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ASEAN-USAID
Buildings Energy Conservation Project
FINAL REPORT

VOLUME III: AUDITS

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PREFACE

THE ASEAN-USAID BUILDINGS ENERGY CONSERVATION PROJECT

Audits is the third in a series of three volumes that culminate an eight-year effort to promote building energy efficiency in five of the six members of the Association of Southeast Asian Nations (ASEAN). The Buildings Energy Conservation Project was one of three energy-related subprojects sponsored by the United States Agency for International Development (USAID) as a result of the Fourth ASEAN-US Dialogue on Development Cooperation in March 1982. It was conceived as a broad and integrated approach to the problem of bringing about cost-effective energy conservation in Indonesia, Malaysia, the Philippines, Singapore, and Thailand (Brunei was the one ASEAN member nation that did not participate).

This volume presents the results of audits that were performed on a large sample of ASEAN commercial buildings. This information was used to create an ASEAN-wide energy use database. The research was largely conducted by ASEAN analysts and professionals in local universities and government institutions. Further findings of the ASEAN-USAID Project are collected in the remaining two volumes of this series, which cover the following topics in depth:

- Volume I - *Energy Standards* summarizes intensive efforts that have resulted in new commercial building standard proposals for four ASEAN countries and revision of the existing Singapore standard.
- Volume II - *Technology* is a compilation of papers that report on specific energy efficiency technologies in the ASEAN environment.

PROJECT PHILOSOPHY AND CONTEXT

Underlying every aspect of the ASEAN-USAID Buildings Energy Conservation Project was a recognition that there were significant social, economic, and environmental benefits to be gained through enhanced energy efficiency. For the ASEAN nations, as for developing countries all over the world, the processes of modernization and industrialization have been accompanied by rapid growth in energy consumption. In the ASEAN region, commercial energy consumption grew from 27 to 85 million tons of oil equivalent (Mtoe), a factor of 3.15, during the period from 1970 to 1987. Electricity consumption increased from 20 to 101 billion kilowatt hours (kWh), or by a factor of five. Both growth rates were substantially in excess of the growth of economic productivity in the region; gross domestic product (GDP) increased by a factor of 2.5 during the same period.

While energy consumption has traditionally been regarded, and encouraged, as a vital input and stimulant of economic growth, the experiences of many of the industrialized nations recently have demonstrated the potential for decoupling economic growth rates from energy consumption growth rates. The benefits of this decoupling in an era of expensive energy sources, limited financial and natural resources, and critical global and local environmental stresses are also increasingly recognized. By supporting efforts toward improved energy efficiency through the ASEAN-USAID Project, the larger hope was to realize the potential for:

- Reduced growth of electricity demand to free capital for other uses, while avoiding the environmental externalities associated with power generation,
- Lower oil imports for many ASEAN countries to reduce balance of payments problems, and
- Money saved on electricity bills to be put to more productive uses.

The ASEAN-USAID Project targeted energy conservation in buildings because growth of electricity consumption in this sector has been particularly rapid throughout the region. In 1970, residential buildings in ASEAN consumed approximately 3.5 billion kWh and commercial buildings, 4.3 billion kWh. By 1987, these figures had grown to 22 billion kWh and 23 billion kWh,

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respectively. Thus, buildings in ASEAN—residential and commercial—currently make up 45% of the demand for electricity in the region. Their consumption has grown almost six-fold during this 17-year period, or at an annual rate of 10.9%.*

One of the immediate implications of increasing energy consumption is financial expense. The total annual cost of electricity for buildings in ASEAN (45 billion kWh) is about $4 billion (U.S.), and if industrial buildings, self-generation, and "public consumption" are counted, the total annual bill may be as high as $5 billion (U.S.). Since electricity consumption in buildings has grown rapidly and is likely to continue to do so, utility costs in the sector are likely to increase markedly over time. Because buildings represent such a significant fraction of electricity consumption in the region, they represent an important target sector for national efforts aimed at reaping the economic and environmental benefits of increased energy efficiency.

The ASEAN-USAID Project focussed on commercial buildings because of the magnitude of potential savings in this energy use sector. As described in greater detail elsewhere in this series, the potential for electricity savings in commercial buildings is significant:

- 10% savings achievable in the near term,
- 20% savings achievable in the intermediate term (5 to 10 years), and
- 40% or more savings achievable in the longer term.

A 10% reduction in commercial building energy use in ASEAN represents $200 million (U.S.) savings in fuel bills per year. Deducting the costs of investments needed to achieve these savings yields net annual savings to ASEAN of $100 to $150 million (U.S.).

A BRIEF HISTORY OF THE ASEAN-USAID BUILDINGS ENERGY CONSERVATION PROJECT

The first phase of the Project was initiated in 1982 with a collaboration by U.S. researchers at Lawrence Berkeley Laboratory (LBL) and the Singapore government. This first effort had several purposes, namely:

- to transfer to Singapore a computer code (DOE-2) to analyze the energy performance of buildings,
- to analyze measures to increase the energy efficiency of buildings in Singapore,
- to use the analysis results to extend and enhance Singapore's standards on energy efficiency in buildings, and
- to establish a process whereby the other ASEAN members can benefit from the experience in Singapore, including the use of DOE-2, the analysis to support energy standards, and the process of adapting and implementing building energy standards.

Detailed results of this first phase were presented at a conference in Singapore in May 1984. The proceedings from this conference are available in a separately bound volume. They include technical studies supporting recommended overall thermal transfer value (OTTV) refinements as well as energy performance simulation results, descriptions of existing energy conservation activities within ASEAN, and papers on several topics related to energy conservation in commercial buildings.

With the initiation of a second phase in 1985, the focus of the ASEAN-USAID Project was expanded to include the other participating ASEAN nations. Its purpose remained to promote the development and implementation of policies to improve the energy efficiency of commercial buildings. In pursuit of this goal, the Project funded 22 different research sub-projects within the five

* Indeed, these consumption estimates underestimate the actual electricity demand attributable to buildings for at least three reasons: (1) a sizeable portion of industrial electricity consumption is for building services, (2) electricity generated on site, either as backup power or for normal use, is counted as self-production even if it is used in buildings, and (3) the category "public electricity consumption" may include considerable use of electricity in buildings. Thus, it is likely that buildings in ASEAN account for considerably more than 45% of total electricity demand—probably in the range of 55 to 60%.

participating ASEAN countries. The current series represents a compilation and synthesis of several of the many research papers that grew out of the overall Project.

Since its inception, the ASEAN-USAID Project has provided training to ASEAN participants, supported research projects throughout ASEAN, conducted research at LBL, and engaged U.S. consultants to work with ASEAN governments and private sector participants to design programs and policies [1]. Within the Project, a key policy focus has been the application of technical tools to the development and assessment of efficiency standards and guidelines. The Project has stressed training (especially in computer simulation of building energy use and energy auditing) and the enhancement of research and development capabilities in ASEAN. Much of the data gathering, analysis, and research activity conducted under Project auspices was directed toward the eventual implementation of energy efficiency standards for ASEAN commercial buildings.

EXECUTIVE SUMMARY

The auditing subproject of the ASEAN-USAID Buildings Energy Conservation Project has generated a great deal of auditing activity throughout the ASEAN region. Basic building characteristic and energy consumption data were gathered for over 200 buildings and are presented in the Database appendix of this volume. A large number of buildings were given more detailed audits and were modeled with either the ASEAM-2 computer program or the more complex DOE-2 program. These models were used to calculate the savings to be generated by conservation measures. Specialty audits were also conducted, including lighting and thermal comfort surveys. Especially significant, many researchers in the ASEAN region were trained to perform energy audits in a series of training courses and seminars.

The electricity intensities of various types of ASEAN buildings have been calculated. A comparison to the electricity intensity of the U.S. building stock tentatively concludes that ASEAN office buildings are comparable, first class hotels and retail stores are more electricity intensive than their U.S. counterparts, and hospitals are less intensive. Philippine and Singapore lighting surveys indicate that illuminance levels in offices tend to be below the minimum accepted standard. Computer simulations of the energy use in various building types generally agree that for most ASEAN buildings, electricity consumption for air-conditioning (including fan power) consumes approximately 60% of total building electricity.

A review of the many studies made during the Project to calculate the savings from energy conservation opportunities (ECOs) shows a median potential savings of approximately 10%, with some buildings saving as much as 50%. Singapore buildings, apparently as a result of previously implemented efficient energy-use practices, shows a lower potential for savings than the other ASEAN nations. Air-conditioning ECOs hold the greatest potential for savings, starting with the no-cost measure of raising the thermostat setpoint and the almost no-cost measure of minimizing outside air intake. Variable air volume controls and heat exchangers for incoming air save over 10% of electric use and also have very low payback periods. Installing power factor-correcting capacitors saves more than 5% of electricity on average. Two Philippine studies done on cogeneration potential - one for a hotel and one for a hospital - show that energy can be saved while net cost savings of from 40% to 60% and paybacks of 1.5 to 2.6 years are achieved.

The breadth and detail of the auditing subproject has made it clear that energy use can be reduced in the ASEAN region, with no reduction in productivity or comfort. Some of those reductions will be a result of simple behavioral changes. Others will involve replacement of technology. Inevitably, each country will have to find the mix of technique and implementation procedure that results in the maximum reductions for the minimum cost.

INTRODUCTION

This volume provides an overview of the energy audit work that was done for the ASEAN-USAID Buildings Energy Conservation Project. Specifically, the following introduction details the purpose, history, and methodology of the project, and includes the key findings on energy consumption and the potential for energy conservation in ASEAN commercial buildings.

The bulk of this volume, however, is composed of nine appendices. The first, and perhaps most useful, is a database containing building characteristic and energy consumption information for over 200 buildings in the ASEAN region. Other appendices include the final report of the Singapore audit group, which summarizes their activities and findings, a number of audits—with varying degrees of detail—on individual buildings, and the report of a lighting survey. An example survey questionnaire form used for collecting data is included at the end.

Before concluding this introduction, a disclaimer is in order. The project has proved so effective in instigating energy audit activity that fully documenting the audit work or comprehensively capturing its results is virtually impossible. Still, we hope this volume will do some justice to the efforts of the researchers who participated in the project.

THE PROJECT

Project Rationale

In brief, the goals of the project have been to conduct energy studies of commercial buildings in the ASEAN nations, and then to analyze the findings. The energy studies of individual buildings have ranged in complexity from simple mailed surveys to intensive, detailed modeling. Simple surveys—which gather such data as building type, conditioned floor area, annual energy consumption, and other building characteristics—are sufficient to give an initial indication of whether a building is energy-efficient or not. Computer modeling the building's energy use can further clarify how a building uses or wastes energy. Modeling becomes especially useful in estimating the energy savings to be gained by implementing energy conservation opportunities (ECOs).

Energy studies of individual buildings are valuable to their owners or operators because the information can help them save money by reducing energy consumption. These studies can also help the utility or energy supplier who wants to reduce demand for energy. Finally, individual audits are beneficial to the nations in which they take place, since, by spurring conservation, they ease pollution problems, lower energy imports required, and free money for consumption or investment in other areas.

The results of a group of individual studies can reveal larger truths as well. On the simplest level, the analysis identifies the average electricity intensity of the various types of buildings in each country and in ASEAN as a whole. A comparison of these intensities both among the ASEAN nations and against the averages of industrialized countries indicates potential energy savings. A tabulation of modeled ECOs provides information about typical savings that may be available per building. An examination of savings and paybacks for various ECO types highlights those ECOs which are especially attractive and should receive special attention in a conservation program.

The audit analysis, which is the focus of this volume, is intended to be of assistance primarily to national energy planners. A determination of the feasibility of various types of conservation measures should point toward the national potential for conservation. This information is crucial in planning the matrix of future energy supply options. By identifying those ECO types which save the most energy or have the shortest paybacks, this analysis will also reveal areas where conservation investment, incentives, or regulation should be directed. Furthermore, the analysis can be useful to other building owners and operators, because it details typical electricity intensities and typical ECO savings.

Because the goal of energy conservation is such an important national priority, it is crucial that energy conservation as an on-going effort be encouraged. An important way to do this is to train energy professionals in the skills of energy auditing.

Training

To support project efforts, a training program to develop and enhance the energy auditing skills of building professionals in Indonesia, Malaysia, the Philippines, Singapore, and Thailand was carried out. The primary goal of this program was to transfer the skills and analytical tools required for the production of effective energy audit reports.

The scope of the basic and advanced energy audit training programs included: establishment of two-week training programs to develop skills in energy auditing and report production; training in the use of diagnostic instrumentation for energy audits; determination of appropriate retrofit measures for tropical climates; and adaptation of the U.S. Department of Energy's ASEAM-2.1 (A Simplified Energy Analysis Method) microcomputer program for analysis of tropical retrofit opportunities. The training was intended as the first phase of national energy audit programs for buildings in the ASEAN countries. Energy audit data collected for ASEAM-2 analysis are expected to be used for assessing potential national and regional conservation projects for the ASEAN commercial building sector. A manual of reference material was also prepared to assist participants in the training sessions.

From November 1986 to November 1988 seven different training courses and workshops were held throughout the ASEAN region. These courses lasted from one to two weeks each and ranged from preliminary training to advanced seminars. In the three basic two-week training courses, an average of approximately 30 participants received instruction in building energy auditing and were introduced to the ASEAM-2 microcomputer program. Participants were grouped into six teams to collaborate on and produce energy audit reports on actual buildings, using a building energy data collection form and working with the ASEAM-2 program.

In a workshop for eight key researchers representing each of the ASEAN countries, specialists from LBL gave presentations focusing on energy standards, policy objectives, data gathering methods, natural ventilation and air-conditioning research, and the use of auditing, monitoring and weather station equipment. A two-week advanced course was held for 22 successful participants in the basic auditing course (or equivalent). This advanced course was intended to provide instruction in the use of advanced features of ASEAM-2, improve field data collection skills, and train participants in the use of field instrumentation for building monitoring. A limited number of classroom lectures complemented a significant amount of hands-on field survey and computer lab work.

The Audit Work

The amount of energy audit work conducted under the auspices of the project has been considerable. Basic information on over 200 buildings was gathered (See Appendix A). Auditors investigated several types of buildings, including hotels, hospitals, retail stores, supermarkets, and others, but focused on office buildings.

Many different types of audits were conducted (see Table 1-1). Energy audits can be characterized by how they gather data, and how they analyze it. There are a number of different ways to gather building data. Questionnaires can be mailed to the building owners or managers, requesting information about air-conditioning, lighting, elevators, and energy conservation measures being implemented. Relevant data also can be garnered from blueprints and other documents available from government agencies. Neither of these investigative routes requires a site visit. The Singapore research team gathered information on 65 buildings using these approaches.

Another way to gather data is to perform a simple walk-through survey and record basic information about mechanical systems, envelope characteristics, and patterns of operation. This type of building study is fairly brief and does not involve making detailed observations or monitoring the use of systems over time. Alternatively, more time can be spent gathering more detailed information about the building. Most of the data gathered under the project auspices were collected in one of these latter two ways.

Finally, building systems can be monitored for periods ranging from 24 hours to a year, depending on the variability of the use pattern and the level of accuracy desired. One office building in Malaysia, for example, was monitored for a one-week period before and one after conservation retrofits were implemented.

Specialty audits can also be conducted. While most of the audit work conducted under the project sought to provide a comprehensive overview of the buildings' energy performance, some work was focused on particular features related to energy consumption. One Philippine research team surveyed the thermal comfort of building occupants in a number of buildings, by measuring such variables as dry- and wet-bulb temperatures, relative humidity, and indoor airspeed. The researchers' intention was to determine the effectiveness of natural ventilation. Another Philippine research team surveyed lighting levels in a number of buildings. The most extensive effort in this area was conducted by the Singapore researchers, partly under the aegis of this project. That lighting study can be found in Appendix H.

In order to gather the information for the database (Appendix A), the LBL research team sent out a questionnaire to the ASEAN participants regarding the buildings they had investigated. The ASEAN participants either returned the completed questionnaire to LBL, where the data were entered, or they entered the data directly into the database.

In support of the ASEAN in-country research projects, LBL reviewed each project's equipment needs, and developed an extensive listing of precision instruments, data acquisition equipment, and accompanying tools. The list of equipment sent to the ASEAN nations is shown in Table 1-2.

Once collected, the data can be used in several ways. Most simply, the data can be presented as they are, as has been done in the database. The data can also be used as inputs for computer models that simulate the building's energy use. The two software packages used most commonly in this project are ASEAM-2 and DOE-2. The DOE-2 model is a sophisticated analytic tool, but the gathering and entering of data and the fine-tuning of the simulation make modeling with this program difficult and laborious. Still, the research team in Thailand used it effectively in modeling the ventilating and air conditioning (VAC) systems of five buildings, each of a different building type.

The ASEAM-2 program is easier and quicker to use, and therefore allows researchers to model more buildings. The inputs required are fewer, and the program even provides default values when required. Most of the modeling done under the project was executed using the ASEAM-2 model.

Data also can be used to calculate the potential savings to be gained by implementing ECOs. Sometimes these calculations can be executed adequately by hand. Generally, however, it is a good practice to calculate potential savings with the help of a computer model, because the interactions between building systems—such as lighting and air-conditioning—can be quite complex. Most of the ECO savings shown in this report were calculated with the aid of the computer models.

Finally, financial feasibility studies of proposed ECOs can be performed. This was done by the Thai investigative team for air-conditioning ECOs (Appendix F) and by the Philippine team for cogeneration scenarios (see Table 1-11 and Appendix E).

THE FINDINGS

Background Issues

Electricity Intensity Index:

For the purpose of comparing building stocks, probably the most useful index is the energy intensity, or energy per unit floor area. In this study, the energy type that has been most closely monitored is electricity. Thus, the index that will be used is kWh/m^2.

The concept of "floor area," however, presents some difficulty. Should floor area include only the portion directly supplied with conditioned air, or should it include the total area within the confines of the building's walls, including parking garages, mechanical rooms, and storage spaces? Would an intermediate definition—including non-conditioned areas like stairways, halls, and storerooms, but not the parking garage—be more appropriate?

There is no simple answer to this question. But examining the exact purpose of the electricity intensity index can help solve the problem of its definition. As noted above, the index allows us to compare the energy performance of a building either to a standard or to other buildings. That means the index can be thought of as a kind of inverse efficiency ratio, with the output on the bottom and the input on the top. It measures how much energy is put into the building compared to how much output—amount of comfortable, usable, well-lit space equipped with the necessary services—is obtained. Floor area for calculating the electricity intensity, then, should be the floor area associated directly with the function of the building. For an office building, this corresponds to the area used by people doing office work—roughly, the conditioned area.

Another way to view the problem is simply as one of comparing the energy use in similar spaces. A parking garage is clearly a different type of space; by this criterion it should not be included. But what about stairwells, hallways, and small storerooms which receive little or no air supply? Ideally, these spaces should be excluded from the floor area since they too are distinctly different from conditioned spaces. To calculate the conditioned floor area, however, it is much easier to simply subtract the area of the parking garage from the total floor area than it is to calculate and then subtract the area of all the unconditioned interior spaces. In the ASEAN database, there is not a consistently followed rule for determining "conditioned area." In this study, the term "conditioned area" remains a somewhat ambiguous term. That is, we have used the "conditioned space" to calculate electricity intensity. This generally excludes parking garages, and it may or may not include stairwells, hallways, and storerooms without supply air.

It may offer some consolation to note that the ASEAN database is not alone with its slightly ambiguous "conditioned area." The Nonresidential Buildings Energy Consumption Survey (NBECS) published by the U.S. Energy Information Administration (U.S. EIA 1989) uses a classification for the proportion of area that is cooled, with one category being "100% cooled." Yet when NBECS survey respondents claimed that their building was 100% cooled, the data collectors had no way to verify that all hallways, stairwells, etc. were in fact conditioned.

Respondents to ASEAN surveys also probably overstate the "conditioned area," of their buildings. But the discrepancy is less striking. Nearly all ASEAN buildings have "gross area" figures which differ significantly from their "conditioned area" figures, whereas the majority of NBECS office buildings were categorized as 100% cooled. As an approximation, therefore, this study supposes that for the purpose of comparing the U.S. stock to the ASEAN stock, only 90% of the floor area belonging to NBECS "100% cooled" buildings actually is conditioned. This effectively raises all electricity intensity values for U.S. buildings, because values are divided by 0.9.

Statistical Significance:

What is the statistical significance of the ASEAN sample? This is a crucial question, as one of the project's primary purposes—namely, the characterization of the building stock—hinges on it. Unlike the statistical analysis of the NBECS study, which involved an intense effort to collect a significant and unbiased sample of the U.S. building stock, the ASEAN project used virtually no sampling methodology. We are confident, however, that the ASEAN sample as a whole is representative, especially for offices and hotels, because the sample is so large in comparison to the ASEAN commercial building stock, and because there seems to be little bias in the sample.

Survey Results

Electricity's Part in Total Energy:

Almost all of the data that were collected in the project relate to electricity consumption. That makes electricity's proportion of total building energy use less clear than would be desirable. Still, some useful generalizations can be made.

First, office buildings and stores in ASEAN nations use electricity almost exclusively. A non-electric fuel source, if used at all, would be only for domestic hot water. The energy required for this end use in these building types is negligible. Second, and conversely, non-electric building energy use can be considerable in other building types. Non-electric fuels are often used for the hotel laundry service, for cooking, and for producing domestic hot water for guests. For example, a study of four hotels in Indonesia shows that expenditures for electricity as a proportion of total energy expenditures range between 57 and 86% (see Table 1-3). When the energy types are converted to common energy units (with electricity measured at 3413 Btu/kWh), electricity's share ranges between 50 and 62%. (The one exception to this is the one hotel in Indonesia, where the share was 6%, due to its use of an absorption chiller.)

Hospitals also use considerable amounts of non-electric fuels, for steam, cooking heat, and hot water. For this reason, hospitals and hotels are often good candidates for cogeneration.

Following the pattern of the ASEAN buildings, but allowing for more non-electric fuels used for heating purposes, electricity in U.S. office buildings comprises 63% of total building energy consumption (NBECS p.29). Electricity for "lodging," "health care," and "mercantile and service" buildings is 39%, 29%, and 53%, respectively.

Electricity Intensity in ASEAN:

Based on a survey of 128 office buildings throughout the ASEAN region, we found that, on average, they have an electricity intensity of 233 kWh/m^2 (see Table 1-4). Hotels averaged a higher electricity intensity, of 318 kWh/m^2. Hospitals were higher still, at 379 kWh/m^2. Retail stores were nearly as high as hospitals, at 352 kWh/m^2.

Comparison among the five countries reveals that Indonesia has by far the lowest electricity intensity among the office buildings sampled, and nearly the lowest average for hotels. The figures for Indonesia are not necessarily significant, however, given the small sample size. Comparisons among the other four countries reveals no pattern of higher or lower indices. At first glance, it may seem surprising that Singapore, which has the most thoroughly implemented building conservation program, does not exhibit the lowest average electricity index. It is possible that Singapore's office buildings have higher internal electric loads from office equipment and lighting. Such loads would raise over-all building consumption even higher, were it not for its national energy policy.

Comparison to U.S. Stock:

It is instructive to compare the ASEAN consumption figures to those of U.S. buildings. It can also be difficult. This is partly because of the tremendous climate difference between the two groups of buildings. It is also because the electricity intensities supplied in the published NBECS report are not disaggregated enough to make a valid comparison between the two building stocks. The response to the first problem is to look only at buildings in the South census region of the U.S., since the weather in this hot and humid area corresponds most closely to that of the ASEAN region. This is not an ideal solution, however, for the weather in the U.S. South is still much cooler than in the ASEAN region. Consequently, U.S. buildings will require more heating and less cooling. The comparative weights of these two counteracting biases is unclear.

To solve this latter problem, we obtained the 1983 NBECS data, and examined several more disaggregated sample groups. The results of this data search are shown in Table 1-4. To provide a better comparison to ASEAN buildings, only those buildings in each size category which matched the typical sizes of ASEAN buildings in the sample are included in the U.S. sample. (These sizes are noted on the table.) Finally, the table displays two sets of U.S. averages—that for buildings built between 1971 and 1983, and that for all buildings standing in 1983. The ASEAN buildings tend to be of more recent vintage, and perhaps should be compared to the more recently built U.S. stock.

Table 1-4 shows a very close match between the electricity intensities of office buildings in the ASEAN region and in the southern United States. Electricity intensity in ASEAN hotels (318 kWh/m^2), however, is higher than the U.S. value for buildings of all vintages (252 kWh/m^2). (The value for U.S. hotels built between 1971 and 1983, 82 kWh/m^2, is based on a relatively small sample size and may be a statistical anomaly). U.S. hospitals are far more electricity-intensive (571 kWh/m^2 average for hospitals of any vintage) than their ASEAN counterparts (379 kWh/m^2). This is probably due to the higher level of equipment consumption in U.S. hospitals. Finally, ASEAN retail stores consume electricity at a higher level than do U.S. stores—352 versus 198 and 270 kWh/m^2.

In summary, ASEAN office buildings consume energy at about the same rate as U.S. offices, ASEAN hospitals use less electricity than their U.S. counterparts, and ASEAN hotels and retail stores use more.

Lighting Surveys:

Table 1-5 summarizes the results of the lighting surveys conducted by investigators in the Philippines and in Singapore. A more in-depth discussion of the Singapore results can be found in Appendix H. The average illuminance levels in offices for both the Philippines and for Singapore is approximately 370 lux, while the average installed lighting power density for both is 19 W/m^2. Most of the Philippine lighting reports noted that illuminance levels in the offices were too low. The Singapore report notes that 40% of the offices surveyed had illuminance levels below the minimum SISIR standard.

Building Simulations

Breakdown of Electricity Use by Component:

Table 1-6 shows a summary of the breakdown of electric use by component for different building types in the different ASEAN countries, as calculated by end-use ASEAM-2 simulations. For offices, hotels, hospitals, schools, and supermarkets, the sum of air conditioning and fans lies roughly between 55 and 70% of total electric use. Lighting and miscellaneous equipment make up the remainder.

Only stores deviate from this pattern, with an air-conditioning and fan total of only 40%. This result may be anomalous, however, as the sample consists of only one building.

Levine *et al.* performed a DOE-2 simulation of a prototypical imaginary office building (ASEAN/USAID 1989, pp. 49-62) based on average building characteristics obtained from a survey of office buildings in the Manila metropolitan area. The simulated building, as shown in Table 1-6, showed an energy consumption pattern similar to the average of the simulated values.

Breakdown of Cooling Load by Component:

The ASEAM-2 program calculates a breakdown of the peak cooling load in the modeled building. The Philippine research team modeled more buildings with ASEAM-2 than any other country. Table 1-7 summarizes the output from their work.

ECOs

Summary of ECOs Studied:

Table 1-8 shows a list of ECO measures for which estimated savings were calculated. The projected savings vary considerably from building to building. Nearly half the buildings have projected savings of more than 10% of total electricity, almost one-quarter show savings of more than 20%, and one office building has a savings potential of more than 50%. The Philippine research group prepared approximately 20 audit reports in which ECOs were identified and savings calculations were made. It is interesting to note that the savings calculations for ECOs in Singapore are quite small. This could be due to the relatively high standard of energy efficiency in their buildings.

A brief examination of Table 1-9 reveals that the measures which save the most energy are those that affect the VAC system. The most highly recommended measure for any building is to raise the thermostat setpoint as far as possible while staying within the comfort zone. Actually, many audit reports note that occupants complain that their building is too cold. This measure saved an average of 3.6% of total building electricity in those cases where it was calculated. In actuality, however, its magnitude depends on the size of the change in the setpoint.

Minimizing outside air intake is also an attractive measure, not the least of which is its low cost. This action generally consists of merely changing the pulleys on the fans. Yet it saved an average of 6.0% for those cases where it was calculated. Maintaining clean air-handling unit filters and cooling coils also garners significant savings.

The three biggest saving air-conditioning measures are variable air-volume (VAV) controls, heat exchangers, and new, efficient chillers. The first two are generally cost-effective (see next section), while the latter may be too expensive to be feasible in many cases, especially those involving retrofits.

Lighting measures have a significant potential for saving energy (an average of 5.1%), but caution is prescribed. Both the Philippine and Singapore lighting surveys found generally low lighting levels. Further reductions in installed capacity must be balanced against the need for good lighting for workers.

Electrical systems can be made more efficient in two ways: by raising the power factor by installing new capacitors, and by reducing transformer energy loss by lowering excess capacity. These strategies also have the potential for considerable savings, although the initial cost of these measures was not mentioned in the reports.

One drawback of the information presented in Table 1-9 is that it does not show whether or not the measure is cost-effective. Some of this information is presented in the following section.

Analysis of Air-Conditioning ECOs:

Table 1-10 shows a summary of ECO financial analyses performed for commercial buildings in Thailand. The air-conditioning systems for an office building, a hotel, a hospital, a library, and a shopping center were modeled using DOE-2. ECOs related to the air-conditioning systems were also modeled. A simplified version of the financial analysis is provided here.

Of the five building types examined, hotel ECOs have the shortest paybacks, followed by the office building, the shopping center, the university library, and the hospital. This order roughly follows the total electric consumption of the buildings, with the largest total consumers having ECOs with the shortest paybacks. This is apparently due to the relatively lower investment cost for larger ECOs. This order is also parallel to the electric intensity of the buildings. The university library and the hospital—the buildings with the lowest electric intensities—have the longest paybacks. In summary, buildings with low electricity consumption and intensity will have the longest payback periods.

All of the ECOs modeled have the potential to save substantial amounts of energy and pay for themselves quickly. Indeed, each ECO type has at least one application where its payback is less than 1.1 years. The ECOs can be combined to provide additional savings, but because of their overlapping nature, the payback periods will increase with combinations.

Clearly the cheapest, quickest way to save energy is to reduce the intake of outside air to the minimum required. This measure was calculated for the office building. Because of the low investment cost involved, the payback is very quick (0.1 years). This measure could not be recommended for the other buildings, since their outside air intake was judged to be already at a minimum.

Two types of VAV ECOs were modeled. The inlet guide vane method of effecting VAV control typically saves nearly twice as much money as the discharge damper method, but because its initial cost is far higher, the inlet guide vane ECO typically has slightly longer paybacks.

Heat exchangers to precondition incoming air with outgoing exhaust air are also cost-effective, with gross savings and investment costs comparable to the amounts for the inlet guide vane ECOs. However, fairly high operating costs lower net savings, and extend payback periods slightly.

In the office building, two ECOs, which involved reducing the amount of window area, were modeled. These measures result in lowered cooling loads and lowered requirements for cool supply air. The office building has a window-to-wall ratio of 0.95. The two measures decreased this ratio to 0.65 and to 0.35 by inserting insulating panels in portions of the windows. Both measures had a payback period of less than one year.

The savings modeled in these buildings are substantial. The individual measure types which produce the greatest savings are the inlet guide vanes and the heat exchangers. Combinations of ECOs—such as in the office building—can eliminate over half of the total electric consumption. In the university library, ECOs save over half of the electricity used by the air-conditioning system.

Cogeneration Analysis:

Philippine analysts performed feasibility studies for cogeneration at a hotel and at a hospital (see Table 1-11). These types of facilities are often suited for cogeneration because of their large heat requirements—for domestic hot water, laundry, and cooking. Several scenarios were investigated at each facility, involving varying chiller types, sizing criteria, and relationships to the utility grid. A number of financing schemes were also investigated, but for simplicity of presentation, this section limits the financial discussion to savings, investment, and payback.

All of the cogeneration scenarios save considerable energy. Net monetary savings range from 28% to 62% of total energy costs. In the hospital, the two scenarios with the lowest paybacks (1.54 and 1.58 years) incorporate absorption chillers to make use of generator waste heat. One of these scenarios, with the generator sized to meet maximum air-conditioning need, includes a sell-back of electricity to the utility. It should be noted that the cost of the chillers was not included in the investment cost, for either the absorption or for the centrifugal chiller cases. The hospital scenarios using centrifugal chillers have a somewhat longer payback. The scenario with the hospital isolated from the utility grid appears to be the worst investment choice, since it is the only one with a payback of more than three years.

The paybacks for the two scenarios for the hotel are not as short as the best hospital scenarios, but are still under three years. The generators in both scenarios are sized to meet the minimum electric demand, but the generators are different sizes because one scenario uses absorption and the other uses centrifugal chiller equipment.

Daylighting Simulation Results:

Philippine analysts have modeled the existing lighting in four office buildings, incorporating both artificial and natural light (see Table 1-12). They have also modeled the buildings' electricity use for the hypothetical case in which there is only artificial light. The resulting analysis, while not exactly a calculation of potential savings from daylighting measures, provides an indication of the effects of natural lighting on building energy use. In brief, natural lighting substantially lowers the need for artificial light, while slightly raising the need for cooling. The overall effect of natural lighting is to lower building energy use.

THE VOLUME

It would be impossible to represent all the auditing work done throughout ASEAN in this volume. Instead, we chose seven studies to provide a sample of both country activities and different building types (Appendices B-H). We also included the ASEAN Building Energy Database, and a sample energy survey form for those analysts interested in doing similar auditing work in their own countries.

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Table 1. Energy Studies Conducted

	Offices	Hotels	Hospitals	Stores	Sprmkts.	Undef'd	Total
Indonesia							
Survey	4	4	0	0	0	0	8
Audit	1	4	0	0	0	0	5
ASEAM	1	4	0	0	0	0	5
DOE-2	0	0	0	0	0	0	0
Malaysia							
Survey	23	4	0	3	0	2	32
Audit	2	2	1	0	0	0	5
ASEAM	12	3	0	1	0	0	16
DOE-2	0	0	0	0	0	0	0
Philippines							
Survey	24	7	9	2	3	0	45
Audit	18	3	2	0	1	0	24
ASEAM	26	9	10	2	4	0	51
DOE-2	3	2	1	0	1	0	7
Singapore							
Survey	65	0	0	3	0	6	74
Audit	4	2	0	0	0	1	7
ASEAM	4	0	0	2	0	0	6
DOE-2	0	0	0	0	0	0	0
Thailand							
Survey	1	1	0	1	0	0	3
Audit	6	14	8	2	0	0	30
ASEAM	0	0	0	0	0	0	0
DOE-2	1	1	1	1	0	2	6

Table 2. Equipment List

With the exception of the Philippines, which received an abbreviated list of auditing equipment, and Singapore, which received a smaller shipment of monitoring equipment, each country's auditing team was sent the following items:

Number of Items	Auditing Equipment
2	Temperature recorder
2	Mercury thermometer
1	Dial thermometer
2	Sling psychrometer
2	Tachometer
2	Light meter
1	Air balance kit
2	Air velocity-static pressure kit
1	Volt-ohm-ammeter

Number of Items	Monitoring Equipment
3	Thermistor temperature probe
1	Thin film humidity sensor
1	Digital clamp-on kH-kHh meter (up to 200 kW, 500 A, 50/60 Hz)
3	Watt transducers - voltage output signal
9	Current transducers - voltage output signal
1	Volt-ohm-ammeter
1	Digital multimeter
1	Data logger system
1	Cassette recorder
1	Recorder interface
1	Cassette computer interface (tape reader card for PC, plus software, recorder cable, ribbon cable)

Table 3. Expenditures on Different Energy Types: Indonesian Hotels

Building	Breakdown by Cost (%)				Total	Breakdown by Energy Equivalent (%)*			
	Elec.	Gas	Diesel Oil	Fuel Oil	($)	Elec.	Gas	Diesel Oil	Fuel Oil
Elmi Hotel	85.8	2.5	8.1	3.6	144,957	62.0	6.9	20.5	10.5
Hyatt Hotel	76.0	3.8	11.3	8.9	394,834	49.3	0.5	28.1	22.1
Simpang Hotel	79.9	5.8	14.4	0.0	101,350	52.4	10.4	37.1	0.0
Garden Hotel	56.7	2.0	41.1	0.2	349,415	6.1	2.2	87.3	4.4

* Electricity is figured at 1 kWh = 3413 Btu.

