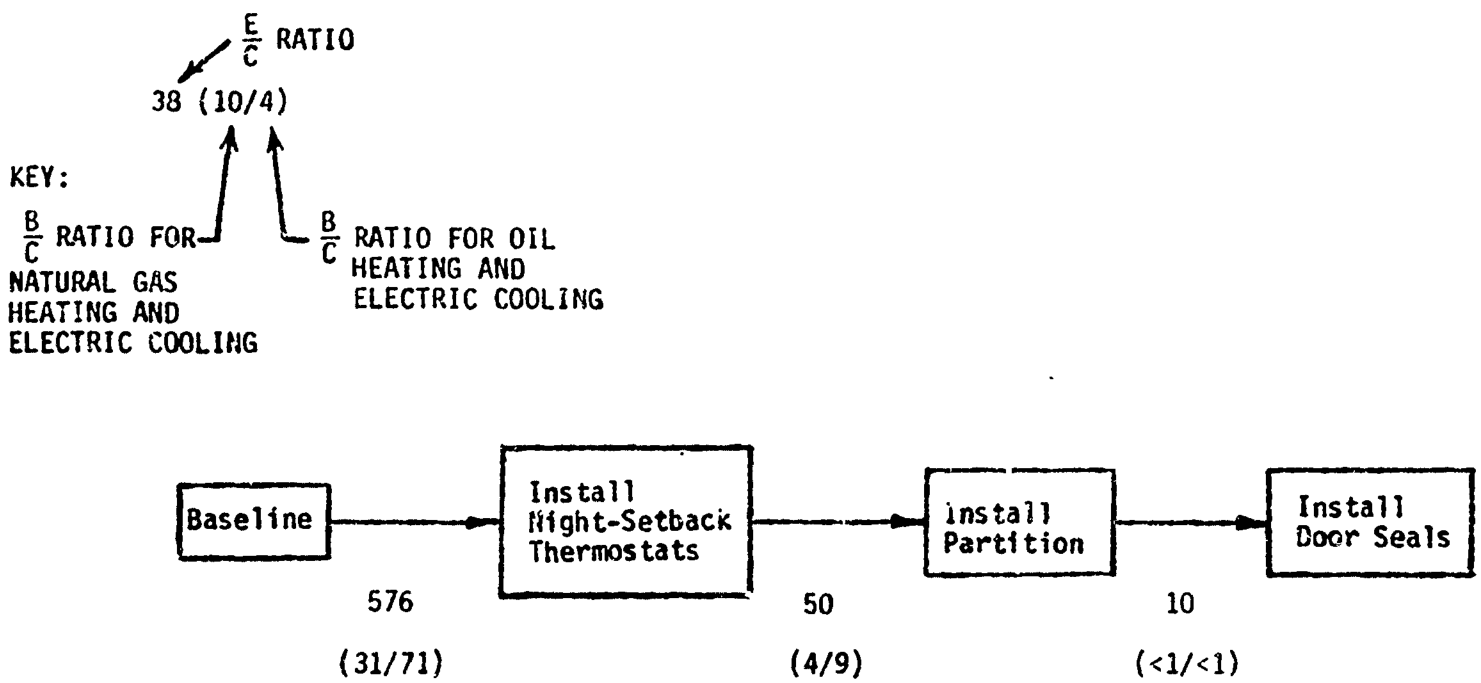

Figure 21. ECIP analysis for the motor repair shop, Phoenix, AZ.

Table 27

ECA Simulation Summary -- Energy Savings for the Battalion Headquarters, Colorado Springs, CO

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Timeclock Hot Water Pump	126.0	6.9	132.9	408	50	23	88	45
A2 Install Thermostat	314.8	0.1	314.9	115	14	6	24	12
A3 Repipe Baseboard and Install Night Setback	407.5	0.1	407.6	144	18	8	32	16
New Baseline = A3								
B1 Insulate Walls	57.1	-0.5	56.6	32	6	3	11	5
B2 Insulate Roof	41.7	0.1	41.8	4	<1	<1	1	<1
B3 Install Storm Windows	22.0	0.0	22.0	7	1	<1	2	1
B4 Install Vestibule	9.3	-0.1	9.2	7	1	<1	2	1
B5 Timeclock Electric Domestic Hot Water Heater	-0.2	2.1	1.9	6	<1	<1	<1	<1
New Baseline = B1								
C1 Install Storm Windows	27.3	-0.1	27.1	9	2	<1	3	1
C2 Install Vestibule	10.8	-0.1	10.7	8	1	<1	3	1
New Baseline = C1								
D1 Install Vestibule	8.9	-0.1	8.8	7	1	<1	2	1

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 28

ECA Simulation Summary -- Energy Savings for the Battalion Headquarters, Columbia, MO

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Timeclock Hot Water Pump	93.0	6.9	99.9	306	38	18	65	34
A2 Repipe Baseboard and Install Night Setback	309.1	0.1	309.2	110	13	6	24	12
New Baseline = A2								
B1 Insulate Walls	48.4	-0.4	48.0	27	5	2	13	5
New Baseline = B1								
C1 Install Storm Windows	21.9	-0.2	21.7	7	1	<1	2	1

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 29

ECA Simulation Summary -- Energy Savings for the Battalion Headquarters, Raleigh, NC

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Timeclock Hot Water Pump	68.0	6.8	74.8	230	29	14	49	25
A2 Repipe Baseboard and Install Night Setback	240.9	0.0	240.9	85	10	4	19	9
New Baseline = A2 B1 Insulate Walls	29.9	-0.9	29.0	16	3	1	3	1

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 30

ECA Simulation Summary -- Energy Savings for the Battalion Headquarters, Fort Worth, TX

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Timeclock Hot Water Pump	45.0	6.9	51.9	159	20	10	33	18
A2 Repipe Baseboard and Install Night Setback	163.0	0.1	163.1	58	7	3	13	6
New Baseline = A2								
B1 Insulate Walls	18.7	-0.4	18.3	10	2	<1	2	<1

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 31

ECA Simulation Summary -- Energy Savings for the Battalion Headquarters, Raleigh, NC

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Timeclock Hot Water Pump	28.8	6.8	35.6	109	14	8	22	12
A2 Repipe Baseboard and Install Night Setback	108.5	0.0	108.5	38	5	2	8	4

*Metric conversion: 1 MBtu = 1.055 GJ.

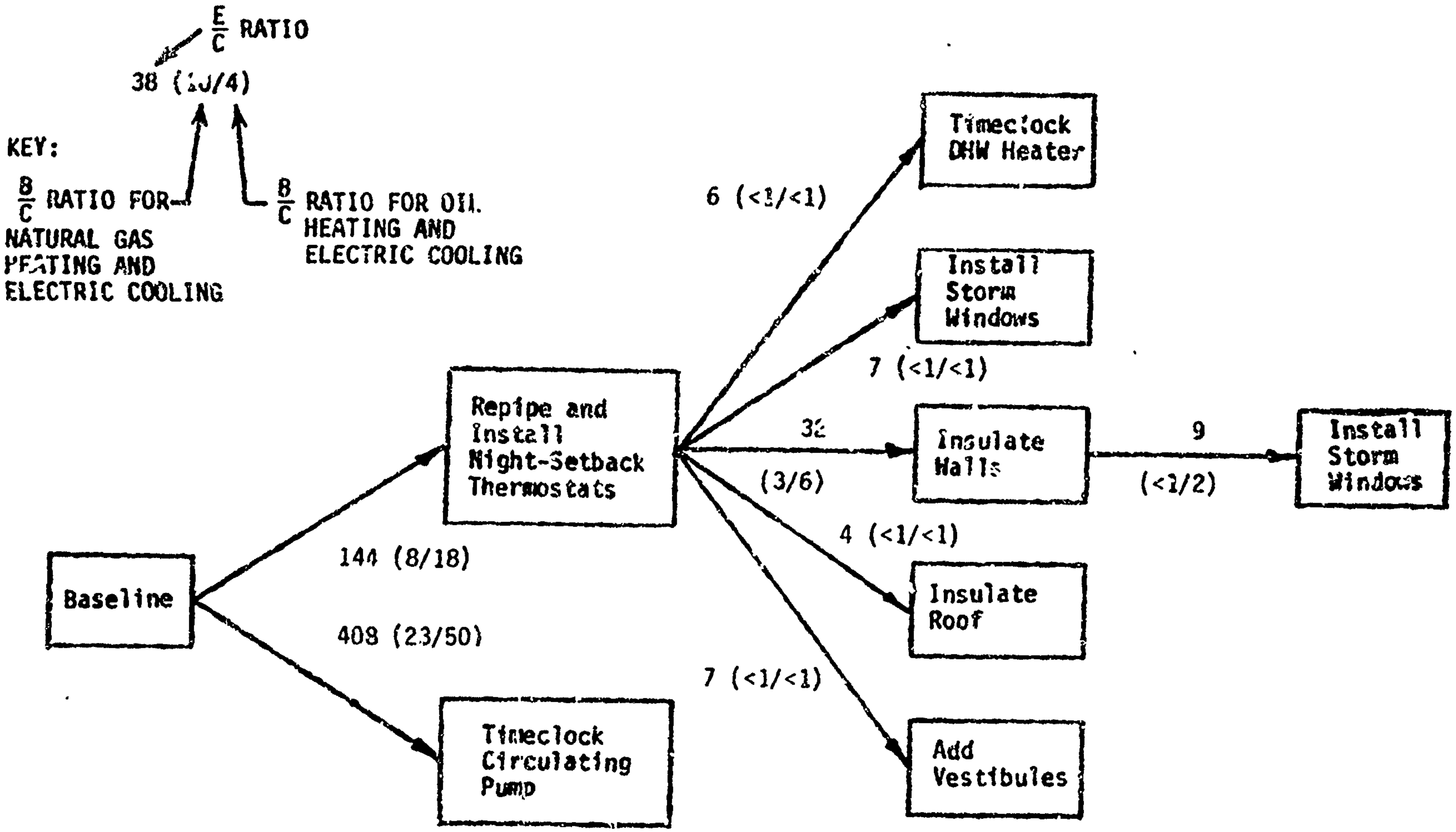

Figure 22. ECIP analysis for the battalion headquarters, Colorado Springs, CO.

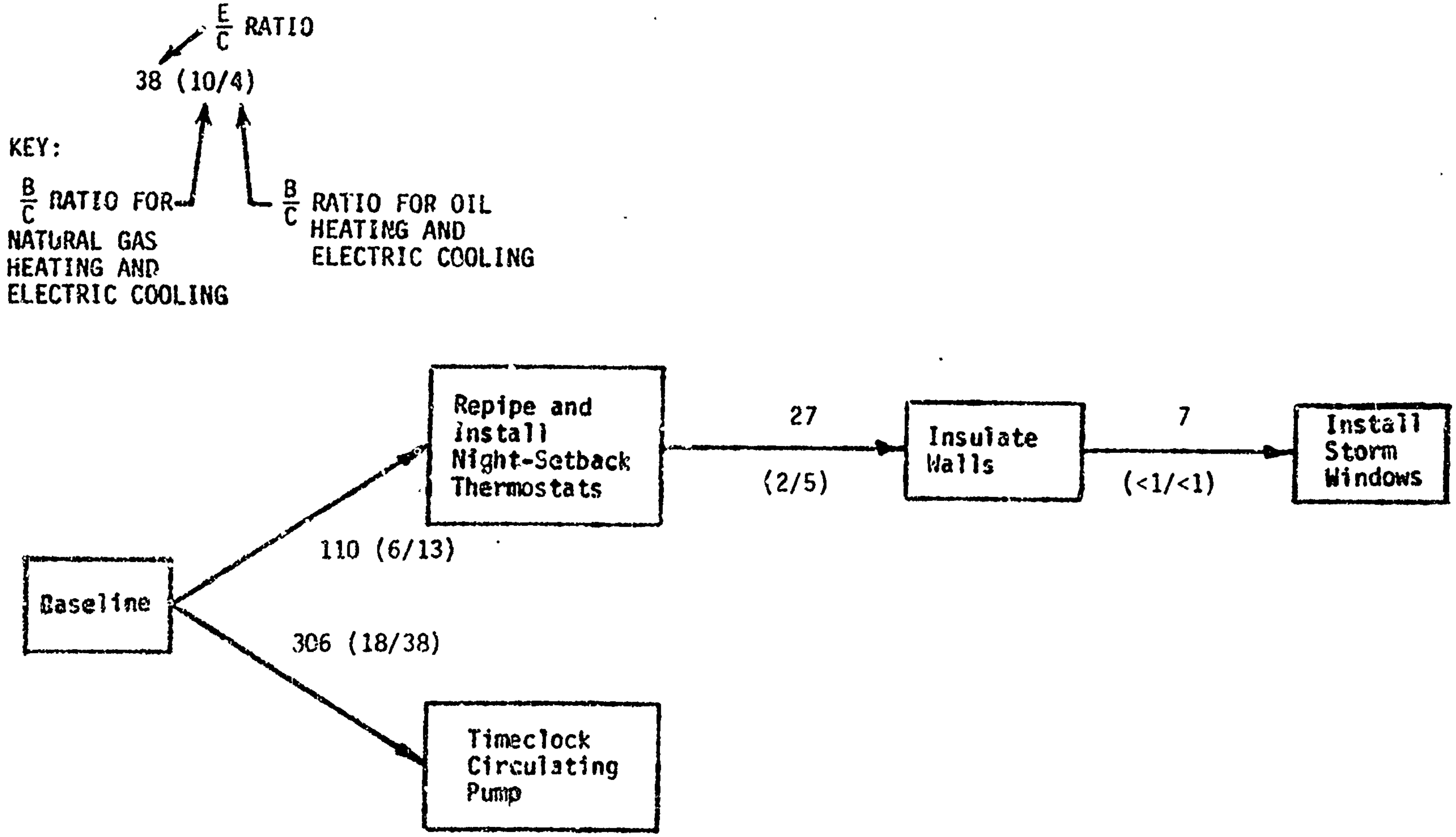

Figure 23. ECIP analysis for the battalion headquarters, Columbia, MO.

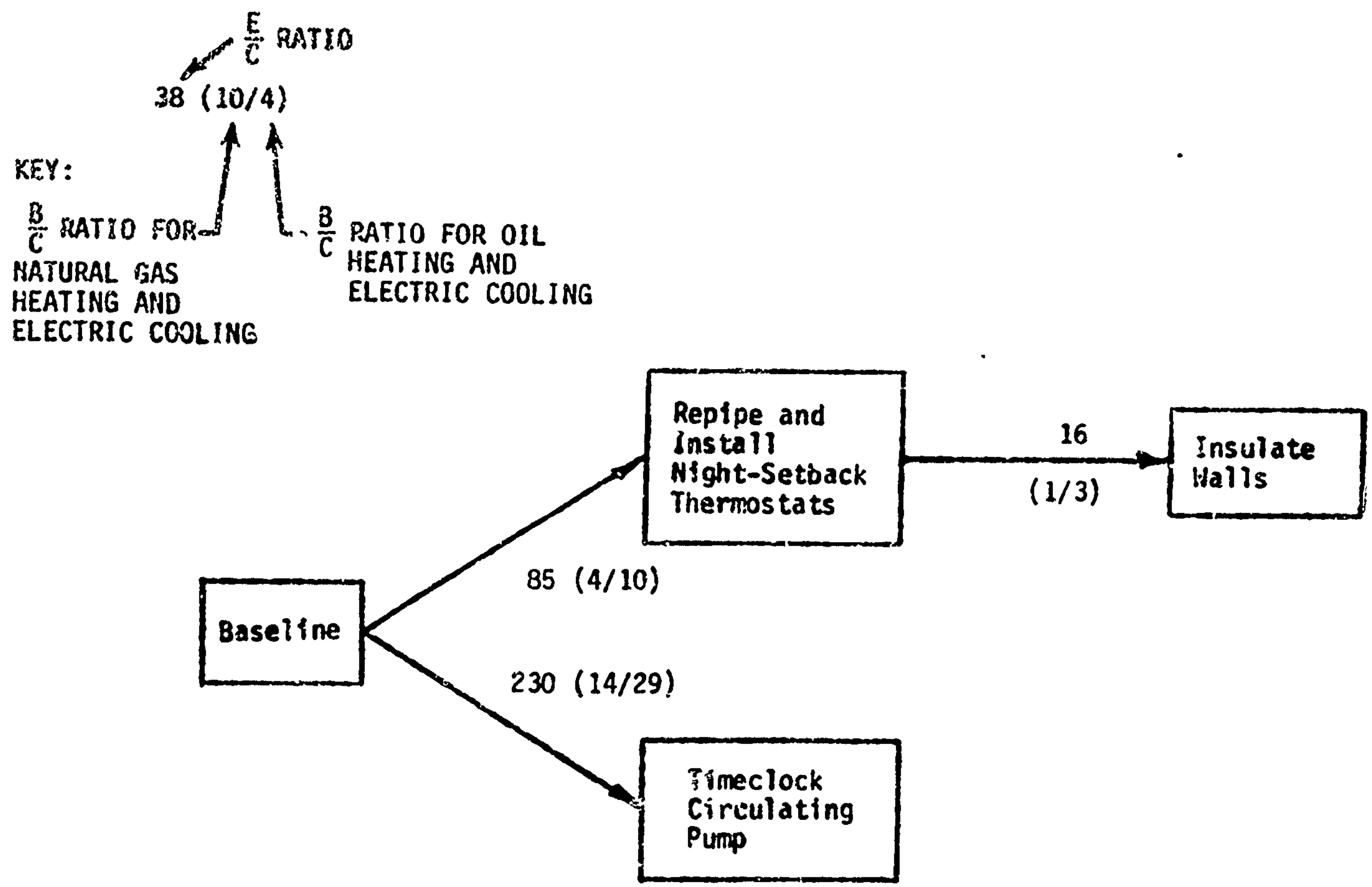

Figure 24. ECIP analysis for the battalion headquarters, Raleigh, NC.

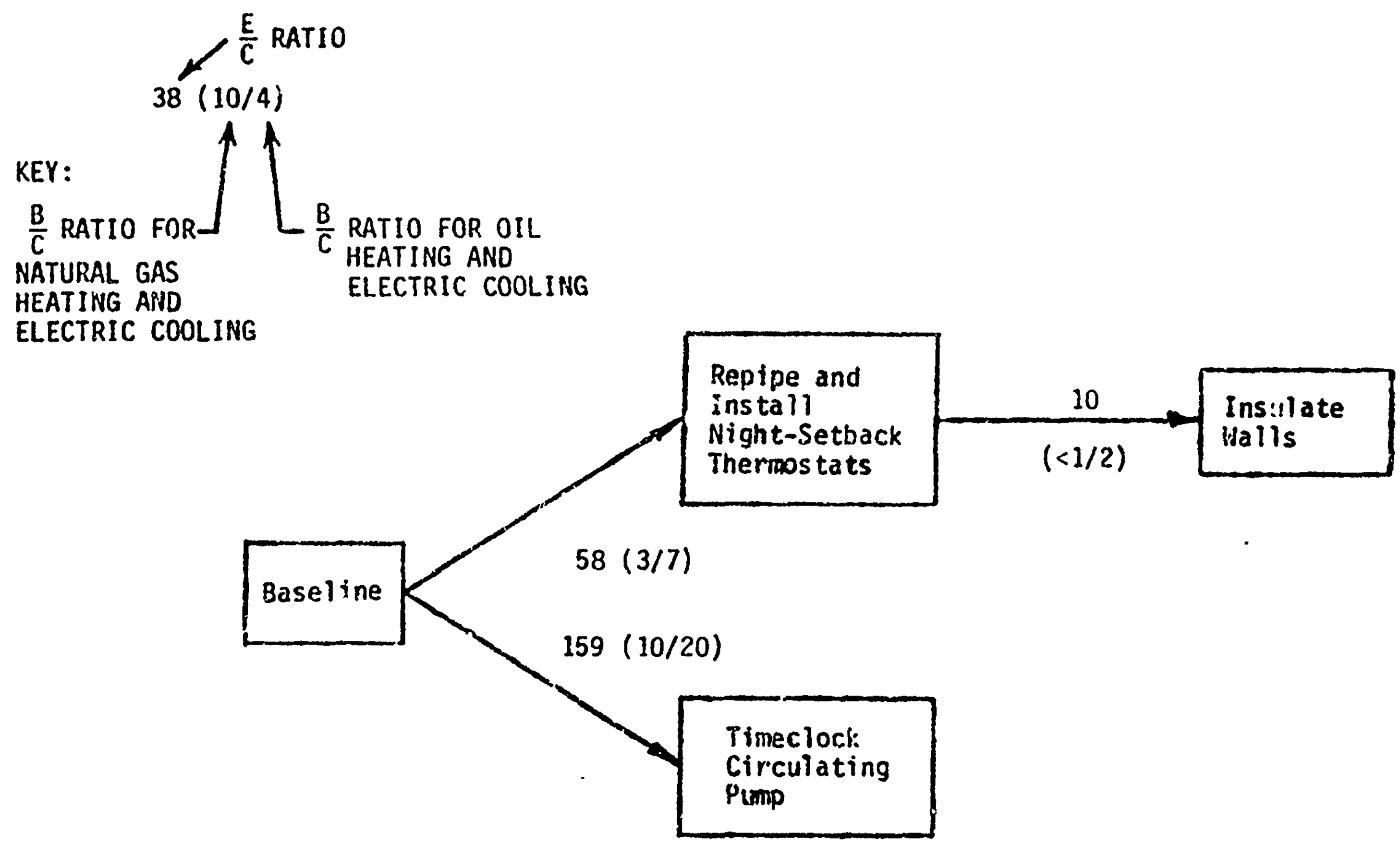

Figure 25. ECIP analysis for the battalion headquarters, Fort Worth, TX.

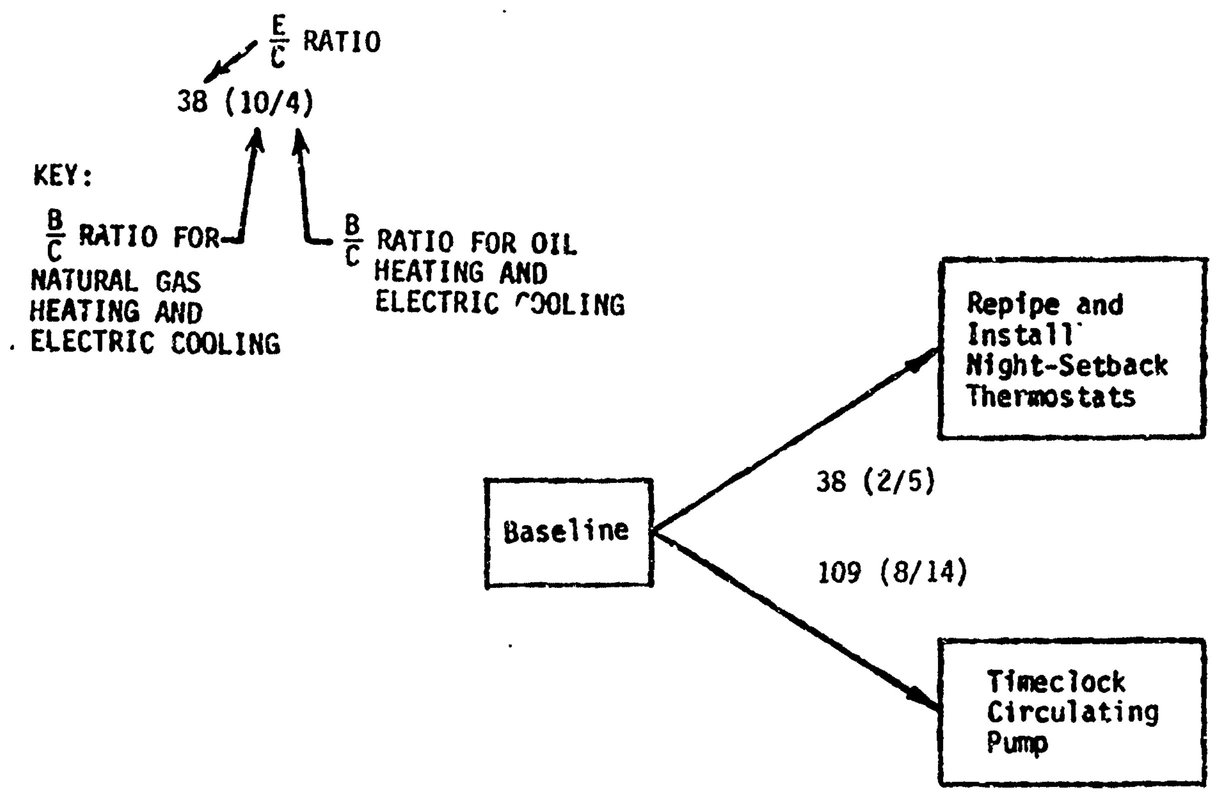

Figure 26. ECIP analysis for the battalion headquarters, Phoenix, AZ.

Table 32

ECA Simulation Summary -- Energy Savings for the Enlisted Personnel Mess Hall, Colorado Springs, CO

Energy Conservation Retrofit Option	System Heating (MBtu)*	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C Oil	B/C Gas	SIR Oil	SIR Gas
A1: Install Programmable Thermostats	1846.5	378.1	2224.7	2305	288	153	310	182
New Baseline = A1								
B1: Install Temperature Economizer	381.5	8.7	390.2	49	6	3	6	3
B2: Replace Lights	-75.7	212.8	137.1	35	5	6	6	7
B3: Cover One-Half of the Windows	199.8	33.0	232.8	44	8	4	9	5
B4: Insulate Walls	260.8	28.6	289.5	21	4	2	4	2
B5: Convert to Variable Air Volume with Economizer	329.3	187.3	329.3	26	4	3	6	4
B6: Recover Kitchen Exhaust Air Heat	781.2	60.8	24	3	1	3	1.5	
New Baseline = B1								
C1: Replace Lights	-56.0	212.7	156.7	39	6	7	6	7
C2: Cover One-Half of the Windows	157.0	33.7	190.7	36	7	4	8	4
C3: Insulate Walls	236.3	29.2	264.9	19	4	2	4	2
C4: Convert to Variable Air Volume	-239.5	178.6	-60.9	-14	<1	5	<1	3
New Baseline = B2								
C5: Install Temperature Economizer	401.2	8.7	409.8	51	6	3	7	3
C6: Cover One-Half of the Windows	284.3	44.5	329.2	63	12	6	13	7
New Baseline = B3								
C7: Install Temperature Economizer	338.7	9.4	348.1	43	5	2	6	3
C8: Replace Lights	8.8	224.7	233.5	59	8	8	9	9
New Baseline = C1 or C5								
D1: Cover One-Half of the Windows	209.8	45.4	255.3	49	9	5	10	5
New Baseline = D1								
E1: Install Heat Recovery in Kitchen Exhaust	676.0	53.7	729.7	18	2	1	2	1

* Metric conversion: 1 MBtu = 1.055 GJ.

Table 33

ECA Simulation Summary — Energy Savings for the Enlisted Personnel Mess Hall, Columbia, MO

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1: Install Programmable Thermostats	1386.5	400.1	1786.6	1851	229	128	251	155
New Baseline = A1								
B1: Install Temperature Economizer	314.7	14.5	329.1	41	5	2	5	3
B2: Replace Lights	-38.2	213.8	180.3	45	6	7	7	7
B3: Cover One-Half of the Windows	59.3	20.3	79.6	15	3	2	3	2
B4: Insulate Walls	29.5	9.0	38.5	3	<1	<1	<1	<1
B5: Convert to Variable Air Volume with Economizer	30.3	143.4	173.7	14	3	3	6	5
B6: Install Heat Recovery in Exhaust Air	686.3	61.2	747.5	21	3	1	3	1

* Metric conversion: 1 MBtu = 1.055 GJ.

Table 33 (Cont'd)

Energy Conservation Retrofit Option	System Heating (MBtu*)	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
New Baseline = B1								
C1: Replace Lights	-28.8	218.3	189.5	48	7	7	7	8
C2: Cover One-Half of the Windows	33.3	20.7	54.0	19	2	1	2	1
New Baseline = B2								
C3: Install Temperature Economizer	324.0	14.2	338.2	42	5	2	6	3
C4: Cover One-Half of the Windows	100.7	29.3	130.0	25	5	3	5	3
New Baseline = C1								
D1: Cover One-Half of the Windows	57.0	29.6	86.6	17	2	3	3	2

* Metric conversion: 1 MBtu = 1.055 GJ.

Table 34

ECA Simulation Summary — Energy Savings for the Enlisted Personnel Mess Hall, Raleigh, NC

Energy Conservation Retrofit Option	System Heating (MBtu)*	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Install Programmable Thermostats	895.2	390.1	1285.3	1332	165	100	183	113
New Baseline = A1								
B1 Install Temperature with Economizer	214.0	19.4	233.4	29	3	1	4	2
B2 Replace Lights	-11.0	227.4	216.4	55	7	8	8	8
B3 Cover One-Half of the Windows	-13.3	3.2	-10.2	-2	<1	<1	<1	<1
B5 Convert to Variable Air Volume with Economizer	-132.0	74.3	-57.7	-5	<1	1	<1	<1
B6 Install Heat Recovery in Exhaust Air	432.7	60.8	493.5	14	2	1	2	<1
New Baseline = B1								
C1 Replace Lights	-15.0	227.2	212.2	53	7	8	8	8
C2 Cover One-Half of the Windows	-3.8	4.3	0.4	<1	<1	<1	<1	<1

*Metric conversion: 1 MBtu = 1.055 GJ.

Table 34 (Cont'd)

Energy Conservation Retrofit Option	System Heating (MBtu)*	Total Electricity (MBtu)	Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
New Baseline = B2								
C3 Install Temperature Economizer	210.0	19.1	229.1	29	3	1	4	2
C4 Cover One-Half of the Windows	5.2	6.8	11.9	2	<1	<1	<1	<1
New Baseline = C1								
D1 Cover One-Half of the Windows	10.2	7.1	17.3	3	<1	<1	<1	<1

* Metric conversion: 1 MBtu = 1.055 GJ.

Table 35

ECA Simulation Summary -- Energy Savings for the Enlisted Personnel Mess Hall, Fort Worth, TX

Energy Conservation Retrofit Option	System Heating (MBtu)*	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Install Programmable Thermostats	526.3	474.6	1000.9	1037	120	82	146	109
New Baseline = A1								
B1 Install Temperature Economizer	151.0	29.9	180.9	23	2	1	3	1.8
B2 Replace Lights	-2.3	231.4	229.1	56	8	8	9	9
B6 Install Heat Recovery in Exhaust Air	334.8	60.8	395.7	11	1	<1	1.3	<1
New Baseline = B1								
C1 Replace Lights	-8.7	231.1	222.4	56	8	8	9	9
New Baseline = B2								
C2 Install Temperature Economizer	14[illegible].7	29.6	174.2	22	2	1	3	2

* Metric conversion: 1 MBtu = 1.055 GJ.

Table 36

ECA Simulation Summary -- Energy Savings for the Enlisted Personnel Mess Hall, Phoenix, AZ

Energy Conservation Retrofit Option	System Heating (MBtu)*	Electricity (MBtu)	Total Energy (MBtu)	E/C	B/C		SIR	
					Oil	Gas	Oil	Gas
A1 Install Programmable Thermostats	243.8	555.7	799.5	828	84	66	130	102
New Baseline = A1								
B1 Install Temperature Economizer	97.5	56.4	153.9	19	2	<1	3	1.8
B2 Replace Lights	-1.0	244.7	243.7	61	8	8	9	9
New Baseline = B1								
C1 Replace Lights	-1.8	231.5	241.5	61	8	8	9	9
New Baseline = B2								
C2 Install Temperature Economizer	96.7	55.1	151.8	19	2	<1	3	1.8

* Metric conversion: 1 MBtu = 1.055 GJ.

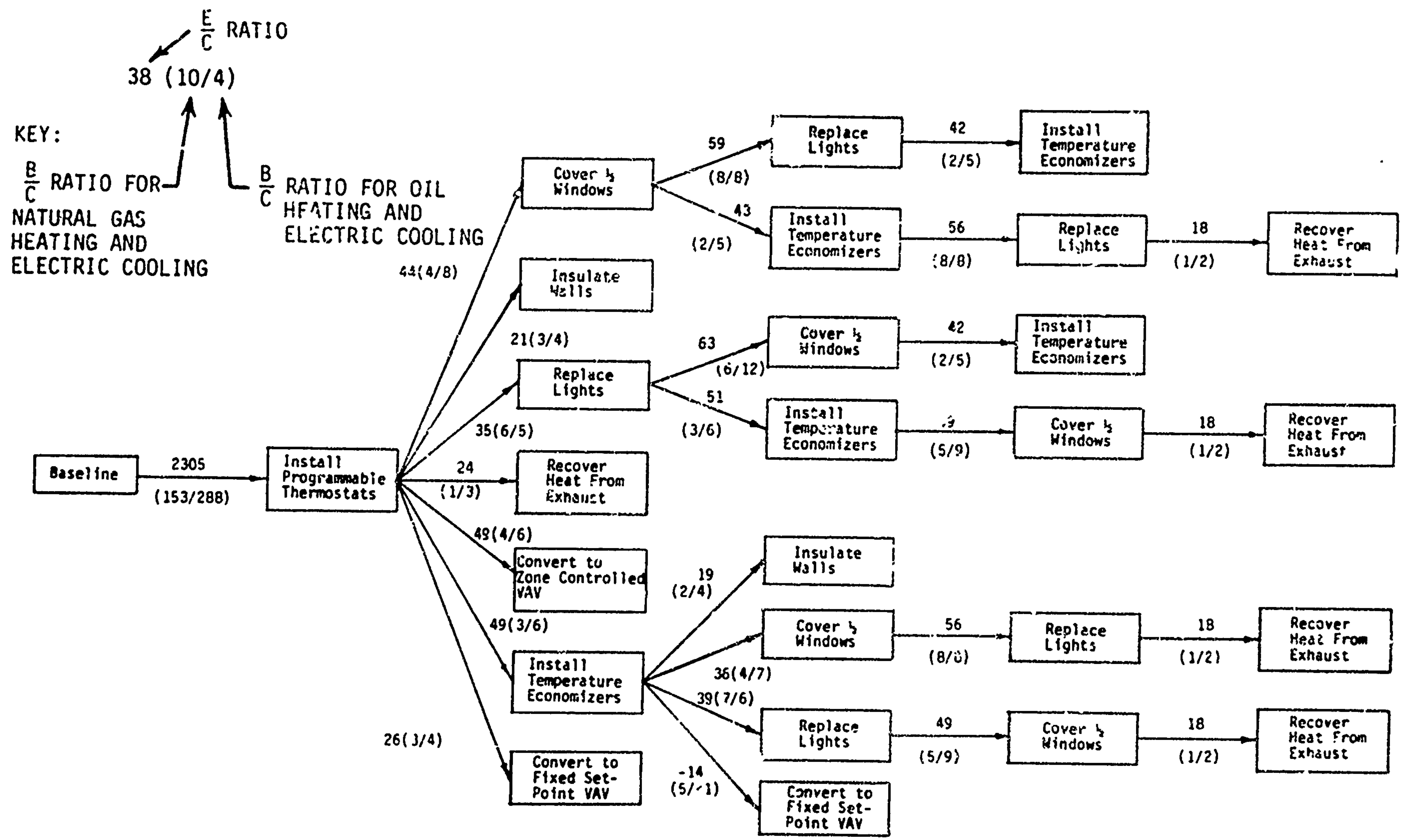

Figure 27. ECIP analysis for the enlisted personnel mess hall, Colorado Springs, CO.