Table 4. Electricity Intensity Averages

Building Type	Country	No. of Buildings	Average Intensity (kWh/m^2)	Standard Deviation
Offices	Indonesia	4	147	18
	Malaysia	26	269	168
	Philippines	26	235	85
	Singapore	65	222	112
	Thailand	7	237	90
	ASEAN	128	233	121
	U.S. South: 1971-83	8,702	263	258
	U.S. South: All years	20,719	233	214
Hotels	Indonesia	4	287	128
	Malaysia	6	285	64
	Philippines	9	342	43
	Singapore	2	429	90
	Thailand	15	311	91
	ASEAN	36	318	91
	U.S. South: 1971-83	116	82	23
	U.S. South: All years	599	252	96
Hospitals	Malaysia	1	250	0
	Philippines	10	430	97
	Thailand	7	324	126
	ASEAN	18	379	122
	U.S. South: 1971-83	3,201	586	240
	U.S. South: All years	3,418	571	243
Retail	Malaysia	2	483	125
	Singapore	2	124	11
	Thailand	3	418	63
	ASEAN	7	352	167
	U.S. South: 1971-83	857	198	231
	U.S. South: All years	3,724	270	237
Supermarket	Philippines/ASEAN	6	265	86

Note: All figures for the U.S. building stock were taken from the 1983 *Nonresidential Buildings Energy Consumption Survey* users tape, supplied by the U.S. Energy Information Administration. All buildings in the U.S. sample are "100% cooled." The U.S. values have been modified (divided by 0.9) to account for possible over-estimation of cooled area.

To provide a better comparison to the ASEAN stock, only U.S. buildings with certain characteristics were included in the sample:

- Office buildings with a floor area greater than 10,000 ft^2.
- Hotels with more than 2 floors and more than 10,000 ft^2 in floor area.
- Hospitals that are large and that are of the in-patient type.
- Retail stores with floor areas between 50,000 and 600,000 ft^2.

Table 5. Summary of Lighting Survey Results - The Philippines and Singapore

Philippines

Activity (no. of cases)*	Working Plane Illuminance (lux) With Artificial Lights				Difference from No-Lights Cond.	Lighting Power Density (W/m^2)			
	Avg.	Max.	Min.	Std. Dev.		Avg.	Max.	Min.	Std. Dev.
Offices (28)	374	1214	85	274	152	19.3	43.3	2.5	8.9
Conf. Rooms (8)	583	2595	132	766	278	17.8	29.8	4.0	9.2
Corridors (9)	268	1250	30	355		15.6	15.6	15.6	0.0
Lobbies (7)	159	380	25	355		11.6	15.6	3.7	5.6
Restaurants (5)	78	160	15	55		15.9	15.9	15.9	0.0
Hosp. Rooms (6)	118	165	48	37	26	10.7	16.6	6.0	4.2

Singapore

Activity (no. of cases)	Working Plane Illuminance (lux) With Artificial Lights				Lighting Power Density (W/m^2)			
	Avg.	Max.	Min.	Std. Dev.	Avg.	Max.	Min.	Std. Dev.
Offices (136)	366	946	94	167	19.0	60.0	5.0	8.0
Shopping (45)	436	1140	128	235	29.0	79.0	11.0	15.0
Circulation (81)	134	518	13	111	16.0	48.0	1.0	11.0
Classrooms (44)	400	865	115	125	10.0	13.0	5.6	1.4
Production Areas (17)	520	887	169	224	24.0	59.0	3.7	14.0

Note: Lighting information was available for all of the ASEAN countries. Philippine and Singapore data are shown here because they are the most extensive.

* A case represents the information about either a single space or about a building. Not all cases contain complete data sets. The illuminance level in each case is either a mean of the readings taken, or the midpoint of the range.

Table 6. Breakdown of Electricity Use by Component - Averages

Building Type	Country	No.of Bldgs.	Consumption by Component (%) A/C	Fans	Ltg.	Misc.
Offices	Indonesia	1	36.6	43.5	11.8	8.1
	Malaysia	5	60.1	8.7	23.1	8.1
	Philippines	24	45.0	16.2	22.5	15.6
	Singapore	4	36.6	13.2	24.2	26.0
	ASEAN *	34	46.0	15.6	22.5	15.5
	DOE-2 Simulation **		40.0	18.0	23.0	18.0
Hotels	Indonesia	4	30.4	27.2	18.5	23.9
	Malaysia	3	47.3	13.8	22.8	16.1
	Philippines	8	45.7	18.2	16.2	18.2
	Singapore	2	48.6	6.8	38.6	6.0
	ASEAN *	17	42.7	18.2	20.6	17.7
Hospitals	Malaysia	1	49.7	28.2	14.7	7.4
	Philippines	8	47.1	9.0	6.6	34.5
	ASEAN *	9	47.4	11.1	7.5	31.5
Stores	Malaysia/ASEAN *	1	26.9	13.2	46.5	13.4
Schools	Singapore/ASEAN *	1	50.0	21.0	22.0	7.0
Supermarkets	Philippines/ASEAN *	4	49.9	9.0	6.6	34.5

* ASEAN averages are weighted by the number of buildings audited per country.

** Levine *et al.* (ASEAN/USAID 1989) simulated an imaginary office building with DOE-2, using average characteristics of buildings in the Manila area as inputs.

Table 7. Breakdown of Peak Cooling Loads - The Philippines

Building Type and Name	Total Load Per Area (Btuh/m^2)	Components (%)										Total (Btu/hr)
		Glass Solar	Glass Conduc.	Wall Conduc.	Roof Conduc.	Opaque Solar	People	Lights	Equip.	Infilt.	Misc. Load	
Offices:												
B A Lepanto	201	21.0%	14.8%	12.1%	0.0%	6.1%	15.4%	16.8%	4.2%	7.0%	2.6%	4,287,491
Cmptr. Info. Sys.	200	20.9%	8.5%	6.1%	4.8%	9.5%	20.2%	10.7%	11.6%	5.7%	2.0%	948,127
King's Court	324	44.2%	23.4%	0.0%	0.6%	7.7%	8.8%	7.5%	5.0%	1.9%	1.0%	3,085,410
PTC, Inc	231	31.4%	8.6%	6.4%	0.6%	6.6%	16.2%	13.7%	11.1%	2.7%	2.7%	293,899
Insular Life	200	28.8%	7.9%	2.9%	0.6%	6.2%	20.1%	24.1%	2.7%	4.4%	2.4%	4,064,522
Eastern Tele.	231	12.2%	7.0%	9.3%	1.1%	10.9%	11.9%	14.8%	23.1%	5.9%	3.8%	2,733,527
Petrophil	296	22.5%	7.5%	9.2%	1.6%	8.3%	14.3%	23.4%	4.8%	6.3%	2.2%	3,277,672
Citibank Ctr.	282	14.9%	4.4%	14.7%	0.0%	8.0%	22.0%	13.8%	15.2%	3.5%	3.5%	5,078,250
Metrobank	252	24.0%	13.6%	9.5%	1.3%	8.5%	12.4%	9.8%	13.7%	5.6%	1.7%	4,655,995
China Bank	455	37.8%	21.9%	0.0%	0.0%	6.0%	11.8%	9.6%	6.3%	3.3%	3.3%	5,847,389
Far East Bank	207	26.7%	10.3%	11.6%	1.1%	5.7%	14.8%	17.2%	2.9%	6.6%	2.9%	1,108,472
Nat. Life Ins.	337	23.4%	11.3%	15.1%	1.0%	10.8%	11.6%	15.9%	5.9%	3.3%	1.6%	3,127,325
PDIC	346	20.7%	9.4%	10.0%	6.2%	14.0%	12.0%	4.8%	8.6%	6.6%	7.6%	514,987
Phil. Coco. Auth.	271	37.5%	19.4%	1.1%	2.3%	9.3%	6.0%	15.0%	5.6%	3.7%	0.2%	1,986,402
Metro W&S Sys.	238	13.5%	9.4%	2.7%	6.3%	7.5%	22.3%	23.1%	10.0%	4.3%	0.9%	5,107,153
Centr Bank	195	7.6%	4.7%	6.9%	5.9%	11.6%	21.0%	26.5%	6.0%	6.3%	3.3%	21,445,662
S S Sys	478	9.8%	7.6%	6.7%	2.5%	9.5%	30.5%	22.0%	6.1%	3.6%	1.6%	6,445,386
Dept T&I	181	11.9%	9.8%	6.7%	6.6%	10.5%	20.7%	16.7%	3.3%	7.6%	6.3%	1,489,697
Bur. of Int. Rev	345	27.5%	17.1%	3.5%	1.2%	8.5%	14.1%	15.3%	5.1%	3.5%	4.2%	6,401,332
Nat. Power.Corp	200	14.5%	6.4%	5.5%	2.3%	8.0%	18.9%	23.1%	8.3%	4.9%	8.1%	1,217,618
Dev. Bank of P	245	17.2%	13.1%	0.4%	1.5%	1.9%	21.8%	18.3%	17.3%	5.7%	2.8%	3,794,789
Tech. Res. Ctr.	250	20.8%	10.8%	5.4%	4.4%	6.9%	7.8%	24.5%	9.5%	3.9%	6.0%	915,334
Nestle Phil.	193	15.7%	7.6%	2.5%	4.1%	9.0%	14.4%	27.8%	9.4%	4.2%	5.1%	1,073,159
Bliss Bldg.	235	18.5%	5.2%	2.3%	3.7%	3.2%	22.2%	19.1%	10.6%	6.7%	8.5%	1,233,636
Hotels:												
Hilton Makati	230	16.8%	6.4%	9.1%	1.3%	9.8%	12.2%	31.2%	5.8%	5.4%	2.2%	5,632,994
Hyatt Manila	181	15.2%	9.3%	8.3%	2.1%	6.9%	10.1%	21.0%	5.0%	4.5%	17.6%	2,971,279
Intercontinental	317	23.7%	11.6%	4.2%	1.7%	6.6%	27.5%	12.8%	6.4%	2.1%	3.4%	4,530,351
Holiday Inn	228	28.0%	18.7%	11.9%	0.5%	6.5%	9.0%	9.9%	5.7%	3.7%	6.1%	4,689,345
Manila Pen	168	23.9%	14.1%	6.0%	3.1%	7.2%	12.8%	13.3%	6.9%	5.8%	7.1%	7,312,060
Phil. Plz. Man	269	28.9%	14.8%	2.8%	3.4%	8.7%	11.0%	19.8%	4.9%	4.7%	1.0%	12,975,950

Table 7. Breakdown of Peak Cooling Loads - The Philippines - Con't.

Building Type and Name	Total Load Per Area ($Btuh/m^2$)	Components (%)										Total (Btu/hr)
		Glass Solar	Glass Conduc.	Wall Conduc.	Roof Conduc.	Opaque Solar	People	Lights	Equip.	Infilt.	Misc. Load	
Mandarin Mak	253	14.8%	8.8%	19.4%	1.6%	7.1%	20.4%	14.7%	7.3%	4.2%	1.8%	7,319,770
Silahi Manila	173	17.0%	10.4%	8.7%	0.7%	5.6%	12.8%	27.7%	6.8%	5.7%	4.6%	5,284,266
Hospitals:												
Makati Med. Ctr	185	17.2%	14.6%	7.0%	1.3%	5.5%	21.7%	17.3%	6.1%	5.9%	3.4%	5,611,755
Lung Center	240	17.1%	13.4%	4.6%	5.4%	9.7%	11.5%	20.4%	7.2%	6.4%	4.4%	5,015,089
FEU Hospital	306	10.5%	6.7%	12.5%	3.4%	16.4%	17.2%	14.5%	3.6%	9.0%	6.2%	846,806
UST Hospital	235	14.5%	7.0%	10.2%	3.4%	6.5%	12.6%	19.3%	7.6%	14.6%	4.3%	4,092,419
St Luke's	310	21.9%	9.7%	8.5%	4.0%	7.9%	10.2%	6.5%	5.2%	15.7%	10.4%	2,021,817
Manila Doctors	259	14.9%	7.2%	12.2%	3.9%	5.3%	15.0%	20.7%	9.7%	6.0%	5.2%	2,255,707
Capitol Med.	294	25.2%	9.3%	10.0%	1.3%	7.2%	11.5%	14.0%	3.9%	12.7%	5.0%	1,210,476
Card. Santos	310	26.0%	14.4%	9.7%	3.2%	7.2%	10.2%	7.1%	13.7%	5.3%	3.1%	2,130,073
Supermarkets:												
Thriftway	263	3.6%	1.0%	5.0%	14.5%	42.6%	19.6%	4.5%	3.2%	4.9%	1.0%	747,610
Glori Del Mt.	349	1.5%	0.7%	3.5%	16.2%	23.5%	35.2%	4.2%	2.2%	11.3%	1.6%	623,367
Glori Roces	277	4.9%	1.8%	6.6%	13.0%	11.4%	29.6%	1.5%	1.7%	21.6%	7.8%	621,622
Glori's Tnd. So	418	5.4%	1.7%	5.5%	17.5%	30.7%	18.4%	4.5%	2.0%	11.9%	2.4%	523,451
Office Average	250	18.9%	10.3%	6.3%	2.8%	8.6%	18.0%	19.1%	7.9%	5.0%	2.9%	3,605,329
Hotel Average	223	22.2%	12.2%	8.3%	2.1%	7.6%	14.2%	18.7%	6.0%	4.6%	4.1%	6,339,502
Hospital Average	237	17.9%	11.3%	8.3%	3.3%	7.4%	14.5%	16.5%	7.3%	8.8%	4.7%	2,898,018
Supermarket Average	310	3.8%	1.3%	5.1%	15.2%	27.7%	25.7%	3.7%	2.3%	12.1%	3.1%	629,013

Table 8. Summary of ECOs

Building Type & Country	Building Name (Annual kWh)	Description of ECO	Indiv. ECO Savings (% of elec.)	Total Savings per Building * (% of elec.)
Offices:				
I	Wisma Sier Bldg.	Eliminate 1-flight elevator trips	0.2	8.8
	(910,000)	Replace incandescent lamps with fluorescent	2.2	
		Replace over-sized cooling tower pumps	7.4	
M	JKR Elec. Blk.	Install A/C controls	(10% of A/C)	
		Install efficient fluor. lamps and ballasts	(28% of ltg)	
M	Public Wks. Dept.	Seal and weatherstrip all windows and doors	0.2	1.4
	(258,000)	Install efficient lamps and ballasts	1.4	
P	Nat. Power Corp.	Install VAV controls	20.2	34.0 **
	(4,799,000)	Install efficient water-cooled chillers	14.6	
		Minimize fresh air intake, to 3.5 l/s/person	14.0	
		Increase thermostat setpoint: 22 C to 25.6 C	7.0	
		Replace inefficient chilled water pumps	1.1	
		Install cabinets on walls for insulation	0.2	
P	—	Switch off half the A/C compressors at lunch	4.8	4.8
		Raise setpoint to 25.5C		
P	—	Reduce lighting schedule by 1-1/2 hours	2.7	12.1
		Reset thermostat to 25.5C	6.2	
		Reduce A/C compressor run time by 30 minutes	4.5	
P	—	Delamp entire building	4.5	6.0
		Install thermostatic compressor controls and reset setpoint to 25.5C	1.7	
		Reduce A/C system time by 30 minutes	0.5	
P	—	Delamping	5.3	10.6
		Raise setpoint to 25.5C	6.5	
P	—	Delamp entire building	20.6	35.6
		Improve system power factor	7.4	
		Raise setpoint to 25.5C	6.0	
		Reduce minimum outside air	5.6	
P	—	Delamp	9.4	22.0
		Improve system power factor	4.9	
		Raise setpoint to 25.5C	6.1	
		Partially reduce chiller hours	4.0	
P	—	Reduce lighting hours by 90 minutes	4.2	5.9
		Raise setpoint to 25.5C	0.8	
		Reduce chiller operating time by 30 minutes	1.5	
P	—	Delamp and install efficient reflectors	14.2	23.2
		Turn off some lights at lunch time	1.4	
		Improve system power factor	1.9	
		Raise setpoint to 25.5C	1.5	
		Reduce A/C equipment run time	6.8	
P	—	Improve system power factor	6.8	10.9
		Raise setpoint to 25.5C	3.1	
		Install package A/C for evening part load	1.0	
		Turn off A/C at lunch time	1.2	
P	—	Delamp and install efficient reflectors	(50% of ltg)	3.6

Table 8. Summary of ECOs - Con't.

Building Type & Country	Building Name (Annual kWh)	Description of ECO	Indiv. ECO Savings (% of elec.)	Total Savings per Building * (% of elec.)
		Raise setpoint to 25.5C	2.4	
		Reduce run time of A/C system	1.6	
P	—	Delamping	5.2	12.4
		Raise setpoint to 25.5C	4.3	
		Reduce A/C equipment run time by 30 minutes	2.9	
		Isolate off-line cooling tower	1.4	
		Raise chiller setpoint one degree	(3% of chlr)	
P	—	Delamping	4.7	8.8
		Raise setpoint to 25.5C	2.0	
		Switch off chiller and aux. 30 minutes early	1.2	
		Reduce ventilation air	0.5	
		Use smaller chiller during lunchtime	1.4	
P	—	Modify air flow to air-cooled condensers	2.8	9.2
		Switch off chiller 30 minutes early daily	2.2	
		Install VAV controls	5.2	
P	—	Install power factor correcting capacitors	4.3	14.4
		Raise setpoint to 25.5C	5.1	
		Reduce A/C equipment run time	3.6	
		Relocate some offices to lower cooling load	3.0	
P	—	Delamping	5.4	5.8
		Raise setpoint to 25.5C	1.0	
		Raise chilled water setpoint one degree	(6% of chlr)	
S	Albert Complex (5,412,000)	Reduce plant operation by one hour	"marginal"	1.6
		Reduce infiltration from 0.25 ACH to 0.1	"marginal"	
		Reduce ventilation rate from 11% to 8%	1.6	
S	URA Building (1,573,000)	Reduce ventilation rate to 8%	1.3	1.3
S	Sanford Bldg. (2,238,000)	Replace single-glazing with double	2.1	8.3
		Reduce plant operation by one hour	5.1	
		Reduce lighting intensity by 10%	2.1	
		Reduce ventilation rate from 7% to 5%	1.3	
S	Jurong Town Hl. (2,037,000)	Reduce lighting wattage by 5%	1.2	2.7
		Delay plant starting by 15 minutes	1.8	
T	Siam Motor Bldg.	Daylighting	(50% of ltg)	
T	Thai Farmers Bk (15,518,000)	Install inlet vane VAV controls	30.5	51.0 ** ##
		Install heat exchanger for incoming air	20.0	
		Minimize fresh air intake	10.6	
		Lower w/w ratio from 0.95 to 0.35	23.3	
Hotels:				
I	Elmi Hotel (2,955,000)	Reduce lamp wattage by 8,730	1.1	10.4
		Reduce infiltration: 2 ACH to 1.5, and 1 to.6	0.3	
		Reduce oper'g hours: 16 to 10	0.7	
		Increase COP: 3.5 to 4.5	9.5	
I	Hyatt Hotel (6,775,000)	Raise thermostat setpoint: 72 F to 77	0.4	0.5
		Reduce operating hours: 12 to 10	0.1	

Table 8. Summary of ECOs - Con't.

Building Type & Country	Building Name (Annual kWh)	Description of ECO	Indiv. ECO Savings (% of elec.)	Total Savings per Building * (% of elec.)
I	Simpang Hotel	Raise thermostat setpoint: 72 F to 77	1.8	6.4
	(1,763,000)	Increase COP: 2.5 to 4.0	5.3	
I	Garden Hotel (870,000)	Daylighting	2.9	2.6
M	Pan Pacific	Replace corridor incandescents with 13W SLs	0.6	15.5
	(13,984,000)	Increase chilled water leaving temperature	0.5	
		Install VAV controls	16.1	
M	Holiday Inn KL	Replace incandescents with fluorescent lamps	9	21.6
	(4,700,000)	Raise setpoint	3	
		Chiller optimiser controls	12	
P	—	Turn off chiller eqpt. for 2 hrs. at night	2.8	2.8
		Raise chilled water set point one degree	(6% of chlr)	
P	Intercon. Manil.	Use only one transformer, reduce losses	0.6	12.0 ##
	(6,989,236)	Install high-efficiency chillers	7.8	
		Install VAV system	3.3	
		Variable speed chilled water pumping	1.6	
		Cogen (scenario B):centrf.chiller,550kW gen.	(40% of engy$)	
T	Central Plaza	Install inlet vane VAV controls	10.8	21.2
	(10,686,000)	Install heat exchanger for incoming air	12.9	##
Hospitals:				
M	Gen.Hos.Ch.Wrd.	Seal and weatherstrip all windows and doors	0.2	2.6
	(807,000)	Replace water-cooled A/C with window unit	1.6	
		Install VAV controls	1.1	
P	—	Delamping	(50% of ltg.)	
P	Makati Med.Ctr.	Cogen (scenario C):abs.chlr.,500kW generatr.	(48% of engy$)	##
	(8,102,000)	Cogen (scenario D):abs.chlr.,720kW generatr.	(62% of engy$)	
Shopping Ctrs:				
T	Charn Issara	Install inlet vane VAV controls	1.9	7.9 ##
	(4,543,000)	Install heat exchanger for incoming air	3.0	
		Combination of VAV and heat exchanger ECOs	3.9	
Supermarkets:				
P	—	Disconnect unused lighting ballasts	3.0	11.8
		Replace over-sized motors	0.2	
		Improve insulation, infil., roof reflectance	2.7	
		Keep fans, filters, and cooling coils clean	7.2	

* When a building has multiple ECOs, the total savings is usually less than the sum of the savings from the individual measures, because of the measures' overlapping effects. Except where noted otherwise by **, the savings total for buildings with multiple ECOs is 10% lower than the sum of the individual measures.

** The building savings total was derived by modeling simultaneously the separate measures.

— For purposes of confidentiality, the building is left anonymous.

\# A/C ECO payback: 2.8 years; lighting ECO payback: 3.3 years.

\## See also separate financial analysis of these ECOs.

Table 9. Summary of Savings by ECO Type

ECO Type	No. of Cases	Average Savings Per ECO (% of Bldg. Elec.)
Electrical System:		
Raise power factor	5	5.1%
Lower excess transformer capacity	1	3.3%
Air Conditioning System:		
Install VAV controls	8	12.6%
InstaLL heat-exchanger for incoming air	3	12.0%
Install high-efficiency chillers	4	9.6%
Maintain clean AHU filters, cooling coils	1	7.2%
Minimize outdoor air intake	7	6.0%
Optimize multiple chiller operation	3	4.9%
Raise A/C condenser temperature	1	4.1%
Replace over-sized electric motors	2	3.8%
Raise setpoint to 25.5C	17	3.6%
Relocate offices to lower cooling load	1	3.0%
Modify airflow to condensers	1	2.8%
Reduce A/C equipment run time	17	2.3%
Install variable speed pumps	1	1.6%
Install small A/C for separate spaces	2	1.3%
Install high-efficiency pumps	2	1.3%
Lighting:		
Lower lighting wattage	17	5.1%
Reduce lighting hours	3	2.8%
Envelope modifications:		
Lower window-wall ratio	1	12.7%
Install double-glazed windows	1	2.1%
Insulation, infiltration, roof absorption	5	0.8%
Elevators:		
Eliminate 1-floor elevator trips	1	0.2%

Table 10. Air Conditioning ECO Financial Analysis - Thailand Audits

Scenario	Avoided Elec.Cost (Baht/yr)	Savings (% of total elec.)	Savings (% of A/C elec.)	Operat'g Cost (Baht/yr)	Net Savings (Baht/yr)	Invest. Cost (Baht)	Simple Payback (yr)
Vibhavadee Hospital: A/C electric - 404,900 kWh							
D	81,168		13.2	26,190	54,978	420,000	7.64
I	130,720		21.2	26,190	104,530	1,110,000	10.62
X	203,605		33.1	41,000	162,605	606,000	3.73
DX	232,865		37.8	67,190	165,675	1,026,000	6.19
IX	258,419		42.0	67,190	191,229	1,716,000	8.97
Hyatt Central Plaza Hotel: A/C - 6,747,000 kWh, total- 10,686,000 kWh							
D	1,012,650	4.2	6.7	33,600	979,050	918	0.00
I	2,607,977	10.8	17.2	33,600	2,574,377	2,604,000	1.01
X	3,105,956	12.9	20.5	400,000	2,705,956	2,800,000	1.03
DX	3,923,620	16.3	25.9	433,600	3,490,020	3,718,000	1.07
IX	5,087,724	21.2	33.5	433,600	4,654,124	5,404,000	1.16
Mahidol University Salaya Campus Library: A/C electric - 881,100 kWh							
D	313,028		23.4	14,400	298,628	522,000	1.75
I	450,607		33.6	14,400	436,207	1,116,000	2.56
X	429,370		32.1	150,000	279,370	1,436,000	5.14
DX	594,048		44.4	164,400	429,648	1,958,000	4.56
IX	693,147		51.8	164,400	528,747	2,552,000	4.83
Thai Farmers Bank Building: total electric - 15,518,000 kWh							
D	3,106,728	19.1		86,400	3,020,328	3,132,000	1.04
I	4,950,336	30.5		86,400	4,863,936	6,696,000	1.38
A	1,727,632	10.6		0	1,727,632	180,000	0.10
AD	4,485,824	27.6		86,400	4,399,424	3,312,000	0.75
AI	5,993,360	36.9		86,400	5,906,960	6,876,000	1.16
B	2,654,224	16.3		0	2,654,224	1,876,101	0.71
BD	5,174,688	31.9		86,400	5,088,288	5,008,101	0.98
BI	6,536,912	40.2		86,400	6,450,512	8,572,101	1.33
C	3,780,696	23.3		0	3,780,696	3,572,202	0.94
CD	6,023,456	37.1		86,400	5,937,056	6,704,202	1.13
CI	7,211,944	44.4		86,400	7,125,544	10,268,202	1.44
X	3,243,823	20.0		803,000	2,440,823	4,880,000	2.00
DX	5,180,858	31.9		889,400	4,291,458	8,012,000	1.87
IX	6,485,054	39.9		889,400	5,595,654	11,576,000	2.07
AX	4,415,661	27.2		803,000	3,612,661	506,000	0.14
ADX	6,019,857	37.1		889,400	5,130,457	8,192,000	1.60
AIX	7,074,995	43.6		889,400	6,185,595	11,756,000	1.90
BX	5,204,907	32.0		803,000	4,401,907	6,756,101	1.53
BDX	6,671,339	41.1		889,400	5,781,939	9,888,101	1.71
BIX	7,619,392	46.9		889,400	6,729,992	13,452,101	2.00
CX	6,164,351	38.0		803,000	5,361,351	8,452,202	1.58
CDX	7,468,243	46.0		889,400	6,578,843	11,584,202	1.76
CIX	8,288,694	51.0		889,400	7,399,294	15,148,202	2.05
Charn Issara Shopping Arcade: total electric - 4,543,000 kWh							
D	182,484	1.1		25,000	157,484	240,000	1.52
I	312,676	1.9		25,000	287,676	388,000	1.35
X	481,288	3.0		75,000	406,288	718,000	1.77
DX	553,814	3.4		100,000	453,814	958,000	2.11
IX	627,097	3.9		100,000	527,097	1,106,000	2.10

ECO Code:

Base case (fixed supply cfm, evap T = 45 F, no heat exchanger)

D = Discharge damper - VAV.
I = Inlet vane guide - VAV.
X = Heat exchanger.

A = Reduced max supply cfm - 712,870. W/w left at 0.95.
B = Reduced max supply cfm - 638,230. W/w lowered to 0.65.
C = Reduced max supply cfm - 548,050. W/w lowered to 0.35.

Table 11. Cogeneration Scenarios - Specifications and Financial Analysis

Makati Medical Center
Intercontinental Hotel Manila

Scenario	Rel.to Grid	Chiller Type	Gen.Size Criterion	Gener. Size (kWe)	Gener. Loading	Abs.Chlr. size (tons)	Elec. Sell-back (kWh)
Mak A	Off	Absorp.	Totl.elec.	1260	Elec.demand	693	N.A.
Mak B	On	Centrif.	Max.therm.	620	Full	N.A.	O
Mak C	On	Absorp.	Min.A/C	500	Full	275	O
Mak D	On	Absorp.	Max.A/C	720	Full	396	656,700
Mak E	On	Centrif.	Min.elec.	750	Full	N.A.	O
Mak F	On	Absorp.	Max.elec.	720	Heat demand	396	O
Int A	On	Absorp.	Min.elec.	350	Full	190	O
Int B	On	Centrif.	Min.elec.	550	Full	N.A.	O

Financial Analysis

Annual Energy Use:

Makati:	Electricity:	P	16,204,000	(8,102,000 kWh)
	Fuel Oil:	P	806,000	(285,768 liters)
	Total:	P	17,010,000	
Intercontinental:	Electricity:	P	13,978,472	(6,989,236 kWh)
	Fuel Oil:	P	1,419,371	(503,323 liters)
	Total:	P	15,397,843	

Cogen Scenario	Expense Avoided (P1000)	Oper'g Costs (P1000)	Net Cost Savings (P1000)	Net Cost Savings (%)	Invest. Cost * (P1000)	Simple Payback (yr)	Comments
Mak A	16,204	7,848	8,356	49.12	30,429	3.64	Excessive waste heat
Mak B	11,474	5,488	5,986	35.19	14,973	2.50	
Mak C	12,697	4,453	8,244	48.47	12,680	1.54	
Mak D	16,861	6,336	10,525	61.88	16,603	1.58	
Mak E	13,706	6,596	7,110	41.80	17,205	2.42	
Mak F	15,730	6,568	9,162	53.86	16,603	1.81	
Int A	9,427	4,993	4,434	28.80	12,075	2.72	
Int B	13,694	7,551	6,143	39.90	16,208	2.64	

* The cost of chillers is not included in the investment cost.

Table 12. Daylighting Simulation - Philippines

Annual Electricity Use

Case 1: As-Is - Both Natural and Artificial Light (kWh)

	Space Clg.	HVAC Aux.	Lights	Misc.	Total
Nat.Steel Corp.	515,630	146,467	144,950	283,492	1,090,539
Phil.Nat.Oil Co.	1,176,963	495,099	435,661	1,007,629	3,115,352
China Bank	1,052,250	383,780	237,918	932,487	2,606,435
Cmptr.Info.Sys.	390,715	180,757	76,900	75,690	724,062
Average	783,890	301,526	223,857	574,825	1,884,097

Case 2: All Artificial Light (% change from Case 1)

	Space Clg.	HVAC Aux.	Lights	Misc.	Total
Nat.Steel Corp.	-0.6%	-6.1%	71.6%	0.0%	8.4%
Phil.Nat.Oil co.	-1.4%	-7.2%	56.8%	0.0%	6.3%
China Bank	0.0%	-3.0%	142.5%	0.0%	12.6%
Cmptr.Info.Sys.	-0.3%	-0.6%	15.7%	0.0%	1.4%
Average	-0.7%	-4.7%	78.4%	0.0%	8.3%

APPENDIX A

ASEAN BUILDING ENERGY DATABASE

ASEAN BUILDING ENERGY DATABASE

Prepared by:

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Building Name	City	Cntry	Bldg Type	Year Built	Analyst	Audit Type	Date	Entered By	Gross Area (sqm)	Cond. Area (sqm)	No. of Floors	No. of Rooms or Beds	Wall Type
Industrial Dept.	Jakarta	I	Off	81	Ditaba	S	5/17/89	Busch	39,655	32,816	20		X
Religion Dept.	Jakarta	I	Off	85	Ditaba	S	5/17/89	Busch	28,250	21,131	8		X
Public Works	Jakarta	I	Off	84	Ditaba	S	5/18/89	Busch	14,678	14,678	8		X
Wisma Sier	Surabaya	I	Off		Prasetio	EAS	5/18/89	Busch	8,835	6,072	6		M
Maybank Tower	KL	M	Off		Kannan	SE	5/19/89	Halim	176,800	86,820	44		
Daya Bumi Complex	KL	M	Off		Kannan	SE	5/19/89	Halim	167,000	108,800	35		
Promet Tower	KL	M	Off		Kannan	SE	5/19/89	Halim	39,100	31,000	34		
Negara Bank	KL	M	Off	85	Akram	S	5/29/89	Deringer	21,888	20,073	19		M
General Post Office	KL	M	Off	80	Kannan	AE	5/18/89	Halim	37,230	26,280	8		M
Tun Razak Tower	KL	M	Off	82	Kannan	E	5/19/89	Halim	61,200	32,000	34		
MAS Building	KL	M	Off		Kannan	SE	5/19/89	Halim	31,500	29,600	35		
Kuwasa Tower	KL	M	Off		Kannan	SE	5/19/89	Halim	52,200	42,700	25		
Min.of Information	KL	M	Off	67	Dangroup	S	7/17/89	Deringer	26,300	25,900	10		
Bumiputra Bank	KL	M	Off	80	Dangroup	S	7/17/89	Deringer	36,800	23,000	34		M
City Hall	KL	M	Off	83	Masjuki	S	5/29/89	Deringer	38,955	28,990	29		
Bagunan Bukota	KL	M	Off	83	Masjuki	S	5/29/89	Deringer	26,658	24,008	24		
Pertamian Bank	KL	M	Off	77	Dangroup	S	7/17/89	Deringer	30,000	20,700	27		
Wisma Sime Darb	KL	M	Off	84	Masjuki	S	5/29/89	Deringer	56,500	45,500	20		
Luth Building	KL	M	Off		Kannan	SE	8/19/89	Halim	33,000	28,500	39		
Plaza MBF	KL	M	Off	84	Masjuki	S	5/29/89	Deringer	29,823	23,781	25		
LLN, Bldg.NLDC	KL	M	Off	77	Dangroup	S	7/17/89	Deringer	16,500	13,600	6		
Empl.Prov.Fund	KL	M	Off	70	Masjuki	S	5/29/89	Deringer	6,496	6,130	5		M
Chung Khiaw Bank	KL	M	Off		Kannan	SE	8/19/89	Halim	15,000	10,400	16		
Min.of Finance, Blk.9	KL	M	Off	77	Dangroup	S	7/17/89	Deringer	18,600	17,500	17		
PNB Tower	KL	M	Off		Kannan	SE	8/19/89	Halim	52,450	47,200	43		
Math Faculty	KL	M	Off	76	Akram	S	5/29/89	Deringer	4,133	2,169	4		M
Geology Faculty	KL	M	Off	76	Akram	S	5/29/89	Deringer	11,120	8,400	5		M
Petronas Bldg.	KL	M	Off	74	Dangroup	S	7/17/89	Deringer	2,700	2,600	9		
Drainage & Irrigation	KL	M	Off		Kannan	E	4/18/90	Loewen	8,281	4,881	4		M
Public Works Dept.	KL	M	Off	72	Kannan	AE	8/18/89	Halim	2,715	1,521	4		M
Agriculture Bank	KL	M	Off		Kannan	S	8/19/89	Halim	28,200	25,500	24		
Central Bank	Manila	P	Off		P6	SE	12/1/87	Santos	129,778	109,791			M
Social Security Sys.	Quezon City	P	Off		P6	ASE		Marasigan	30,753	13,492	12		M
B A Lepanto	Makati	P	Off		P6	SE	9/3/87	Santos	31,076	21,315	20		M
Citibank	Makati	P	Off		P6	ASE	2/14/89	Santos	23,963	17,999	18		M
Eastern Telecoms.	Makati	P	Off		P6	ASE		Santos	19,784	11,842	13		M
Metrobank	Makati	P	Off		P6	ASE	2/17/88	Santos	23,068	18,463	20		M
National Power Corp.	Quezon City	P	Off		P6	ADE	2/16/88	Santos	18,290	15,881	3		M
Dev't Bank of Phil.	Makati	P	Off		P6	SE	1/25/88	Santos	24,328	15,506	12		M
Metro W & S System	Quezon City	P	Off		P6	ASE	11/21/88	Marasigan	25,257	21,474	6		M
Insular Life	Makati	P	Off		P6	ASE	10/21/88	Santos	25,721	20,323	14		M
Bur.of Internal Rev.	Quezon City	P	Off		P6	SE	1/11/88	Santos	30,494	18,572	12		M
Petrophil Corp.	Makati	P	Off		P6	ASE	11/4/88	Santos	14,451	11,057	12		M
China Bank	Makati	P	Off	69	P6	ASED	11/23/88	Loewen	13,273	10,597	15		C
National Life Ins.	Makati	P	Off		P6	ASE	1/10/89	Santos	13,142	9,269	12		M
King's Court	Makati	P	Off		P6	SE	9/14/87	Santos	11,663	9,516	3		M
National Steel Corp	Makati	P	Off	74	P6	ASE	10/4/88	Loewen	9,040	6,426	7		M
Phinma	Makati	P	Off		P6	ADE	8/31/88	Santos	4,053	2,683	8		M
BLISS Building	Makati	P	Off		P6	SE	7/29/88	Santos	7,150	5,251	5		M
Nestle Philippines	Makati	P	Off		P6	SE	7/26/88	Santos	7,625	5,555	5		M
Tech.Research Ctr.	Makati	P	Off		P6	ASE	12/9/88	Santos	4,256	3,668	5		M
Dept.of Trade & Ind.	Makati	P	Off		P6	ASE	11/9/88	Santos	9,322	8,220	5		M
Phil.Coconut Authorit	Quezon City	P	Off		P6	ASE	3/15/89	Marasigan	9,441	7,332	8		M
Computer Info Syste	Pasig	P	Off	84	P6	ASE	3/9/89	Loewen	7,506	4,739	3		M
Far East Bank	Manila	P	Off		P6	SE	11/3/87	Santos	6,771	5,348	8		M