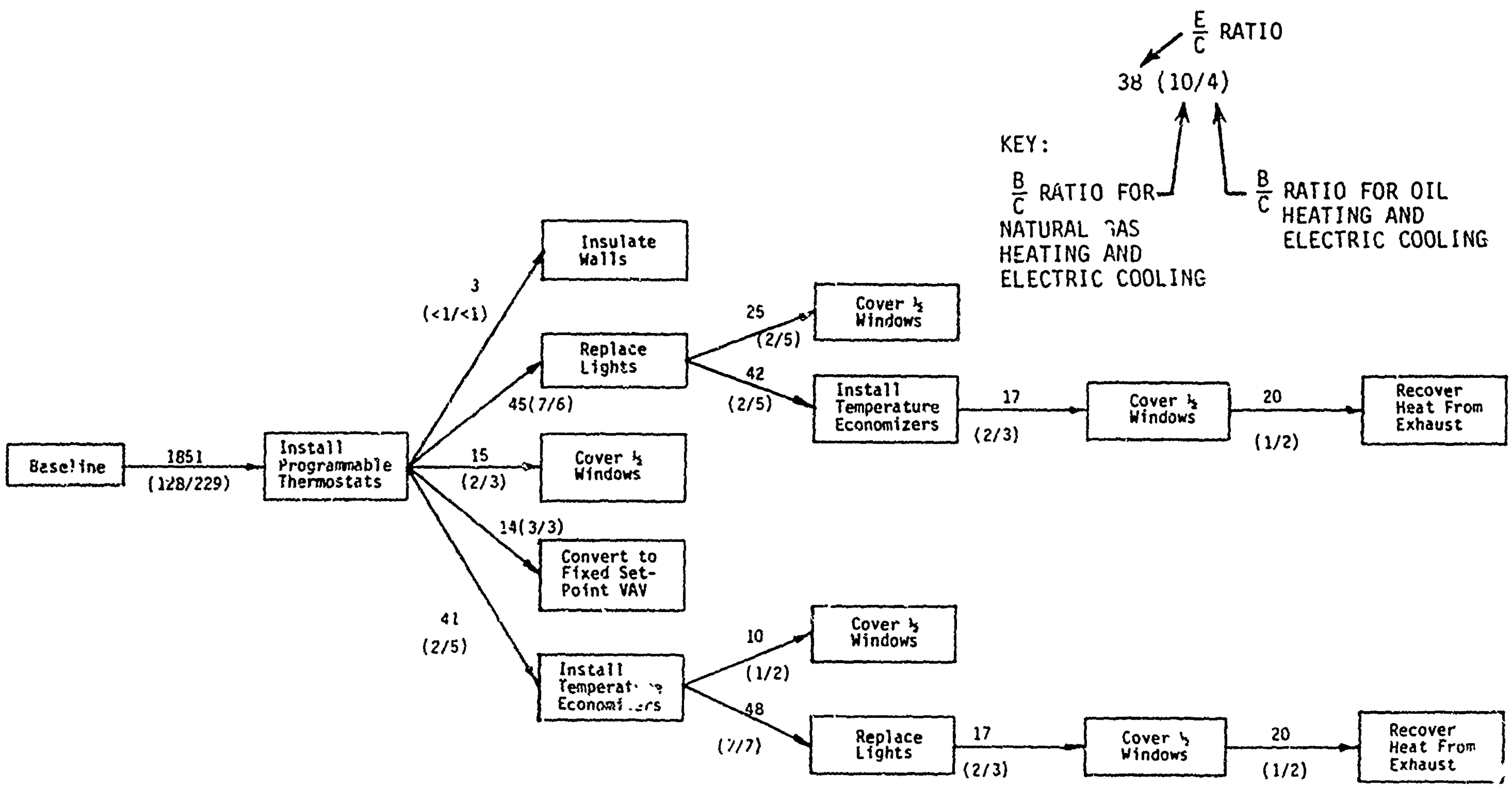

Figure 28. ECIP analysis for the enlisted personnel mess hall, Columbia, MO.

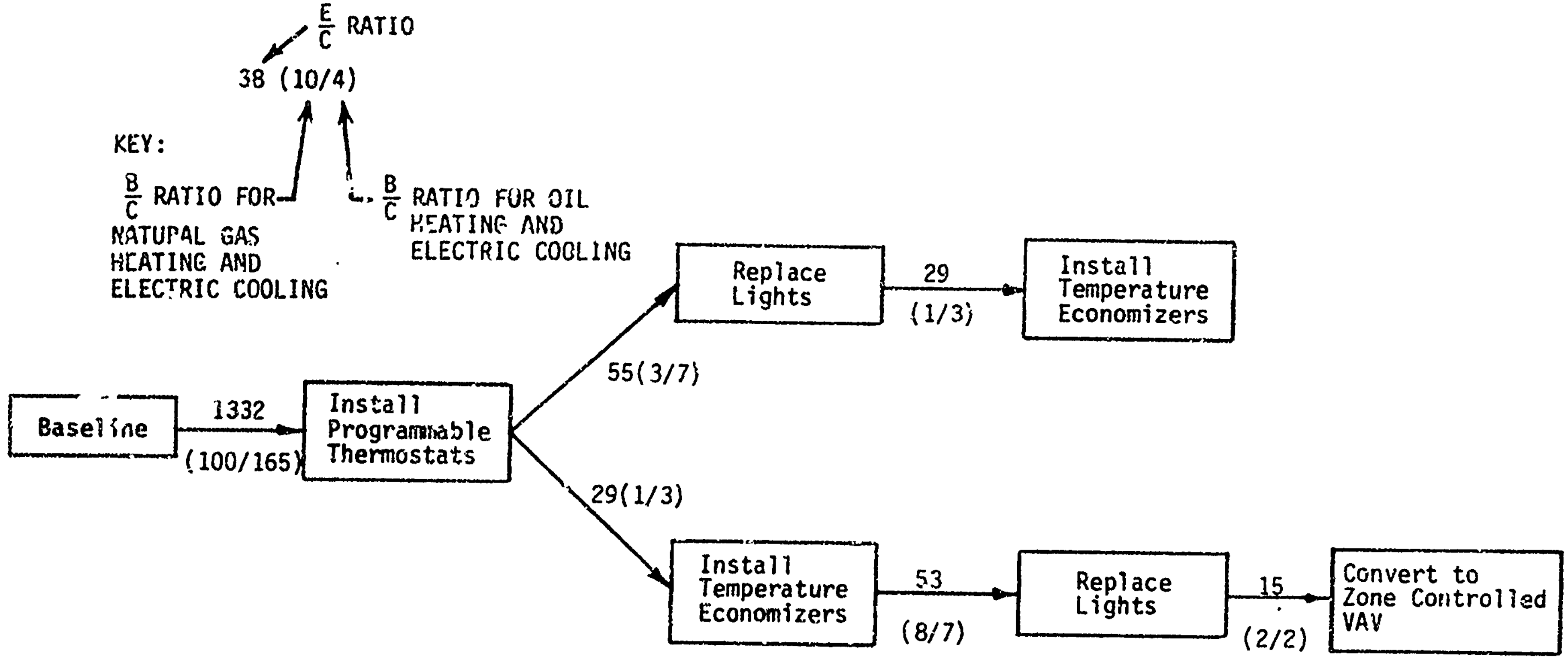

Figure 29. ECIP analysis for the enlisted personnel mess hall, Raleigh, NC.

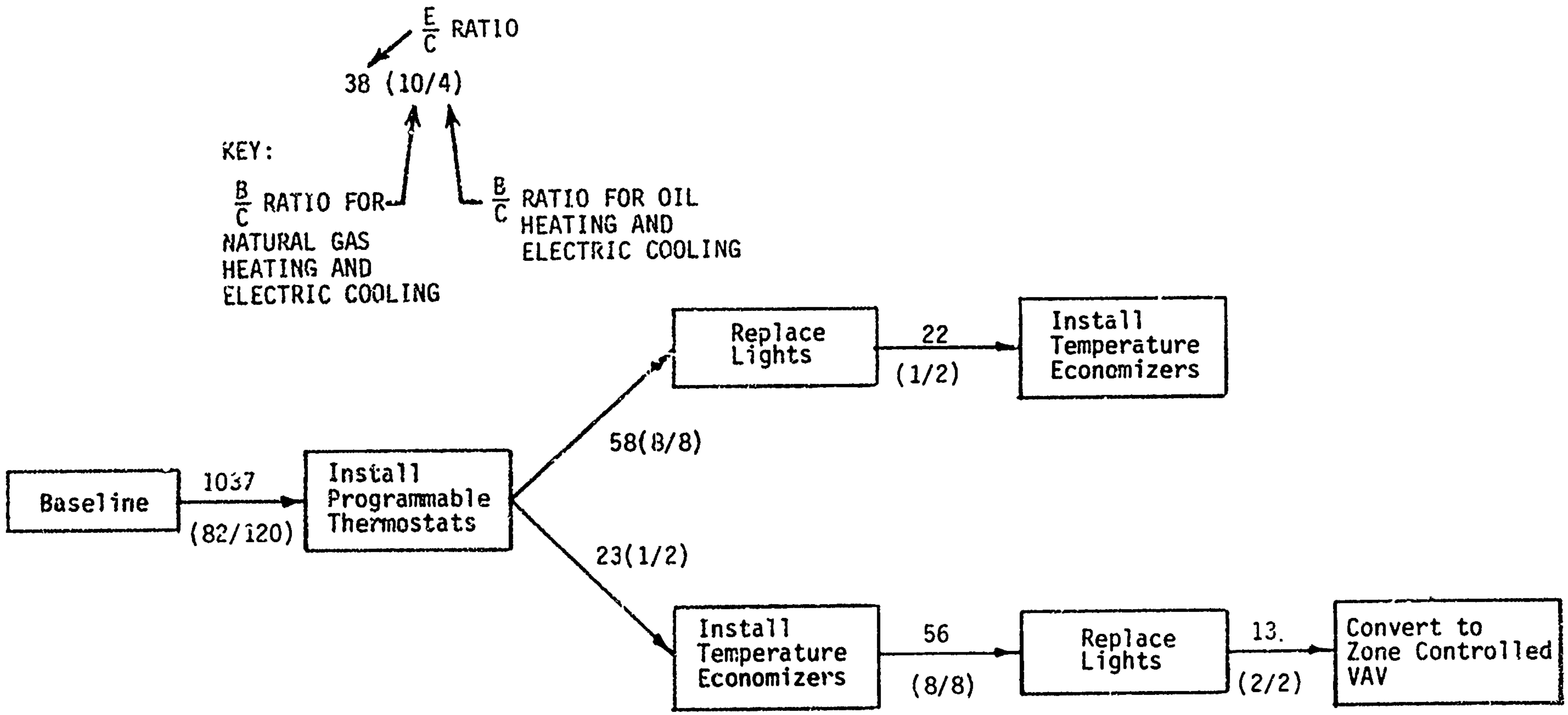

Figure 30. ECIP analysis for the enlisted personnel mess hall, Fort Worth, TX.

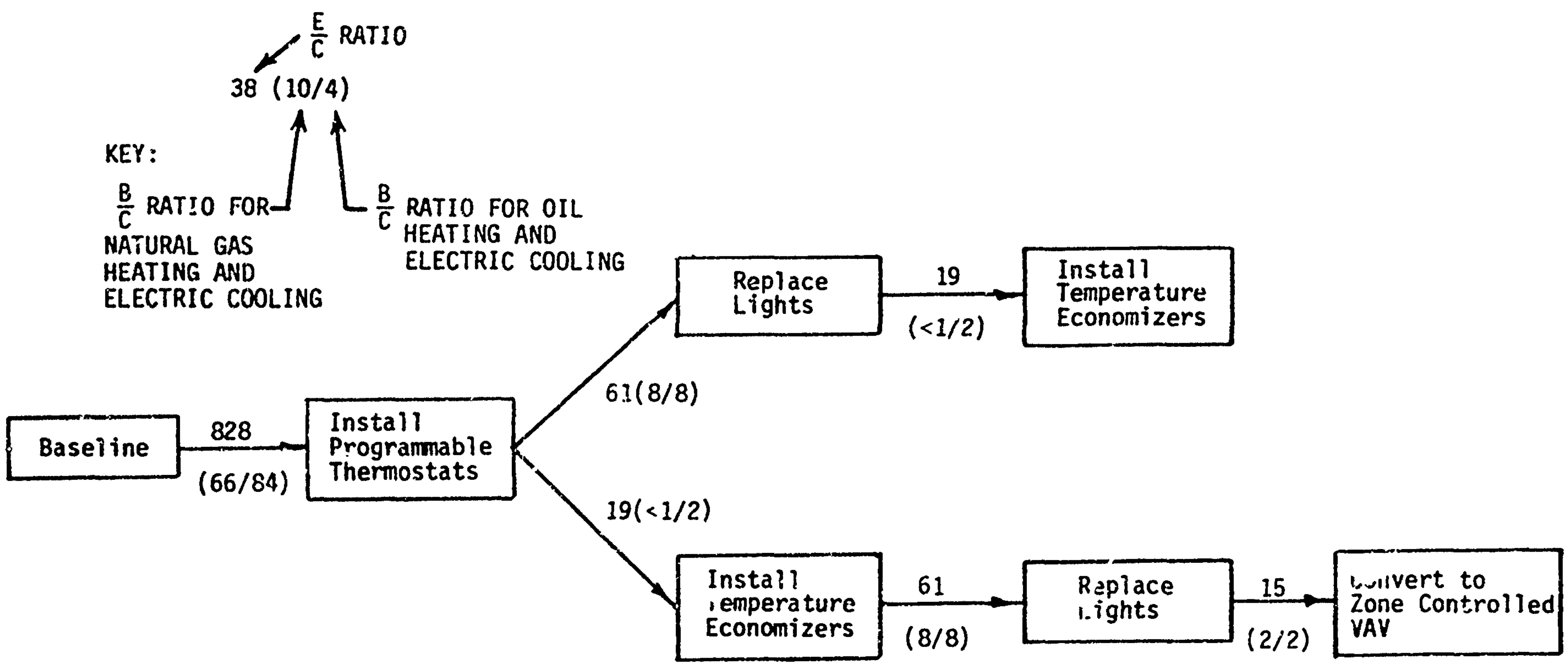

Figure 31. ECIP analysis for the enlisted personnel mess hall, Phoenix, AZ.

Table 37

ECIP Analysis Summary -- Rolling-Pin Barracks

ECA	E/C Ratio*					SIR*,**				
	L1	L2	L3	L4	L5	L1	L2	L3	L4	L5
A1 Block Fan/Coils	804	532	440	371	401	93 213	61 138	50 115	40 86	41 81
New Baseline = A1										
B1 Insulate Walls	58	49	37	32	26	6 15	5 12	4 9	3 7	2 4
B2 Add Storm Windows	43	39	27	24	15	5 12	4 10	3 7	3 6	1.5 3
B3 Block Windows	12	13	10	9	8	1.3 3	1.4 3	1.0 2	0.9 2	0.7 1.0
New Baseline = B1										
C1 Add Storm Windows	44	40	28	24	15	5 15	4 11	3 7	3 6	1.5 3
New Baseline = C1										
D1 Block Windows	1+	3+	2+	3+	4+	0 0	0.2 0.3	0.2 0.1	0.2 0.2	0.3 0.2

* See p 87 for key.
**Top: electricity and gas. Bottom: electricity and oil.
+B/C ratio <1.

Table 38

ECIP Analysis Summary -- Type 64 Barracks

CA	B/C Ratio* L1	L2	L3	L4	L5	SIR*,** L1	L2	L3	EL4	L5
A1 Disconnect Roof AHUs	1618	1981	2559	2156	1734	150	156	204	171	141
						264	186	254	208	186
New Baseline = A1										
B1 Add Storm Windows	38	32	22	20	14	4	4	2	2	1.4
						10	8	5	4	2
B2 Add Exterior Insulation	12	9	7	6	5+	1.3	1.0	0.7	0.6	0
						3	2	2	1.3	0.8
B3 Block Two-Thirds of the Windows	11	12	9	9	10	1.2	1.2	0.9	0.9	0.8
						3	3	2	2	1.1
B4 Add Roof Insulation	11	10	8	7	6+	1.2	1.1	0.8	0.7	0
						3	3	2	1.4	0.8
B5 South Overhang	-10	-4	-2	0	8*	-1	0	0	0	0.6
						-3	-2	-2	-1	0
New Baseline = B1										
C1 Exterior Insulation	11	10	7	6	5+	1.2	1.0	0.7	0.6	0
C2 Block Windows	0+	3+	2+	3+	5+	3	2	2	1.3	+0.8
						0	0	0	0	0
						0	0	0	0	0
New Baseline = B2										
D1 Block Windows	38	41	30	31	32	4	4	3	3	3
						9	9	6	5	4
New Baseline = B3										
E1 South Overhangs	-14	-6	-5	-4	6+	-2	-1	-0.6	0	0
						-4	-3	-2	-2	0
New Baseline = C1										
F1 Block Windows	6+	12	10+	13	19	0.5	1.0	0.8	1.1	2
						0	1.4	0.9	1.2	2
New Baseline = D1										
G1 Add Roof Insulation	13	13	10	8	7	2	1.4	1.0	0.8	0.6
G2 South Overhangs	-13	-6	-4	-4	6+	3	3	2	2	1.0
					-4	-2	-1	-1	0	0
						-4	-2	-2	-2	0
New Baseline = G1										
H1 South Overhangs	-13	-6	-4	-3	7+	-2	-1	-0.6	0	0
						-4	-2	-2	[illegible]	0

*See p 87 for key.
**Top: electricity and gas. Bottom: electricity and oil.
+B/C ratio <1.