Building Name	City	Cntry	Bldg Type	Year Built	Analyst	Audit Type	Date	Entered By	Gross Area (sqm)	Cond. Area (sqm)	No. of Floors	No. of Rooms or Beds	Wall Type
Phil.Deposit Ins. Corp	Makati	P	Off	74	P6	ASE	10/28/88	Marasigan	1,737	1,488	4		M
Phil.Transm.Carriers	Makati	P	Off		P6	ASE		Santos	2,084	1,274	5		M
COM CENTRE	Singapore	S	Off	78	Wong	S	8/16/89	Tan	57,878	37,816	33		M
SDB18	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	77,037	50,907			
SDB26	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	75,021	61,291			
SDB29	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	114,151	69,784			
SDB74	Singapore	S	Off	1974	Gan, Hui	S	5/7/90	Loewen	29,671	25,336	30		
PUB Bldg.	Singapore	S	Off	77	Wong	S	8/16/89	Tan	77,218	41,575	17		M
CPF Building	Singapore	S	Off	76	Wong	S	8/16/89	Tan	50,329	31,770	46		M
UOB Building	Singapore	S	Off	74	Wong	S	8/16/89	Tan	24,418	15,316	30		M
SDB50	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	39,086	24,031			
SDB59	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	45,095	41,018			
SDB27	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	38,622	28,526			
Albert Complex	Singapore	S	Off	83	Wong	A	8/16/89	Tan	36,079	26,647	19		C
SDB36	Singapore	S	Off	1979	Gan, Hui	S	5/7/90	Loewen	21,124	12,302	21		
SDB71	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	53,483	34,153			
SDB32	Singapore	S	Off	1974	Gan, Hui	S	5/7/90	Loewen	24,278	12,618	12		
SDB24	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	31,929	19,144			
SDB31	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	12,297	10,615			
Sim Lim Tower	Singapore	S	Off	80	Wong	S	8/16/89	Tan	22,049	12,448	17		M
Inchape House	Singapore	S	Off	74	Wong	S	8/16/89	Tan	20,319	9,598	12		C
Straits Trading	Singapore	S	Off	72	Wong	S	8/16/89	Tan	17,342	14,709	21		M
SDB69	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	24,150	17,297			
SDB47	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	12,483	11,566			
SDB33	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	50,252	32,196			
SDB42	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	19,272	14,153			
MArine House	Singapore	S	Off	78	Wong	S	8/16/89	Tan	18,631	12,506	21		M
Sanford Building	Singapore	S	Off	83	Wong	A	8/16/89	Tan	22,225	11,355	16		M
SDB68	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	14,284	12,932			
SDB79	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	10,183	6,666			
SDB70	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	8,608	6,975			
SDB62	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	65,525	39,684			
JTC Bldg	Singapore	S	Off	75	Wong	A	8/16/89	Tan	22,296	16,722	5		M
SDB49	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	15,578	9,609			
UOL Building	Singapore	S	Off	75	Wong	S	8/16/89	Tan	14,747	6,313	16		C
Bank of Bangkok	Singapore	S	Off	78	Wong	S	8/16/89	Tan	16,404	8,491	17		M
SDB39	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	9,667	7,116			
SDB66	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	14,847	9,182			
URA Building	Singapore	S	Off	77	Wong	A	8/16/89	Tan	21,906	13,601	9		M
Moscow Narodyn	Singapore	S	Off	75	Wong	S	8/16/89	Tan	7,533	5,622	16		M
Central Building	Singapore	S	Off	81	Wong	S	8/16/89	Tan	10,495	7,964	5		C
SDB76	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	11,854	6,537			
SDB61	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	27,279	17,850			
Denmark House	Singapore	S	Off	58	Wong	S	8/16/89	Tan	5,948	4,442	9		M
ACB Building	Singapore	S	Off	80	Wong	S	8/16/89	Tan	11,529	5,667	15		M
SDB2	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	7,661	5,166	12		
SDB19	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	6,383	3,818			
SDB21	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	9,804	5,659			
Bank of China	Singapore	S	Off	53	Wong	S	8/16/89	Tan	8,779	5,759	17		M
SDB28	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	5,911	4,505			
Asia Chambers	Singapore	S	Off	82	Wong	S	8/16/89	Tan	10,847	7,676	18		M
SAN CENTRE	Singapore	S	Off	73	Wong	S	8/16/89	Tan	11,706	9,187	12		M
Liat Towers	Singapore	S	Off	79	Wong	S	8/16/89	Tan	5,896	2,402	21		M
SDB25	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	5,815	4,193			
SDB12	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	40,913	17,530	7		

Building Name	City	Cntry	Bldg Type	Year Built	Analyst	Audit Type	Date	Entered By	Gross Area (sqm)	Cond. Area (sqm)	No. of Floors	No. of Rooms or Beds	Wall Type
Bank of East Asia	Singapore	S	Off	75	Wong	S	8/16/89	Tan	3,914	2,848	14		C
Reality Center	Singapore	S	Off	71	Wong	S	8/16/89	Tan	4,872	4,024	12		M
SDB9	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	3,195	2,163	8		
SDB6	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	3,265	2,617	6		
SDB77	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	7,241	4,154			
SDB30	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	13,808	9,353			
SDB23	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	2,162	1,470			
SDB81	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	3,730	3,317			
SDB43	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	3,963	1,614			
Sin Chew Jit Po	Singapore	S	Off	75	Wong	S	8/16/89	Tan	11,634	6,949	11		M
Commercial Union	Singapore	S	Off	76	Wong	S	8/16/89	Tan	4,036	3,101	12		M
SDB20	Singapore	S	Off		Gan, Hui	S	5/7/90	Loewen	3,301	2,277			
Ocean Building	Singapore	S	Off	74	Wong	S	8/16/89	Tan			29		M
OCBC Center	Singapore	S	Off	76	Wong	S	8/16/89	Tan			51		M
Faber House	Singapore	S	Off	72	Wong	S	8/16/89	Tan			12		C
Thai Farmers Bank	Bangkok	T	Off	80	Busch	SD	5/24/89	Busch	47,536	36,765	18		C
Bangkok Bank	Bangkok	T	Off		Vechphutti	A	6/22/89	Busch		122,000	32		
Ua-Chuliang Bank	Bangkok	T	Off		KMITT	A	6/22/89	Busch	20,520	20,520	9		
BKK Metro Bank	Bangkok	T	Off	76	NEA/AF-E	A	6/22/89	Busch	17,900	17,900	16		
Thai Military Bank	Bangkok	T	Off		MITR/KMITT	A	6/22/89	Busch	14,184	13,333	14		
Thai Shell	Bangkok	T	Off		MITR/KMITT	A	6/22/89	Busch	12,165	10,462	9		
Srivikorn	Bangkok	T	Off	82	NEA/AF-E	A	6/22/89	Busch	6,336	4,800	12		
Hyatt Bumi	Surabaya	I	Hot	75	Prasetio	EAS	5/18/89	Busch	31,049	18,512	11	169	M
Elmi Hotel	Surabaya	I	Hot	78	Prasetio	EAS	5/18/89	Busch	10,998	7,530	8	144	M
Natour Simpang	Surabaya	I	Hot	79	Prasetio	EAS	5/18/89	Busch	6,022	5,510	7	100	M
Garden Palace	Surabaya	I	Hot	83	Prasetio	EAS	5/18/89	Busch	17,150	12,618	11	154	M
Hilton Hotel	KL	M	Hot	72	Dangroup	SE	7/17/89	Deringer	85,100	60,200	38	600	M
Pan Pacific	KL	M	Hot	86	Kannan	AE	8/18/89	Halim	49,290	35,340	31	600	M
Regent Hotel	KL	M	Hot	74	Dangroup	S	7/17/89	Deringer	64,000	51,000	21	350	
Merlin Hotel	KL	M	Hot	72		S	7/17/89	Deringer	51,000	37,000	20		
Holiday Inn	KL	M	Hot	80	Kannan	AE	8/18/89	Halim	17,930	12,050	19		M
Equatorial Hotel	KL	M	Hot	73	Dangroup	S	7/17/89	Deringer	26,700	20,300	16	300	
Philippine Plaza	Manila	P	Hot		P6	SE	3/15/88	Borja	65,143	48,157	11		M
Manila Peninsula	Makati	P	Hot		P6	ASE	1/18/89	Borja	70,250	43,631	12		M
Mandarin Hotel	Makati	P	Hot		P6	SE	4/26/88	Borja	41,496	28,898	17		M
Silahis International	Manila	P	Hot		P6	SE	4/6/88	Borja	41,896	30,584	18		M
Manila Garden	Makati	P	Hot		P6	SE	6/8/88	Borja	55,602	35,305	17		M
Hilton Hotel	Makati	P	Hot		P6	SE	6/8/88	Borja	38,973	24,441	20		M
Intercontinental	Makati	P	Hot		P6	ADE	4/12/88	Marasigan	27,985	21,351	14	390	M
Holiday Inn	Manila	P	Hot		P6	SE	3/8/88	Marasigan	31,335	20,542	20		M
Hyatt Regency	Manila	P	Hot		P6	ADE	5/15/89	Marasigan	39,154	16,393	10		M
Century Park Sherato	Singapore	S	Hot	76	Wong	A	8/16/89	Tan	31,496	28,313	15	588	M
Golden Landmark	Singapore	S	Hot	83	Wong	A	8/16/89	Tan	13,935	12,205	19	400	M
Ambassador Hotel	Bangkok	T	Hot		NEA/AF-E	A	6/22/89	Busch	112,825	112,825		1030	
Shangrila		T	Hot		Surapong	A	4/18/90	Loewen	40,664	39,100	25	697	
Royal Orchid	Bangkok	T	Hot	82	NEA/AF-E	A	6/22/89	Busch	54,500	54,500	28	775	
Hyatt Central Plaza	Bangkok	T	Hot		Busch	SD	5/24/89	Busch	42,777	38,500	24	600	M
Montien	Bangkok	T	Hot		KMITT	A	6/22/89	Busch	24,826	22,311	18	483	
Siam Intercontinental	Bangkok	T	Hot		KMITT	A	6/22/89	Busch	30,156	21,555	5	396	
Sheraton	Bangkok	T	Hot		MITR/KMITT	A	6/22/89	Busch	14,864	13,104	11	263	
Tawana Ramada	Bangkok	T	Hot	70	NEA/AF-E	A	6/22/89	Busch	14,000	13,000		300	
Rama Gardens	Bangkok	T	Hot	81	NEA/AF-E	A	6/22/89	Busch	27,465	27,465		372	
Montien Pattaya	Pattaya	T	Hot	74	NEA/AF-E	A	6/22/89	Busch	15,000	14,000	15		
Chieng Mai Orchid	Chieng Mai	T	Hot		KMITT	A	6/22/89	Busch	18,570	16,700		267	

Building Name	City	Cntry	Bldg Type	Year Built	Analyst	Audit Type	Date	Entered By	Gross Area (sqm)	Cond. Area (sqm)	No. of Floors	No. of Rooms or Beds	Wall Type
First	Bangkok	T	Hot	70	NEA/AF-E	A	6/22/89	Busch	7,100	7,100	10	222	
Manhattan	Bangkok	T	Hot		Surapong	A	4/18/90	Loewen	12,052	8,436		200	
Chieng Inn	Chieng Mai	T	Hot		KMITT	A	6/22/89	Busch	10,800	10,800		170	
Lee Garden	Bangkok	T	Hot		KMITT	A	6/22/89	Busch	7,347	6,465		122	
Gen.Hosp.-Childs.Wa	KL	M	Hos	87	Kannan	A	8/18/89	Halim	5,540	3,270	2	60	M
Makati Med Ctr	Makati	P	Hos		P6	SE	11/4/87	Marasigan	32,152	30,369	10		M
Lung Center	Quezon City	P	Hos		P6	SE	1/28/88	Marasigan	39,026	20,859	3		M
UST Hospital	Manila	P	Hos		P6	SE	2/5/88	Marasigan	19,336	17,420	5		M
Manila Doctors	Manila	P	Hos		P6	SE	1/22/88	Marasigan	11,191	8,724	7		M
St.Luke's	Quezon City	P	Hos		P6	ASE		Marasigan	15,179	6,521	6		M
Cardinal Santos	Greenhills	P	Hos		P6	ADE		Marasigan	11,365	6,877	5		M
Manila Medical	Manila	P	Hos		P6	SE	6/15/88	Marasigan	19,981	7,410	11		M
Capitol Medical	Quezon City	P	Hos		P6	SE	4/3/88	Marasigan	7,560	4,122	7		M
UDMC	Manila	P	Hos		P6	SE	6/3/88	Marasigan	12,868	4,459	11		M
FEU Hospital	Manila	P	Hos		P6	SE	2/2/88	Marasigan	7,534	2,769	5		M
Nakorn Chieng Mai	Chieng Mai	T	Hos		KMITT	A	6/22/89	Busch	58,614	58,614		440	
Hua Chiew	Bangkok	T	Hos	77	NEA/AF-E	A	6/22/89	Busch		15,400		750	
Sametivej	Bangkok	T	Hos	80	NEA/AF-E	A	6/22/89	Busch	16,500	16,500		200	
Bumrungraj	Bangkok	T	Hos		KMITT	A	6/22/89	Busch	15,811	9,395	7	200	
St.Louis	Bangkok	T	Hos	79	NEA/AF-E	A	6/22/89	Busch	24,000	5,000		220	
Sukumvit	Bangkok	T	Hos	56	NEA/AF-E	A	6/22/89	Busch	7,600	7,600		72	
Kluay Nam Tai	Bangkok	T	Hos		KMITT	A	6/22/89	Busch	5,533	963		250	
Ampang Park S.C.	KL	M	Sto	71	Dangroup	S	7/17/89	Deringer	27,000	13,000	4		
Jaya Complex	KL	M	Sto	73	Dangroup	S	7/17/89	Deringer	15,500	12,000	4		
Sungai Wang Plaza	KL	M	Sto	77	Dangroup	SE	7/17/89	Deringer	89,000	56,000	5		
World Trade Center	Singapore	S	Sto	78	Wong	S	8/16/89	Tan	90,923	43,159	13		M
Clifford Ctr.	Singapore	S	Sto	75	Wong	S	8/16/89	Tan	42,147	26,850	29		M
Maxwell House	Singapore	S	Sto	71	Wong	S	8/16/89	Tan			13		M
Metro Dept. Store	Bangkok	T	Sto	81	NEA/AF-E	A	6/22/89	Busch		10,100	4		
Charn Issara Sh.Ctr.	Bangkok	T	Sto	85	Busch	SD	5/24/89	Busch	9,900	9,900	4		M
Cathay Dept. Store	Bangkok	T	Sto	82	NEA/AF-E	A	6/22/89	Busch	5,000	4,000	4		
Glori's - Roces	Quezon City	P	Sup		P6	SE	6/3/88	Marasigan	3,266	2,242	1		M
Cherry - Shaw Ave.	Mandaluyon	P	Sup		P6	SE	7/7/88	Marasigan	3,260	2,404			M
Glori's - Del Monte	Quezon City	P	Sup		P6	SE	6/1/88	Marasigan	2,135	1,784	2		M
Glori's - T.Sora	Quezon City	P	Sup		P6	SE	6/16/88	Marasigan	2,206	1,251	1		M
Thriftway	Quezon City	P	Sup		P6	ADE		Marasigan	4,354	2,845	1		
Queen's	Quezon City	P	Sup		P6	SE	7/6/88	Marasigan	403	292	1		
Pertama Complex	KL	M	X	76	Dangroup	S	7/17/89	Deringer	55,000	31,000			
Campbell S.C.	KL	M	X	74	Dangroup	S	7/17/89	Deringer	23,000	19,500			
Shell (Raffles)	Singapore	S	X	82	Wong	S	8/16/89	Tan	75,797	57,690	47		M
Midland Building	Singapore	S	X	83	Wong	S	8/16/89	Tan	3,723	2,584	9		M
Thong Chai Bldg.	Singapore	S	X	76	Wong	S	8/16/89	Tan	7,488	5,191	10		M
Ching Kwan House	Singapore	S	X	70	Wong	S	8/16/89	Tan			22		M
Shaw House	Singapore	S	X	58	Wong	S	8/16/89	Tan			10		M
Tat Lee Bldg.	Singapore	S	X	84	Wong	S	8/16/89	Tan			16		M

Building Name	Window Type	Window Shade Coef	Ext. Shade Type	Window to-Wall Ratio	OTTV (W/sqm)	Lights (W/sqm	Proces Loads Type	Occup Density (sqm/ pers)	Occup. Hours (hrs/ wk)	Zone Temp (C)	Supply Air (1000 l/s)	VAC Type	Chiller Type	Chiller Capac. (Tons)
Industrial Dept.	T								48			C	C	900
Religion Dept.	T								48			CS	C	850
Public Works	T								48			S		720
Wisma Sier	T	0.53		0.45		7.6			51	20.0		RW		
Maybank Tower	T	0.60		0.60	54		VC			24.0	287	V	C	750
Daya Bumi Complex	R	0.70		0.83	44		VC			23.0	457	V	C	1,000
Promet Tower	R	0.27		0.51	63		VC			24.0	171	C	C	400
Negara Bank	T		E	0.67		14.0		10.2	45	24.0		V	C	
General Post Office	T	0.60	H	0.58	66		VC	20.6	105	23.0	192	C	C	1,200
Tun Razak Tower	T	0.28		0.80	45		VC			23.0	232	C	C	400
MAS Building	R	0.53		0.67	50		VC			23.0	158	V	C	400
Kuwasa Tower	R	0.27		0.40	30		VC			25.0	504	V	C	600
Min.of Information			H				V						C	555
Bumiputra Bank	T		H	0.21	61							PC		
City Hall				0.00										
Bagunan Bukota				0.00										
Pertamian Bank			H				V						C	
Wisma Sime Darb				0.00										
Luth Building	T	0.50		0.52	51		VC				213			
Plaza MBF				0.00										
LLN, Bldg.NLDC	C		E			18.0				24.0			C	
Empl.Prov.Fund	T		H	0.00		15.0			47					
Chung Khiaw Bank	R	0.40		1.00	77		VC			23.0	82	V	C	300
Min.of Finance, Blk.9	C		H				V							
PNB Tower	T	0.68		0.27	45		VC			23.0	364	V	C	450
Math Faculty			V	0.00		15.0			50	24.0		C	C	
Geology Faculty			V	0.00		12.0			50					
Petronas Bldg.					77							S		
Drainage & Irrigation		0.00		0.60	51					24.0	55	C		170
Public Works Dept.	T	0.70	H	0.60	41	13.6	C	14.1	39	22.0	14	C	R	
Agriculture Bank	T	0.68		0.43			VC							
Central Bank	T		E	0.26		20.6	VKX	10.3	53	23.0		C	C	2,100
Social Security Sys.	C	1.00	E	0.40		21.5	VKRX	5.4	50	24.0		CS	R	1,248
B A Lepanto	T	0.83	E	0.38		12.8	VKX	19.2	65	21.0		C	C	670
Citibank	C	0.96	H	0.21		16.3	VKX	6.2	66	23.0		VC	C	606
Eastern Telecoms.	T	0.80	E	0.33		13.6	VKX	15.7	45	23.0		V	C	315
Metrobank	T	0.67	V	0.46		10.1	VKX	13.8	45	23.0		C	CR	802
National Power Corp.	T		H	0.71		17.8	VKX	10.8	52	23.0		C	C	624
Dev't Bank of Phil.	T	0.80	E	0.64		20.2	VKX	9.5	58	24.0		CS	CR	1,100
Metro W & S System	T	0.83	H	0.63		21.8	VXK	8.0	45	24.0		CS	CR	755
Insular Life	C	0.96	E	0.59		2.0	VKX	12.3	64	25.0		C	C	900
Bur.of Internal Rev.	T	0.83	H	0.56		20.9	VXK	10.7	48	25.0		C	C	616
Petrophil Corp.	T	0.80	E	0.26		24.9	VKX	10.5	48	24.0		VC	C	582
China Bank	T	0.64	H	1.00		17.7	VKX	9.3	60	23.0		C	C	640
National Life Ins.	T	0.80	E	0.63		21.8	VKX	21.3	55	25.0		C	C	300
King's Court				1.00		9.6	VKX	14.6	55	24.0		C	C	550
National Steel Corp	T	0.64	H	0.42		12.2	VKX	11.2	49	25.0		C	R	270
Phinma	T	0.83	E	0.52		25.0	VKX	6.1	49	25.0		S	R	180
BLISS Building	T	1.00	E	0.51		17.9	VKX	9.2	50	21.0		S	R	220
Nestle Philippines	T	0.91	V	0.60		21.3	VKX	17.3	45	22.0		S	R	288
Tech.Research Ctr.	T	1.00	H	0.51		23.1	VKX	25.3	60	22.0		S	R	164
Dept.of Trade & Ind.	C	1.00	E	0.49		12.0	VKX	11.2	45	22.0		CS	R	228
Phil.Coconut Authorit	T	0.96	E	0.10		16.7	VXK	28.9	45	25.0		C	C	250
Computer Info Syste	C		H	0.40		11.0	KX	13.9	52	24.0		C	R	210
Far East Bank		0.91	H	0.45		14.0	VKX	7.5	45	25.0		CF	R	220

Building Name	Window Type	Window Shade Coef	Ext. Shade Type	Window to-Wall Ratio	OTTV (W/sqm)	Lights (W/sqm	Proces Loads Type	Occup Density (sqm/ pers)	Occup. Hours (hrs/ wk)	Zone Temp (C)	Supply Air (1000 l/s)	VAC Type	Chiller Type	Chiller Capac. (Tons)
Phil.Deposit Ins. Corp	C	0.64	E	0.35		6.5	VKX	9.8	43	22.0		S	R	90
Phil.Transm.Carriers	T	0.83	H	0.38		13.7	VKX	11.6	48	24.0		S	R	60
COM CENTRE	T	0.70					KVCX			24.0		C	C	
SDB18														
SDB26														
SDB29				0.55	41									
SDB74				0.43					55					4,100
PUB Bldg.	T	0.70	V				KVCX		53	24.0		C	C	6,331
CPF Building	T	0.70					KVCX		50	24.0		C	C	5,944
UOB Building	R	0.60		0.76			KVCX		55	24.0		C	C	4,115
SDB50				0.65	45									
SDB59				0.31	44									
SDB27				0.33	45									
Albert Complex	T	0.50		0.60		13.0	KVCX		74	24.0		CF	C	980
SDB36				0.39	45				81					1,400
SDB71				0.50	44									
SDB32				0.60	32				53					2,270
SDB24														
SDB31				0.24	34									
Sim Lim Tower	T	0.70	H				KVCX		95	24.0		C	C	36,929
Inchape House	R	0.60					VCX		53	24.0		C	C	2,272
Straits Trading	T	0.70					KVCX		55	24.0		C	C	600
SDB69				0.41	44									
SDB47														
SDB33														
SDB42				0.29	39									
MArine House	T	0.70	H				VCX		55	24.0		C	C	2,638
Sanford Building	A	0.45		0.74		12.0	KVCX		56	24.0		VF	C	480
SDB68				0.66	37									
SDB79														
SDB70				0.00	45									
SDB62				0.39	44									
JTC Bldg	T	0.65	E	0.43		12.5	VCX		50	24.0		C	C	400
SDB49														
UOL Building	T	0.70		0.85			KVCX		15	24.0		C	C	525
Bank of Bangkok	T	0.70	H				VCX		55	24.0		C	S	1,407
SDB39														
SDB66														
URA Building	C	0.90	E	0.36		10.5	VCX		47	24.0		C	C	190
Moscow Narodyn	T	0.70	H	0.73			VCX		50	24.0		C	C	
Central Building	T	0.70		0.71			KVCX		61	24.0		C	C	
SDB76														
SDB61														
Denmark House	C	0.90					VCX		50	24.0		C	C	1,020
ACB Building	T	0.70	V	0.55			KVCX		52	24.0		C	C	956
SDB2				0.34	44									
SDB19				0.96	44									
SDB21				0.26										
Bank of China	C	0.90	V	0.30			VCX		55	24.0		C	C	185
SDB28														
Asia Chambers	T	0.70	V	0.76			KVCX		58	24.0		C	C	260
SAN CENTRE	C	0.90	V				VCX		40	24.0		C	R	956
Liat Towers	R	0.60		0.63			KVCX		81	24.0		C	C	1,407
SDB25				0.29	42									
SDB12				0.36	46									

Building Name	Window Type	Window Shade Coef	Ext. Shade Type	Window to-Wall Ratio	OTTV (W/sqm)	Lights (W/sqm	Proces Loads Type	Occup Density (sqm/ pers)	Occup. Hours (hrs/ wk)	Zone Temp (C)	Supply Air (1000 l/s)	VAC Type	Chiller Type	Chiller Capac. (Tons)
Bank of East Asia	T	0.70					VCX		61	24.0		C	C	1,407
Reality Center	T	0.70					VCX		50	24.0		C	C	
SDB9				0.40	46									
SDB6				6.40	45									
SDB77														
SDB30														
SDB23				0.36	43									
SDB81				0.28	44									
SDB43					45									
Sin Chew Jit Po	C	0.90	V				KVCX		55	24.0		C	C	
Commercial Union	T	0.70					VCX		55	24.0		C	C	200
SDB20														
Ocean Building	T	0.70					VCX		59	24.0		C	C	
OCBC Center	T	0.50					VCX		45	24.0		C	C	6,336
Faber House	C	0.90					VCX		56	24.0		C	C	280
Thai Farmers Bank	T	0.34		0.95		24.2	KVCX	7.4	45	24.0	425	C	CR	2,320
Bangkok Bank										22.5				
Ua-Chuliang Bank					44	10.4				26.0				
BKK Metro Bank						20.0	VC							750
Thai Military Bank												V	C	750
Thai Shell												C	C	720
Srivikorn				0.25			VC		58	24.0		C		525
Hyatt Bumi	T	0.90	V	0.26		12.5			168	22.2		VF	C	800
Elmi Hotel	T	0.69	E	0.64		16.7			168	26.7		CF	R	480
Natour Simpang	T	0.69	V	0.62		12.1			168	23.9		BF	C	125
Garden Palace	T	0.85		0.24		7.1			168	23.9		BF	A	400
Hilton Hotel			H		52		KVL		168	22.5		FC		
Pan Pacific	T	0.48	H	0.35	41	5.1	KVLR		168	22.0		CF	C	2,100
Regent Hotel			H				KV		168			FC	C	1,170
Merlin Hotel			E				KVL					FCW	R	
Holiday Inn	T	0.65	V	0.35	41		KVLR		168	22.0		CF	C	600
Equatorial Hotel			E				KVR		168			F	C	800
Philippine Plaza		0.67	E	0.48		19.8	VKLX	14.3	168	24.0		C	C	750
Manila Peninsula		0.89	E	0.54		9.5	VKLX	19.1	168	24.0		C	C	500
Mandarin Hotel	T	0.83	E	0.21		15.9	VKLX	9.1	168	25.0		C	C	530
Silahis International		0.83	H	0.38		23.7	VKLX	18.5	168	24.0		C	C	600
Manila Garden		0.83	H	0.76		15.1	VKLX	16.0	168	25.0		C	C	450
Hilton Hotel		0.83	E	0.39		27.6	VKLX	14.9	168	25.0		C	C	450
Intercontinental	T	0.67	E	0.45		19.1	VKLX	14.1	168	25.0		C	C	450
Holiday Inn		0.67	E	0.45		8.6	VKLX	13.6	168	24.0		C	C	500
Hyatt Regency	T	0.89	E	0.41		15.1	VKLX	17.3	168	25.0		C	C	400
Century Park Sherato	T	0.70	H	0.90			KVCX		168	24.0		CF	C	560
Golden Landmark	T	0.70		0.70			KVCX		168	24.0		CF	C	500
Ambassador Hotel							KVLR		168			FC		3,750
Shangrila						3.9				22.0				
Royal Orchid							KVLO		168			FC		2,000
Hyatt Central Plaza	T	0.35	H	0.30		19.2	KVLCX	19.3	168	24.0	225	CF	C	1,500
Montien					50	11.5								
Siam Intercontinental						8.9				22.0				
Sheraton				0.39					168			C		600
Tawana Ramada							KLV		168			FS		600
Rama Gardens							KVR		168	25.0		CF		954
Montien Pattaya						6.7	KVLR		168	24.0		FS		430
Chieng Mai Orchid														

Building Name	Window Type	Window Shade Coef	Ext. Shade Type	Window to-Wall Ratio	OTTV (W/sqm)	Lights (W/sqm	Proces Loads Type	Occup Density (sqm/ pers)	Occup. Hours (hrs/ wk)	Zone Temp (C)	Supply Air (1000 l/s)	VAC Type	Chiller Type	Chiller Capac. (Tons)
First							VKL		168	22.5		R		350
Manhattan														
Chieng Inn														
Lee Garden														
Gen.Hosp.-Childs.Wa	T	1.00	H	0.80	42		X			23.0	31	C	R	140
Makati Med Ctr			E	0.52		12.1	VKX	10.7	168	22.0		CW	C	450
Lung Center			H	0.64		19.5	VKX	8.8	168	24.0		CW	C	600
UST Hospital			H	0.34		17.4	VKX	16.4	168	24.0		CSW	R	292
Manila Doctors			E	0.23		19.1	VKX	11.7	168	24.0		SW		222
St.Luke's			E	0.37		8.6	VX	6.0	168	25.0		W		219
Cardinal Santos			E	0.48		7.2	VKX	11.6	168	25.0		CSW	C	236
Manila Medical				0.42		10.6	VKX	13.3	168	24.0		SW		292
Capitol Medical				0.33		16.9	VKX	14.4	168	26.0		CF	R	300
UDMC			H	0.31		9.6	VX	17.8	168	24.0		W		174
FEU Hospital			E	0.29		17.1	VX	7.9	168	25.0		W		143
Nakorn Chieng Mai														
Hua Chiew							KVL		168			CFS		750
Sametivej							KLV		168			FSC		656
Bumrungraj					58	9.2				26.0				
St.Louis							KL		168			SFW		100
Sukumvit														320
Kluay Nam Tai														
Ampang Park S.C.							V		84			C		750
Jaya Complex							V					CR	C	800
Sungai Wang Plaza					31	34.0	V			26.0		C	C	456
World Trade Center	T	0.70	H	0.43			KVCX		93	24.0		C	C	15,488
Clifford Ctr.	T	0.70		0.66			KVCX		60	24.0		C	C	1,482
Maxwell House	T	0.70					KVCX		60	24.0		C	C	1,231
Metro Dept. Store									74	26.0		CS		600
Charn Issara Sh.Ctr.	T	0.63	S	0.35		53.6	VC	19.8	63	25.0	128	CS	R	294
Cathay Dept. Store												FSR		165
Glori's - Roces			H	0.10		1.5	KR	7.5	84	24.0		S		105
Cherry - Shaw Ave.			H	0.12		13.4	RX	11.0	77	26.0		S		32
Glori's - Del Monte				0.07		7.4	RX	4.0	77	24.0		SW		75
Glori's - T.Sora			H	0.16		12.7	RX	7.9	84	25.0		SW		62
Thriftway			H	0.14		4.0	RX	71.1	28	26.0		SW		33
Queen's			H	0.24		7.8	RX	11.2	60	26.0		W		54
Pertama Complex							V						C	1,200
Campbell S.C.							V					CS	C	525
Shell (Raffles)	T	0.50					KVCX		55	24.0		V	C	6,330
Midland Building	T	0.70		0.85			VCX		79	24.0		C	C	177
Thong Chai Bldg.	C	0.90		0.39			VCX		55	24.0		C	C	
Ching Kwan House	T	0.70	E				VCX		55	24.0		C	C	3,517
Shaw House	C	0.90	V				KVCX		55	24.0		C	C	878
Tat Lee Bldg.	T	0.70					KVCX		51	24.0		C	S	2,110

Building Name	No.of Chlrs.	Chlr. Fuel	DHW Type	DHW Fuel	Total Elec. (MWh)	Peak Demand (kW)	Total Energy (MWh)	Info. Source	Elect. Intensity (kWh/ sqm)	Elect. Intensity (kWh/rm or bed)	AC Density (sqm/ ton)
Industrial Dept.	2	E			4,044		4043		123		36
Religion Dept.	6	E			3,048		3048		144		25
Public Works	0	E			2,532		2532		173		20
Wisma Sier					910		910	B	150		
Maybank Tower					27,782			B	320		
Daya Bumi Complex					10,336			B	95		
Promet Tower					10,075			B	325		
Negara Bank	3				8,880	3000		B	442		
General Post Office	2	E			8,190			S	312		22
Tun Razak Tower					8,160			B	255		
MAS Building					7,400			B	250		
Kuwasa Tower					7,088			B	166		
Min.of Information	3	E			6,700				259		47
Bumiputra Bank	4				6,300				274		
City Hall					5,794			B	200		
Bagunan Bukota					4,992			B	208		
Pertamian Bank	3				4,800				232		
Wisma Sime Darb					4,400			B	97		
Luth Building					4,161			B	146		
Plaza MBF					4,049			B	170		
LLN, Bldg.NLDC	4				4,000				294		
Empl.Prov.Fund					3,400			B	555		
Chung Khiaw Bank					3,120			B	300		
Min.of Finance, Blk.9					2,900				166		
PNB Tower					2,643			B	56		
Math Faculty					1,896	551		B	874		
Geology Faculty					1,896			B	226		
Petronas Bldg.					1,300				500		
Drainage & Irrigation					561				115		
Public Works Dept.	2	E			258			S	170		
Agriculture Bank								B	0		
Central Bank		E			23,034			B	210		52
Social Security Sys.		E			6,028			B	447		11
B A Lepanto		E			5,327			B	250		32
Citibank		E			5,177			B	288		30
Eastern Telecoms.		E			4,938			B	417		38
Metrobank		E			4,751			B	257		23
National Power Corp.		E			4,375		4375	B	275		25
Dev't Bank of Phil.		E			4,271			B	275		14
Metro W & S System		E			4,217			B	196		28
Insular Life		E			4,024			B	198		23
Bur.of Internal Rev.		E			3,909			B	210		30
Petrophil Corp.		E			3,235			B	293		19
China Bank	2	E			2,858			B	270		17
National Life Ins.		E			2,239			B	242		31
King's Court		E			1,864			B	196		17
National Steel Corp	3	E			1,325			B	206		24
Phinma		E			1,085			B	404		15
BLISS Building		E			988		988	B	188		24
Nestle Philippines		E			981		981	B	177		19
Tech.Research Ctr.		E			954		954	B	260		22
Dept.of Trade & Ind.		E			924			B	112		36
Phil.Coconut Authorit		E			765			B	104		29
Computer Info Syste	3	E			709			B	150		23
Far East Bank		E			632			B	118		24

Building Name	No.of Chlrs.	Chlr. Fuel	DHW Type	DHW Fuel	Total Elec. (MWh)	Peak Demand (kW)	Total Energy (MWh)	Info. Source	Elect. Intensity (kWh/ sqm)	Elect. Intensity (kWh/rm or bed)	AC Density (sqm/ ton)
Phil.Deposit Ins. Corp		E			295			B	198		17
Phil.Transm.Carriers		E			227			B	178		21
COM CENTRE		E			26,663				705		
SDB18					15,784				310		
SDB26					12,050				196		
SDB29					12,004				172		
SDB74					10,439				412		
PUB Bldg.	2	E			7,740				186		7
CPF Building	4	E			6,664				210		5
UOB Building	7	E			6,310				412		4
SDB50					6,036				251		
SDB59					5,881				143		
SDB27					5,706				200		
Albert Complex	5	E			5,412				203		27
SDB36					4,846				393		
SDB71					4,567				133		
SDB32					4,422				350		
SDB24					4,377				228		
SDB31					4,280				403		
Sim Lim Tower	2	E			3,731	300			300		
Inchape House	2	E			3,364				350		4
Straits Trading	2	E			3,003				204		25
SDB69					2,679				154		
SDB47					2,601				224		
SDB33					2,522				78		
SDB42					2,340				165		
MArine House	2	E			2,334				187		5
Sanford Building	3	E			2,238				197		24
SDB68					2,161				167		
SDB79					2,144				321		
SDB70					2,141				306		
SDB62					2,061				52		
JTC Bldg	1	E			2,038				122		42
SDB49					1,995				208		
UOL Building	2	E			1,939				307		12
Bank of Bangkok	2	E			1,909				225		6
SDB39					1,827				257		
SDB66					1,691				184		
URA Building	2	E			1,617				119		72
Moscow Narodyn		E			1,532	273			273		
Central Building		E			1,465	184			184		
SDB76					1,393				213		
SDB61					1,355				76		
Denmark House	2	E			1,325				298		4
ACB Building		E			1,150				203		6
SDB2					1,147				221		
SDB19					1,102				288		
SDB21					1,097				193		
Bank of China	2	E			1,086				189		31
SDB28					1,082				240		
Asia Chambers	4	E			1,081				141		30
SAN CENTRE	3	E			997				109		10
Liat Towers	2	E			946				394		2
SDB25					831				198		
SDB12					809				46		

Building Name	No.of Chlrs.	Chlr. Fuel	DHW Type	DHW Fuel	Total Elec. (MWh)	Peak Demand (kW)	Total Energy (MWh)	Info. Source	Elect. Intensity (kWh/ sqm)	Elect. Intensity (kWh/rm or bed)	AC Density (sqm/ ton)
Bank of East Asia	4	E			747				262		2
Reality Center		E			740	184			184		
SDB9					721				333		
SDB6					693				264		
SDB77					668				160		
SDB30					615				66		
SDB23					501				341		
SDB81					442				133		
SDB43					327				202		
Sin Chew Jit Po		E			315	45			45		
Commercial Union	2	E			211				68		16
SDB20					162				710		
Ocean Building		E									
OCBC Center	2	E									
Faber House	1	E									
Thai Farmers Bank	5	E			15,518	4160	15518	B	422		16
Bangkok Bank					14,800	4560			121		
Ua-Chuliang Bank					3,425				167		
BKK Metro Bank	3	E			3,263		3263	B	182		24
Thai Military Bank	3				3,215				241		18
Thai Shell	4	E			2,772				265		15
Srivikorn	3				1,237	560	1237	B	258		9
Hyatt Bumi	2	E			6,775		6775		366		23
Elmi Hotel	2	E			2,955		2955		392		16
Natour Simpang	2	E			1,763		1763		320		44
Garden Palace	2	D			870		3877		69		32
Hilton Hotel	4				14,200				236	23667	
Pan Pacific	3	E	H	D	13,075			S	370	21792	17
Regent Hotel	3	E	H		12,200				239	34857	44
Merlin Hotel	9	E	H	O	11,100				300		
Holiday Inn	2	E	H	D	4,700			S	390		20
Equatorial Hotel	2	E	H	D	3,500				172	11667	25
Philippine Plaza		E			16,294			B	338		64
Manila Peninsula		E			11,616			B	266		87
Mandarin Hotel		E			10,781			B	373		55
Silahis International		E			10,461			B	342		51
Manila Garden		E			10,440			B	296		78
Hilton Hotel		E			9,758			B	399		54
Intercontinental		E			6,989			B	327		47
Holiday Inn		E			6,742			B	328		41
Hyatt Regency		E			6,684			B	408		41
Century Park Sherato	2	E			9,596				339	16320	51
Golden Landmark	1	E			6,328				518	15820	24
Ambassador Hotel	7	E	S	O	25,600		37300	B	227	24854	30
Shangrila					17,712				453	25412	
Royal Orchid	4	E	SI	OI	12,859		20886	B	236	16592	27
Hyatt Central Plaza	3	E	S	O	10,686		18449	B	278	17810	26
Montien					8,112				364	16795	
Siam Intercontinental					7,787				361	19664	
Sheraton	2				5,748				439	21856	22
Tawana Ramada	2	E	W	O	5,334			B	410	17780	22
Rama Gardens	3	E	S	O	4,872	900	6897	B	177	13097	29
Montien Pattaya	2	E	S	O	3,757	730	3961	B	268		33
Chieng Mai Orchid					3,360				201	12584	

Building Name	No.of Chlrs.	Chlr. Fuel	DHW Type	DHW Fuel	Total Elec. (MWh)	Peak Demand (kW)	Total Energy (MWh)	Info. Source	Elect. Intensity (kWh/sqm)	Elect. Intensity (kWh/rm or bed)	AC Density (sqm/ton)
First		E	S	D	2,976	460	4746	B	419	13405	20
Manhattan					2,927				347	14635	
Chieng Inn					2,147				199	12629	
Lee Garden					1,824				282	14951	
Gen.Hosp.-Childs.Wa	2	E			817			S	250	13617	
Makati Med Ctr		E			8,888			B	293		67
Lung Center		E			8,038			B	385		35
UST Hospital		E			5,434			B	312		60
Manila Doctors		E			4,371			B	501		39
St.Luke's		E			3,557			B	545		30
Cardinal Santos		E			2,986			B	434		29
Manila Medical		E			2,770			B	374		25
Capitol Medical		E			2,552			B	619		14
UDMC		E			1,761			B	395		26
FEU Hospital		E			1,227			B	443		19
Nakorn Chieng Mai					7,177				122	16311	
Hua Chiew	3	E	S	O	5,556	1400	12431	B	361	7408	21
Sametivej	2	E	S	O	5,040	960	7762	B	305	25200	25
Bumrungraj					2,668				284	13340	
St.Louis	2	E	S	O	2,568		3888	B	514	11673	50
Sukumvit	3	E	S	D	1,640		1860	B	216	22778	24
Kluay Nam Tai					446				463	1784	
Ampang Park S.C.	3				7,900				608		17
Jaya Complex	2				4,300				358		15
Sungai Wang Plaza	4	E	H	E							123
World Trade Center	6	E			4,901				114		3
Clifford Ctr.	2	E			3,613				135		18
Maxwell House	1	E									
Metro Dept. Store	2	E			4,701		4701	B	465		17
Charn Issara Sh.Ctr.	3	E			4,543	1442	4543	S	459		34
Cathay Dept. Store	3	E			1,314	410	1314	B	329		24
Glori's - Roces		E			638			B	285		21
Cherry - Shaw Ave.		E			572			B	238		75
Glori's - Del Monte		E			534			B	299		24
Glori's - T.Sora		E			530			B	424		20
Thriftway		E			502			B	176		86
Queen's		E			49			B	168		5
Pertama Complex	3				10,000				323		26
Campbell S.C.	3	E			3,200				164		37
Shell (Raffles)	3	E			14,256				247		9
Midland Building	2	E			620				240		15
Thong Chai Bldg.		E			574	111			111		
Ching Kwan House	2	E									
Shaw House	1	E									
Tat Lee Bldg.	2	E									

APPENDIX B

ENERGY MANAGEMENT

SINGAPORE

This report provides an excellent summary of Singapore's energy auditing activities and findings undertaken during the joint ASEAN-USAID Project. Singapore, which already had a well-developed energy policy prior to the Project, used the opportunity to enhance its auditing skills.

FINAL REPORT

PROJECT S3 – ENERGY MANAGEMENT

PHASE III ASEAN-US ENERGY CO-OPERATION PROGRAMME

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ABSTRACT

This report presents the findings of Project S3 on Energy Management under Phase III of the ASEAN-US Energy Co-operation Programme. The work included a survey on office building energy performance and energy audits on several selected buildings. The Singapore average energy Intensity for office buildings was found to be 210 kWh/m^2/yr, about 15% lower than the ASEAN average for office buildings. Broad guidelines for energy management and conservation opportunities were identified. Recommendations were made for incorporation of these guidelines into a revised handbook and for the establishment of performance targets and indicators for other classes of commercial buildings.

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INTRODUCTION

This project on Energy Management is sponsored under the Singapore Workplan for Phase III of the ASEAN-US Energy Co-operation Programme. The objective of this project is to prepare a manual on energy management in buildings for use by building owners and professionals in the building construction and maintenance industry.

The scope of work includes energy audits of existing buildings in order to collect sufficient data to establish the specific energy consumption of various categories of buildings. Energy simulation studies on selected buildings, including simulation of energy conservation options, are to be performed to consider the viable options in these studies. Finally, a manual on energy management would be prepared based on the findings of the studies.

Energy Survey

A preliminary study of 81 office buildings in Singapore was conducted [1,2]. These buildings were identified from a list of about 200 buildings classified as public buildings. Public buildings are mostly commercial buildings, housing offices, retail stores, and hotels. Questionnaires were sent to building managers requesting details of the air-conditioning, lighting, vertical transportation, and other mechanical services in their buildings. Questions were also asked about also energy conservation or management measures in use. Of these, 38 replies, about 44%, were received by the due date in September 1986.

Some findings of the postal survey are shown in Table B-1. Energy conservation measures taken by the buildings' management included de-lamping in car parks and in areas of light human traffic; increasing use of fluorescent lamps, power factor correction; and retro-fitting chiller load optimization and management systems. It was also noted that the increased use of micro-computers and mini-computer systems for data processing in the office has resulted in a general rise in equipment load within buildings.

Besides data collected from the postal survey, a compilation of data on each of the buildings from records made available by the Building Control Division (BCD) of the Public Works Department (PWD) was made. These data included floor area based on architectural plans, separated into air-conditioned and non-air-conditioned areas; Overall Thermal Transmittance Value (OTTV); fenestration and wall areas; and overall energy consumption based on metered tariff records. Altogether, data from 65 buildings were obtained.

The data were analysed to determine the average building energy performance based on annual energy use per unit gross area (kWh/m^2/yr). Figure B-1 shows the distribution of the buildings in the survey by gross floor area. Areas used for parking cars were not included in the computation. The majority of buildings were found to be in the small to medium-size range with built-in areas ranging from 5,000 m^2 to 20,000. On average, the net conditioned area is about 75% of the gross area. Figure B-2 shows the distribution of buildings according to annual energy use per unit gross area. The average energy intensity was found to be about 170 kWh/m^2/yr and most buildings in the sample would lie within the range of 130 to 210 kWh/m^2/yr. The intensities on the basis of the net conditioned area were 210 kWh/m^2/yr, and 163 to 262 kWh/m^2/yr, for the average intensity and the range, respectively. The annual energy consumption for 1983, 1984, and 1985 were used in the computation. The data collected in this survey formed the Singapore contribution to the ASEAN Commercial Building Energy Database [3].

Energy Audits

Complete audits were conducted on four office buildings. The emphasis of the study was on office buildings, as these formed the largest group within the stock of public buildings in Singapore. The other criteria of selection were building age and building size. The office buildings monitored were about 20,000 m^2 in gross area. As can be seen from Figure B-1, most office buildings in the survey were within this size range. Constraints of monitoring equipment in the quantity of transducers available and measuring capacity of the transducers also limited the study to buildings within this size range. The buildings should also not be too old and two of the buildings selected were built in late 1970s, while the other two buildings were more recent. This would give some indication of any changes due to technical progress on building energy performance. Consent and co-operation of the building management in an audit were sought before the audit process began. Even after obtaining agreement to audit a building, the audit may not be conducted. In one case, the audit was abandoned after a preliminary visit to the site showed that it was beyond the capability of the equipment to monitor the installation.

Each complete audit could be divided into three stages. Stage one consisted of a preliminary audit, where the architectural plans and plans for the air-conditioning and mechanical ventilation systems, as well as the electrical system, were studied to plan the instrumentation and zoning for the next two stages. Data on electrical billings for the period of the previous one year was obtained to check the consumption pattern. A building survey form was used as a check-list for collection of information such as air-conditioning plant data and building operation schedules. This was followed by a walkthrough of the building to confirm and augment information collected.

The next stage was diagnostic monitoring of the electrical system. This took place over a period of about two weeks. The building's main and sub-distribution circuits were monitored. At the same time, air flow measurements in the air-conditioning system were taken and checked against the design values.

The final stage was energy consumption simulation. The ASEAM-2.1 [4] software was used in the project. The simulation results were matched with the building data to obtain the base simulation case against which parametric runs to test the viability of various energy conserving opportunities were conducted. Energy-conserving opportunities such as reduction of system operating hours, adjusting space temperature and humidity, adjusting ventilation rates, and improvement of chiller COP were considered.

In addition, electrical consumption monitoring was conducted on two hotels and an institutional building. The hotels were of 400 rooms and 588 rooms capacity and were completed in 1983 and 1976, respectively. The institutional building houses a professional school in a university.

Brief information of the office buildings and other buildings audited are shown in Tables B-2 and B-3, while the detailed description of each building and the analyses performed can be found in the section on Case Studies.

Discussion

The energy intensities of the four office buildings audited ranged from 96.6 to 201.9 kWh/m^2/yr. This is below the Singapore average of 210 kWh/m^2/yr, based on conditioned area. Comparing these values, in Table B-4, against the ASEAN office building average of 246 kWh/m^2/yr [3] and setting the latter to an index value of 100, it was noted that the Singapore average intensity results in a significantly lower value of 85.4.

The difference between the ASEAN average and the Singapore average can be attributed to several factors. The first explanation is that the Singapore climate is milder than the other ASEAN sites. It was noted by Levine *et al* [3] that in DOE-2 computer simulations on a generic office building model, using weather tapes from the four ASEAN cities of Bangkok, Manila, Jakarta, and Singapore, the results for the Singapore model had the lowest energy intensity. Secondly, the fact that the Singapore buildings were already complying to the existing regulations [5] and standards of OTTV, air-conditioning, and lighting intensities could possibly explain the lower intensities. Thirdly, it was noted in the audits that the building management had already adopted some energy conservation measures, such as the generally low lighting intensities of between 12 to 15 W/m^2 (albeit at an illuminance level of the range of 200 - 300 lux only), extensive use of fluorescent lighting, de-lamping, and reduced operation of air handling units (AHUs) fans during lunch break, among others.

However, some consideration must also be given to contributing factors such as below average occupancy in the case of URA building, change to high COP chillers in Jurong Town Hall, and the generally above average quality of building maintenance.

Energy use according to systems are shown in Table B-5 to be of a similar order in the office buildings, subject to the site monitoring constraints that were imposed by the electrical distribution system serving the various services in each building.

In summary, the limited number of cases of full audits conducted in the present project prevents identification of the *specific* energy conservation opportunities in Singapore. Nevertheless, it is possible to make several broad observations. These are:

- Good maintenance practices will result in improved building energy performance.
- Computer simulations using ASEAM-2.1 have shown that energy cost savings could be obtained in reducing plant operation time.
- Measures like raising the setpoint temperature and reducing infiltration produced only marginal results.
- Reducing AHU operation during lunch breaks is effective.
- Replacement of old chillers with ones having high COP should be considered in older buildings.
- Reduced lighting energy intensity by using high-efficiency fluorescent lighting is effective.
- Energy monitoring helps in identifying waste. Long-term energy monitoring is useful in building management.

Experience gained in the project has shown the advantages of short-term monitoring of energy consumption in buildings. As a result, a requirement for the provision of facilities for short-term energy monitoring in commercial buildings was incorporated into the 1989 revision of the Building Regulations [5].

In the long term, the broad guidelines on energy management and conservation would be refined and incorporated into a revised energy handbook. Energy performance indicators and targets for all building types would be established.

CASE STUDIES

Albert Complex

The Albert Complex, Figure B-3, is a new building, having been completed in early 1987. This building has retail space with a net conditioned area of 12,454 m^2 (21,308 m^2 gross area, including 8,854 m^2 basement carpark) in a three-story podium, above which sits office space with a net conditioned area of 14,129 m^2 (14,784 m^2 gross area) distributed in 14 stories. The whole building is clad with a curtain wall with double-glazed panes at the window areas.

There are two air-conditioning plants serving this building because of a difference in operating schedules; the retail space operates from 1000 hour to 2130 hour all year round, and the office space operates from 0830 hour to 1900 hour on weekdays and 0830 hour to 1300 hour on Saturdays. The retail space and the office space are each served by a constant volume central air-conditioning system.

The building was first audited in early January 1988 during the fit-up for the major tenant in the office space. A second audit was performed in April 1988 after the building was fully occupied.

The electrical consumption profile for the building is shown in Figure B-4. The base case simulation energy intensity of the building was 319.6 kWh/m^2/year for the retail space and 96.9 kWh/m^2/year for the office space. The overall performance was 198.7 kWh/m^2/year. The energy intensities are computed from the energy consumed by the building per unit area over the period of one year. Areas for car parks are not included in the computation.

The energy consumed by the various building services are shown in Figure B-5. The percentages are as follows:

Air-conditioning plants	42.5%
AHU fans and cooling towers	12.8%
Lighting and Power (tenants)	15.5%
Miscellaneous (lifts, general lighting, water pumps, basement ventilation fans, restaurant stand-alone air-conditioning units).	29.3%

As the building is new, many energy-conserving features have been incorporated into its design. These include the use of high-efficiency fluorescent lighting for all areas and chillers of high COP. A chiller optimization controller was installed but not put into operation. Nevertheless energy conservation measures studied included:

- Shorten plant operating hours (average 1 hour per day);
- Reduce infiltration rate from 0.25 to 0.1 air change per hour; and
- Reduce ventilation rate from 11% to 8%.

It was found that savings from the first two measures were marginal. The saving from reduced ventilation was about 85,595 kWh per annum - a 1.6% reduction in energy consumed.

One noteworthy benefit shown by the diagnostic monitoring was that it demonstrated to the building operator that the load from facade decorative lighting installed for the festive season from December to January was 50 kW.

URA Building

The URA Building, Figure B-6, is about ten years old. It houses the administrative offices of the Urban Redevelopment Authority. It has 11,987 m^2 of office space spread over one basement level and four upper levels. A mechanically-ventilated carpark of 6,900 m^2 is sandwiched between the first story and the fifth story. The building is rectangular in form with one of the shorter walls abutting an adjoining building and the opposite short wall is without any windows. The windows on the long side walls are shaded by deep fins and horizontal overhangs.

The air-conditioning system consists of a central chilled water plant serving a constant volume central air system. There were several stand-alone water-cooled packages used for cooling the computer installation.

The building was 60% occupied at the time of the study and the energy intensity based on energy billings the previous year was about 131.2 kWh/m^2/year. This low value could be due to the energy-conserving measures already adopted by the building operator. These include:

- De-lamping surplus fluorescent tubes,
- Installing solar control films on all windows, and
- Close monitoring of chillers and running only one chiller whenever possible. The chiller COP was a 4.2.

The annual energy performance from the base simulation run was 1,672,216 kWh, 6.3% higher than the past year's energy bills. The base run suggests that operating one chiller was not sufficient for the load. Yet there were no complaints from the occupants. Further investigations are in progress. The energy intensity was 139.5 kWh/m^2/year based on the simulation results.

Again, reducing the ventilation to 8% air supply rate gave a marginal saving in energy of 1.3% annual consumption. Reducing the air supply rate was another alternative, as the design ventilation rates seemed high. Site measurements, however, showed that these already had been adjusted down.

The electrical consumption profile is shown in Figure B-7. The stand-alone air-conditioning for the computer system can be seen to be frequently shut down at night, whereas it was assumed in the simulation that constant 24-hour cooling was provided. This could be the cause of the discrepancy in the estimate.

Figure B-8 shows the electricity consumption by the various services. These are as follows:

Air-conditioning plants	30.7%
AHU fans	10.0%
Computer Services	6.9%
Air-conditioning for computers	9.6%
Lighting, Power and miscellaneous (lifts, water pumps, ventilation fans)	42.8%

Sanford Building

Sanford Building, Figure B-9, is a 16-storey office building of 11,357 m^2 net conditioned space (22,233 m^2 gross area, including 10,874 m^2 carpark). It consists of a central core connecting two hexagonal shaped wings. The building envelope consists of a reinforced concrete structure with infill panels of dark tint laminated glass at the windows and insulated glazed spandrel panels.

The air-conditioning plant consists of a central chilled water plant serving a central variable air volume system in the conditioned space. The chillers COP is 4.70. The building was first occupied in mid-1983. The building is fitted with energy-conserving mirror optics fluorescent luminaires. These fittings are ventilated by return air. The lighting energy intensity was about 12 W/m^2.

The annual energy consumption simulated from the base run was 2,292,974 kWh which gave an intensity of 201.9 kWh/m^2/year. Current occupancy is about 85%.

Electrical consumption profile is shown in Figure B-10. Nothing unusual was discovered in the consumption pattern during the period of the monitoring. Percent consumption by services is shown in Figure B-11. These are as follows:

Air-conditioning plant	32.3%
AHU fans	8.6%
Lighting and Power (Tenants)	30.8%
Miscellaneous (lifts, water pumps, general lighting, carpark ventilation fans)	28.4%

Various energy-conserving measures were simulated; the corresponding reduction in energy consumption were as follows:

Replace single-glazing with double-glazing	2.1%
Reduce plant and system operation by one hour daily	5.1%
Reduce lighting intensity by further 10%	2.1%
Reduce ventilation from 7% to 5% air supply rate	1.3%
Combined measures 2, 3 and 4	8.3%

Jurong Town Hall Building

The Jurong Town Hall building, Figure B-12, is about 13 years old, having been completed in the mid-1970s. This building sits on a hill site. It has a gross area of 22,300 m^2, of which about 16,700 m^2 is conditioned area. The building has a semi-basement level and four upper levels. A penthouse is situated on the fifth level. The building has a unique design whereby the floors on the upper levels overhang the lower one. This, combined with side fins on either side of the windows, provide very effective solar shading. The exterior was painted an off-white colour.

The building houses the administrative offices of the government body responsible for the development of industrial infrastructure in Singapore. These offices are located at the basement level, and the first, third, and fourth levels of the building. The second level is leased as office space to commercial tenants. In addition, there is one large hall, one theatrette, and the penthouse. These latter facilities are leased to civic groups for their gatherings on weekends. There is also a staff sports and recreation clubhouse located on the grounds of the building. This clubhouse draws its electrical power supplies from the Town Hall building. Power supplied to the clubhouse was recorded manually everyday. The annual consumption was subtracted from the values for the main building and hence not considered.

The building is served by a central chilled water plant supplying chilled water to central air-conditioning systems in the building. The central chilling plant has two 400 RT chillers with COP of 5.87 (0.6 kW/RT). At any one time, one chiller would be operating. The central chilling plant is new, having been completely replaced about three years ago. The chillers, condenser and chilled water pumps, and cooling tower fans are provided with frequency-controlled variable speed drives, their capacities being controlled by monitoring the systems' load on the plant. However, at the time of the audit, these energy saving features were not operational. The reason for manual control of the system was that monitoring work was being conducted by the building operators.

Typically, the offices from the second to the fourth levels are divided into four zones on each level, each served by an AHU. The mall meeting rooms on the first story are served by chilled water fan coils while central systems serve the large hall and theatrette. There is also a packaged chiller serving the theatrette. This either augments the central system or operates independent of the central plant during the off period. Finally, there are several unitary air-conditioning units that serve the basement offices and the penthouse.

The plant is operated from 0720 to 1640 hour every weekday, and to 1240 hour on Saturday. On Sundays, the plant is operated from 0830 to 1240 hour. On weekdays, AHU fans serving non-essential zones are switched off for one half hour at 1300 as an energy-conserving means. All the switching operations are controlled from a central programmable time controller.

The electrical consumption profile for the building is shown in Figure B-13. From monthly records of electrical energy use, the annual consumption for the 12 months September 1987 to August 1988 was about 2,037.6 MWh. The base case simulation energy use of the building was 2,608.3 MWh, giving an estimate of about 28% over the metered value. The actual energy intensity was 122 kWh/m^2/year against a value of 142 kWh/m^2/year based on the base case estimate. The energy intensities are computed from the energy consumed by the building per unit conditioned-area over the period of one year.

The energy consumed by the various building services obtained from metered consumption data are shown in Figure B-14. The percentages are as follows:

Air-conditioning plant, including cooling towers	29.0%
AHU fans and general power	21.2%
General Lighting	26.3%
Miscellaneous (lifts, security lighting, water pumps, mechanical ventilation fans, and (stand-alone air-conditioning units)	23.5%

Although the building was completed before the introduction of energy saving measures such as OTTV into Singapore building regulations in 1979, it has several features already incorporated into its design. The list of energy-conserving features noted in the building were:

- Effective shading by the use of side fins and floor overhang on the upper floors.
- Weather seals were installed in all windows.
- Replacement chillers with COP of 5.87. Benefiting from hind-sight, the building operators were able to select the optimum-sized chillers to meet the system demand.
- Use of variable speed controllers for chillers, chilled and condenser water pumps, and cooling tower fans.
- Use of programmable timers for control of the air-conditioning plant and AHU fans. This enabled non-essential zones of the air-conditioning system to be switched off for one half hour during lunch. It was estimated from the monitored energy use profile

that an annual saving of 20,642 kWh or about 1% annual energy saving could be realised by this measure alone.

While most of the energy conservation opportunities listed above are already in practice, there were some areas that could still be considered. Some of these are as follows:

- It was noted that while the average lighting power use intensity was about 12 W/m^2, the luminaires were not giving the necessary lighting level at the working plane because most diffusers were removed. It is recommended that new mirror-optics type luminaires that could produce adequate lighting level while maintaining or even lowering energy use should be considered. It was estimated that a 5% reduction in connected lighting wattage would reduce overall annual consumption by 31 MWh or 1.2% of annual consumption.
- By delaying the start-up of the plant by 15 minutes each day, savings of about 45.6 MWh per year, or 1.8% annual consumption, could be realized.

It was found that savings from other measures were marginal. These included reduction of outside air ventilation rate and increasing wall insulation, among others.

Century Park Sheraton Hotel

The Century Park Sheraton Hotel, Figure B-15, is a deluxe class hotel with 588 guest rooms. It has 28,313 m^2 of conditioned space out of 31,496 m^2 gross area. The hotel was completed in 1976. The building consists of a slightly curved block housing the guest rooms above the slightly larger podium occupied by the public areas and function rooms. The hotel occupancy was above 80%.

The chiller plant serving the AHUs in the public areas and fan coil units in the guest rooms consists of three centrifugal chillers of which one is a stand-by machine. Each machine has a capacity of 915 kW (260 RT) at the rated COP of 4.3. Although the maintenance was generally good, the age of the system has began to affect the building performance. This could be seen in the power consumption profile, Figure B-16, and the percentage use by individual systems in Figure B-17. The consumption profile was regular throughout the week, peaking at 1.3 MW between 1900 to 2200 hour and a minimum of 0.9 MW between 0100 to 0600 hour.

The chiller plant took up 50% of the energy consumed followed by 41% for lighting and power. It was observed that the air-conditioning to the function rooms and restaurants were operating at constant flow throughout the day. Conservation opportunity in the form of reduced air flow to these areas during off-peak hours could be considered. It was also noted that reheat had to be applied in the guest rooms to maintain the relative humidity. There were some problems encountered with formation of moulds in the guest rooms caused by the high humidity. The long-term solution lies in controlling the infiltration to these spaces.

The extensive use of incandescent lighting in the hospitality industry was evident from the results. Some recognition of energy conservation opportunities was shown in the change to fluorescent lamps wherever possible or removal of excessive bulbs where not required. The annual energy intensity was found to be 339 $kWh/m^2/yr$. Computer simulation was not carried out for this audit.

Golden Landmark Hotel

The Golden Landmark Hotel, Figure B-18, was completed in 1988. It has 400 rooms in 12,205 m^2 of conditioned space out of 13,935 m^2 gross area. The hotel is situated in the tower of the Golden Landmark Building. The podium of this building is a shopping complex. Part of the hotel lobby and entrance is in the podium. The hotel has it own mechanical and electrical systems and is functionally independent of the shopping complex.

The chiller plant serving the AHUs in the public areas and the fan coil units in the guest rooms consists of two centrifugal chillers of which one is a stand-by machine. Each machine has a capacity of 1760 kW (500 RT) at the rated COP of 5.1. Hotel operation had only begun shortly before the time of the audit and room occupancy was rather low. This caused the chiller to operate at low partial load and the effect could be seen in the horizontal power consumption profile (Figure B-19). Consequently, the chiller consumed a constant 330 kW, making up to 42% of the total energy (Figure B-20). The consumption profile was regular throughout the week, averaging a low of 700 kW between 0100 to 0600 hour and then gradually increasing throughout the day to peak at about 900 kW between 2100 to 2200 hour.

It was noted that several energy conservation features were incorporated into the design. These included a heat pump for domestic hot water, energy recovery wheel to pre-cool the incoming fresh air supplied to guest rooms with air exhausted from the guest rooms, and a key tag master switch system in all guest rooms to automatically switch off all services in vacant guest rooms.

Figure B-20 also showed that the electrical lighting used 35% of total energy. Some savings could be achieved by replacing incandescent lamps with fluorescent ones. Computer simulation was not carried out.

School of Accountancy, NTI

The School of Accountancy Building in Nanyang Technological Institute was completed in June 1987. It has 6 stories designated as storey 1, and B1 to B5. The building houses the School's administrative offices, staff offices, a three-story library, two 350 seat lecture theatres, tutorial rooms, and a computing laboratory in 11,577 m^2 conditioned space out of 19,440 m^2 gross area. The long axis of the building is parallel to the east-west direction, thus all windows faces the north or south direction only. In addition, the windows are well-shaded with a 1.2 m or more setback from the building structure line. All walls are either made of plastered brickwork or 100 mm thick concrete with plaster. Figure B-21 shows the general outline and plan of the building.

The building is served by its own electrical system and air-conditioning plant. The plant consists of three centrifugal chillers of 1056 kW capacity (300 RT) each, one being a stand-by unit. The chillers' COP is 4.98. The offices are served by a variable air volume system, while the lecture theatres have constant volume systems with face-and-bypass control, and a constant volume system serving the library has reheat control. During term time, the plant is operated from 0800 till 2130 on weekdays, and to 1700 on Saturdays. However, only the air-conditioning to the library is in use outside of normal working hours. During vacation, the operating hours are shortened considerably. The building is lit almost entirely with fluorescent lighting and has a lighting density of about 12 W/m^2.

The building did not have detailed energy billings because all electricity consumed is consolidated under the Institute's account. Nevertheless, during two months of short term monitoring, it was possible to estimate the annual energy intensity to be about 227 $kW/m^2/yr$. The electrical consumption profile is shown in Figure B-22. Energy monitoring has shown that there was unscheduled operation of the plant outside the normal schedules. This was brought to the attention of the maintenance staff.

The energy consumed by the various services is shown in Figure B-23. These are as follows:

Air-conditioning plant	50.2%
AHU fans	21.5%
Lighting	21.5%
Equipment and power (including lifts)	6.8%

Computer simulation was not carried out.

CONCLUSION

The project had established an indicator of the energy performance in Singapore office buildings at 210 $kWh/m^2/yr$. This was found to be about 15% lower than the ASEAN average for office buildings. Broad guidelines for energy management and conservation were also developed from the results of building energy audits and computer simulations. The project has shown the way for future work on establishing indicators for other building types and on establishing energy targets on building energy performance.

Other achievements of the project may be summarised as follows:

- Dissemination of information to professionals on energy usage in buildings through seminars, and through publication of technical papers in proceedings of conferences (See List of Publications at the end of this Appendix).
- Transfer of knowledge on building energy auditing through participation in courses under the ASEAN project (See Courses Attended section at the end of this chapter), and through experience gained on the field.
- The creation of the ASEAN Commercial Building Energy Database for reference and further work by researchers and professionals.
- Transfer of ASEAM-2.1 software analysis tool to Singapore.

Several valuable contacts had been established during the many opportunities provided during courses, conferences, and collaboration with the following organisations:

With the United States:

- Lawrence Berkeley Laboratory, University of California.
- ASEAM-2 and audit course supervisors in W.S. Fleming and Associates, Inc., Albany, NY.

Within ASEAN:

- Universiti Teknologi Malaysia, Malaysia
- King Mongkut's Institute of Technology, Thonburi, Thailand
- Chiang Mai University, Thailand
- Departmen Pekerjaan Umum, Direktorat Jendral Cipta Karya, Direktorat Tata Bangunan, Indonesia

Within Singapore:

- The Building Control Division, Public Works Department, Ministry of National Development
- Public Utilities Board

REFERENCES

1. Wong, Y.W., "An Energy Index for Office Buildings in Singapore," Proceedings of the 4th ASEAN Energy Conference - Energy Technology, Singapore: ASEAN Working Group on Non-conventional Energy Research, 1987.
2. Wong, Y.W., "Energy Performance of Office Buildings in Singapore," *ASHRAE Transactions,* Vol. 94, Part 2, 1988.
3. Levine, M.D., Busch, J.F., and Deringer, J.J., "Overview of Building Energy Conservation Activities in ASEAN," Proceedings of the ASHRAE Far East Conference on Air Conditioning in Hot Climates, Kuala Lumpur Malaysia, 1989.
4. Fireovid, J.A. and Fryer, L.R. "ASEAM-2.1 - A Simplified Energy Analysis Method - User Manual," American Consulting Engineers Research and Management Foundation, 2nd Ed., Washington DC, 1987.
5. "The Building Control Regulations, 1989," Government Gazette No. 15, Singapore, 1989.

LIST OF PUBLICATIONS

1. Wong, Y.W., "An Energy Index for Office Buildings in Singapore," Proceedings of the 4th ASEAN Energy Conference - Energy Technology, Singapore: ASEAN Working Group on Non-conventional Energy Research, 1987.
2. Wong, Y.W., "Energy Performance of Office Buildings in Singapore," *ASHRAE Transactions,* Vol. 94, Part 2, 1988.
3. Wong, Y.W., "Energy Conservation in Buildings through the Energy Audit," DTG Technology Seminar on Building and Infrastructure, Ministry of Defence, Singapore, 1989.