Table 39

ECIP Analysis Summary -- Motor Repair Shop

ECA	E/C Ratio* L1	E/C Ratio* L2	E/C Ratio* L3	E/C Ratio* L4	E/C Ratio* L5	SIR*,** L1	SIR*,** L2	SIR*,** L3	SIR*,** L4	SIR*,** L5
A1 Night Setback	1682	1497	1224	962	576	182 367	162 326	133 266	105 208	62 126
New Baseline = A1										
B1 Insulate Walls	38	(a)	(a)	(a)	(b)	6 13	(a)	(a)	(a)	(b)
B2 Insulate Roof	3+	(b)	(b)	(b)	(b)	<1 1 2	(b)	(b)	(b)	(b)
B3 Cover One-Half of the Windows	1[illegible]	(a)	(a)	(b)	(b)	6	(a)	(a)	(b)	(b)
B4 Install Door Seals	116	(a)	(a)	(a)	(a)	5 10	(a)	(a)	(a)	(a)
B5 Replace Lights	9	(b)	(b)	(b)	(b)	1 <1	(b)	(b)	(b)	(b)
B6 Install Partition	125	124	116	88	50	19 42	19 42	17 39	13 30	8 17
New Baseline = B6										
C1 Install Door Seals	99	97	55	36	10+	4 8	4 8	2 [illegible]	2 3	(a)
New Baseline = C1										
D1 Insulate Walls	32	26	15	9+	(b)	5 11	4 9	2 5	1 3	(b)
D2 Cover Windows	14	(a)	(a)	(b)	(b)	2 5	(a)	(a)	(b)	(b)
New Baseline = D1										
E1 Cover Windows	16	14	8+	(b)	(b)	3 6	2 5	1 3	(b)	(b)

* See key, p 87.
** Top: electricity and gas. Bottom: electricity and oil.
\+ B/C ratio <1.

(a) ECA simulated with different baseline building.
(b) ECA does not meet ECIP criteria at this location.

Table 40

ECIP Analysis Summary -- Battalion Headquarters

ECA	B/C Ratio* L1	L2	L3	L4	L5	SIR*,** L1	L2	L3	L4	L5
A1 Install Timeclock on Circulating Pump	408	306	230	159	109	45 88	34 65	25 49	18 33	12 22
A2 Repipe Baseboard and Install Night-Setback Thermostats	144	110	85	58	38	16 32	12 24	9 19	6 13	4 8
New Baseline = A2										
B1 Insulate Walls	32	27	16	10*	(b)	5 11	5 13	1 3	<1 2	 (b)
B2 Insulate Roof	4+	(b)	(b)	(b)	(b)	1 1	 (b)	 (b)	 (b)	 (b)
B3 Install Storm Windows	7+	(a)	(b)	(b)	(b)	1 2	 (a)	 (b)	 (b)	 (b)
B4 Add Vestibules	7+	(b)	(b)	(b)	(b)	1 2	 (b)	 (b)	 (b)	 (b)
B5 Timeclock Electric Domestic Hot Water Heater	6+	(b)	(b)	(b)	(b)	1 1	 (b)	 (b)	 (b)	 (b)
New Baseline = B1										
C1 Install Storm Windows	9+	7+	(b)	(b)	(b)	1 3	1 2	 (b)	 (b)	 (b)

*See p 87 for key.
**Top: electricity and gas. Bottom: electricity and oil.
+B/C ratio <1.

(a) ECA simulated with different baseline building.
(b) ECA does not meet ECIP criteria at this location.

Table 41

ECIP Analysis Summary --, Enlisted Personnel Mess Hall

ECA	E/C Ratio* L1	L2	L3	L4	L5	SIR*,** L1	L2	L3	L4	L5
A1 Install Programmable Thermostats	2305	1851	1332	1037	828	182 310	155 251	113 183	109 146	102 120
New Baseline = A1										
B1 Install Temperature Economizer	49	41	29	23^{+}	19+	3 6	3 5	2 4	2 3	2 3
B2 Replace Lights	35	45	55	58	61	7 6	7 7	8 8	9 9	9 9
New Baseline = B1										
C1 Replace Lights	39	48	53	56	61	7 -6	8 -7	8 -8	9 -9	9 -9
C2 Cover One-Half of the Windows	36	10	<1^{+}	1^{+}	6^{+}	4 8	1 2	<1^{+} <1^{+}	8	8
C3 Insulate Walls	19	2^{+}	(b)	(b)	(b)	2 4	(b)	(b)	(b)	(b)
C4 Convert to Variable Air Volume	-14^{+}	(b)	(b)	(b)	(b)	<3 <1	(b)	(b)	(b)	(b)
New Baseline = B2										
C5 Install Temperature Economizer	51	42	29	22	19^{+}	5 7	3 6	2 4	2 3	2 3
C6 Cover One-Half of the Windows	63	25^{+}	2^{+}	*	7^{+}	7 13	3 5	(b)	*	*
New Baseline = C1 or C5										
D1 Cover One-Half of the Windows	49	17	3^{+}	*	6^{+}	10 5	3 2	<1 <1	*	*
D2 Convert to Variable Air Volume with Zone-Controlled Deck	*	20	15	13	15	*	*	*	*	*
D3 Recover Kitchen Exhaust Air Heat	21	19	13^{+}	10^{+}	5^{+}	*	*	*	*	*
New Baseline = D1										
E1 Recover Kitchen Exhaust Air Heat	18	*	*	*	*	2 1	*	*	*	*

*No data available.
**See key, p 87.
+B/C ratio <1.

(a) ECA simulated with different baseline.
(b) ECA does not pay back at this location.

Table 42

Recommended Projects for Rolling-Pin Barracks (FY84)

ECA	Cost of Retrofit ($)	L1**	Energy Savings (MBtu)* L2	L3	L4	L5
1. Block Fan/Coils	1,569	1,197	789	653	553	601
2. Insulate Walls	17,987	992	843	618	541	448
3. Add Storm Windows	27,720	1,154	1,060	721	625	393
Energy Totals		3,343	2,692	1,992	1,719	1,442
Project E/C Ratio		70	56	42	36	30

*Metric conversion: 1 MBtu = 1.055 GJ.
**See p 87 for key.

Table 43

Recommended Projects for Type 64 Barracks (FY84)

ECA	Cost of Retrofit ($)	L1**	Energy Savings (MBtu)* L2	L3	L4	L5
1. Disconnect Roof AHUs	728	1,294	1,546	1,947	1,666	1,358
2. Add Storm Windows	31,500	1,125	945	651	586	432
Energy Totals		2,419	2,491	2,598	2,522	1,790
Project E/C Ratio		75	77	81	70	56

*Metric conversion: 1 MBtu = 1.055 GJ.
**See p 87 for key.

Table 44

Recommended Projects for Motor Repair Shop (FY84)

ECA	Colorado Springs MBtu* Saved	Colorado Springs Cost** ($)	Columbia MBtu Saved	Columbia Cost ($)	Raleigh MBtu Saved	Raleigh Cost ($)	Fort Worth MBtu Saved	Fort Worth Cost ($)	Phoenix MBtu Saved	Phoenix Cost ($)
1. Install Programmable Thermostats	506.1	301	450.3	301	368.3	301	289.5	301	173.4	301
2. Partition Interior	154.9	1,240	154.1	1,240	143.6	1,240	109.7	1,240	61.8	1,240
3. Install Vehicle Door Seals	193.0	1,960	189.8	1,960	107.8	1,960	69.5	1,960		
4. Insulate Walls	129.5	4,070	106.8	4,070						
5. Cover One-Half of the Windows	56.0	3,400								
Project Totals	1,039.5	10,971	901.0	7,571	619.7	3,501	468.7	3,501	235.2	1,541
Project E/C Ratio	95		119		177		134		153	

*Metric conversion: 1 MBtu = 1.055 GJ.
**Implementation cost plus 6 percent projected from FY82 to FY84.

Table 45

Recommended Projects for Battalion Headquarters (FY84)

MBtu* ECA	Colorado Springs MBtu* Saved	Colorado Springs Cost** ($)	Columbia MBtu Saved	Columbia Cost ($)	Raleigh MBtu Saved	Raleigh Cost ($)	Fort Worth MBtu Saved	Fort Worth Cost ($)	Phoenix MBtu Saved	Phoenix Cost ($)
1. Repair and Install Night-Setback Thermostats	407.6	2,[illegible]	309.2	2,820	240.9	2,820	163.1	2,820	108.5	2,820
2. Insulate Walls	56.6	1,783	48.0	1,783						
3. Install Storm Windows	27.1	3,121								
Project Totals	491.3	7,724	357.2	4,603	240.9	2,820	163.1	2,820	108.5	2,820
Project E/C Ratio	64		78		85		58		38	

*Metric conversion: [illegible] = 1.055 GJ.
**Implementation cost [illegible] six percent SIOH projected from FY82 to FY84.

Table 46

Recommended Projects for Enlisted Personnel Mess Hall (FY84)

ECA	Colorado Springs MBtu* Saved	Colorado Springs Cost** ($)	Columbia MBtu Saved	Columbia Cost ($)	Raleigh+ MBtu Saved	Raleigh+ Cost ($)	Fort Worth+ MBtu Saved	Fort Worth+ Cost ($)	Phoenix+ MBtu Saved	Phoenix+ Cost ($)
1. Install Programmable Thermostats	2,224.2	965	1,786.6	965	1,285.5	965	1,000.9	965	799.5	965
2. Install Temperature Economizer	390.2	8,020	329.1	8,020	229.1	8,020	174.2	8,020	151.8	8,020++
3. Replace Lights	156.7	3,970	189.5	3,970	214.4	3,970	229.1	3,970	243.7	3,970
4. Cover One-Half of the Windows	255.3	5,259	86.6	5.259						
5. Recover Kitchen Exhaust Air Heat	729.7	39,627								
Project Totals	3,756.1	57,841	2,391.8	18,214	1,730.8	12,955	1,404.2	12,955	1,195.0	12,955
Project E/C Ratio	65		131		134		108		92	

* Metric conversion: 1 MBtu = 1.055 GJ.
** Implementation cost plus 6 percent SIOH projected from FY82 to FY84.
\+ Project No. 3 implemented before Project No. 2.
\++ Recommended only where fuel oil is used for heating.

Table 47

Recommended Projects for Rolling-Pin Barracks (FY85)

ECA	Retrofit Investment ($)	Energy Savings (K$) L1* Oil	L1* Gas	L2 Oil	L2 Gas	L3 Oil	L3 Gas	L4 Oil	L4 Gas	L5 Oil	L5 Gas
1. Block Fan/Coils	1,569	338	149	223	102	184	83.1	154	82.6	166	103
2. Insulate Walls	17,987	280	123	237	111	174	80.6	150	84.0	122	90
3. Add Storm Windows	27,720	326	139	300	130	204	87.7	175	89.4	108	69.2
Savings Totals		944	411	760	343	562	251	475	256	396	262
Project SIR		20	8.7	16	7.3	12	5.3	10	5.4	8.4	5.5

* See p. 87 for key.

Table 48

Recommended Projects for Type 64 Barracks (FY85)

ECA	Retrofit Investment ($)	Energy Savings (K$) L1* Oil	L1* Gas	L2 Oil	L2 Gas	L3 Oil	L3 Gas	L4 Oil	L4 Gas	L5 Oil	L5 Gas
1. Disconnect Roof AHUs	728	350	268	408	385	515	479	440	413	360	327
2. Add Storm Windows	31,500	319	138	267	122	184	84.4	163	89.6	118	81.6
3. Add Exterior Insulation	72,800	220	95.6	193	89.3	139		116			
4. Block Two-Thirds of the Windows	23,100			306	199			185			
Total Savings		689	502	1174	795	838	563	907	503	478	409
Project SIR		8.5	4.8	9.2	6.2	8.0	7.1	16	15	13	

* See p 87 for key.

Table 49

Recommended Projects for Motor Repair Shop (FY85)

ECA	Retrofit Investment ($)	Energy Savings (K$) L1* Oil	L1* Gas	L2 Oil	L2 Gas	L3 Oil	L3 Gas	L4 Oil	L4 Gas	L5 Oil	L5 Gas
1. Install Programmable Thermostats	301	64.9	32.9	57.8	29.4	47.3	23.5	37.2	19.2	22.2	11.2
2. Install Partition	1,240	31.1	14.0	30.9	13.9	28.8	13.0	22.0	10.0	12.4	5.6
3. Install Door Seals	1,960	9.6	4.9	9.5	4.8	5.4	2.7	3.5	1.8		
4. Insulate Walls	4,070	26.0	11.4	21.5	9.4	12.2	5.4	7.5	3.3		
5. Cover One-Half of the Windows	3,400	11.3	4.9	9.5	4.2	5.1	2.2				
Total Savings		143	68.1	129	61.7	98.8	46.8	70.2	34.3	34.6	16.8
Project SIR		13	6.2	12	3.6	9.0	4.3	9.2	4.5	23	11

* See p 87 for key.

Table 50

Recommended Projects for Battalion Headquarters (FY85)

ECA	Retrofit Investment ($)	Energy Savings (K$) L1* Oil	Gas	L2 Oil	Gas	L3 Oil	Gas	L4 Oil	Gas	L5 Oil	Gas
1. Repipe and Install Night-Setback Thermostats	2,820	52.2	26.1	39.6	19.8	30.8	15.4	20.9	10.4	13.9	6.9
2. Insulate Walls	1,783	11.4	4.9	9.7	4.3	5.8	2.5	3.7			
3. Install Storm Windows	3,121	5.5	2.4	6.4	1.9						
Total Savings		69.1	33.4	53.7	26.0	36.6	17.9	24.6	10.4	13.9	6.9
Project SIR		9.6	4.3	7.0	3.4	8.0	3.9	5.4	3.7	4.9	2.4

* See p 87 for key.

Table 51

Recommended Projects for Enlisted Personnel Mess Hall (FY85)

ECA	Retrofit Investment ($)	Energy Savings (K$) L1* Oil	Gas	L2 Oil	Gas	L3 Oil	Gas	L4 Oil	Gas	L5 Oil	Gas
1. Install Programmable Thermostats	965	292	172	236	146	172	114	137	103	113	96.9
2. Replace Lights	3,[illegible]70	21.5	26.4	26.5	29.0	32.0	32.7	33.7	33.8	35.8	35.8
3. Install Temperature Economizer	8,020	52.7	26.6	43.6	22.6	29.7	16.1	22.9	13.5	20.5	14.2
4. Cover One-Half of the Windows	5,259	50.7	27.0	17.0	10.6						
5. Recover Kitchen Exhaust Air Heat	39,627	94.5	50.6								
Total Savings		511	303	323	208	236	163	194	150	169	147
Project SIR		9	5	16	11	18	13	15	12	13	11

* See p 88 for key.

6 CONCLUSIONS AND RECOMMENDATIONS

1. The 257 rolling-pin-shaped barracks, the 399 Type 64 barracks, the 83 motor repair shops, the 93 battalion headquarters, and the 103 enlisted personnel mess halls are prime candidates for ECIP projects.

2. Standard BLAST models run for each building type and retrofits simulated for different climatic zones indicate several ECA options have favorable E/C ratios (Tables 37 through 51).

3. The charts given in this report can be used to estimate the E/C ratio of energy conservation projects, even if other projects have already been completed. They also show the energy-savings contribution of each individual ECA option.

4. The approach used to develop the E/C ratio, the B/C ratio, and the SIR for the five standard designs studied defines (by example) a general method for future ECIP studies.

5. Enough ECIP data are presented to speed the preparation of DD Form 1391s for conservation projects for the building types studied. The energy savings calculated by climatic zone can be used for individual ECIP analyses (interpolating, as necessary) and do not have to be repeated. The cost calculations can be used with little or no modification, except to account for local price variations.

6. If applied to all potential buildings, the ECIP projects recommended below will save 1.79×10^6 MBtu/year (1.8×10^6 GJ/year) and yield life-cycle cost savings of $469 million for oil heating and electric cooling and $314 million for gas heating and electric cooling using the FY84 criteria. Using the FY85 guidelines, the savings would be 2.133×10^6 MBtu/year (2.2×10^6 GJ/year) and yield life-cycle savings of $544 million for oil heating and electric cooling and 2.00×10^6 MBtu (2.1×10^6 GJ/year) and $325 million for gas heating and electric cooling. These dollar savings are based on estimated fuel prices adjusted for 5 years of inflation. They are the savings for the lifetime of the project.

7. The total capital investment for the recommended retrofits for all buildings in all climates is $26 million. For oil and gas heating with the FY84 guidelines, the savings are about $45 million.

8. The energy savings calculated by climatic zone can be used for individual ECIP analyses for any location in that zone. The cost calculations can be used after they are adjusted for local conditions.

All rolling pin barracks should be retrofit to (1) block the fan/coils' outside air vents,* (2) add cavity insulation, and (3) add storm windows. The savings would be 5.8×10^5 MBtu/year (6.1×10^5 GJ/year).

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* Where a recommendation has been made to abandon forced ventilation, it is expected that the minimum fresh air requirement of 5 cfm per person will still be achieved through infiltration even when storm windows are used. See ASHRAE Handbook of Fundamentals, 1981, Chapter 22.

Under the FY84 guidelines, all Type 64 barracks should be retrofitted to disconnect the roof AHUs* and add storm windows. The savings would be 9.2 x 10^5 MBtu/year (9.7 x 10^5 GJ/year). Beginning with FY85, all Type 64 barracks (except those in climatic Zone 6) should also have exterior insulation. The windows should be blocked on buildings in climatic Zone 3. The savings should be 1.25 x 10^6 MBtu/year (1.3 x 10^6 GJ/year).

Using the FY84 guidelines, all motor repair shops should have automatic night-setback thermostats, partitions and vehicle door seals should be installed (except in areas with very mild winters), and insulation should be installed on the walls in colder regions. The savings should be 5.42 x 10^4 MBtu/year (5.7 x 10^4 GJ/year). Using the new guidelines, all motor repair shops should have automatic night-setback thermostats. Where possible, the vehicle repair area should be physically separated from the office/tool storage area and maintained at a lower temperature, except in Phoenix, where vehicle door seals should be installed and the walls insulated. In colder regions, the windows should be half-covered. The savings should be 5.70 x 10^4 MBtu/year (6.0 x 10^4 GJ/year).

Under the guidelines in effect until FY84, the heating system for the battalion headquarters should be modified to make it responsive to actual heating demands. In colder regions, insulation should be installed on the walls. The savings would be 2.5 x 10^4 MBtu/year (2.73 x 10^4 GJ/year). Beginning with FY85, the guidelines suggest that the heating system should be modified. In colder regions, the walls should be insulated and storm windows should be put up. The savings would be 2.6 x 10^4 MBtu/year (2.74 x 10^4 GJ/year).

The enlisted personnel mess halls should be retrofit with programmable thermostats, temperature economizers, and fluorescent lighting fixtures.** In colder climates, the windows should be partially covered and heat recovery loops should be attached to the kitchen and exhaust. The savings would be 2.16 x 10^5 MBtu/year (2.2 x 10^5 GJ/year).

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* Where a recommendation has been made to abandon forced ventilation, it is expected that the minimum fresh air requirement of 5 cfm per person will still be achieved through infiltration even when storm windows are used. See ASHRAE Handbook of Fundamentals, 1981, Chapter 22.

**The change to fluorescent fixtures may entail a change in chromatic content of the lighting. Because color rendition of food is an important consideration in the lighting design, proper color should be assured before implementing this retrofit.

APPENDIX A:

BLAST DESCRIPTION

The Building Loads Analysis and System Thermodynamics (BLAST) program is a comprehensive set of subprograms for predicting energy consumption and energy systems performance and cost in buildings. There are three major subprograms (see Figure A1).

1. The Space Load Predicting Subprogram computes hourly space loads in a building or zone based on user input and weather data.

2. The Air Distribution System Simulation Subprogram uses the computed space loads, weather data, and user inputs describing the building air-handling system to calculate hot water, steam, gas, chilled water, and electric demands.

3. The Central Plant Simulation Subprogram uses weather data, results of air-distribution system simulation, and user input describing the central plant to simulate boilers, chillers, onsite power generating equipment, and solar energy systems to compute monthly and annual fuel and electrical power consumption.

Apart from its comprehensiveness, the BLAST program differs in four key respects from similar programs used in the past.

1. The BLAST program uses extremely rigorous and detailed algorithms to compute loads, simulate fan systems, and simulate boiler and chiller plants.

2. The program has its own user-oriented input language and is accompanied by a library which contains the properties of all materials, wall, roof, and floor sections listed in the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Handbook of Fundamentals.[10]

3. The program execution time is brief enough to allow many alternatives to be studied economically.

4. The program is not proprietary and is, therefore, open to inspection by its users and those who rely on its results.

Scope

In addition to library data, the BLAST input language provides for the use of default equipment performance and fan system data. This permits generic systems to be investigated easily and rapidly. It also lets the user change only those variables for which defaults are inappropriate.

[10] Handbook of Fundamentals (American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1977).

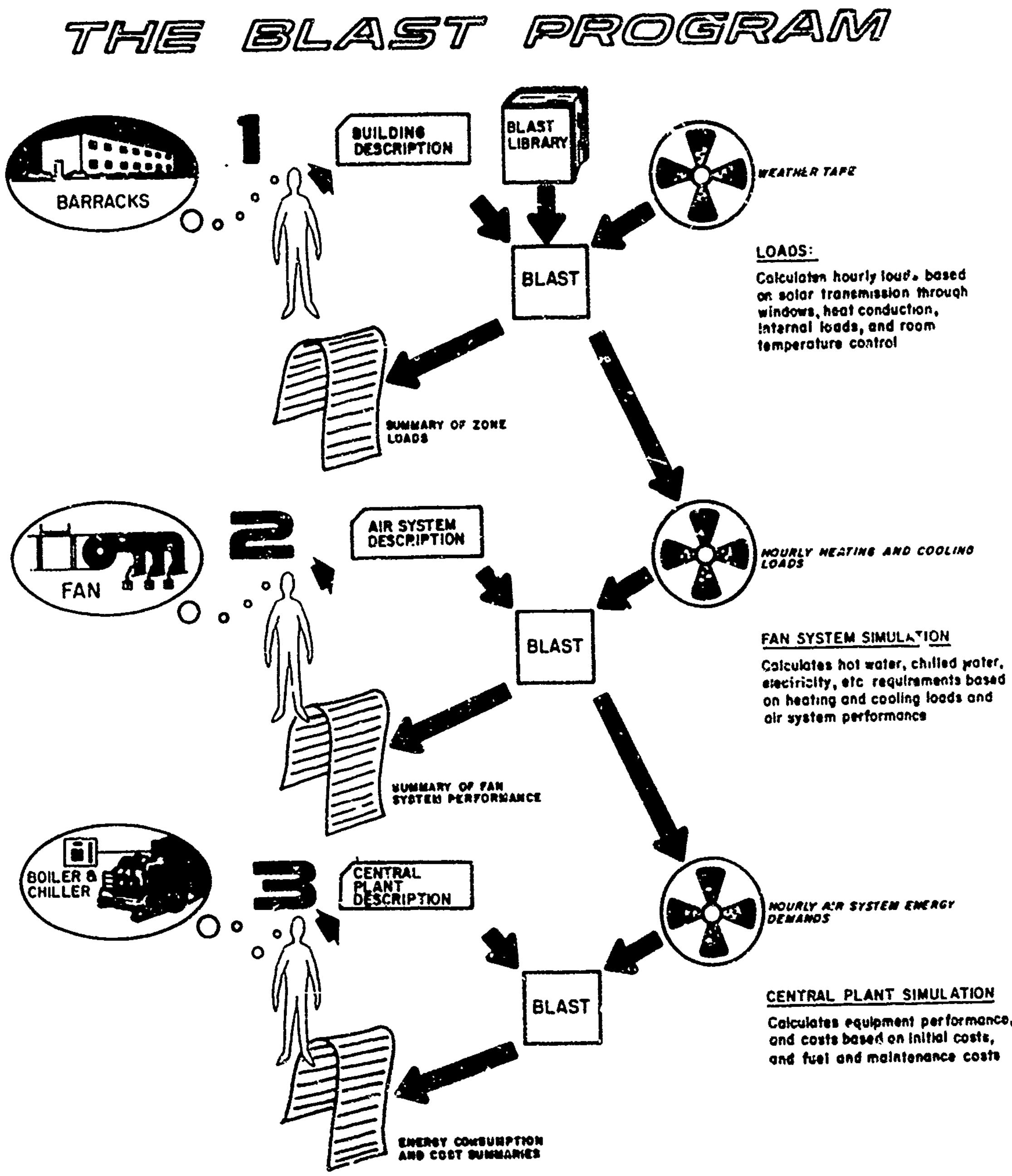


Figure A1. The BLAST program.

The Space Loads Predicting Subprogram

The heart of space loads prediction is the room heat balance. For each hour simulated, BLAST performs a complete radiant, convective, and conductive heat balance for each surface of each zone described and for the room air. This heat balance includes transmission loads, solar loads, internal heat gains, infiltration loads, and the temperature control strategy used to maintain the space temperature. Some of the important features of the loads predicting subprogram are:

1. Calculates response factors and conduction transfer functions for all zone surfaces. This permits the careful and complete analysis of transient heat conduction through walls and of heat storage in rooms.

2. Calculates the shaded and sunlit area for all exterior surfaces shaded by attached or detached shadow-casting surfaces (wings, overhangs, or other buildings). Also, the shading of windows caused by reveals is fully accounted for.

3. Exactly calculates the solar flux transmitted through single- and multipane windows with or without interior shades using either basic optical principles or "shading coefficients" specified by the user.

4. Accounts for the effects of both inside surface solar and infrared absorptivities and outside surface solar absorptivities.

5. Uses approximate shape factors to calculate radiant heat transfer between zone surfaces as part of the room heat balance. Also calculates the radiant interchange between exterior surfaces (i.e., walls, roofs, windows) and the earth and sky.

6. Accounts for the effects of surface roughness and hourly variations in windspeed on outside wall convective heat transfer coefficients (air film resistance).

7. Adjusts the inside surface convective heat transfer coefficient (air film resistance) for ceilings, roofs, and floors based on whether the surfaces are hotter or colder than the room air.

8. Accounts for temperature differences between a zone and an attic or crawl space by actually simulating the attic or crawl space.

9. Includes approximate methods for calculating the heat flow between zones of differing temperatures.

10. Allows arbitrary (user-specified) room temperature control strategies. Different control strategies can be specified for different hours during the day and different days during the week.

11. Appropriately allocates radiant, convective, and latent fractions of the heat from people, lights, and equipment, and allows these internal gains to be scheduled differently for each hour of the day and each day of the week.

12. Simulates the radiant and convective effects of outside air-controlled baseboard heating.

13. Accounts for the effects of windspeed, temperature, and time of day on zone infiltration.

14. Allows surfaces bounding a zone to be of arbitrary shape, three- and four-sided, and at any tilt or azimuth.

15. At the discretion of the user, allows calculated loads for each zone to be saved on tape or disk for future use in examining many alternate fan system configurations, without recalculating space loads.

16. Simulates as many as 100 zones at one time (many more than are usually required).

<u>The Air Distribution System Simulation Subprogram</u>

Once zone loads are calculated, they must be translated into hot water, chilled water, and electrical demands on a central plant or utility system. This is done by using basic heat and mass balance principles in the system simulation subprogram of BLAST. The major types of air-distribution systems that BLAST can analyze are:

1. Multizone and dual duct systems

2. Three-deck multizone systems

3. Single-zone fan systems with subzone reheat

4. Unit ventilators with or without heating coils

5. Two-pipe fan coil systems

6. Four-pipe fan coil systems

7. Variable volume fan systems with optional reheat or thermostatically controlled baseboard heat

8. Constant volume terminal reheat systems

9. Dual duct variable air-volume systems

10. Packaged direct-expansion systems

11. Single-zone drawthrough systems.

In addition, built-up direct-expansion cooling can be specified to serve the fan systems listed above, or chilled water can be the cooling source. Air-to-air heat recovery is also possible on most of the systems listed above.

Default values are supplied for most of the pertinent fan system variables. All defaults can, however, be overridden by the user. Many combinations of mixed- and delivery-air control strategies are available for most of the air distribution systems.

The fan system simulation subprogram is unusually flexible and precise in its analysis of fan system performance. This subprogram includes the following significant features:

1. The user may adjust both the full-load efficiency and total fan pressure for supply, return, and exhaust fans as well as the part-load performance characteristics of the supply and return fans.

2. Both cold and hot decks can be controlled (a) at a fixed temperature set point, (b) at a temperature varied with outdoor air temperature, or (c) on the basis of the zone requiring the most heating or cooling.

3. The user-specified or the default-throttling range of the cold and hot deck controllers is fully accounted for.

4. Three different economy cycles can be used for most fan systems. The mixed-air temperature may be fixed or floating, depending on the user's specification.

5. Minimum and maximum outdoor air quantities can be scheduled for each hour of the weekday or weekend.

6. Various preheat coil configurations can be simulated.

7. Minimum and maximum outdoor air quantities can be specified. Maximum total fan volumes may be specified for variable volume systems. The variable volume maximum and the maximum outdoor air quantity can be less than the sum of the air distributed to all zones.

8. Humidifiers can be specified for most systems.

9. Fan, heating coil, preheat coil, cooling coil, and heat recovery operation can be scheduled on a daily and seasonal basis.

10. Users may simulate any cooling coil by specifying cooling coil design parameters consisting of typical catalog data for one coil operating point.

11. At the discretion of the user, the results of fan system simulations may be saved on tape or disk for future use in examining many alternate central plant configurations (without repeating the fan system simulations).

12. BLAST can simulate as many as 100 separate systems at one time (many more than are usually required).

The Central Plant Simulation Subprogram

Once the hot water, chilled water, and electrical demands of the building fan system are known, the central plant must be simulated to determine the building's final purchased electrical power or fuel consumption. The central plant subprogram of BLAST can simulate any thermodynamically feasible system consisting of any or all of the following central plant components:

1. Boilers
2. Centrifugal or reciprocating chillers
3. Absorption chillers (one and two stages)
4. Double-bundle chillers
5. Heat pumps (with or without solar assist)
6. Solar collectors and storage tank systems
7. Hot thermal storage
8. Cold thermal storage
9. Cooling towers
10. Diesel engine generators
11. Gas turbine generators
12. Steam turbine generators
13. Heat recovery from generator prime movers
14. Utility company power.

Generic data for each component model are present in BLAST, but the user may vary one or more sets of equipment performance coefficients to simulate a particular manufacturer's product.

Some of the principal features of the central plant simulation program are:

1. Accounts for the effects of ambient temperature, chilled and hot water temperature, and other operating variables on plant performance and equipment capacity.

2. Accounts for the change in equipment coefficient of performance (COP) or efficiency resulting from part-load operation.

3. Allows default equipment assignment strategies to be overridden, thereby permitting the user to select the operating strategy of his or her choice.

4. Allows the user to change equipment performance parameters so available equipment can be modeled exactly.

5. Allows detailed energy accounting which permits accurate costing of energy, particularly of purchased electricity which may have complicated block rate schedules.

6. Tabulates equipment-use statistics (hours of operation and average part-load ratio for each plant component) as well as energy consumption data, thereby permitting BLAST output to be used as the basis for equipment selection.

7. Simulates as many as 100 central plants in one run.

Life-Cycle Costing

The last step in the BLAST central plant subprogram is the calculation of life-cycle costs using present worth life-cycle costing techniques. User inputs include building construction and operating costs (excluding energy), fan system construction and maintenance costs, and user-supplied and default capital and maintenance costs for plant components. In addition, users may select appropriate fuel cost adjustment factors and discount and inflation rates.

APPENDIX B:

CALIBRATION OF BLAST BUILDING DESCRIPTION

Although most of the information needed for a BLAST building description can be taken directly from the building's plans, some information must be estimated. If the estimates are reasonable, the BLAST building description will respond as the real building does. However, if the estimates do not reflect the real building, the BLAST analysis could be misleading. Thus, the standard BLAST building descriptions were calibrated to the buildings being simulated for this study.

Equations which correlate Heating Degree Days (HDD) and Cooling Degree Days (CDD) to energy usage for a variety of Army building categories were developed during an earlier study.[11] The rolling-pin barracks falls into the "new nonmodular barracks" category, which includes barracks built after 1966 (except for the modern Army modular type). The dependence of daily heating energy consumption, E_h, on the daily HDD, HDD_d, for this category is

$$E_h = 81.91 + 7.4 \times HDD_d \text{ (Btu/sq ft/day)*.} \quad \text{[Eq B1]}$$

The dependence of daily electrical consumption, E_e, on the daily cooling degree days, CDD_d, is given by

$$E_e = 0.01516 + 0.001275 \times Cdd_d \text{ (kWh/sq ft/day).} \quad \text{[Eq B2]}$$

The Type 64 barracks was considered to be in the "old barracks" category; i.e., barracks built before 1966, including the World War II type. The daily heating energy requirement for this category is

$$E_H = 130.5 + 15.99 \times HDD_d \text{ (Btu/sq ft/day).} \quad \text{[Eq B3]}$$

The daily electrical consumption was considered the same as for the new, nonmodular barracks category, given in Eq B2.

The enlisted personnel mess hall was considered part of the "community facilities" category, which for dining facilities and commissaries has a daily heating energy usage of

$$E_H = 231.8 + 12.42 \times HDD_d \text{ (Btu/sq ft/day).} \quad \text{[Eq B4]}$$

[11]B. J. Sliwinski, et al., 1979.
* Metric conversions: 1 Btu = 1.055 GJ; 1 sq ft = 0.092 m^2.

The data for community facilities electrical usage did not correlate with CDD. The average daily electric consumption for community facilities category for May through September was

$$E_e = 0.0684 \text{ (kWh/sq ft/day).} \quad \text{[Eq B5]}$$

The average for October through April was

$$E_e = 0.0662 \text{ (kWh/sq ft/day).} \quad \text{[Eq B6]}$$

The motor repair shop was put into the "production/maintenance facilities" category, which does not include major process-type production buildings such as ammunition plants, but only those with production activities such as machining, assembly, and other activities associated with installation maintenance. The equation for daily heating energy consumption for production/maintenance facilities were

$$E_H = 138.4 + 35.73 \times HDD_d \text{ (Btu/sq ft/day).} \quad \text{[Eq B7]}$$

The data for electric energy consumption showed no correlation with CDD. The value obtained for daily electric energy usage for May through September was

$$E_e = 0.0235 \text{ (kWh/sq ft/day).} \quad \text{[Eq B8]}$$

The value obtained for October through April was

$$E_e = 0.0293 \text{ (kWh/sq ft/day).} \quad \text{[Eq B9]}$$

The battalion headquarters was considered part of the "administration/training facilities" category. The equation for daily heating energy usage in this category is

$$E_H = 76.71 + 18.97 \times HDD_d \text{ (Btu/sq ft/day).} \quad \text{[Eq B10]}$$

Data for daily electric energy usage did not correlate well with CDD. The average daily electric energy usage calculated for the months of May through September was:

$$E_e = 0.0512 \text{ (kWh/sq ft/day).} \quad \text{[Eq B11]}$$

For October through April, the average was

$$E_e = 0.0215 \text{ (kWh/sq ft/day).} \qquad \text{[Eq B12]}$$

By using these equations and the HDD and CDD given in Table B1 for the five building locations considered during this study, the BLAST building descriptions were calibrated to the energy consumption of real buildings in their respective categories.