COURSES ATTENDED

1. Building Energy Audit Course, Kuala Lumpur, Malaysia, September 14 - 25, 1987 conducted by W.S. Fleming and Associates, Albany, NY.
2. Advanced Energy Audit Course, Singapore, November 7 - 18, 1988 conducted by W.S. Fleming and Associates, Albany, NY.

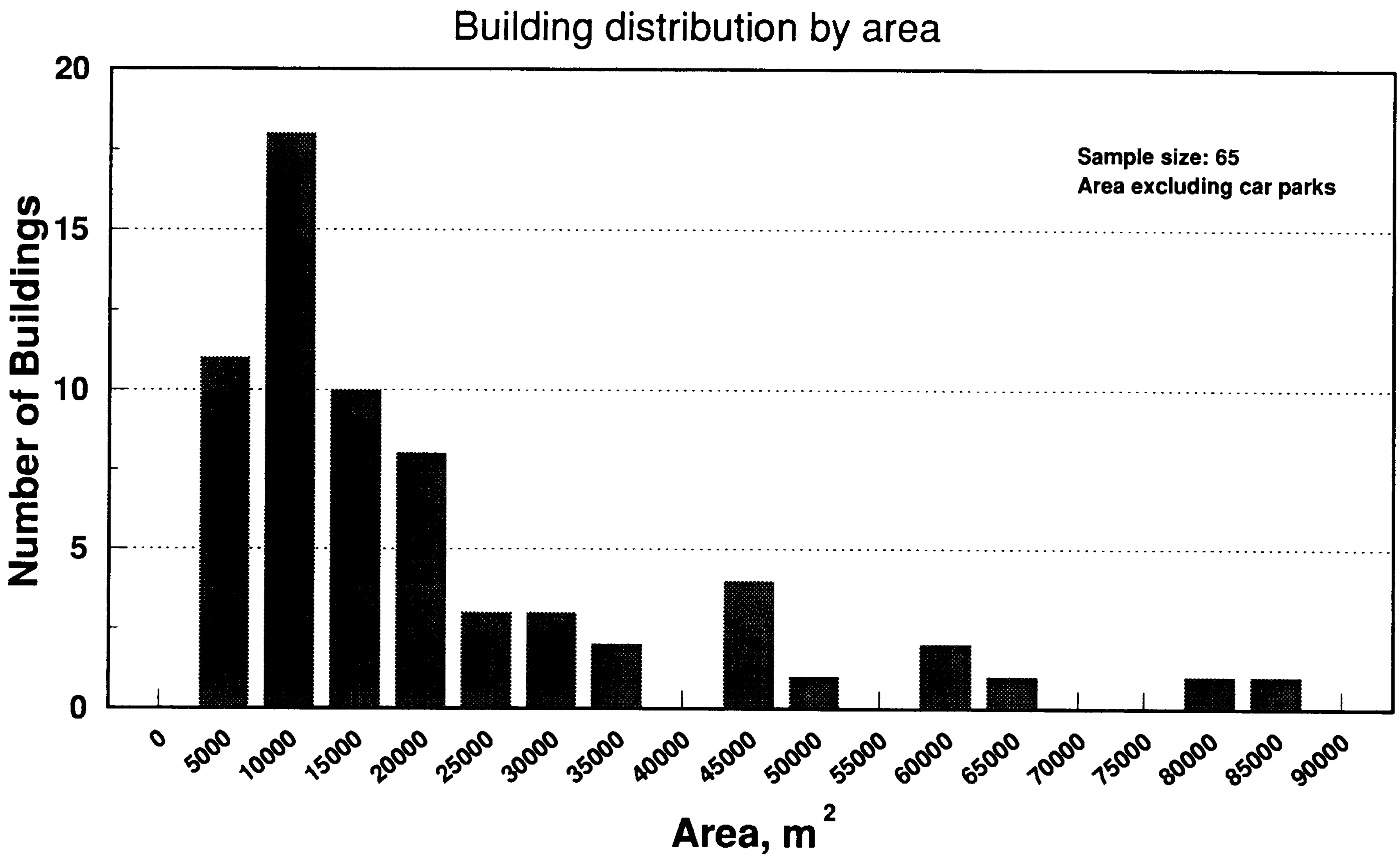

Building distribution by area
Sample size: 65
Area excluding car parks
Number of Buildings
0
5
10
15
20
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
60000
65000
70000
75000
80000
85000
90000
Area, m 2

Figure B-1

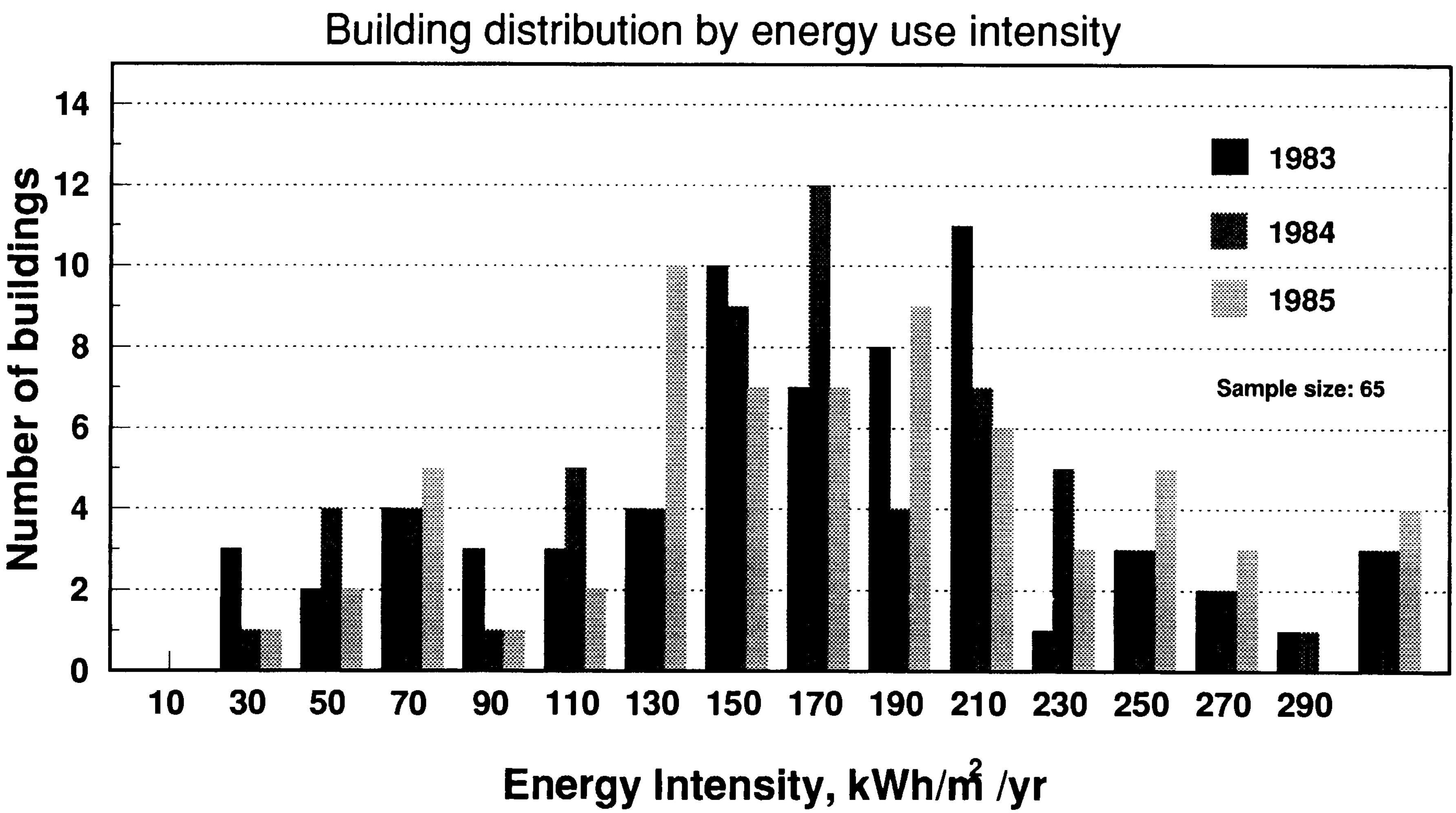

Building distribution by energy use intensity
Number of buildings
0
2
4
6
8
10
12
14
1983
1984
1985
Sample size: 65
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
Energy Intensity, kWh/m2 /yr

Figure B-2

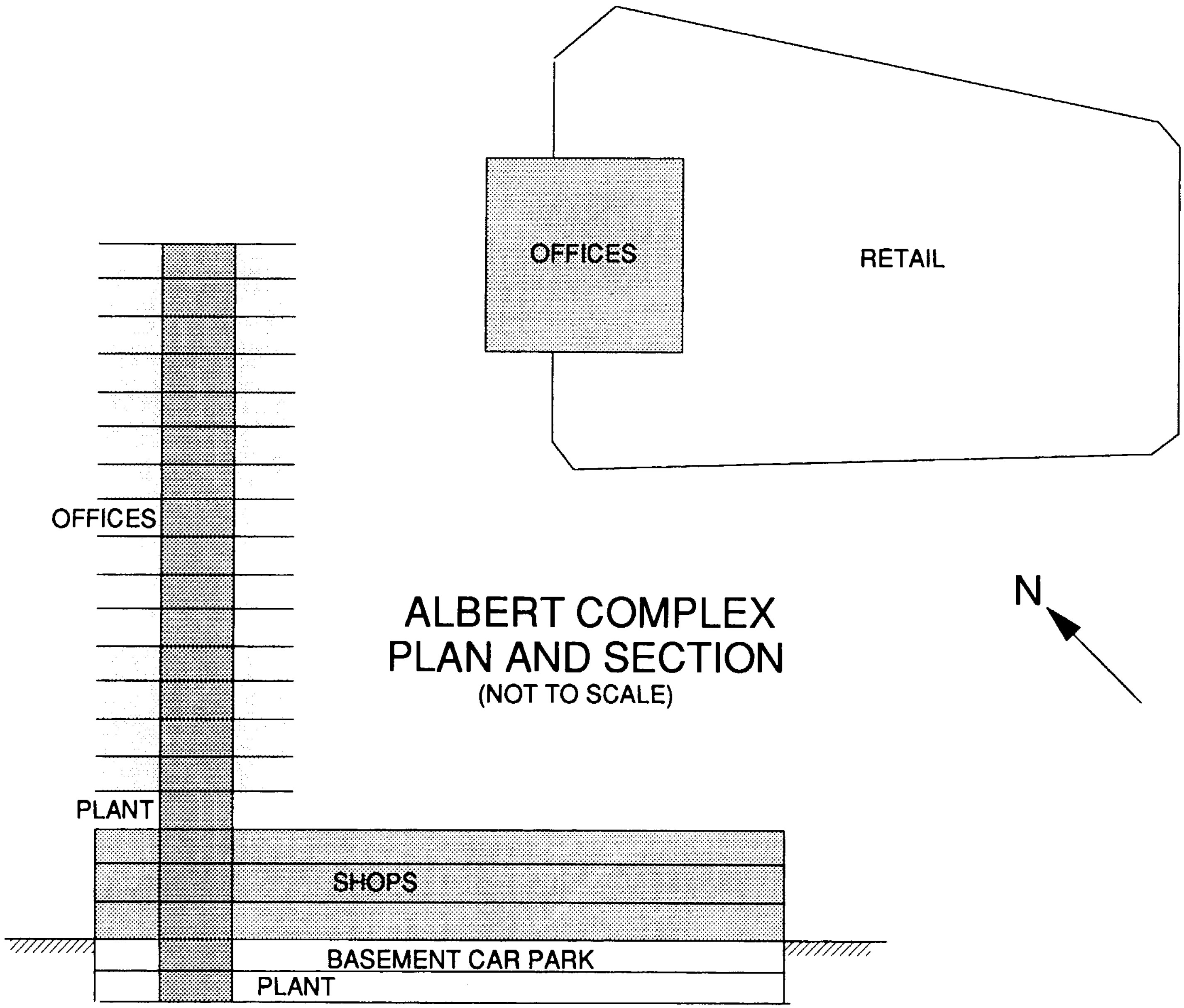

OFFICES
RETAIL
OFFICES
PLANT
SHOPS
BASEMENT CAR PARK
PLANT
ALBERT COMPLEX
PLAN AND SECTION
(NOT TO SCALE)
N

Figure B-3

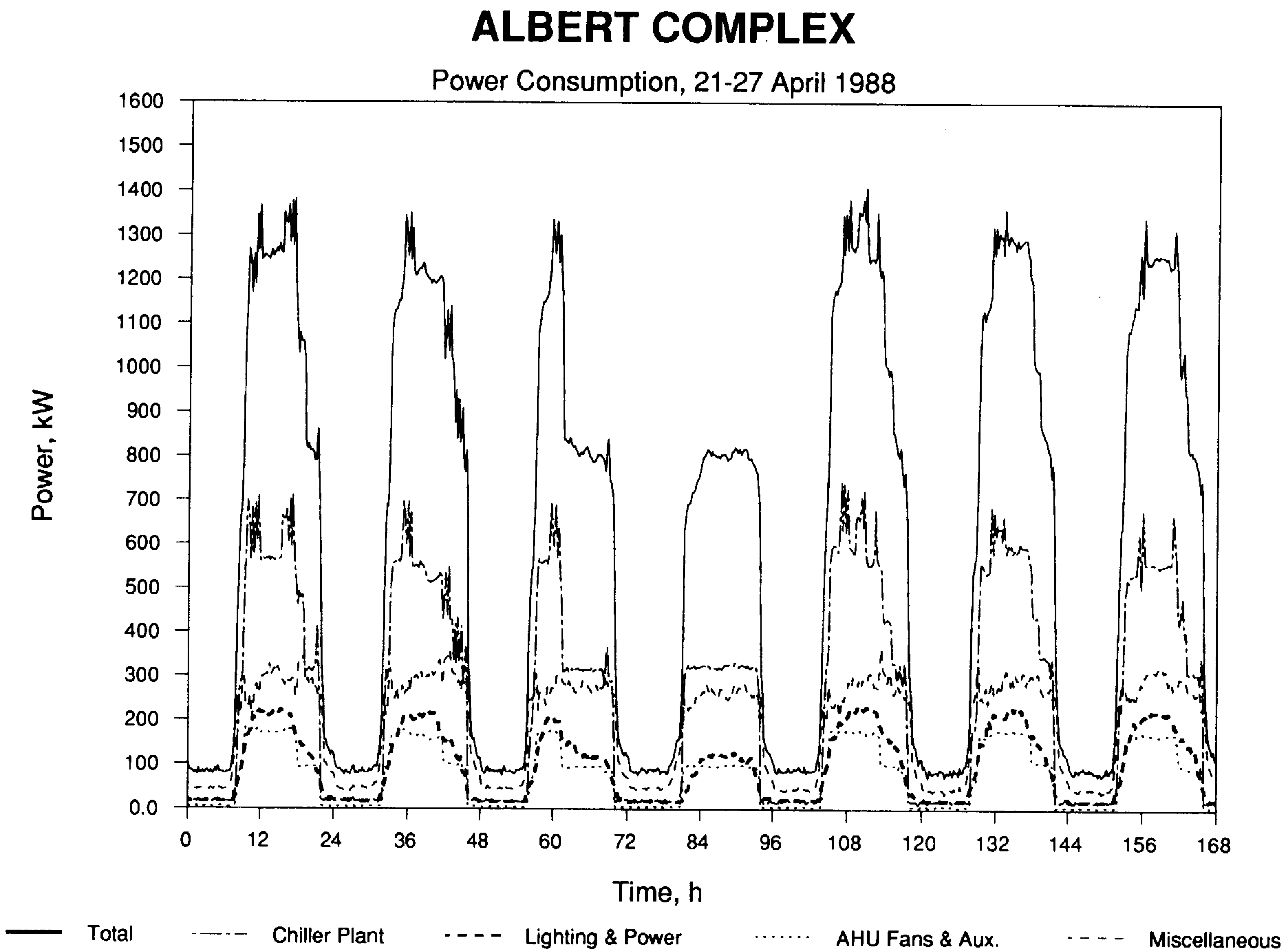

ALBERT COMPLEX
Power Consumption, 21-27 April 1988
Power, kW
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0.0
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
Time, h
Total
Chiller Plant
Lighting & Power
AHU Fans & Aux.
Miscellaneous

Figure B-4

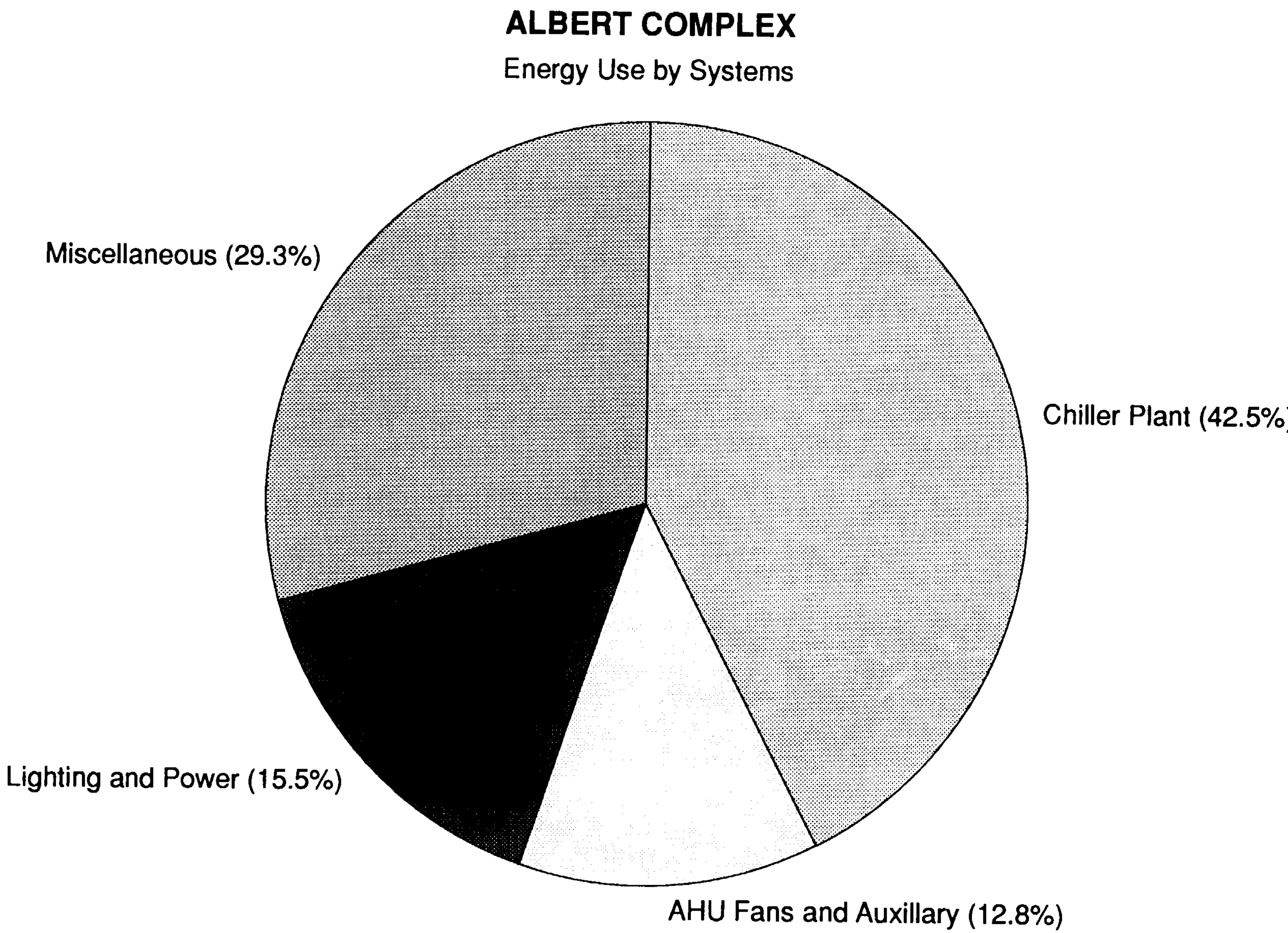
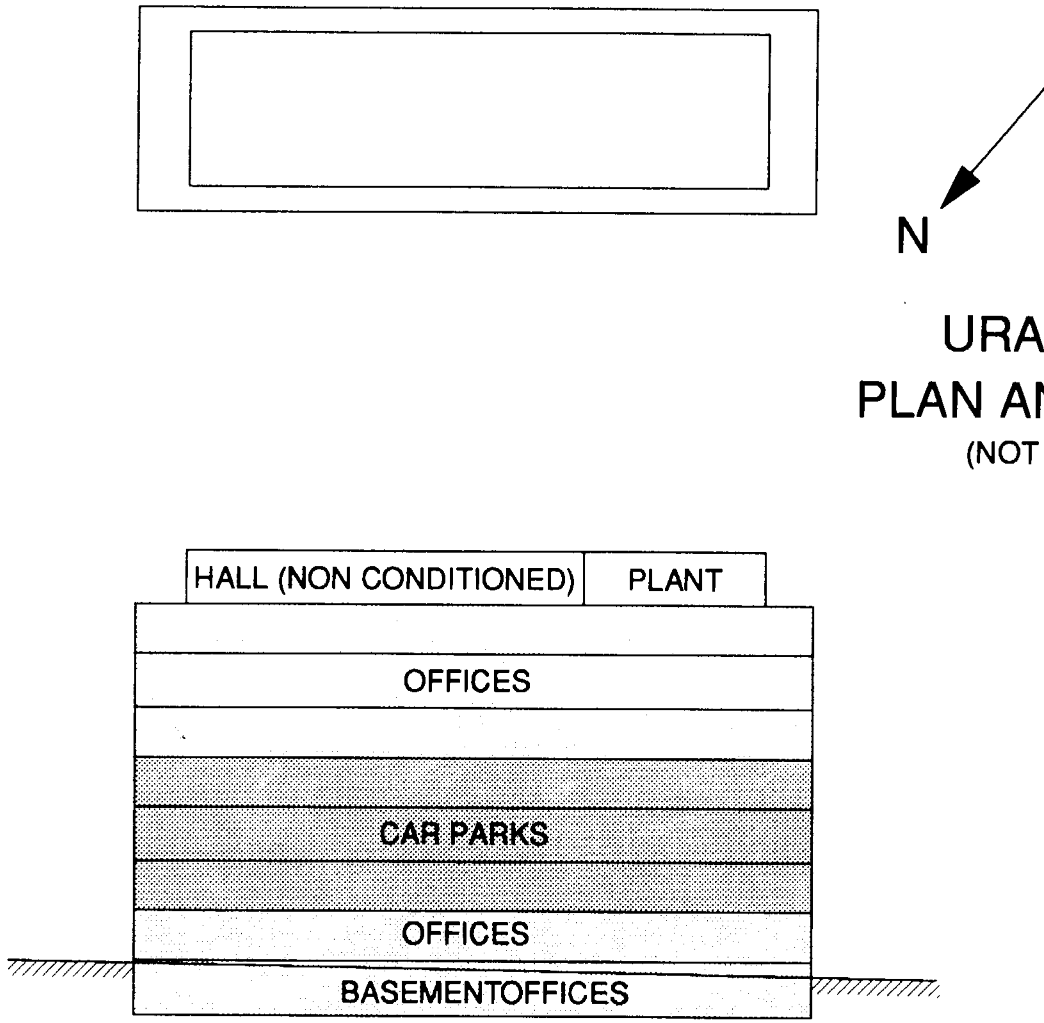

ALBERT COMPLEX
Energy Use by Systems
Miscellaneous (29.3%)
Chiller Plant (42.5%)
Lighting and Power (15.5%)
AHU Fans and Auxillary (12.8%)

Figure B-5



URA BUILDING
PLAN AND SECTION
(NOT TO SCALE)

Figure B-6

URA BUILDING

Power Consumption, 21-27 March 1988

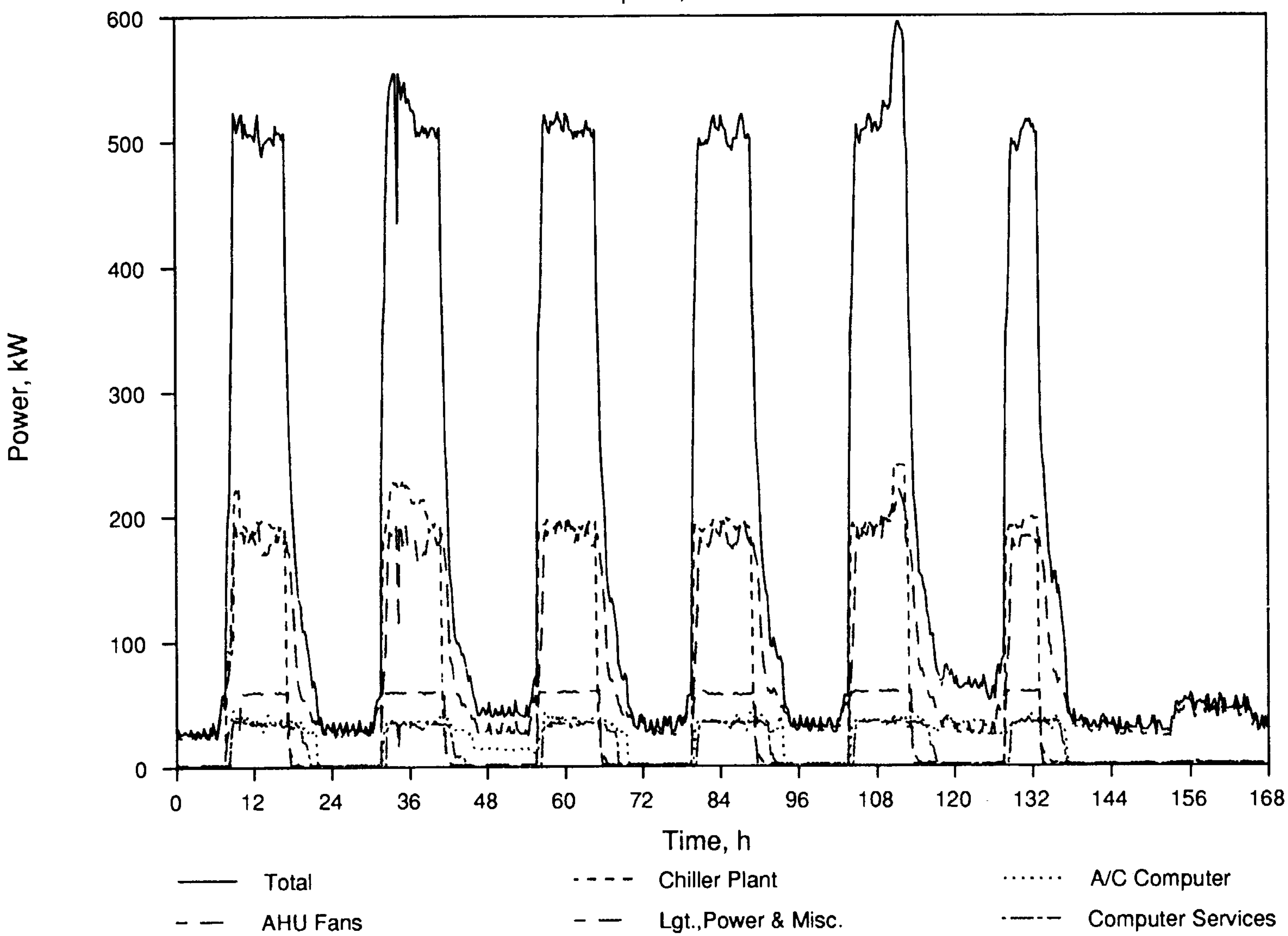


Figure B-7

URA BUILDING

Energy Use by Systems

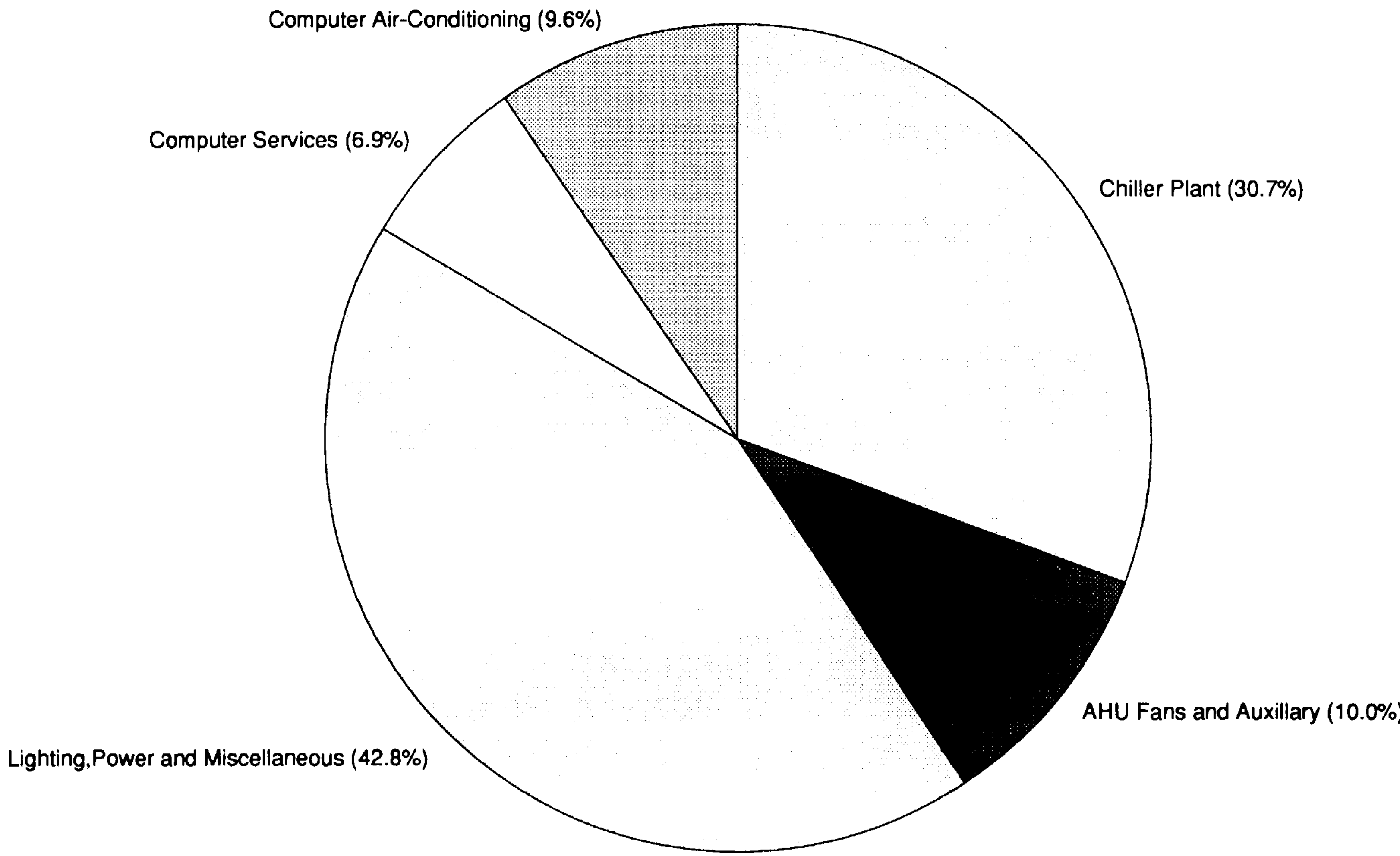


Figure B-8

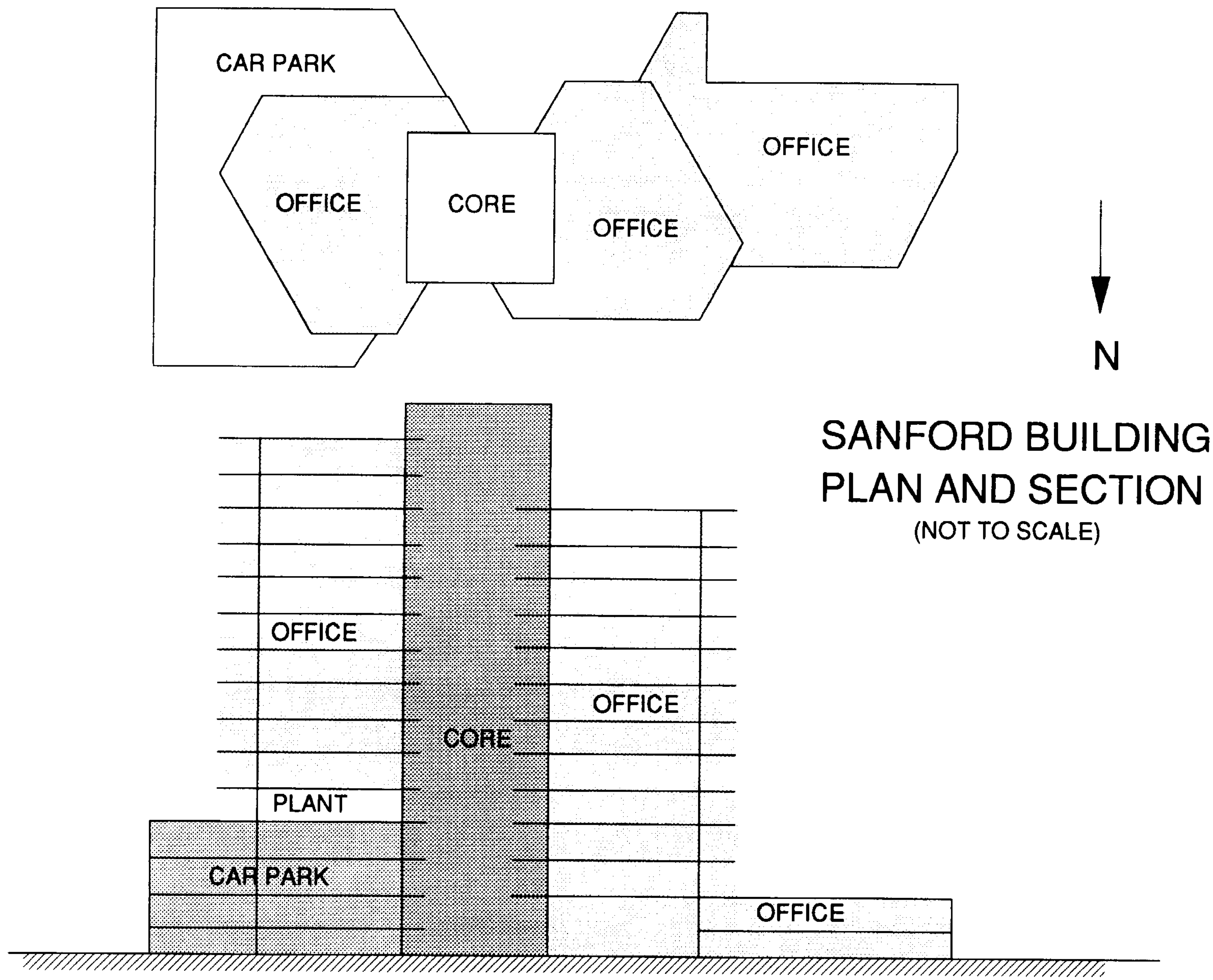

CAR PARK
OFFICE
CORE
OFFICE
OFFICE
N
SANFORD BUILDING
PLAN AND SECTION
(NOT TO SCALE)
OFFICE
CORE
OFFICE
PLANT
CAR PARK
OFFICE

Figure B-9

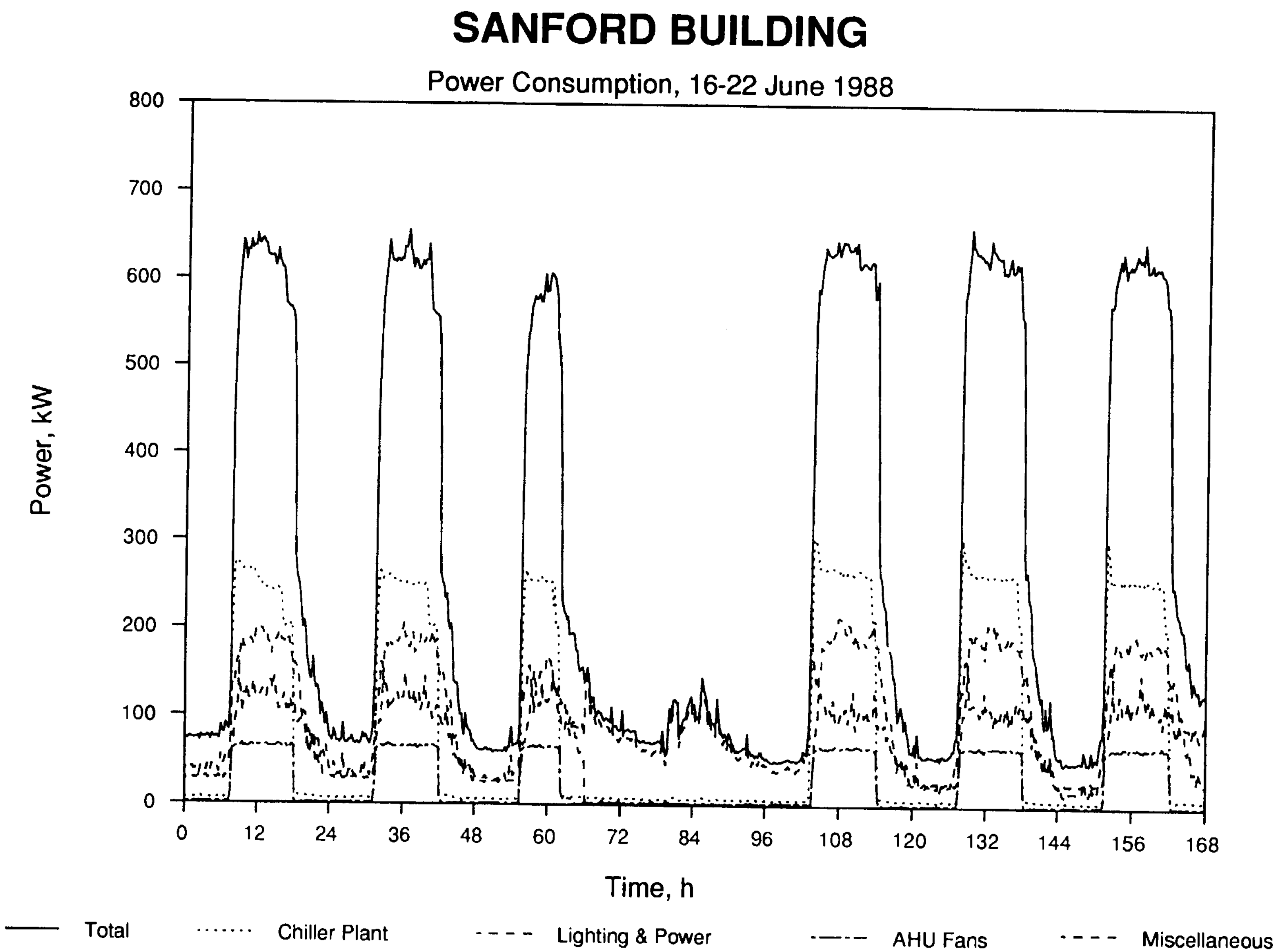

SANFORD BUILDING
Power Consumption, 16-22 June 1988
Power, kW
800
700
600
500
400
300
200
100
0
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
Time, h
Total
Chiller Plant
Lighting & Power
AHU Fans
Miscellaneous

Figure B-10

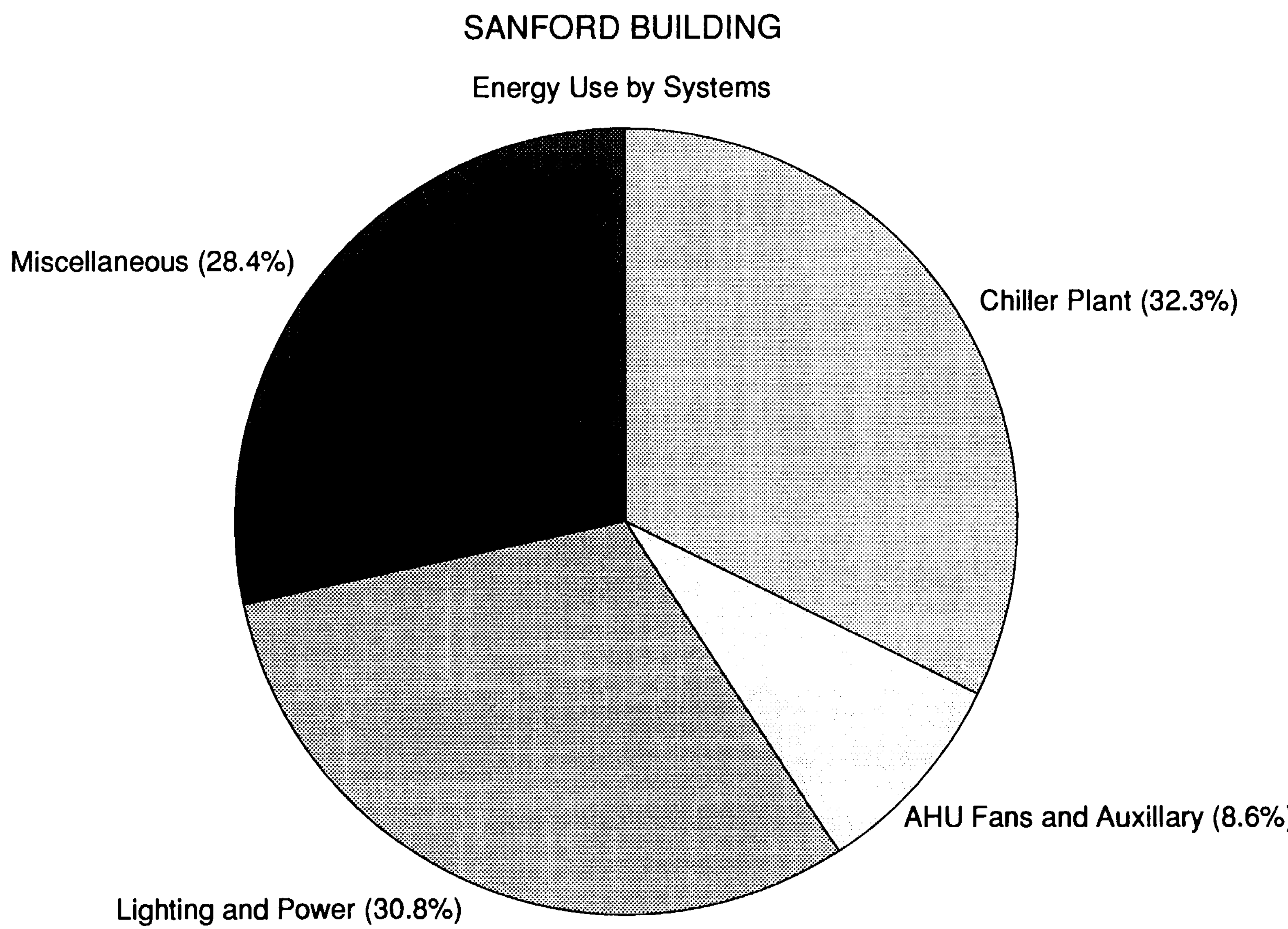

SANFORD BUILDING
Energy Use by Systems
Miscellaneous (28.4%)
Chiller Plant (32.3%)
AHU Fans and Auxillary (8.6%)
Lighting and Power (30.8%)

Figure B-11

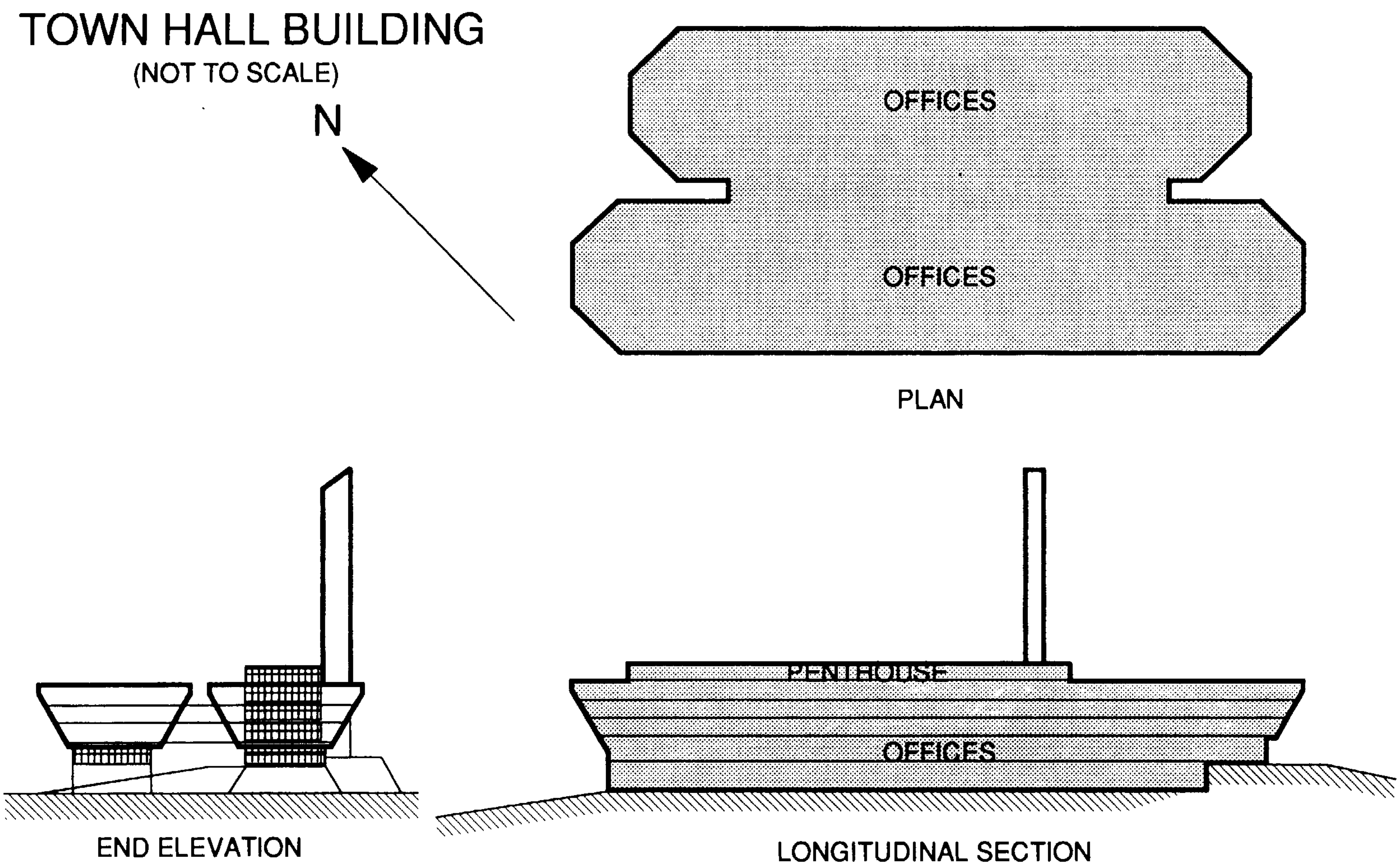

TOWN HALL BUILDING
(NOT TO SCALE)
N
OFFICES
OFFICES
PLAN
PENTHOUSE
OFFICES
END ELEVATION
LONGITUDINAL SECTION

Figure B-12

JTC BUILDING

Power Consumption, 23-29 November 1988

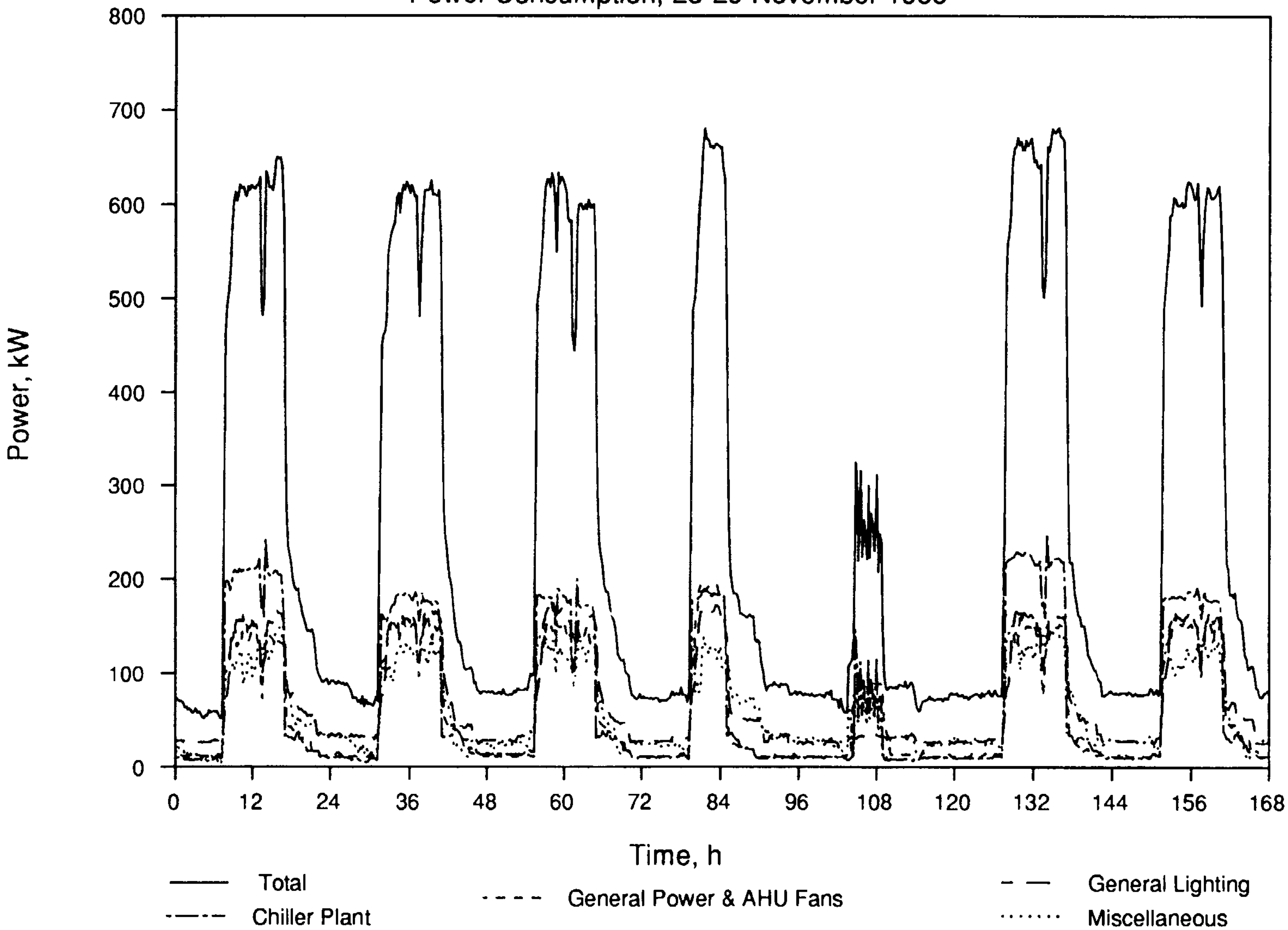


Figure B-13

JTC BUILDING

Energy Use By Systems

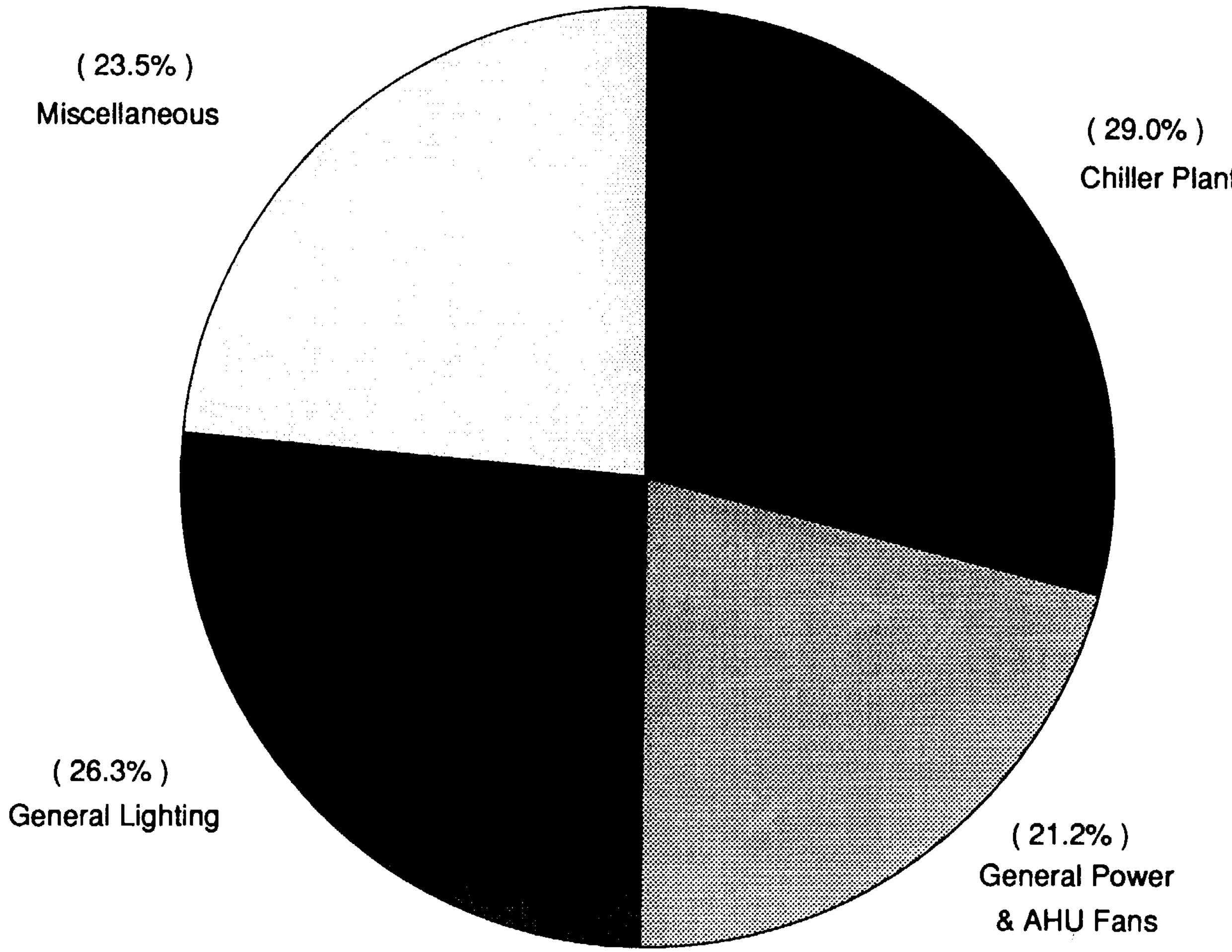
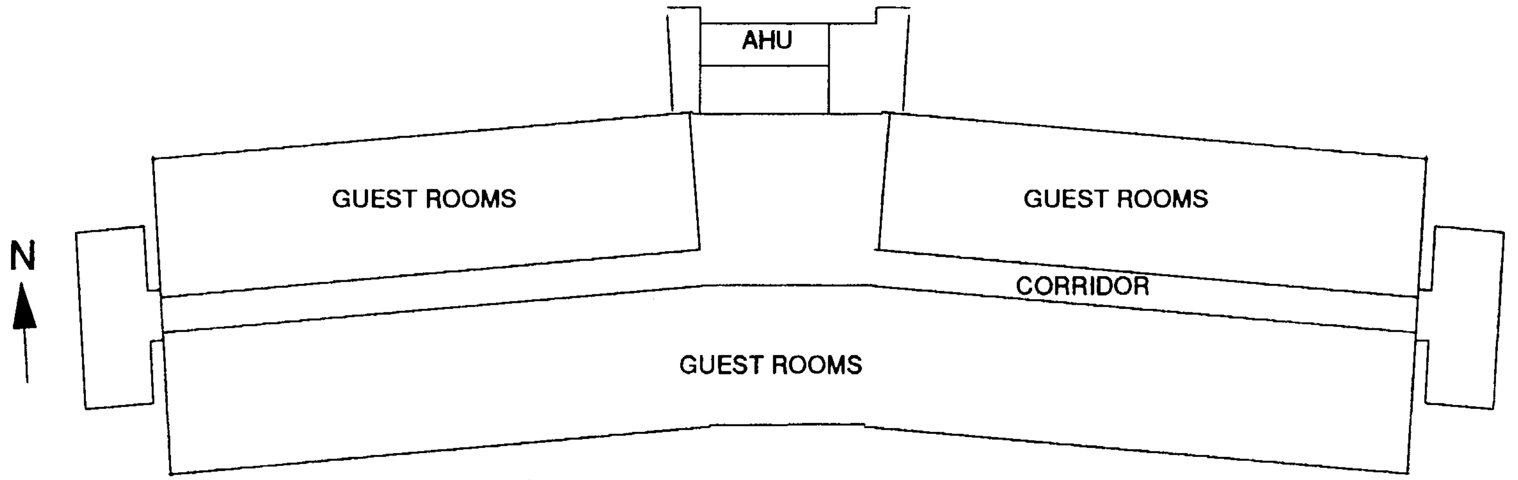


Figure B-14



CENTURY PARK SHERATON
PLAN AND SECTION
(NOT TO SCALE)

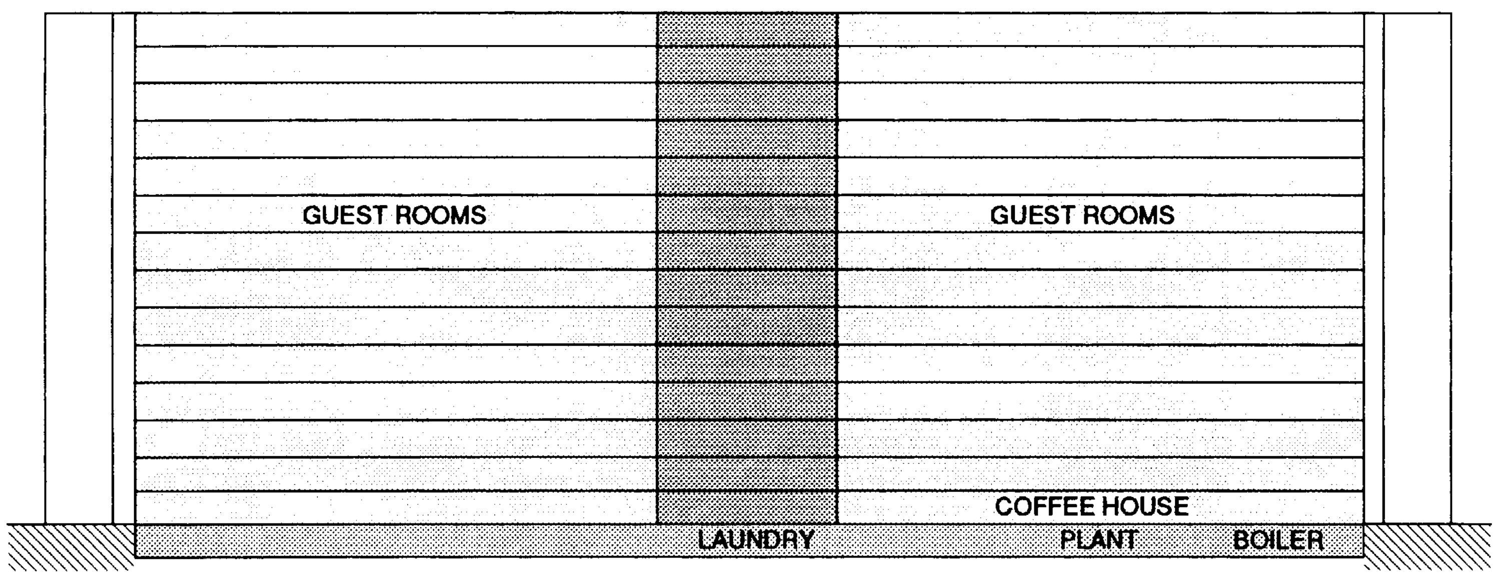


Figure B-15

Century Park Sheraton

Power Consumption, 5-11 July 1989

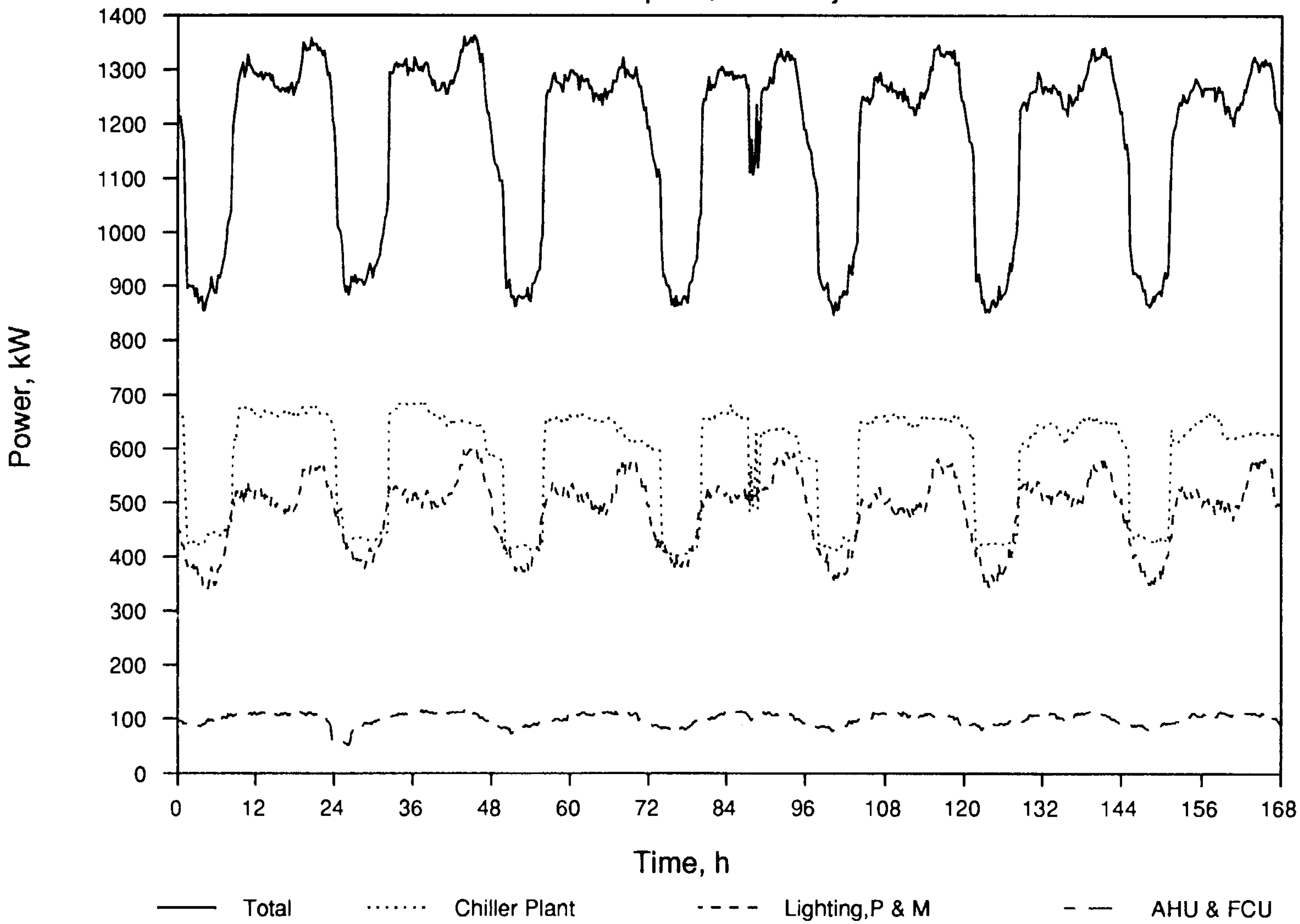


Figure B-16

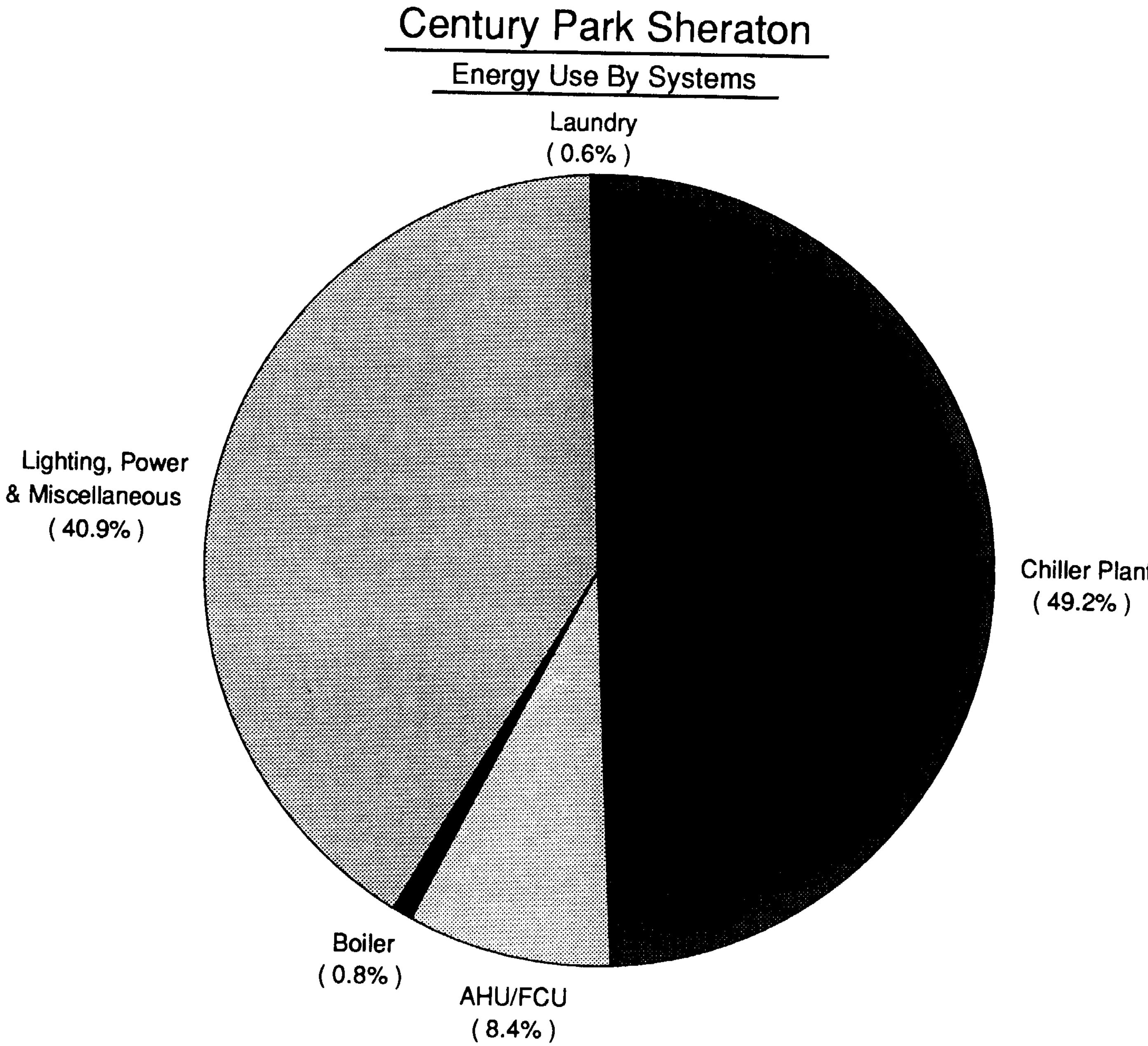

Century Park Sheraton
Energy Use By Systems
Laundry
(0.6%)
Lighting, Power
& Miscellaneous
(40.9%)
Chiller Plant
(49.2%)
Boiler
(0.8%)
AHU/FCU
(8.4%)

Figure B-17

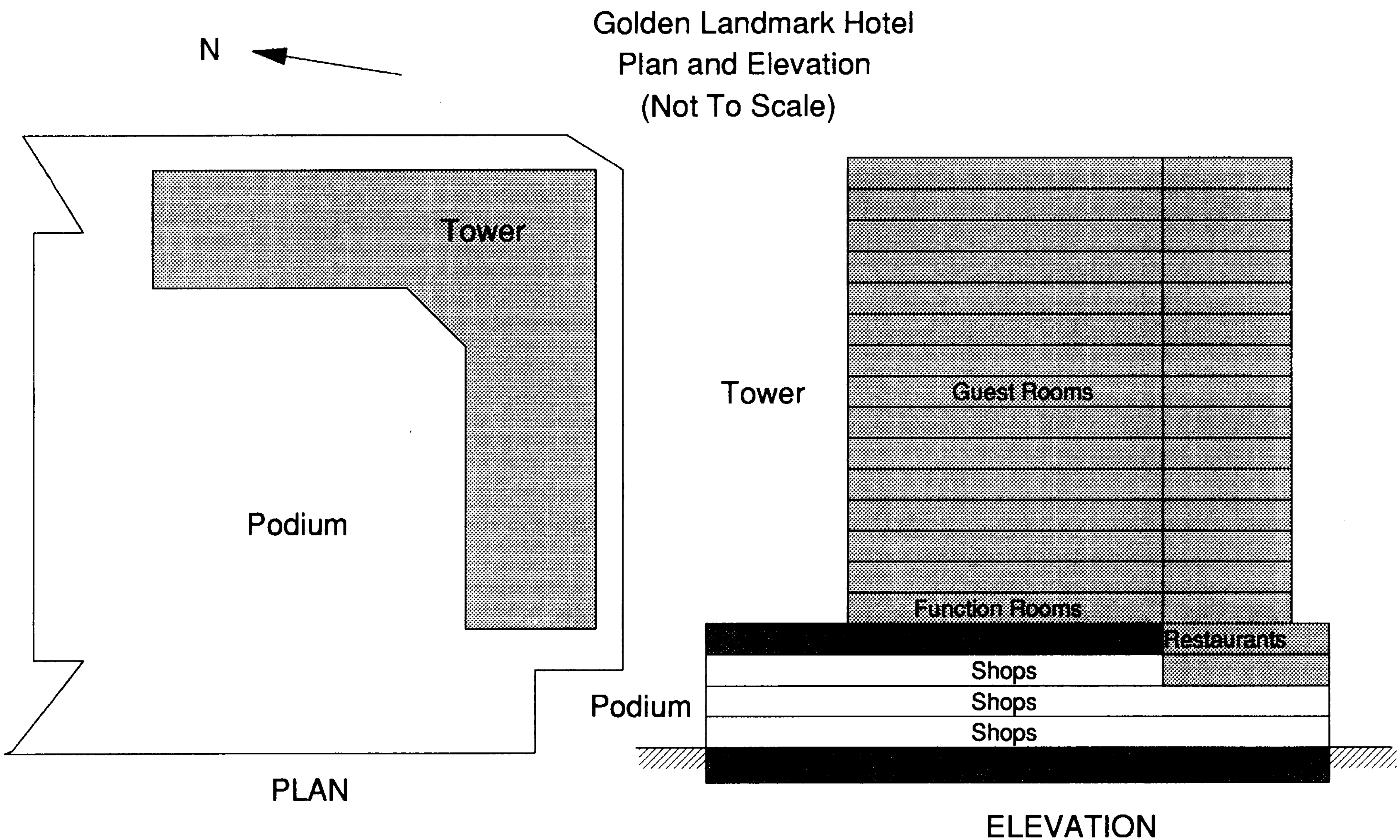

Golden Landmark Hotel
Plan and Elevation
(Not To Scale)
N
Tower
Podium
PLAN
Tower
Guest Rooms
Function Rooms
Restaurants
Shops
Shops
Shops
Podium
ELEVATION