Figures B1 through B5 show the relationship between HDD and energy usage for the buildings analyzed during this study. In four of the figures, the line that graphs the energy usage equation is bounded by a set of P and C curves. The area between the P curves is where an individual building's energy usage for that particular category would be expected to fall 95 percent of the time (i.e., the prediction limit). The area between the C curves is where the average energy usage of a large group of buildings that cover a cross-section of that particular category would be expected to fall 95 percent of the time (i.e., the confidence limit). Because the buildings analyzed during this study represent only one building design in their respective categories, the BLAST models were adjusted until they were within the P curves. The model for the battalion headquarters (Figure B4) very closely corresponds to the graph of energy usage (Eq B10) for administration/training facilities category.

Infiltration and lighting were ambiguous inputs for both the rolling-pin and Type 64 barracks designs. These baseline BLAST building descriptions were calibrated by adjusting the infiltration and lighting for Colorado Springs so the results fell within the P curves.

Table B1

HDD for Each
Weather Site

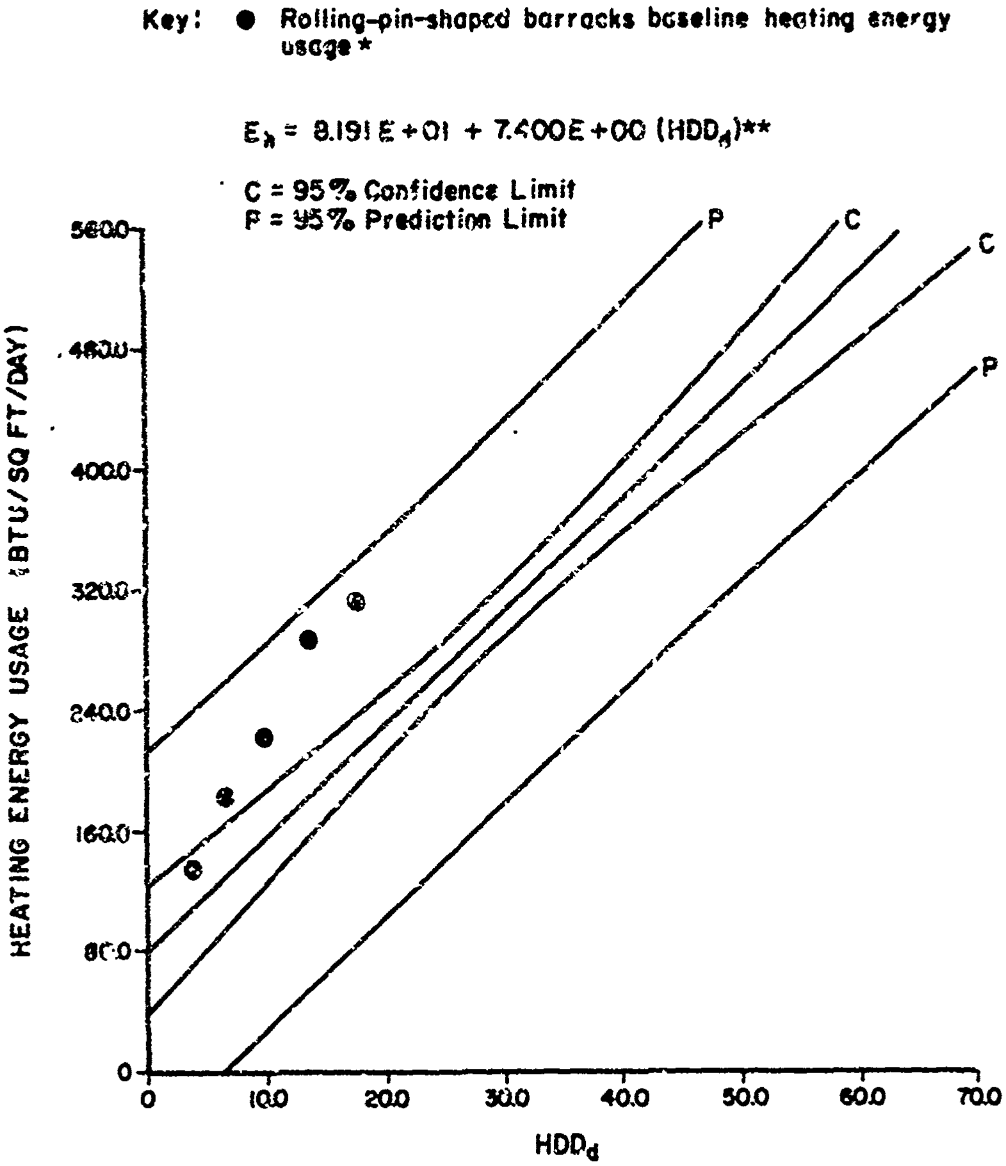
Weather Site	HDD	HDD Per Day
Colorado Springs, CO	6415	17.6
Columbia, MO	5007	13.7
Raleigh, NC	3579	9.8
Phoenix, AZ	1390	3.8
Fort Worth, TX	2387	6.5

The BLAST default coefficients that adjust the infiltration based on the indoor-outdoor air temperature difference and windspeed were not used. Instead, the coefficients A = 7.34E-1, B = 2.86E-3, C = 2.85E-4, and D = 1.97E-8 were used. These default coefficients over-predicted the amount of infiltration during cold periods.

The formula used for calculating the amount of infiltration was:

Infiltration = one air change per hour + exhaust - outside air from the fan system

The only other baseline modification needed was to add the night-setback thermostats to the enlisted personnel mess hall baseline.

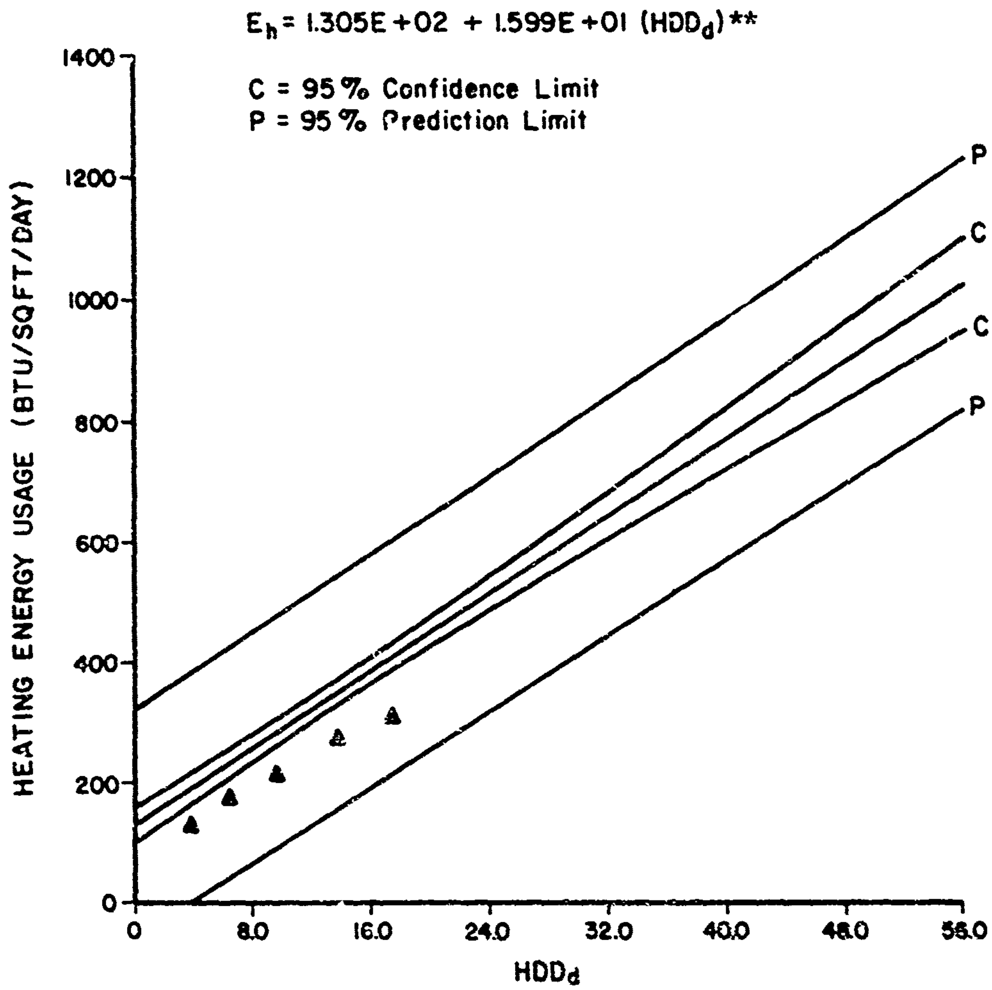


* Domestic hot water = 88 Btu/sq ft/day

** Reference 7, p 22.

Figure B1. Heating energy usage vs HDD_d for the rolling-pin barracks.

Key: ▲ Type 64 barracks baseline heating energy usage*



* Domestic hot water = 86 Btu/sq ft/day
** Reference 7, p 22.

Figure B2. Heating energy usage vs HDD_d for the Type 64 barracks.

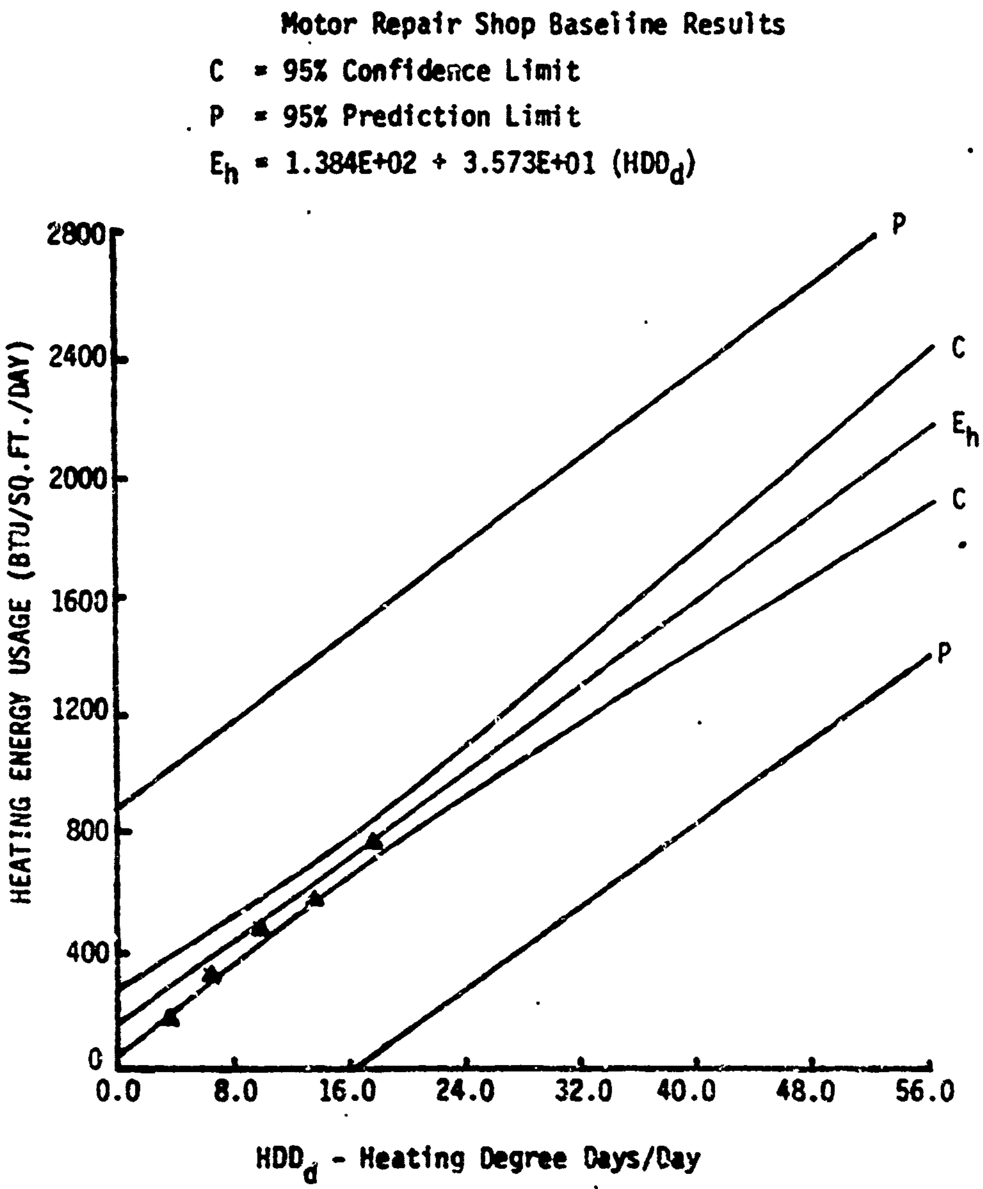


Figure B3. Heating energy usage vs HDD_d for the motor repair shop.

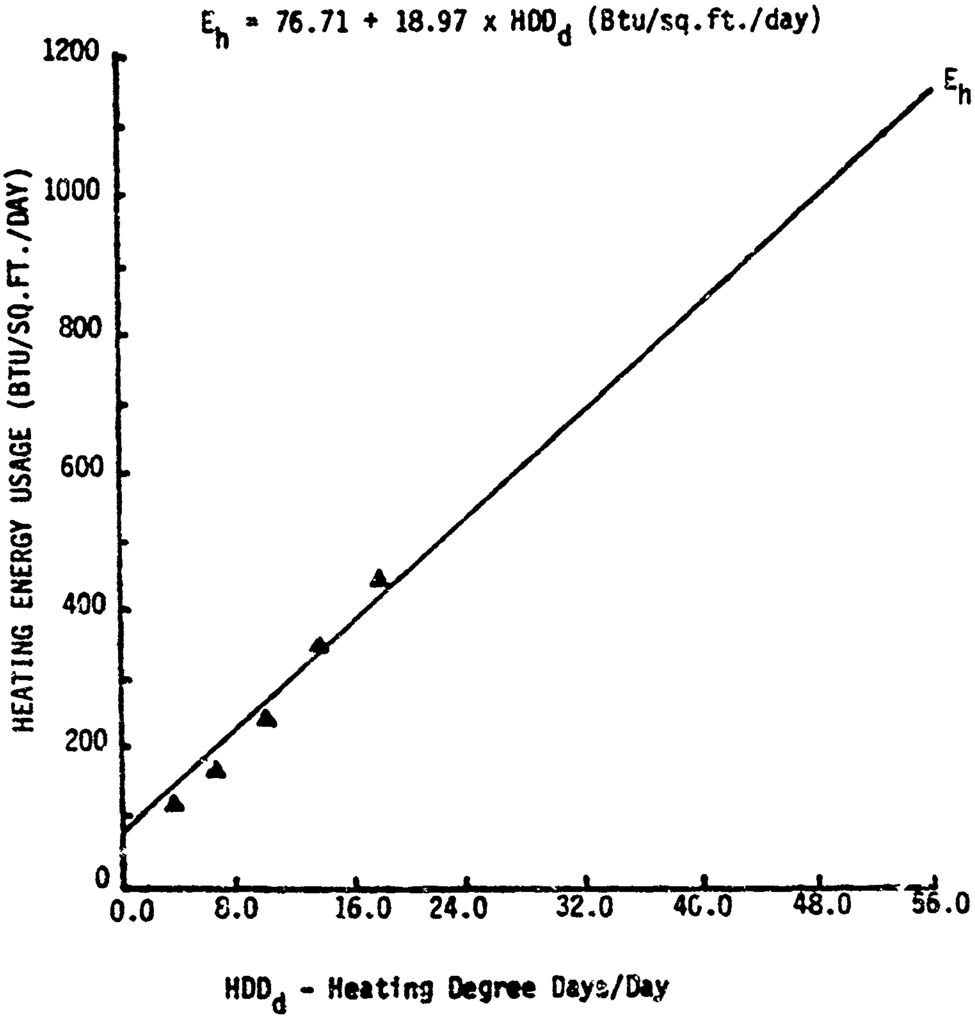


Figure B4. Heating energy usage vs HDD_d for the battalion headquarters.