Figure B-18

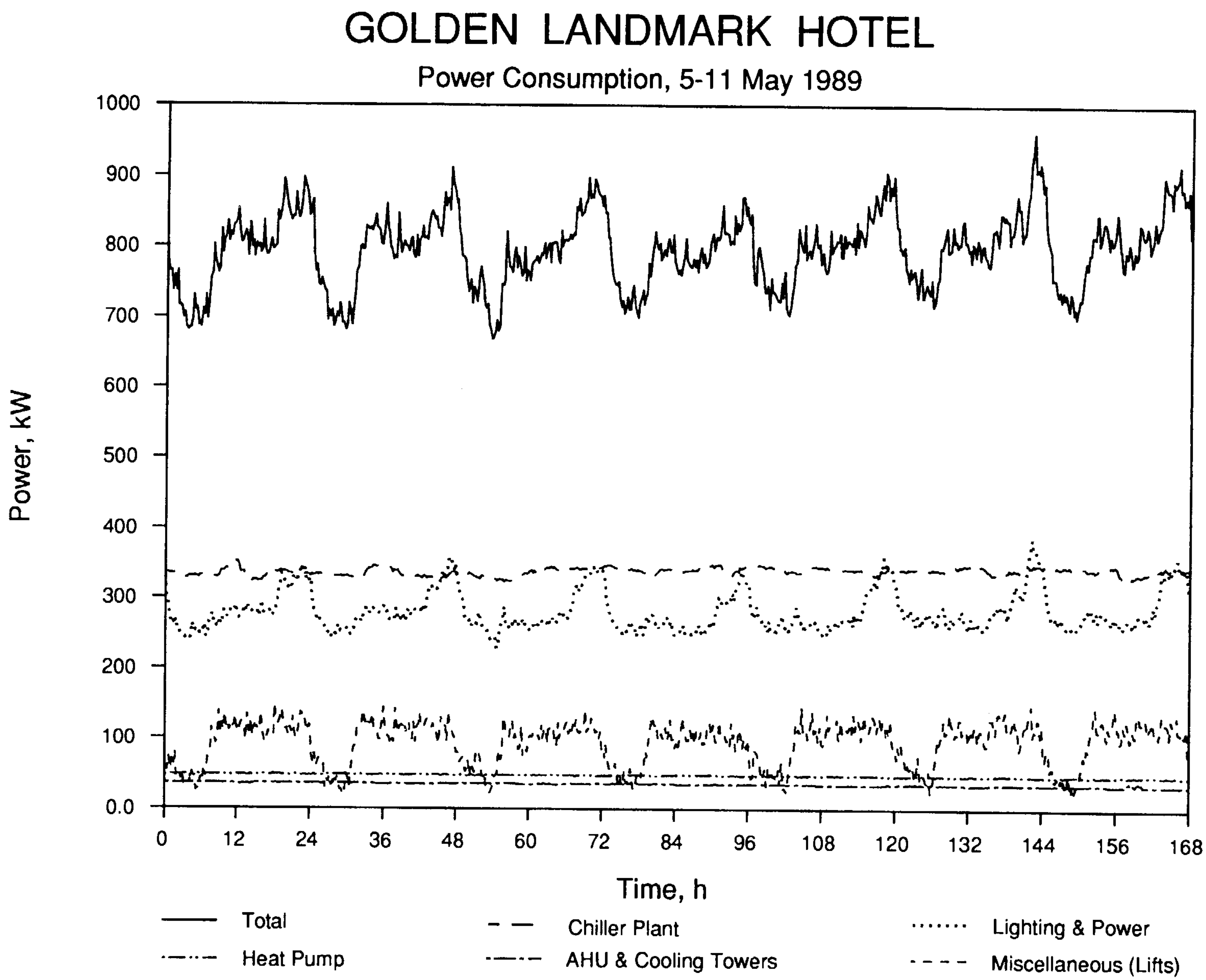

GOLDEN LANDMARK HOTEL
Power Consumption, 5-11 May 1989
Power, kW
1000
900
800
700
600
500
400
300
200
100
0.0
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
Time, h
Total
Chiller Plant
Lighting & Power
Heat Pump
AHU & Cooling Towers
Miscellaneous (Lifts)

Figure B-19

GOLDEN LANDMARK HOTEL

Energy Use By Systems

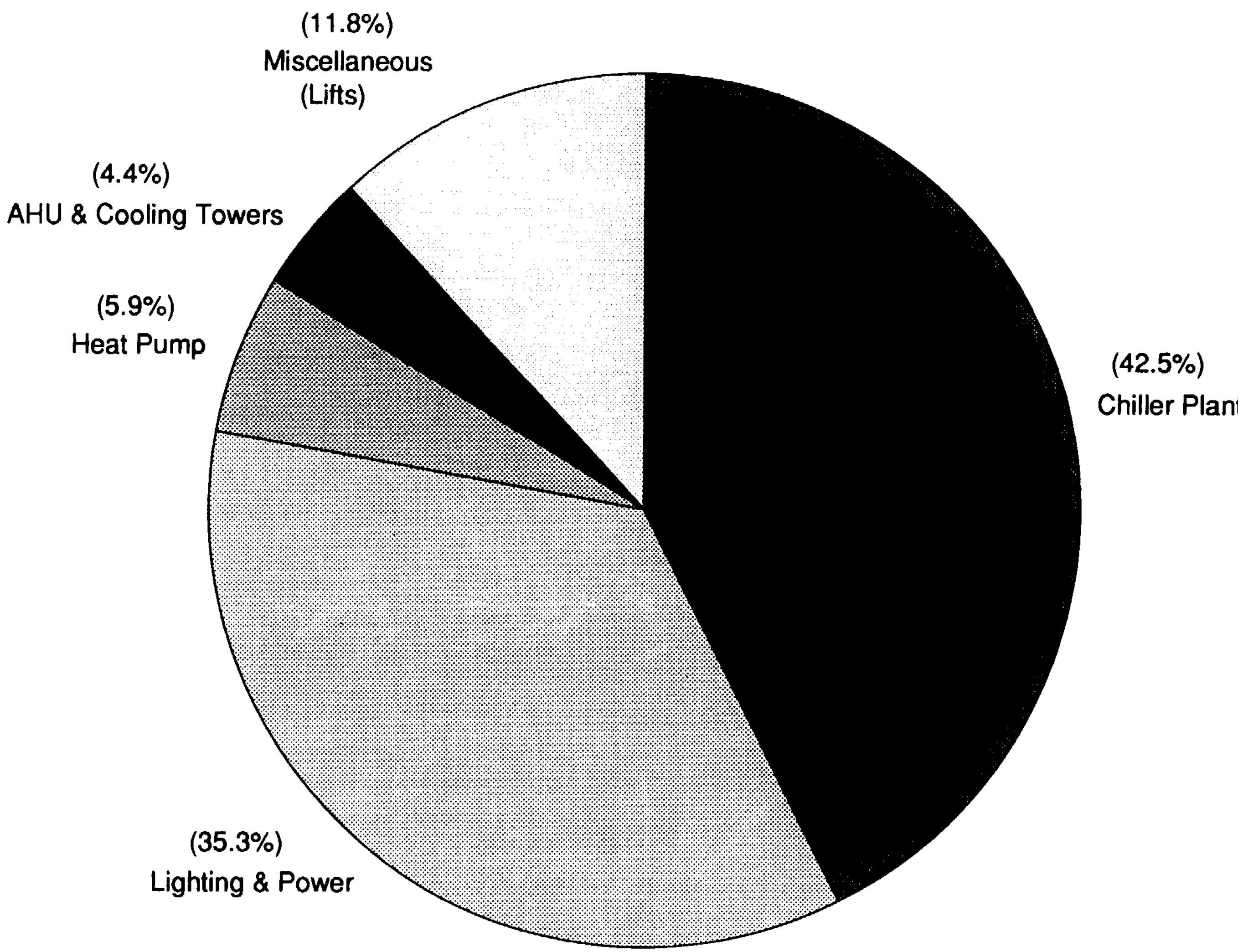
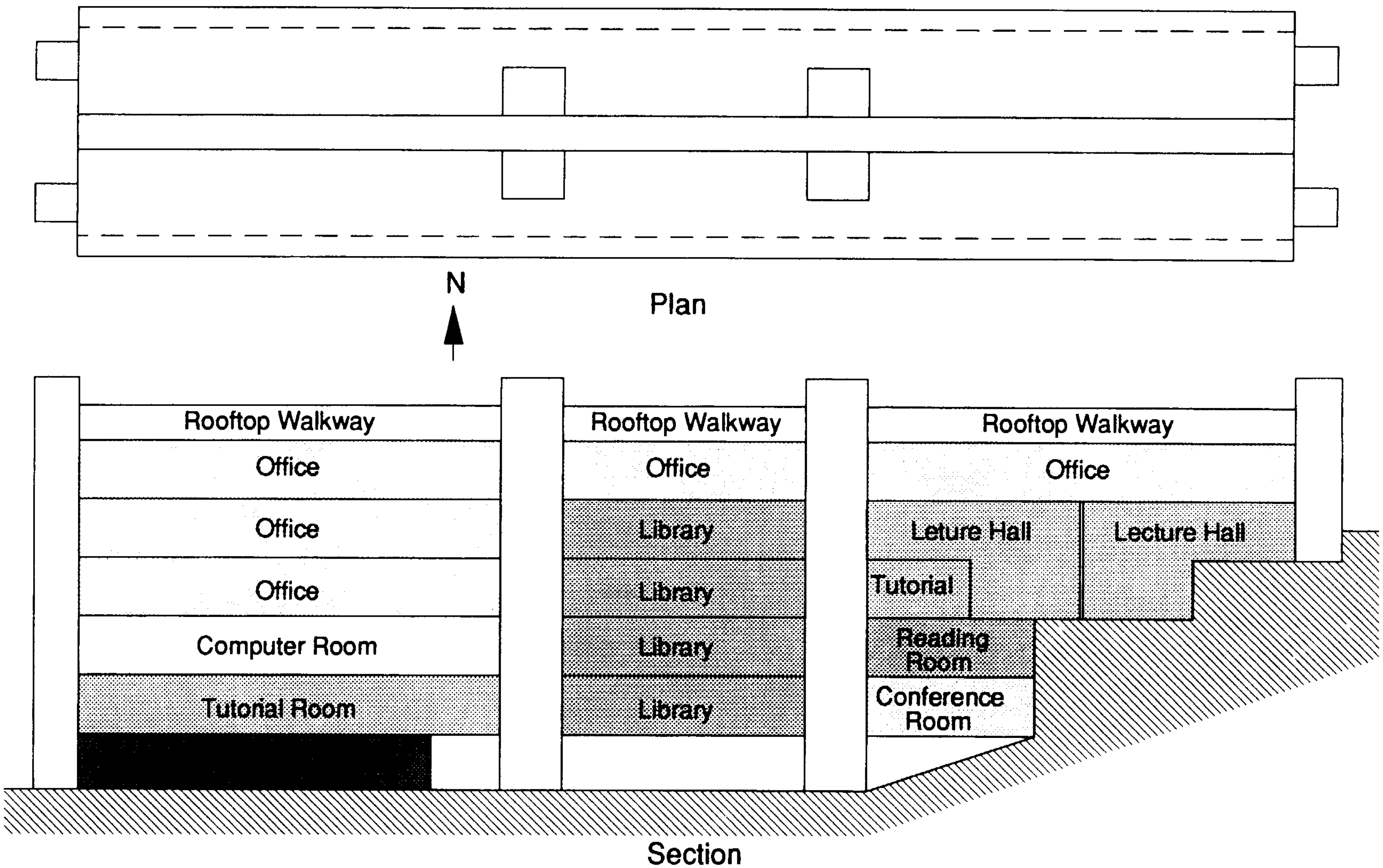


Figure B-20



School of Accountancy, NTI
(Not to Scale)

Figure B-21

School Of Accountancy & Commerce

Power Consumption, 4-10 September 1989

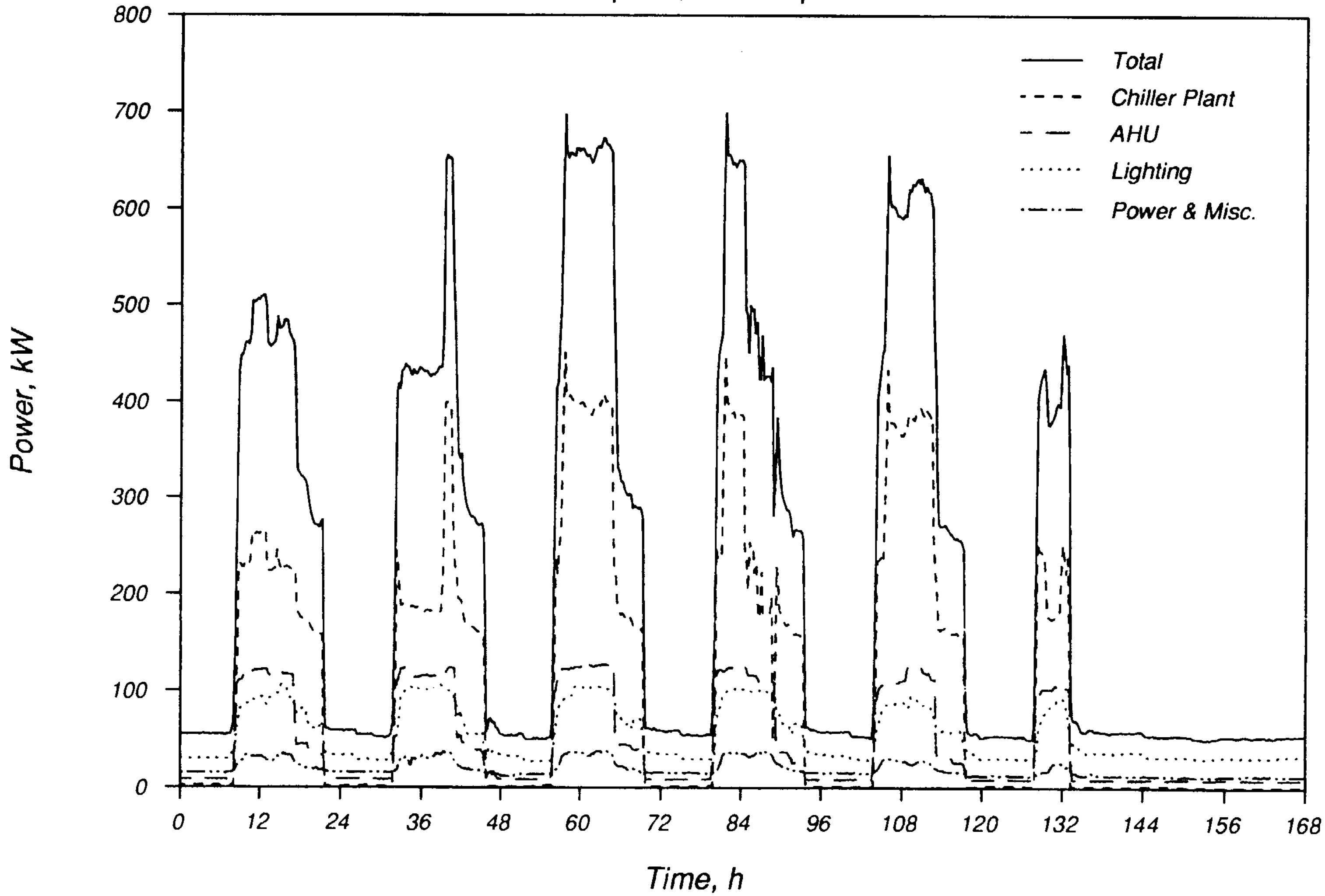


Figure B-22

School Of Accountancy & Commerce

Energy Use By Systems

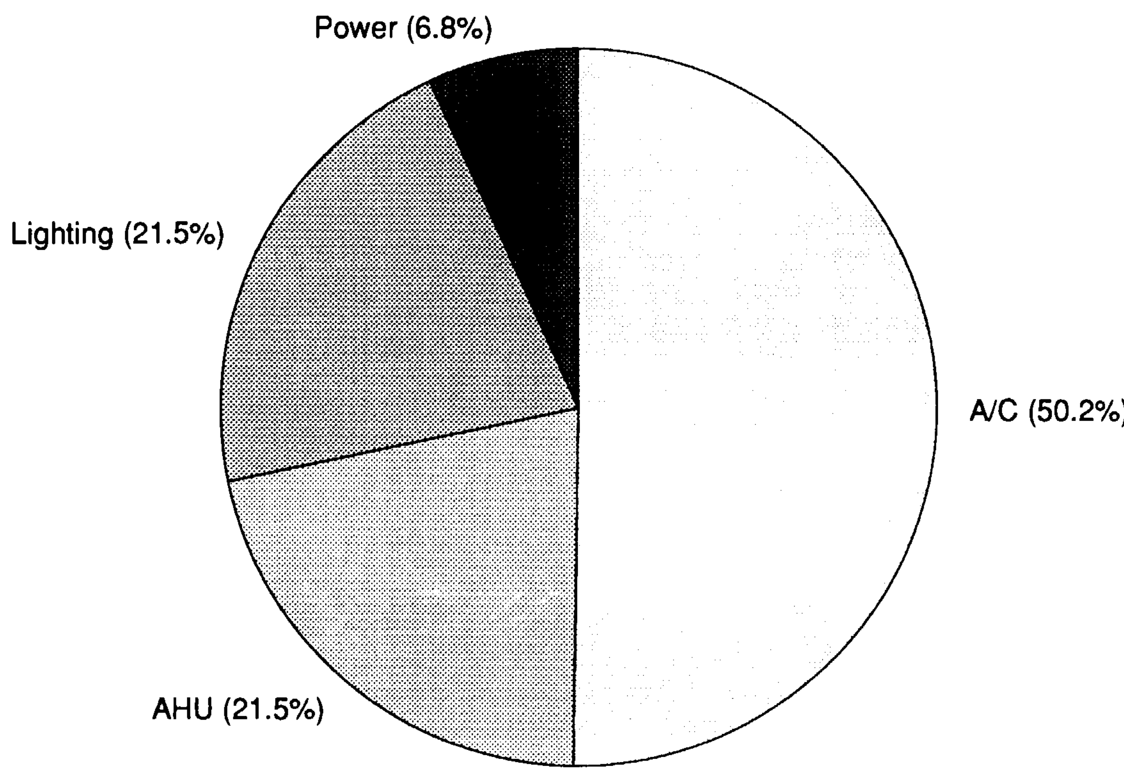


Figure B-23

Table B-1. Summary of Postal Survey Results

Total questionnaires posted	81
Total replies received	38 (100%)
Buildings with energy conservation programs	17 (45%)
Buildings with computerised building management systems	6 (16%)
Buildings with significant loads from computers	14 (37%)
Average workday	9.8 hours

Table B-2. Summary of Office Buildings Monitored

Building	Albert Complex		URA Building	Sanford Building	Jurong Town Hall
Type	Office	Retail	Office	Office	Office
Gross Area	14,784 m^2	21,308 m^2	18,887 m^2	22,233 m^2	22,300 m^2
Conditioned Area	14,129 m^2	12,454 m^2	11,987 m^2	11,357 m^2	16,700 m^2
Year Completed	1987		1978	1983	1975
Envelope	Curtain wall Double glazed	Curtain wall Double glazed	Brick infill walls Single glazed with solar film	Semi curtain wall Single glazed heat absorbing	Brick infill walls Single glazed tinted
Plant schedules Weekday Saturday Sunday	 0800 - 1900 0800 - 1300 Not Operating	 0900 - 2145 0900 - 2145 0900 - 2145	 0730 - 1645 0730 - 1300 Not Operating	 0715 - 1800 0715 - 1400 Not Operating	 0720 - 1640 0720 - 1240 0830 - 1240
HVAC system	Constant Volume	Constant Volume	Constant Volume	Varaible Volume	Constant Volume
Chiller Rated COP	4.81	4.84	4.2	4.7	5.87
Annual Energy Use Intensity	96.9 kWh/m^2/yr	319.6 kWh/m^2/yr	131.2 kWh/m^2/yr	201.9 kWh/m^2/yr	122.0 kWh/m^2/yr
Energy Conservation Measures	- High efficiency fluorescent fittings	- High efficiency fluorescent fittings	- Extensive window shading - Solar control film on windows - De-lamping	- High efficiency fluorescent lighting - Chiller optimization	- Chiller optimization - High chiller COP - Variable speed pumps - Extensive window shading - Shut down AHU fans during lunch hour - Programmable timers to operate fans
Recommendation	NIL	- Shorten hours for external decorative lighting - Reduce plant operation by 1 hour	- Replace chiller with higher COP - Install high efficiency fluorescent lighting - Shut off air-conditioning to computer room when system shuts down	- Reduce plant operation by 1 hour	- Install high efficiency fluorescent lighting

Table B-3. Summary of Other Building Types Monitored

Building	Century Park Sheraton	Golden Landmark Hotel	School of Accountancy
Type	Hotel	Hotel (Tower only)	Educational
Gross Area	31,496 m^2	13,935 m^2	19,440 m^2
Conditioned Area	28,313 m^2 (588 rooms)	12,205 m^2 (400 rooms)	11,577 m^2
Year Completed	1976	1988 (Tower)	1987
Envelope	Brick infill wall Single glazed tinted	Semi curtain wall Single glazed tinted	Brick infill walls Single glazed tinted
Plant schedules Weekday Saturday Sunday	Continuous	Continuous	 0800 - 1700 0800 - 1300 Not Operating
HVAC system	AHU/FCU	AHU/FCU	Constant Volume Variable Volume
Chiller Rated COP	4.3	5.1	4.98
Annual Energy Use Intensity	339 kWh/m^2/yr	518 kWh/m^2/yr	227 kWh/m^2/yr
Energy Conservation Measures	- High efficiency fluorescent lighting - De-lamping	- Energy recovery wheel for room exhaust - Heat pump system for hot water - De-lamping - Room key tag central switch system	- Chiller optimization - BAS - All windows face N/S direction - Fixed external shading - Shut down lecture room AHU fans when not in use
Recommendation	- Reduce air supply to restaurants and function rooms during off periods - Replace incandescent bulbs to fluorescent bulbs in corridors - Stop using reheat to control humidity in guest rooms	- Install chiller optimization system - Reduce extensive use of incandescent lighting and replace with fluorescent ones	- Reduce exfiltration through windows/doors - Raise thermostat setpoint in library

Table B-4. Comparison of Energy Intensities

Building	Energy Intensity kWh/m^2/yr	Index
ASEAN Average Office	246	100.0
Singapore Average (Net)	210	85.4
Albert Complex (Office)	96.9	39.4
URA Building	131.2	53.3
Sanford Building	201.9	82.1
Jurong Town Hall	122.0	49.6
ASEAN Average Hotel	307	100.0
Golden Landmark	518	168.0
Century Park Sheraton	339	110.0
ASEAN Average Retail	332	100.0
Albert Complex (Retail)	319.6	96.3

Table B-5. Energy Use by Systems

Service	Energy Use by System % of total			
	Albert Complex	URA Building	Sanford Building	Jurong Town Hall
Air-Conditioning	42.5	30.7	32.3	29.0
Fans	12.8	10.0	8.6	21.2[a]
Lighting and Power	15.5	42.8[b]	30.8	26.3
Miscellaneous Equipment	29.2	16.5[c]	28.3	23.5
Total	100.0	100.0	100.0	100.0

a. Including general power.
b. Including miscellaneous equipment.
c. Including power for computer system and environmental support system.

APPENDIX C

A SURVEY OF ENERGY USE IN COMMERCIAL BUILDINGS

INDONESIA

This report summarizes an extensive energy audit performed on five Indonesian commercial buildings. Energy conservation opportunities are identified and potential energy savings from them are estimated.

ASEAN-USAID PROJECT ON ENERGY CONSERVATION IN BUILDINGS

PROJECT I.2

ENERGY AUDIT SUMMARY REPORT

A SURVEY OF ENERGY USE IN COMMERCIAL BUILDINGS

Performed by:

The Surabaya Energy Audit Group

Dra. Lea Prasetio, Principal Researcher
Ir. Didiek Basuki Rakhmat
Ir. Jimmy Priatman
Ir. Nugroho Susilo
Drs. Gontjang Prajitno
Drs. Doni Djatikusumo
Drs. Eko Budi Purwanto
Drs. Bagus Jaya Santosa
Dr. Ir. Mas Santosa
Drs. Sudirman
Nining Lutmiati
M. Zainul Asrori
Dino Kiliaan
Hariyono
Tjioe Tji Liek
Lina Tjendrawasih
Rudy Markie

December 1989

ACKNOWLEDGEMENT

This research work was sponsored by USAID under the ASEAN-USAID Buildings Energy Conservation Project.

We extend special thanks to the following institutions which have contributed to this project:

- The Research and Development Centre for Applied Physics – The Indonesian Institute of Sciences, for giving us the opportunity to be involved in this project.
- DITABA – Public Works Department, for its kind coordination efforts and support.
- Lawrence Berkeley Laboratory, for its helpful guidance and for sending us relevant literature.
- P.T. Sier, the Natour Simpang Hotel, the Hyatt Bumi Surabaya Hotel, the Garden Palace Hotel, and the Elmi Hotel, for their willingness to have their buildings audited.

INTRODUCTION AND SUMMARY OF RESULTS

Scope

An energy consumption audit is a study conducted to determine a building's energy consumption. This study includes energy consumption audits for five commercial buildings: one office and four hotels.

The buildings audited were:

- The Wisma Sier : a six-story, 8,835 m^2 suburban office building
- The Elmi Hotel : an eight-story, 11,000 m^2 hotel
- The Garden Palace Hotel : an eleven-story, 17,190 m^2 hotel
- The Hyatt Bumi Hotel : an eleven-story, 31,079 m^2 hotel
- The Natour Simpang Hotel : a seven-story, 6,028 m^2 hotel

Objectives

The primary objective of this study was to gain a better understanding of energy consumption levels and energy use patterns in commercial buildings. However, the study was also designed to increase our understanding of the mechanics of performing an audit and the workings of the ASEAM-2 (A Simplified Energy Analysis Method), an energy simulation program used to analyse a building's annual energy consumption.

Commercial buildings typically have high energy consumption, for a number of reasons. First, commercial buildings many end uses. Second, commercial buildings are usually designed and constructed with little consideration of their energy use. And third, because building managers always aim for high customer satisfaction, they sometimes overconsume energy, either by providing excessive cooling or lighting, or through general operating inefficiencies. The audit and retrofit challenge, then, is to use energy more efficiently, while maintaining and even improving comfort conditions in the building.

This report, which summarizes the audit findings, shows the pattern and amount of energy consumption in the chosen commercial buildings during 1986 and 1987, the amount of energy used by the buildings' air-conditioning systems, lighting systems, elevators, and electrical equipment.

General Description of the Buildings

Table C-1 provides a brief description of the buildings audited. Detailed audits are available that provide more in-depth information about each building.

Summary of Results

Distribution of Types of Energy:

Table C-2 shows total kWh consumption by fuel type, and Table C-3 shows the costs of those different fuels. Figures C-1a & b diagram the energy consumption per m^2 of conditioned space and per room. The prices of energy per m^2 and per room are shown in Figures C-2a & b.

Only electricity consumption was analysed in the energy audits conducted. This is because, although diesel oil consumption in the buildings was sometimes quite high, it costs very little in terms of rupiah. The Garden Palace is an exception, for its diesel oil consumption is extremely high and the cost of the diesel oil used is significant. This is because the Garden Palace used an absorption chiller, which accounts for its radically different energy use, as seen in Tables C-2 and C-3, and Figures C-1a & b and C-2a & b.

The electrical energy consumption of the other three hotels is in the range of the electrical consumption measured for the sample of 34 hotels surveyed throughout ASEAN (see Vol. I of this report, *Policy,* Chapter ?). >From that data base, the average of all 34 hotels surveyed was 307 kWh/m^2 per year. The Elmi and Simpang are slightly higher and the Hyatt is slightly lower.

The electrical consumption of the Wisma Sier office building, at 166 kWh/m^2, is lower than the average office building consumption of 246 kWh/m^2 from a similar survey of 71 ASEAN office buildings. A likely reason is the very low installed lighting power at 10.3 W/m^2, whereas the average W/m^2 for lighting in the buildings surveyed throughout ASEAN was in the range of 17 W/m^2.

Monthly Distribution of Electricity Consumption:

The distribution of electricity consumption was quite uniform from month to month, as Figure C-3 shows (the maximum deviation from the mean was only 10%).

Distribution of Electricity Consumption by Building End-Use:

Table C-4 shows, for the buildings' base case, the estimated annual electricity consumption by end-use. Figures C-4a & b present the same information in bar graph form, allowing for easier comparison among both buildings and end-uses.

ENERGY ANALYSIS METHODS

The Energy Audit

An energy audit, which reveals energy use patterns in a building, should identify where and how energy waste occurs. Possible improvements to building operations, maintenance, and equipment can then be recommended.

This study chose to use the following auditing process:

- Auditing historical data.
- Conducting a walk-through survey.
- Conducting detailed investigations and analyses.

Each of these steps is briefly described below. Figure C-5 shows the overall process.

The Audit of Historical Data:

Historical data was collected from electricity or other fuel bills, or, as a last resort, from the records sometimes maintained by a building's utility department. When conducting the detailed investigations and analyses, the data gathered served as a useful reference, since it could be compared to the computer-based simulation of the building's energy consumption per year (using the ASEAM-2 program).

The Walk-Through Survey:

A site survey—a fairly quick, low-cost preliminary investigation of the existing data on actual conditions in the building—was conducted after each historical audit. To make these surveys efficient, the architectural, mechanical, and electrical blueprints for the buildings were obtained. The surveys revealed obvious energy inefficiencies and highlighted priority areas for further investigation of likely inefficient or inappropriate energy systems.

Detailed Investigation and Analysis:

Finally, and most importantly, one must conduct detailed analyses of the areas identified in the walk-through survey as inefficient. A main challenge in this part of the process is to identify all possible candidate ECOs and to perform appropriate analysis on each one. Such analyses can include parametric analyses of the impacts of various potential ECOs.

The ASEAM-2 Computer Program

Most of the data collected were analysed using ASEAM-2, a simplified DOE-2 computer program most suitable for analysing simple buildings. The buildings were divided into "thermal zones," areas with similar thermal and system loads. Thermal zones were then subdivided into lighting zones.

The data were entered into ASEAM-2 for each zone and each system, as were any factors affecting energy consumption, (e.g., type and conditions of windows and doors, typical lighting, people density, comings and goings out of the building). All the information allowed the computer to simulate the buildings' energy consumption under various weather conditions and schedules of occupancy and use. Possible ECOs identified at this time were examined.

The ASEAM-2 results were validated by comparing them to the reference data gathered from the historical audit. When significant differences existed between the historical data and calculated consumptions, benchmarking was necessary; the parameters of the program were adjusted until the two sets of data matched well. The computer-generated data was then used as the reference or base case data in the ASEAM-2 program.

The most important application of the building analyses was allowing comparison among the efficiencies of different alternatives. An input data file for each ECO identified was created, and its potential energy savings then determined by comparing the ECO analysis results with the base case results. Combining the potential savings from all the ECOs gave the total potential savings that could be obtained in one year. Even when the base case runs were not quite in agreement with the historical data, the estimated comparative savings from different ECOs should have been reasonably accurate.

Energy Prices

As the data description makes clear, most of the energy used was in the form of electricity, though some non-electrical energy was used as well.

The prices of various energy forms are as follows:

Non-electrical:

- City gas : 175 Rp/litre *
- Elpiji (LPG) : 580 Rp/litre
- Diesel Oil : 210 Rp/litre
- Kerosene : 225 Rp/litre

Electrical:

- The Wisma Sier office building, in the U-3 electricity tariff group (all commercial buildings are in Group U), had a fixed tariff of 2,300 Rp/kVA, a peak load tariff from 6:00 P.M. to 10:00 P.M. of 158 Rp/kWh, and an off-peak tariff of 99 Rp/kWh.
- The hotels, which belong to the I-3 Group (which includes all industrial buildings), had rather different tariffs: 90 Rp/kWh for the peak load and 56 Rp/kWh for the off-peak load. (See Table C-10 for more information).

Weather Data

Running the ASEAM-2 program requires weather and solar data. The hourly Surabaya weather data were not available, so Jakarta's 1986 weather data were obtained from Ir. Soegijanto † and was reformatted into the format required by ASEAM-2. A printout of the weather data in ASEAM-2 format can be found in Appendix 2 of the original Indonesian Project 1.2 Final Report on auditing tasks.

ANALYSIS AND CONCLUSION

Impact of Energy Conservation Opportunities (ECOs)

Figure C-6 gives a summary of the ECOs and their potential impact on total annual energy consumption for all the buildings audited. Table C-11, which compares the energy consumption of the five buildings in the study, makes analysing the data simpler. For reasons of consistency, comparative analysis was performed only on the hotels. This survey did not evaluate the cost of

* The conversion rate used, as of June, 1990, was 1,836 Indonesian Rupiah to 1 U.S. Dollar.

† See Vol. III, Chapter 5, of this report for a full description of the Jakarta data.

implementing the various ECOs, so payback periods were not calculated.

The Wisma Sier Office Building:

Since the air-conditioning and ventilation systems accounted for 83% of the energy consumed in the building (see Table C-4), these areas provided the most likely ECOs, a hypothesis confirmed by the analysis in this study.

The ECOs examined that had the most potential were a reduction in cooling capacity from 265 to 166 TR (2.4% energy savings or a 24,564 kWh annual energy reduction) and an improvement in pump efficiency from 30 kW to 18.5 kW (a 5% or 49,920 kWh savings).

Considering that the fourth floor and some of the third floor were not being used, Wisma Sier's cooling capacity is larger than necessary (see Table C-5), and energy was obviously wasted. A serious effort should be made to rent the empty space. Further, the occupants of the building complained of being too cold.

Lighting and elevator ECOs were also identified and analysed. However, since these end-uses accounted for only a small portion of total energy consumption, such ECOs would have a relatively small impact on total energy consumption. Table C-5 summarizes the ECOs mentioned and their potential savings.

ECOs for improving lighting systems are often very effective for office buildings. However, because the lighting installed in the Wisma Sier was already very energy-efficient at 10.3 W/m^2, we did not identify significant lighting ECOs to be used for this building.

Likewise, we did not identify cost-effective building envelope ECOs, even though the building has 45% glass, which has a high solar heat gain load through the tinted glass and no external shading. While external shading devices would be less effective ECOs for retrofitting, they would be good strategies to incorporate into new office design.

Comparatively little could be determined about the Wisma Sier since it was the only office building audited. The Wisma Sier consumed the least amount of non-electrical energy (see Table C-11), and had the highest electricity-to-total-energy-usage ratio (item M divided by P). Because the office is used for fewer hours per week, and possibly because the building had a large amount of unrented floor space, the total electricity costs and costs of energy-per-unit-floor-area were far less than those of the hotels. Consequently, the Wisma Sier had relatively high total energy costs per kWh, especially compared to the Garden Palace's (item Q).

The Hotels:

The Natour Simpang Hotel. All the hotels presented mainly housekeeping ECOs, or else ECOs which only require additional sensors to limit unnecessary operation of a system (fans, for instance). Lighting ECOs were recommended as well. Table C-6 summarizes the ECOs for the Natour Simpang and their potential savings.