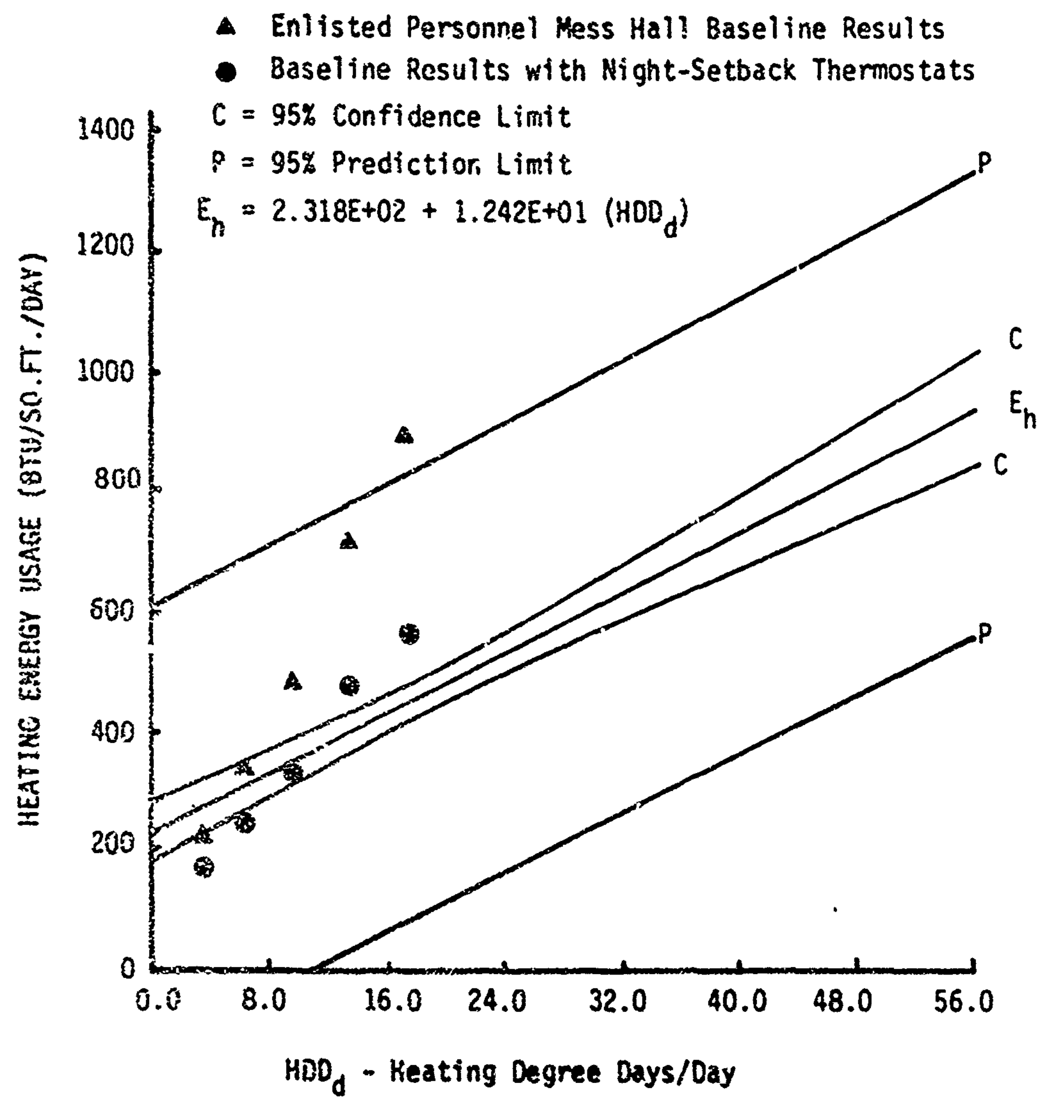


Figure B5. Heating energy usage vs HDD_d for the enlisted personnel mess hall.

APPENDIX C:

SAMPLE ECIP ECONOMIC ANALYSES

This appendix gives examples of economic analyses done for both the FY84 and the FY85 guidelines. These analyses were based on the energy data given in this report. The samples were done for the 37 two company, rolling-pin-shaped barracks for enlisted personnel at Fort Leonard Wood, MO. It was assumed that these buildings had not been modified since they were built. Tables C1 and C3 show the examples. Tables C2 and C4 show where the numbers are taken from in this report and how additional calculations were made.

Note that before an actual ECIP proposal could be made, the actual buildings would have to be surveyed to see if any retrofits had already been made. The retrofit costs given in this report should be checked to see if they reflect local construction costs, but the energy analysis does not have to be repeated.

Table C1

ECIP Economic Analysis Summary for Rolling-Pin Barracks

Location: Fort Leonard Wood, MO (15 October 1980)
FY: 84
Project: Retrofit 37 enlisted men two-company (rolling-pin-shaped) barracks by blocking outside air fan/coil vents and adding cavity wall insulation and storm windows
Economic Life: 25 Years Date Prepared: FY82 Prepared by:

COSTS

1. Nonrecurring Initial Capital Costs:	$ 1,656,000
a. CWE	$ 94,000
b. Design	$ 0
c. Other	$ 1,750,000
d. Total	

BENEFITS

2. Recurring Benefit/Cost Differential Other Than Energy:	
a. Annual Labor Decrease (+)/Increase (-)	$ ______
b. Annual Material Decrease (+)/Increase (-)	$ ______
c. Other Annual Decrease (+)/Increase (-)	$ ______
d. Total Costs	$ ______
e. 10% Discount Factor	$ ______
f. Discounted Recurring Cost (d x e)	$ ______
3. Recurring Energy Benefit/Costs:	
a. Type of Fuel: Oil	
(1) Annual Energy Decrease (+)/Increase (-)	96,385 MBtu
(2) Cost P MBtu	$ 14.000/MBtu
(3) Annual Dollar Decrease/Increase [(1)x(2)]	$1,349,000/Year
(4) Differential Escalation Rate (8%) Factor	20.05
(5) Discounted Dollar Decrease/Increase [(3)x(4)]	$ 27,047,000
b. Type of Fuel: Electricity	
(1) Annual Energy Decrease (+)/Increase (-)	974 MBtu
(2) Cost Per MBtu	$ 16.60/MBtu
(3) Annual Dollar Decrease/Increase [(1)x(2)]	$ 16,168/Year
(4) Differential Escalation Rate (7%) Factor	18.049
(5) Discounted Dollar Decrease/Increase [(3)x(4)]	$ 292,000
c. Type of Fuel:	
(1) Annual Energy Decrease (+)/Increase (-)	______ MBtu
(2) Cost Per MBtu	$ ______/MBtu
(3) Annual Dollar Decrease/Increase [(1)x(2)]	$ ______/Year
(4) Differential Escalation Rate (_%) Factor	______
(5) Discounted Dollar Decrease/Increase [(3)x(4)]	$ ______
d. Type of Fuel:	
(1) Annual Energy Decrease (+)/Increase (-)	______ MBtu
(2) Cost Per MBtu	$ ______/MBtu
(3) Annual Dollar Decrease/Increase [(1)x(2)]	$ ______/Year
(4) Differential Escalation Rate (__%) Factor	______/MBtu
(5) Discounted Dollar Decrease/Increase [(3)x(4)]	$ ______
e. Discounted Energy Benefits [3a(5)+3b(5)+3c(5)+3d(5)]	$ 27,339,000
4. Total Benefits (Sum 2f + 3e)	$ 27,339,000
5. Discounted Benefit/Cost Ratio (4 ÷ 1d)	16
6. Total Annual Energy Savings [3a(1)+3b(1)+3c(1)+3d(1)]	97,359 MBtu
7. Energy/Cost Ratio (6 ÷ 1a/1000)	59
8. Annual Dollar Savings [2d+3a(3)+3b(3)+3c(3)+3d(3)]	$ 1,365,000
9. Payback Period [(1a - Salvage) ÷ Line 8]	1.2 Years

Table C2

Cost Data for ECIP Economic Analysis in Table C1

Location: Fort Leonard Wood, MO (Figure 1, Climatic Zone 3)
FY: 84 (used for economic analysis; does not affect the energy savings calculations)

Project: Retrofit all of Fort Leonard Wood's 37 two company, rolling-pin-shaped barracks for enlisted personnel (Table 2). Figure 5 shows that blocking outside air fan/coil vents, adding cavity wall insulation, and adding storm windows all exceed the minimum E/C ratio of 17. However, blocking one-third of the windows does not meet the minimum E/C ratio requirement.

COSTS

1. Nonrecurring Initial Capital Costs: (from Table D1)

Construction = 37 [($13.5/sq ft)(83 sq ft)+($.80/sq ft)(1606 sq ft)
+ ($4.5/sq ft)(4400 sq ft)]
= 37 ($33768)
= $1,249,416

SIOH at 5% = $62,471

Unescalated CWE = $1,311,887

Unescalated design cost at 6% CWE = $78,713

Escalated CWE (from FY82 to FY84, Table D4) = $1,311,887
(1.06)(1.06)(1.06)(1.06) = $1,656,227
(enter $1,656,000 on line 1a)

Escalated design costs (from FY81 to FY83) = $78713
(1.06)(1.06)(1.06) = $93748
(enter $94,000 on line 1b)

Total = $1,656,000 + $94,000 = $1,750,000

BENEFITS

2. Recurring Benefit/Cost Differential Other Than Energy: None

3. Recurring Energy Benefit/Costs:

a. Type of fuel = oil (heating energy savings) (enter on line 3a)

(1) Annual Energy Decrease: (from Table 13)
A1 Block fan/coils: 755 MBtu/year
B1 Insulate walls: 790 MBtu/year
C1 Add storm windows: 1060 MBtu/year
System energy savings: 2605 MBtu/year
Total savings = 37(2605) = 96,385 MBtu/year

(2) Cost per MBtu:
Oil (Table D3) = $7.13/MBtu
Escalated oil price from FY80 to FY84, Table D4) =
($7.13/MBtu)(1.16)(1.14)(1.14)(1.14)(1.14) = $14.00/MBtu
[enter on line 3a(2)]

(3) Annual dollar decrease = (96385 MBtu)($14.00/MBtu) = $1,349,000
[enter on line 3a(3)]

Table C2 (Cont'd)

(4) Differential escalation rate:
Oil differential escalation rate (Table D5) = 7%
[enter on line 3a(4)]
Recurring benefit/cost factors (Table D5) = 20.05

(5) Discounted dollar decrease = ($1,349,000)(20.05) = 27,047,000
[enter on line 3a(5)]

b. Type of fuel = electricity (cooling energy savings) (enter on line 3b).

(1) Annual energy decrease: (from Table 13)
A1 Block fan/coils: 34 MBtu/year
B1 Insulate walls: 53 MBtu/year
C1 Add storm windows: 0
System electricity: 87 MBtu/year
Total: (37)(87) = 3220 MBtu/year

(2) Cost per MBtu:
Electricity (Table D3) = $8.8/MBtu
Escalated electricity price
(from FY80 to FY84,
Table D4) = ($8.8/MBtu)(1.16)(1.13)(1.13)(1.13)(1.13) =
$16.60/MBtu [enter on line 3b(2)]

(3) Annual dollar decrease = (3220 MBtu)($16.60/MBtu) = $53,452
[enter on line 3b(3)]

(4) Differential escalation rate:
Electricity differential escalation rate (Table D5) = 7%
[enter on line 3b(4)]
Recurring benefit/cost factors (Table D5) = 18.049
[enter on line 3b(4)]

(5) Discounted dollar decrease = ($53,452)(18.049) = 964,800
[enter on line 3b(5)]

e. Discounted energy benefits = $27,047,000 + $964,800 = $28,010,000
(enter on line 3e)

4. Total Benefits = $0 + $28,010,000 = $28,010,000 (enter on line 4)

5. Discounted benefit/cost ratio = $28,010,000/$1,750,000 = 16
(enter on line 5)

6. Total annual energy savings = 96 385 MBtu + 3220 MBtu = 99,605 MBtu
(enter on line 6)

7. E/C ratio = (99,605 MBtu/$1,656,000/1000) = 60 MBtu/k$

8. Annual dollar savings = $1,349,000 + $53,452 = $1,402,00/year
(enter on line 8)

9. Payback period = ($1,656,000)/($1,402,000/year) = 1.2 years

Table C3

Life-Cycle Cost Analysis for Retrofits to Rolling-Pin Barracks

Location: Fort Leonard Wood, MO   Project Number ________

Project Title: Retrofits to Rolling Pin Barracks   Fiscal Year: FY85

Analysis Date: FY82   Economic Life: 25 Years   Prepared by: GSP3

1. Investment
   a. Construction cost $1,752,371
   b. SIOH $ 87,619
   c. Design cost $ 103,177
   d. Energy credit calculation (1a+1b+1c)x0.9 $1,748,850
   e. Salvage value   -$ 0
   f. Total investment (1d-1e) $1,748,850

2. Energy savings (+) / cost (-)
   Analysis data annual savings, unit cost, and discounted savings

Fuel	Unit Cost $MBtu(1)	Savings MBtu/Year(2)	Annual $ Savings(3)	Discount Factor(4)	Discounted Savings(5)
a. Oil	$15.65	96,385	$1,508,425	17.80	$26,850,000
b. NG	$	0	$		$ 0
c. Elec	$18.32	3,219	$ 58,972	13.93	$ 821,500
d. Coal	$	0	$		$ 0
e. ___	$		$		$
f. Total		99,604	$1,567,397		$.7,672,000

3. Nonenergy savings (+) / cost (-)

   a. Annual recurring (+/-) $_______0
      (1) Discount factor (Table A) ____
      (2) Discounted saving/cost $_______0

   b. Nonrecurring cost $_______0
      (1) Year of cost
      (2) Discount factor (Table B) ____
      (3) Discounted cost   -$_____0

   c. Nonrecurring savings $_______0
      (1) Year of savings ____
      (2) Discount factor ____
      (3) Discounted savings $_______0

   d. Total discounted savings/cost [(3a2+3b+3c3) $_______0

   e. Project qualification test

      (1) 25% calc [2f5 x 0.33] $________

         (a) If 3e(1) is = or > 3d, go to item 4

         (b) If 3e(1) is < 3d, calc SIR [2f(5)+3e(1)]/1f ____

         (c) If 3e(1)(b) = > 1 go to item 4

         (d) If 3e(1)(b) < 1 project does not qualify

4. Average annual dollar savings 2f3+3a+(3b+3c)/years economic life $1,567,400

5. Total net discounted savings [2f5+3d) $27,672,000

6. Discounted savings ratio (SIR) (5/1f)   16
   If < 1, does not qualify

Table C4

Cost Data for Life-Cycle Cost Analysis in Table C3

Location: Fort Leonard Wood, MO

Project Title: Retrofit to two company, rolling pin-shaped barracks for enlisted personnel: block outside air fan/coil vents, add cavity wall insulation, and add storm windows.

Fiscal Year: FY85

Analysis Date: FY82

Economic Life: 25 years

1. Investment

   a. Construction cost = 37 [($13.5/sq ft)(83 sq ft) + ($0.3/sq ft) (16,060 sq ft) + ($4.5/sq ft)(4400 sq ft)] = 37 [$33,768] = $1,249,416

      Escalation from FY81 to FY85 = $1,249,416(1.07)(1.07)(1.07)(1.07)(1.07) = $1,752,371

   b. SIOH at 5% of 1a = $62,471

      Escalation from FY81 to FY85 = $62,471 (1.07)(1.07)(1.07)(1.07)(1.07) = $87,619

   c. Design cost at 6% of unescalated (1a + 1b) = ($1,249,416 + $62,471) x 0.06 = $78,713

      Escalation from FY81 to FY84 = $78,713(1.07)(1.07)(1.07)(1.07)(1.07) = $103,177

   d. Energy credit calculation: (1a + 1b + 1c) x 0.9 = ($1,752,371 + $87,619 + $103,177) x 0.9 = $1,748,850

   e. Salvage value: none

   f. Total investment: (1d - 1e) = $1,748,850

2. Energy savings (+)/cost (-)

3. Analysis date annual savings, unit cost, and discounted savings

Fuel	Unit Cost $MBtu (1)	Savings MBtu/Year (2)	Annual $ Savings (3)	Discount Factor (4)	Discounted Savings (5)
a. Oil	$15.65	96,385	$1,508,425	17.80	$26,849,965
b. Elec	$16.32	3,219	$ 58,972	13.93	$ 821,481
c. Total		99,604	$1,567,397		$27,671,44[illegible]

   a. Oil

      (1) Unit cost escalated from FY80 to FY85 (from Tables F1 and F2) = ($7.13/MBtu)(1.14)(1.14)(1.14)(1.14)(1.14)(1.14) = $15.65/MBtu

      (2) Savings MBtu/year (from Table 13)
      A1 Block fan/coils: 755 MBtu/year
      B1 Insulate walls: 790 MBtu/year
      C1 Add storm windows: 1060 MBtu/year
      System heating energy savings: 2605 MBtu/year
      Total savings: 37(2605) = 96385 MBtu/year

Table C4 (Cont'd)

(3) Annual savings: [2a(1) x 2a(3)] $15.65 x 96,385 = $1,508,425

(4) Discount factor (from Table F3): 17.80

(5) Discounted savings: [2a(3) x 2a(4)] $1,508,425 x 17.80 = $26,849,965

c. Electricity

(1) Unit cost, escalated from FY80 to FY85 (from Tables F1 and F2) = ($8.8/MBtu)(1.13)(1.13)(1.13)(1.13)(1.13)(1.13) = $18.32/MBtu

(2) Savings MBtu/year (from Table 13)
A1 Block fan/coils: 34 MBtu/year
B1 Insulate walls: 53 MBtu/year
C1 Add storm windows: 0
System electricity: 87 MBtu/year
Total: 37(87) = 3219 MBtu/year

(3) Annual savings: [2c(1) x 2c(3)] ($18.32/MBtu) x (3219 MBtu) = $58,972

(4) Discount factor (from Table F3): 13.93

(5) Discounted savings: [2c(3) x 2c(4)] ($58,972) x (13.93) = $821,481

3. Nonenergy savings (+)/cost (-): none

4. Average annual dollar savings: [2f(3) + 3a + (3b + 3c)/years of economic life] = $1,567,397 + 0 + 0/25 year = $1,567,397

5. Total net discounted savings: [2f(5) + 3d] = $27,671,446 + 0

6. Discounted savings ratio (SIR): (5/1f) = $27,671,446/$1,748,850; SIR = 15.8

APPENDIX D:

ECIP ANALYSIS METHOD THROUGH FY84: ROLLING-PIN AND TYPE 64 BARRACKS

To do an ECIP analysis, both retrofit costs and energy savings must be calculated. Retrofit costs fall into four groups:

1. Construction costs

2. SIOH costs

3. Design costs

4. Fuel costs.

These costs must be figured in light of escalation and differential escalation rates, and economic life.

Construction cost estimates for the sample analyses in Appendix C were taken, where possible, from actual construction contract estimates for similar jobs, or estimated from standard cost data.[12] SIOH and design costs, escalation and differential calculation rates, and economic life data were based on ECIP guidelines. Fuel costs were averages taken from Army installation data.[13] For specific ECIP analyses, the values given for these four cost groups should be verified against local rates and conditions.

Although the retrofit construction costs for the rolling-pin and Type 64 barracks are similar, they are listed separately in this appendix. Some retrofit costs depend on what other retrofits are being done (e.g., blocking windows while putting on exterior insulation as opposed to just blocking the windows). Table D1 gives the retrofit construction costs for the rolling-pin barracks. Table D2 gives the retrofit construction costs for the Type 64 barracks.

The SIOH cost is 5 percent of the construction cost. The design cost is 6 percent of the sum of the construction cost and the SIOH cost. The design cost is escalated to 1 year before the project year. All other costs are escalated to the project. Table D3 lists the fuel prices. The escalation rates are given in Table D4, and the long-term differential escalation rates are given in Table D5. The project year was taken to be FY84. The construction, SIOH, and design costs were escalated from FY81. The fuel prices were escalated from FY80.

Metric conversions for the tables in this appendix are: 1 sq ft = 0.092 m^2; 1 in. = 25.4 mm; 1 MBtu = 1.055 GJ.

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[12] The 1981 Berger Building & Design Cost File, Volume 1: General Construction Trades, Unit Prices/Western Edition (Van Nostrand Reinhold Company, 1981); and Robert Sturgis Godfray, editor, Building Construction Cost Data 1981 (Robert Snow Means Company, Inc., 1980).

[13] Annual Summary of Operations Fiscal Year 1980 (DAEN-MPO-R, 1980).

Table D1

Retrofit Construction Costs for the Rolling-Pin Barracks

Retrofit	$/Sq Ft	Sq Ft
Block outside air fan/coil vents	13.5	83
Add cavity wall insulation	0.8	16,060
Add storm windows	4.5	4,400
Block one-third of the windows	15.0	1,466

Table D2

Retrofit Construction Costs for the Type 64 Barracks

Retrofit	$/Sq Ft	Sq Ft
Close off AHUs	40	13
Add storm windows	4.5	5,000
Add storm windows and block two-thirds of the windows	4.5	1,700
Add 2 in. of exterior insulation	4	13,000
Block two-thirds of the windows	15	3,300
Block two-thirds of the windows and add 2 in. of exterior insulation	5	3,300
Add 8 in. of roof insulation	1	10,000
Put up south overhangs	7	1,600
Put up south overhangs and block two-thirds of the windows.	7	530

Table D3

Fuel Prices

Fuel	$/MBtu
Electricity	8.8
Natural gas	3.07
Oil	7.13

Table D4

Escalation Rates

Cost	FY80 (%)	FY81 (%)	FY82 (%)	FY83 (%)	FY84 (%)
Construction	—	6	6	6	6
SIOH	—	6	6	6	6
Design	—	6	6	6	—
Electricity	16	13	13	13	13
Natural gas	15	14	14	14	14
Oil	16	14	14	14	14

Table D5

Long-Term Differential Escalation Rates

Cost	Differential Escalation Rate (%)	Recurring* B/C Factors
Electricity	7	18.049
Natural gas	8	20.05
Oil	8	20.05

*Economic life is equal to 25 years.

APPENDIX E:

ECIP ANALYSIS METHOD THROUGH FY84: MOTOR REPAIR SHOP, BATTALION HEADQUARTERS, AND ENLISTED PERSONNEL MESS HALL

An economic analysis for each recommended ECA was done according to the method outlined in the ECIP Guidance Memorandum dated December 20, 1977.

All projects were assumed to be awarded in FY84. Estimated construction costs were escalated according to project duration: costs for 3-month projects were multiplied by a factor of 1.1825 (10 percent for 1-3/4 years), and 6-month projects were multiplied by a factor of 1.2100 (10 percent for 2 years). SIOH and design costs were calculated as 6 percent of construction costs. The escalation factor used for design costs was 1.550 (10 percent for 1-1/2 years). The SIOH was escalated by the same factor as construction costs. The sum of the escalated construction costs and SIOH is the current working estimate (CWE). The total initial cost (TIC) equals the CWE plus the design costs.

For each ECA, the energy savings for each fuel were adjusted for thermal and distribution losses. Heating systems were assumed to be 60 percent efficient. Cooling systems were assumed to be 90 percent efficient. The adjusted fuel) savings were multiplied by unit costs (according to fuel) to obtain FY82 annual dollar savings. The fuel unit costs used by CERL were:

Electric	$8.80/MBtu
Natural gas	$3.07/MBtu
Fuel oil	$7.13/MBtu
Chilled water	$2.64/MBtu

A COP of 3.0 was incorporated into the unit cost for chilled water. Maintenance costs for each project were calculated as a percentage of construction costs (from 0.0 to 5.0 percent, based on the ECA) and were subtracted from the sum of the annual dollar savings for all fuels to obtain the total FY82 annual dollar savings.

Each component of the total FY82 annual dollar savings was escalated to the time of project completion based on its projected annual rate of increase. The escalation rates for these annual savings/costs were:

Electric	1.3599 (13 percent for 2-1/2 years)
Natural gas	1.3906 (14 percent for 2-1/2 years)
Fuel oil	1.3906 (14 percent for 2-1/2 years)
Chilled water	1.3599 (13 percent for 2-1/2 years)
Maintenance	1.1464 (5.6 percent for 2-1/2 years)

The sum of the escalated annual savings/costs is the total annual dollar savings at the time of project completion. The net present value of the annual dollar savings over the economic life of the project (the benefit) was obtained by multiplying each component of the total annual dollar savings by the appropriate differential escalation rate factor (DERF). The DERF that was applied depended on the economic life of the project and the differential inflation rate of the savings/cost. The economic life of the recommended ECAs was assumed to be 15 years for mechanical and control modifications and 25 years for architectural options (with the exception of door seals, which were rated at 5 years). The DERFs were obtained directly from the ECIP Guidance Memorandum:

	Differential Inflation Rate (%)	Economic Life		
		5	15	25
Electric	7	4.670	12.278	18.049
Natural gas	8	4.777	13.112	20.050
Fuel oil	8	4.777	13.112	20.050
Chilled water	7	4.670	12.278	18.049
Maintenance	0	3.977	7.980	9.524

The remainder of this appendix contains construction cost estimate sheets which detail what is required to implement each recommended ECA. The major source of cost information was the Means Repair and Remodeling Data 1982, Commercial/Residential, 3rd Annual Edition (Robert Snow Means Company, 1982). Manufacturers' cost data were used when available. Labor and material costs are included in the cost per unit figure.

Metric conversions for this appendix are: 1 in. = 25.4 mm; 1 ft = 0.3066 m; 1 sq ft = 0.092 m^2; 1 hp = 0.74 watts; 1 cu ft = 0.028 m^3.

Building: Motor Repair Shop

ECA: Install Night-Setback Thermostat

ECA	No. of Units	Unit Measure ($)	Cost Per Unit ($)	Cost ($)
Remove existing thermostat, install and wire new setback thermostat	3	Each	78.85	237
Total Cost ($)				237

Building: Motor Repair Shop

ECA: Insulate Exterior Wall
Reduce overall wall U-Factor from 0.51 Btu/hr-sq ft-°F (3.7 W/m^2-°K) to 0.07 Btu/hr-sq ft-°F (0.4 W/m^2-°K)

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Furring, wood strips on walls, 1 x 3 in. on masonry wall	2029	Linear feet	0.52	1,055
Fiberglass batts, 3-1/2 in. thick, R11	2852	Square feet	0.32	913
Drywall-gypsum plasterboard 1/2-in.-thick, fire-resistant	2852	Square feet	0.42	1,198
Total Cost ($)				3,166

Building: Motor Repair Shop

ECA: Insulate Roof
Reduce roof wall U-Factor from 0.24 Btu/hr-sq ft-°F (1.4 W/m^2-°K) to 0.08 Btu/hr-sq ft-°F (0.45 W/m^2-°K)

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Remove existing roofing	4808	Square feet	1.18	5,673
Roof insulation, polystyrene extruded, 2-in.-thick, R8	4808	Square feet	0.87	4,183
Install new roofing	4808	Square feet	1.18	5,673
Rubbish handling	4808	Square feet	0.47	2,260
Total Cost ($)				17,789

Building: Motor Repair Shop

ECA: Cover One-Half of the Windows With Insulating Metal Panel

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Steel siding, factor sandwich, galvanized 2 sides, with 2-in.-thick polystyrene*	570	Square feet	4.64	2,645
Total Cost ($)				2,645

*Prefabricated panels for this ECA are of comparable price.

Building: Motor Repair Shop

ECA: Install Vehicle Door Seals
Reduce Base Infiltration by 50 Percent

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Weatherstrip vehicle doors with neoprene gaskets	279	Linear feet	5.60	1,562
Total Cost ($)				1,562

Building: Motor Repair Shop

ECA: Replace Fluorescent Lighting in Vehicle Repair
with Metal Halide Lighting

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Interior demolition of ceiling-hung electric fixtures	54	Each	9.55	516
Interior lighting fixtures, metal halide, low-bay unit with 250-watt DX lamp, installed	10	Each	310.00	3,100
Total Cost ($)				3,616

Building: Motor Repair Shop

ECA: Install Insulating Interior Partition

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Metal stud partition, nonload bearing, 24-in. OG, 24 GA, 3-5/8 in. wide	360	Square feet	0.65	234
Gypsum drywall, 4 to 8 in. thick, fire-resistant	360	Square feet	0.46	166
Fiberglass batts, 3-1/2 in. thick, R11	360	Square feet	0.32	115
Taping and finishing wall	360	Square feet	0.22	79
Baseboard, painted	80	Linear feet	0.22	18
Painting, 2 coats, roller	360	Square feet	0.22	79
Hollow metal door frame, 7 ft-0 in. by 3 ft-9 in.	1	Each	83.00	83
Hollow metal door, interior commercial, flush-mounted	1	Each	150.00	150
Door hardware, including logic set	1	Each	66.30	63
Total Cost ($)				987

Building: Battalion Headquarters

ECA: Install Hot Water Circulating Pump Timeclock

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Install 7-day timer with reserve power	1	Each	260	260
Total Cost ($)		260		

Building: Battalion Headquarters

ECA: Repipe Baseboard and Install Night-Setback Thermostats

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Thermostatically controlled modulating radiator valve	3	Each	133.00	399
Black steel pipe (schedule 40, 1-1/2 in.)	132	Linear feet	7.90	1,043
Fiberglass pipe insulation, with all-service jacket, 1 in. thick	132	Linear feet	2.97	392
Balancing tees	3	Each	36.00	108
90° Elbows, 1-1/2 in. pipe	6	Each	24.00	144
Install and wire new setback thermostat	2	Each	78.85	158
Total Cost ($)				2,244

Building: Battalion Headquarters

ECA: Insulate Exterior Walls
Reduce overall wall U-Factor from 0.51 Btu/hr-sq ft-°F (3.7 W/m²-°K) to 0.07 Btu/hr-sq ft-°F (0.7 W/m²-°K)

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Furring, wood strips on walls, 1 x 3 in. on masonry wall	848	Linear feet	0.52	441
Fiberglass batts, 3-1/2 in. thick, R11	1,271	Square feet	0.32	407
Dry wall gypsum plasterboard, 1/2 in. thick, fire resistant	1,272	Square feet	0.42	534
Total Cost ($)				1,382

Building: Battalion Headquarters

ECA: Insulate Roof
Reduce roof wall U-factor from 0.24 Btu/hr-sq ft-^{o}F (1.4 W/m^{2}-^{o}K) to 0.09 Btu/hr-sq ft-^{o}F (0.51 W/m^{2}-^{o}K)

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Remove existing roofing	2.581	Square feet	1.18	3,046
Roof insulation, polystyrene extruded, 2 in. thick, R8	2,581	Square feet	0.87	2,245
Install new roofing	2,581	Square feet	1.18	3.046
Rubbish handling	2,581	Square feet	0.47	1,213
Total Cost ($)				9,550

Building: Battalion Headquarters

ECA: Install Storm Windows

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Magnetic interior storm window	444	Square feet	5.60	2,486
Total Cost ($)				2,486

Building: Battalion Headquarters

ECA: Add Vestibules

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Pour 4-in. concrete slab over 6-in. crushed stone base	24	Square feet	4.50	108
Erect masonry block walls to match existing, 8-in.-thick, hollow lightweight block	64	Square feet	4.14	265
Roof framing and covering	24	Square feet	5.36	129
Door frame	2	Each	75.00	150
Door	2	Each	195.00	390
Total Cost ($)				1,042

Building: Battalion Headquarters

ECA: Install DHW Timeclock

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Install 7-day tier with reserve power	1	Each	260	260
Total Cost ($)				260

Building: Enlisted Personnel Mess Hall

ECA: Install Night-Setback Thermostats

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Remove existing thermostat, install and wire new setback thermostat	8	Each	78.85	631
Total Cost ($)				631

Building: Enlisted Personnel Mess Hall

ECA: Install 24-hour Programmable Thermostat

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
24-hour programmable thermostat for dining room air-conditioning units	2	Each	150.00	300
Remove existing thermostat, install and wire setback thermostat	6	Each	78.85	473
Total Cost ($)				773

Building: Enlisted Personnel Mess Hall

ECA: Insulate Walls with Blown-In Insulation in Wall Air Cavity

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Cutouts in masonry walls, 4 in. thick	214	Each	33.0	7,062
Blown-in insulation, cellulose 3 in. thick R11	2385	Square feet	0.35	835
Brick up cut-outs, 4 in. thick	428	Square feet	6.70	2,868
Total Cost ($)				10,765

Building: Enlisted Personnel Mess Hall

ECA: Cover One-Half of the Dining Room Windows

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Steel siding, factory sandwich, galvanized 2 sides, painted to match existing, with 2-in.-thick polystyrene	617	Square feet	4.64	2,863
Demolition and disposal	617	Square feet	2.00	1,234
Total Cost ($)				4,097

Building: Enlisted Personnel Mess Hall

ECA: Replace Incandescent Lighting with Fluorescent Lighting

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Interior demolition ceiling-mounted electric fixtures	42	Each	9.55	401
Interior lighting fixtures, recessed, fluorescent, 2 x 4 ft 4 to 40 watt bulbs	28	Each	99.00	2,772
Total Cost ($)				3,173

Building: Enlisted Personnel Mess Hall

ECA: Install Economizers

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Install enthalpy cycle economizer, 10 to 20 tons	2	Each	3,200	6,400
Total Cost ($)				6,400

Building: Enlisted Personnel Mess Hall

ECA: Conversion to Variable Air Volume

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Variable speed drive	2	Each	1,534.00	3,068
Rebalance system	1	Each	450.00	450
Total Cost ($)				3,518

Building: Enlisted Personnel Mess Hall

ECA: Install Heat Recovery Glycol Loop in Kitchen Exhaust

	No. of Units	Unit Measure	Cost per Unit ($)	Cost ($)
Spiral fan/coil	15	kcfm	1,364.00	20,460
Pump (single stage)	2 at 1 hp	hp	*	6,500
Piping	25	Linear feet	14.93	373
Miscellaneous:				
Three-way valve actuator	1	Each	1,450.00	1,450
Expansion tank	1	Each	100.00	100
Motor starter	1	Each	255.00	255
Safety switch	1	Each	135.00	135
Ethylene glycol	50	Gallon	4.50	225
30-A breaker	1	Each	205.00	205
Wiring and conduit	100	Feet	4.40	440
Various valves, strainers, etc.			118.00	118
Grease filters	15	Kcfm	24.20	363
Total Cost ($)				31,614

*Pump cost = 3,350 + 50 (hp-3)

APPENDIX F:

ECIP ANALYSIS METHOD BEGINNING WITH FY85

Beginning with the FY85 program, projects will be ranked based on their greatest potential life-cycle cost payback SIR as calculated according to National Bureau of Standards (NBS) Handbook 135, Life-Cycle Cost Manual for the Federal Energy Management Program. If two or more projects have the same SIR, those projects will be ranked based on their greatest petroleum savings or mission support (at the discretion of the military department or defense agency with jurisdiction). Each discrete portion of each project must be life-cycle cost effective or be essential to completing other portions of the project. Care must be taken to ensure that energy savings are not duplicated between projects or portions of projects.[14]

All projects were assumed to be awarded in FY85, 1 year later than FY84 guidelines. All escalations were extended accordingly. The SIOH and design costs were calculated as a percentage of construction costs as given in the FY84 guidelines. The base construction costs were also the same as the FY84 cost calculations. Because the retrofits are intended to save energy, there is an additional ECIP calculation which reduces the project cost by 10 percent. The fuel prices are the same as those listed in Table F1. The escalation rates are as given in Table F2, and the long-term differential escalation rates are as given in Table F3. Both rates differ from previous guidelines. All economic lifetimes remain the same.

[14] Millard Carr, p 1.

Table F1

Fuel Pri

Fuel	$/MBtu*
Electricity	8.8
Natural gas	3.07
Oil	7.13

*Annual Summary of Operations Fiscal Year 1980 (DAEN-MPO-R, 1980).

Table F2

Escalation Rates

Cost	Escalation Rate (%/Year)
Construction	7
Electricity	13
Natural gas	14
Oil	14

Table F3

Long-Term Differential Escalation Rate Factor

Cost	DERF		
	5*	15*	25*
Electricity	4.72	10.87	13.93
Natural gas	5.19	13.01	18.10
Oil	4.41	11.36	17.80

*Economic life in years. These "modified" uniform present-worth discount factors are based on a 7 percent discount rate and include the EIA projected real escalation rates in energy prices developed from the Mid-Term Energy Forecasting System. These factors are the national averages as reported in the November 18, 1981, Federal Register.

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