The Hyatt Bumi Hotel. Because an already energy-conscious staff runs this hotel, the ECOs recommended mainly concerned lighting replacements (see Table C-7).

The Garden Palace Hotel. Because the Garden Palace used an absorption chiller, which reduces electricity consumption, the electricity ECOs were limited (see Table C-8).

The Elmi Hotel. The Elmi provided a chance to audit a hotel that had been audited just a year before, in 1987. Energy awareness among the management appeared to have improved since the first audit. In one policy switch, unnecessary lamps are now switched off. Another recommended ECO, replacing light bulbs with ones of lower wattage, has been at least partially adopted. The hotel now keeps only 40 Watt and 60 Watt incandescent bulbs in its stockroom, whereas it formerly kept lots of 100 Watt bulbs. As each old bulb burns out, it is replaced by a new, more efficient one. Also, the number of bulbs in use appeared to have declined. Table C-9 shows the recommended ECOs.

Observations on the Hotels

The existing total and proportional conditioned and non-conditioned areas of the different hotels were measured and compared, as follows:

- Items A, B, C, F and H of Table C-11 show that the Hyatt and the Garden Palace had the largest gross conditioned area. They also had more rooms than did the Elmi or the Simpang. However, the Hyatt and Garden Palace did not have the highest percentage of air-conditioned spaces—29% of the total floor area in the Hyatt was not air-conditioned.
- The Hyatt and Garden Palace, despite having only slightly more rooms than the other two hotels, had floor-to-room ratios between 1.5 and 3.5 times higher than those of the Elmi and Simpang (item H).
- Although the Simpang had the smallest amount of gross and conditioned floor space (1/5 of the Hyatt's), it had the highest percentage of air-conditioned space.
- The Simpang's comparatively small conditioned and gross floor area per room (items G and H) is explained by its paucity of—albeit usually air-conditioned—non-bedroom spaces (e.g., function rooms, banquet hall, restaurants, lobbies, etc.).

Our explanations for the hotels' different energy consumption patterns follow:

- The Hyatt had the highest total energy costs per room (Item I) because it used a comparatively high percentage of its floor space for purposes other than guest rooms (shopping arcades, a bar, a coffee shop, a restaurant, large banquet halls, a fitness centre, lobbies, and other function rooms).
- The Garden Palace had the second highest cost-per-room ratio, an expected finding since the hotel had the second largest total and conditioned floor space.
- Items L, M, and N show that the Garden Palace consumed the most energy (in kWh) per room and per unit of floor area. The frequent usage of its banquet halls and other function rooms may have been responsible, since the hotel's room occupancy rate was lower than the Elmi's. The Garden Palace's room occupancy rate and number of rooms occupied were still quite high, however.
- Although the Garden Palace consumed more energy than the other hotels, (see Table C-1 and preceding paragraph), most of its energy was generated from diesel oil rather than coming from the city's electricity supply. This caused the hotel's electricity consumption to be rather low. The Garden Palace consumed the least electricity among these four hotels (items O and P), and its consumption per room was less than half of the Hyatt's.
- The Hyatt may have consumed more energy per room than the other hotels because of its huge floor-area-to-room ratio.
- The Elmi had the highest occupancy and equivalent occupancy rates of the four hotels, making it the largest consumer of electricity per unit floor space, even though the Garden Hotel consumed more total energy. However, since the Garden Palace owns a non-electrically powered air-conditioning system, it did use less electricity than the Elmi and Hyatt.

Some Concluding Thoughts

One general rule of thumb for gauging energy costs is that as the ratio of air-conditioned to gross floor area increases, the energy costs per unit floor area also increase.

Higher occupancy rates increased energy usage. However, data show that the cost per room became cheaper when the occupancy rate was higher (compare the Garden to the Hyatt and the Elmi to the Simpang). Even so, the cost per floor area when occupancy rates rose was not always lower, since the costs also depended on the activities in the non-bedroom areas.

Although the window-to-wall ratio influenced a building's energy consumption, neither this ratio nor the orientation and shading type of the windows had a major effect on overall energy consumption. Lighting too, proved relatively unimportant. The space conditioning design proved itself the key to total consumption. Even though the Hyatt and Garden Palace had the lowest window-to-wall ratio and the smallest wattage per unit floor area of lighting installed, they still consumed more energy than the other buildings audited.

The Wisma Sier used the highest percentage of electricity, while the Garden Palace used the smallest percentage. The Wisma Sier paid five times more per kWh than did the Garden Palace. Using a non-electrical energy source to supply the main part of the building energy system would be one feasible suggestion for achieving significant energy cost savings. In the long run, overall energy costs would fall significantly, assuming non-electric power sources remained cheaper than electricity.

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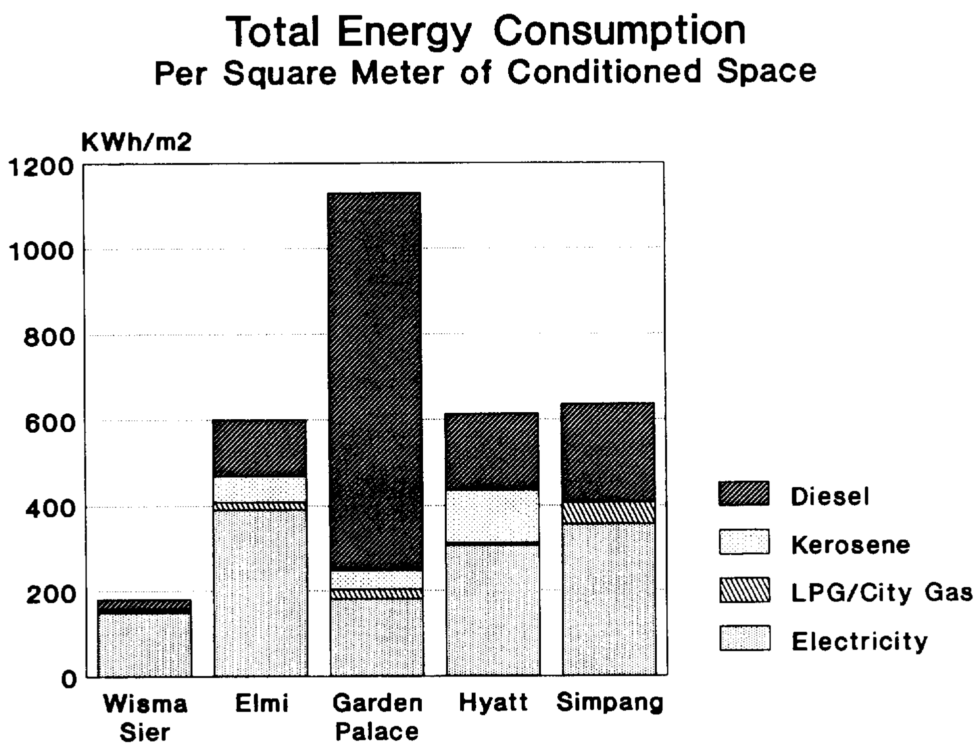

Figure C-1a

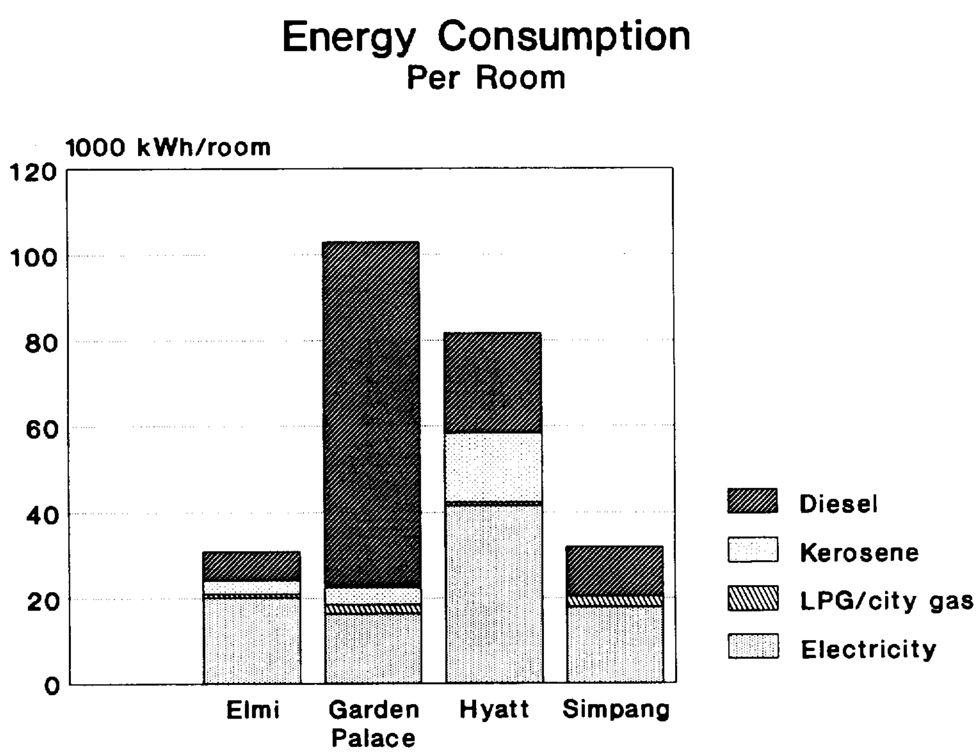

Figure C-1b

Energy Prices
Per Square Meter

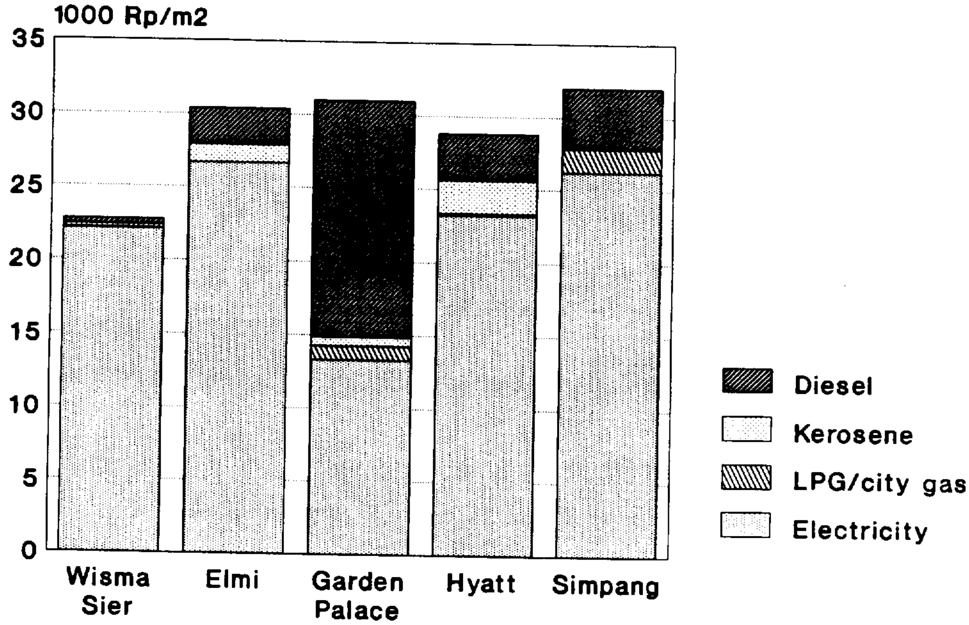

Figure C-2a

Energy Prices
Per Room

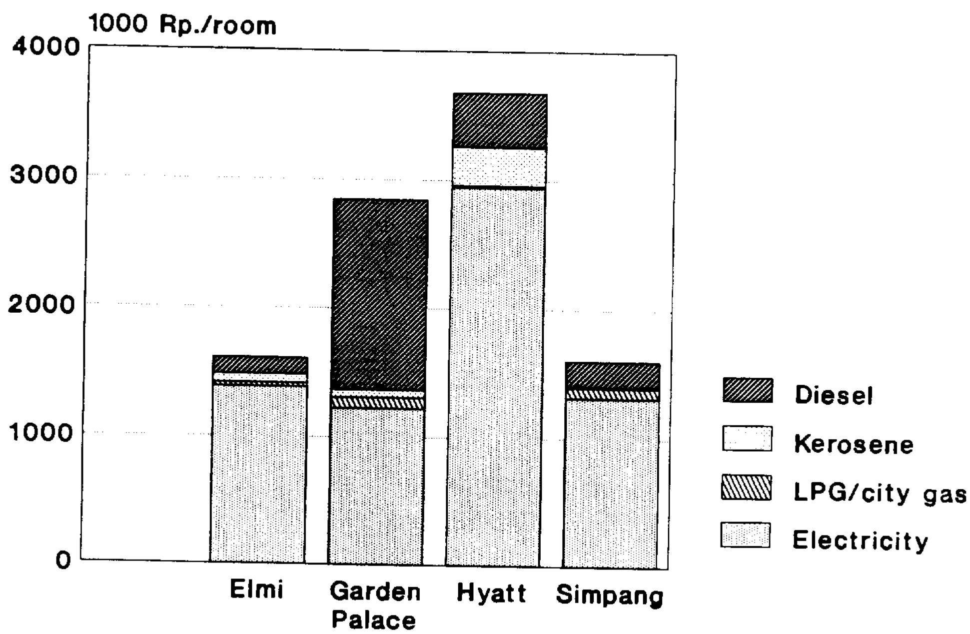

Figure C-2b

Monthly Electricity Consumption Profiles

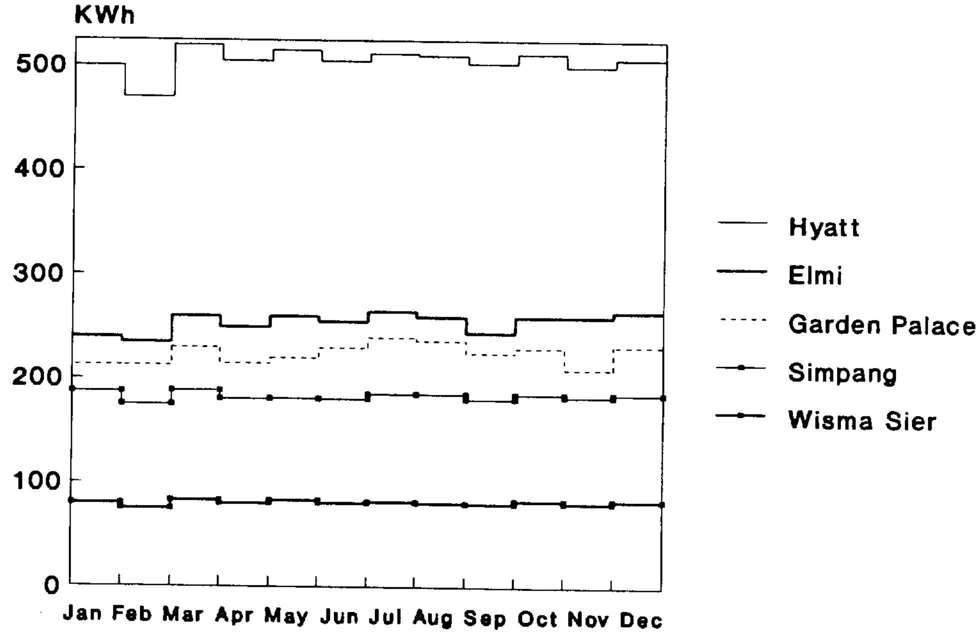

Figure C-3

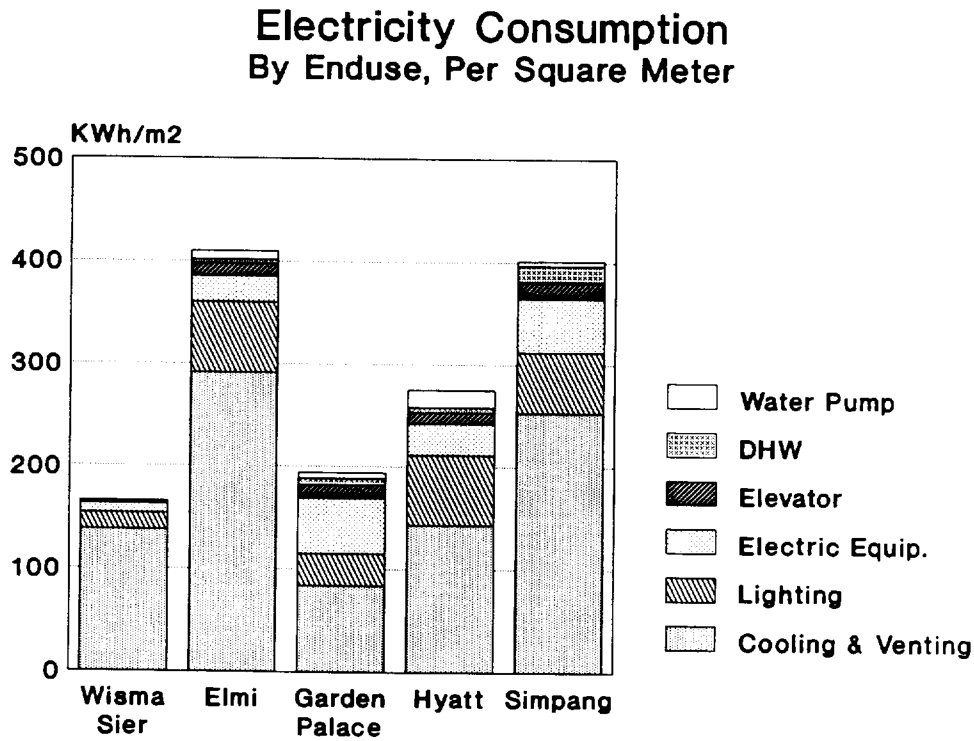

Figure C-4a

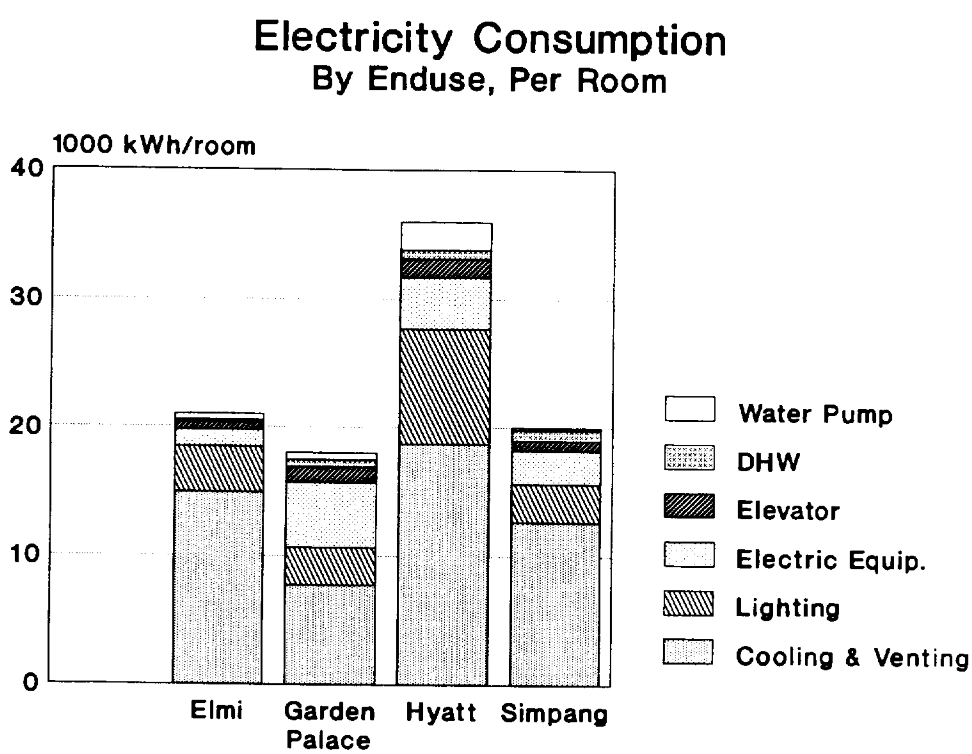

Figure C-4b

Schematic Diagram of the Audit Process

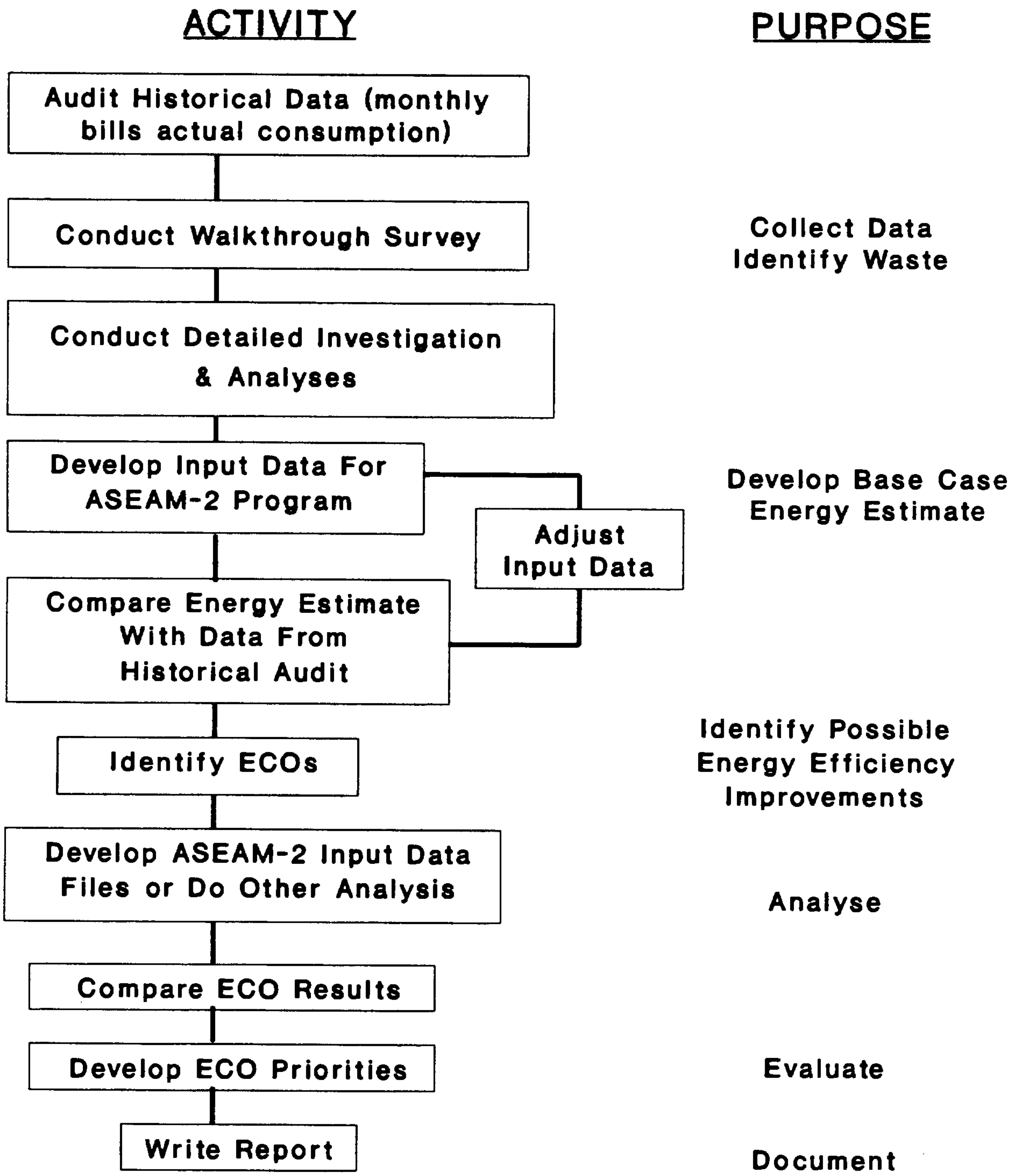

Figure C-5

Energy Consumption
Potential ECO Savings

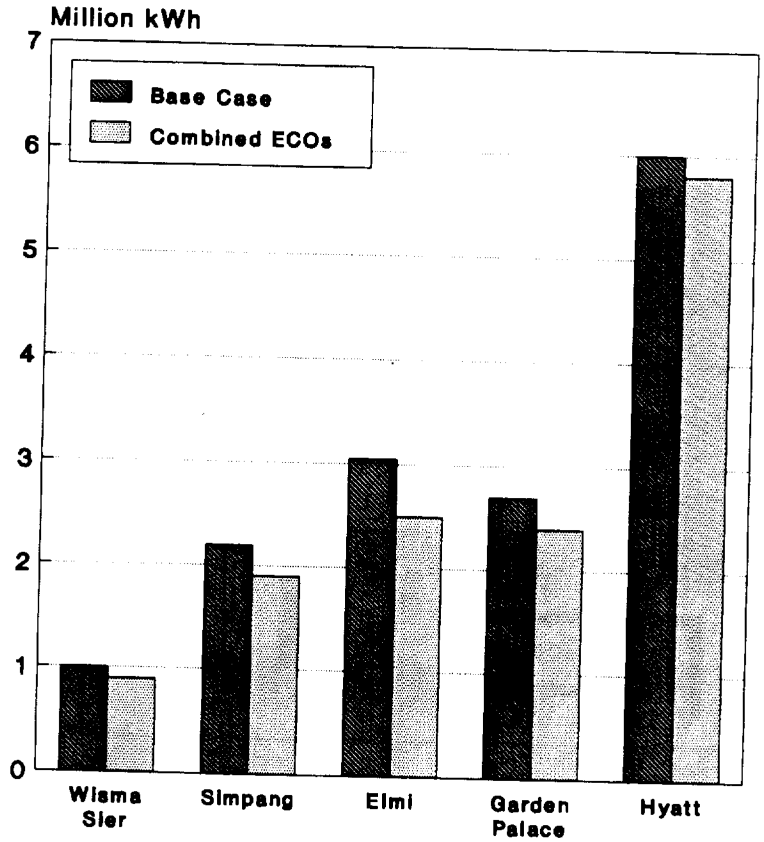

Figure C-6

Table C-1. General Description of the Buildings Audited

	BUILDING NAME				
ITEM	WISMA SIER	SIMPANG	ELMI	GARDEN PALACE	HYATT
Building Type	Office	Hotel	Hotel	Hotel	Hotel
Year Built	1984	1979	1978	1983	1975
Gross Floor Area (in m^2)	8,835	6,028	11,000	17,190	31,079
Conditioned Floor Area (in m^2)	6,072	5,510	7,530	14,032	21,939
Number of Storeys	6	7	8	11	11
Number of Rooms	-	110	144	154	169
Occupancy Rate	-	68%	83%	74%	59%
Wall Type	Masonry	Masonry	Masonry	Masonry	Masonry
Window Type	Tinted	Tinted	Tinted	Tinted	Tinted
Window Shading (Coefficient)	0.53	0.69	0.69	0.69	0.69
Shading Type	None	Vertical	Eggcrate	None	Eggcrate
Window-to-Wall Ratio	45%	39%	38%	21%	21%
Lighting Installed (in Watt/m^2)	10.3	13.5	14.3	16.2	10.8
Typical Operating Hours(in hrs/week)	51	168	168	168	168
Typical Zone Temperature	68°F = 20°C	72°F = 22°C	78°F = 26°C	75°F = 24°C	72°F = 22°C
HVAC Type	Rooftop DX System & Some Window Units Units	Chilled Water System, Ceiling by Pass & Fan Coil	Chilled Water Const. Volume & Fan Coil	Chilled Water System, Ceiling by Pass & Fan Coil	Chilled Water System, VAV & Fan Coil
Chiller Type	–	Centrifugal	Reciprocating	Absorption	Centrifugal
Number of Chillers	–	1	1	2	2
Total Cooling Capacity (in tons)	265	135	240	400	800
Chiller Fuel	–	Electric	Electric	Diesel Oil	Electric
DHW Type	–	Steam	Steam	Steam	Steam
DHW Fuel	–	Diesel	Diesel	Diesel	Diesel
Total kWh/year	1,098,330	3,507,720	4,529,051	15,868,429	13,466,160
Total Electricity/Year (in kWh)	910,000	1,958,400	2,954,801	2,548,459	6,775,200
Total Rupiah/Year	137,394,000	176,550,000	231,933,650	438,375,500	622,167,000

Table C-2. Total KWh Consumption as Calculated from Historical Data*

ITEM	BUILDING NAME				
	WISMA SIER	ELMI	GARDEN PALACE	HYATT	SIMPANG
Electricity	910,000 = 83%	2,954,801 = 65%	2,548,459 = 16%	6,775,200 = 50%	1,958,400 = 56%
LPG/City Gas	8,400 = 1%	139,650 = 3%	331,800 = 2%	75,376 = 1%	293,640 = 8%
Kerosene	43,680 = 4%	453,600 = 10%	562,170 = 4%	2,750,706 = 20%	–
Diesel Oil	136,250 = 12%	981,000 = 22%	12,426,000 = 78%**	3,864,878 = 29%	1,255,680 = 36%
Total	1,098,330 = 100%	4,529,051 = 100%	15,868,429 = 100%	13,466,160 = 100%	3,507,720 = 100%
kWh/m^2 (Cond)	181	601	1,131	614	637
10^3 kWh/room	–	31	103	80	32

* The conversion factors are:

Product	Gross Energy	
	per unit mass	per unit volume
LPG/City Gas	14 kWh/kg	7.1 kWh/1
Kerosene	–	10.5 kWh/1
Diesel Oil	–	10.9 kWh/1

** Absorption chiller used.

Table C-3. Total Energy Paid Per Year (10^3 Rupiah/Year)

ITEM	BUILDING NAME				
	WISMA SIER	ELMI	GARDEN PALACE	HYATT	SIMPANG
Electricity	133,660 = 96%	199,112 = 86%	187,260 = 43%	497,842 = 80%	143,904 = 82%
LPG/City Gas	277 = 0.2%	5,785 = 2%	10,948 = 3%	2,487 = 0.4%	9,376 = 5%
Kerosene	936 = 1%	8,316 = 4%	10,288 = 2%	50,338 = 8.1%	–
Diesel Oil	2,521 = 1.8%	18,720 = 8%	229,880 = 52%	71,500 = 11.5%	23,270 = 13%
Total	137,394 = 100%	231,933 = 100%	438,376 = 100%	622,167 = 100%	176,550 = 100%
1000 Rp/m^2 (Cond)	23	31	31	28	32
1000 Rp/Room	–	1,611	2,846	3,681	1,605

Table C-4. Energy Consumption by End-Use

COMPONENT	BUILDING NAME				
	WISMA SIER	ELMI	GARDEN PALACE	HYATT	SIMPANG
Chiller/Evaporator	551,237 = 54%	1,371,341 = 44%	–	1,260,578 = 21%	499,084 = 23%
Fans	156,898 = 15%	415,808 = 14%	443,840 = 16%	1,085,602 = 18%	613,200 = 28%
Cooling pumps	130,000 = 13%	163,520 = 5%	256,806 = 10%	394,200 = 6%	58,504 = 3%
Other AC	3,164 = 1%	–	–	–	–
Cooling Tower	–	256,546 = 8%	216,975 = 8%	242,725 = 4%	198,331 = 9%
Exhaust Fan	–	–	263,223 = 9%	219,000 = 3%	–
Total Cooling & Ventilation	841,299 = 83%	2,207,215 = 71%	1,180,844 = 43%	3,202,105 = 52%	1,369,119 = 63%
Lighting	99,591 = 10%	522,350 = 17%	427,958 = 16%	1,479,279 = 25%	342,225 = 15%
Electrical Equipment	45,973 = 5%	181,572 = 6%	754,796 = 28%	636,990 = 11%	310,090 = 13%
Elevator	22,880 = 2%	96,360 = 3%	198,560 = 7%	246,375 = 4%	96,360 = 4%
DHW	–	13,122 = 1%	80,168 = 3%	121,945 = 2%	78,732 = 4%
Water Pump	–	69,335 = 2%	80,312 = 3%	350,400 = 6%	13,140 = 1%
Total	1,009,743 = 100%	3,089,954 = 100%	2,722,638 = 100%	6,037,094 = 100%	2,209,666 = 100%
kWh/m^2	166	410	194	275	401
1000 kWh	–	21	18	36	20

Table C-5. Summary of ECOs - Wisma Sier

ECO #	Description	Annual Savings kWh	% Savings (partial)	% Savings (overall)
1	Cooling Tower Pump 30 kW to 18.5 kW	49,920	38	5
2	Cooling Capacity 265 TR to 166 TR	24,564	4.5	2.4
3	Lighting ECO: (a) Incandescent to PL (b) Incandescent SL	 18,714 18,129	 18.8 18.2	 1.9 1.8
4	Elevator: Employees do not use elevators for "one-floor travel"	1,373	6	0.1
Total (1+2+3a+4)		94,571		9.4

Table C-6. Summary of ECOs - Simpang Hotel

ECO #	Description	Annual Savings kWh	% Savings (partial)	% Savings (overall)
1	Setpoint Temperature 72°F to 77°F	4,484	0.3	0.2
2	Lighting ECO: (a) TL to TLD & Incandescent to PL (b) TL to TLD & Inc to SL	 180,456 168,713	 53 49	 8.0 7.6
3	Operate fan according to load	123,630	20	5.6
4	Reduce leakage and infiltration	5,700	0.4	0.3
Total (1+2a+3+4)		314,270		14.1

Table C-7. Summary of ECOs - Hyatt Hotel

ECO #	Description	Annual Savings kWh	% Savings (partial)	% Savings (overall)
1	Change Setpoint From 72°F to 77°F	42,349	1.4	0.7
2	Replace TL to TLD & Incandescent to PL or SL lamps	117,711	8.0	1.9
3	Reduce leakage and infiltration	36,281	1.2	0.6
Annual Total Savings		196,341		3.2

Table C-8. Summary of ECOs - Garden Palace Hotel

ECO #	Description	Annual Savings kWh	% Savings (partial)	% Savings (overall)
1	Replace TL or TLD & Incandescent to PL or SL lamps	129,109	30.2	4.7
2	Operate fan according to load & reduce air intake	159,378	17.3	5.8
Annual Total Savings		288,487		10.5

Table C-9. Summary of ECOs - Elmi Hotel

ECO #	Description	Annual Savings kWh	% Savings (partial)	% Savings (overall)
1	Replacement of incandescent lamps with smaller wattage (implemented)	130,917	27.4	4.2
2	Replace T1 with TLD and incandescent with PL or SL lamps	310,717	65.9	10.1
3	Reduce leakage and infiltration	21,541	0.4	0.7
4	Replace cooling tower pump from 28 to 22 kW	35,040	8.3	1.1
Total (2+3+4)		367,298		11.9

Table C-10. Tariff Schedule for Groups U and I

Group	Load Capacity VA	Fixed Tariff Per KVA Rp.	Tariff Per kWh Rp.
U - 1	250 - 2,200	3,680,-	134.-
U - 2	2,201 - 200 K	3,680,-	150,-
U - 3	more than 201 K	2,300,-	WBP*: 158,- LWBP**: 99,-
I - 1	0 - 99 K	2,300,-	WBP: 99,50 LWBP: 60,50
I - 2	100 K - 200 K	2,300,-	WBP: 92,50 LWBP: 57,50
I - 3	more than 201 K	2,100,-	WBP: 90,50 LWBP: 56,00
I - 4	more than 5000 K	1,970,-	WBP: 77,00 LWBP: 48,50

* WBP = peak load : 22.00 - 18.00
** LWBP = off peak : 18.00 - 22.00

Table C-11. Table of Energy Usage Comparison

No.	Item	Unit	ET	DS	SIER	ELMI	SIMPANG	GARDEN	HYATT
A	Gross Floor Area	m^2	–	X	8,835	11,000	6,028	17,190	31,079
B	Cond. Floor Area	m^2	–	X	6,072	7,530	5,510	14,032	21,939
C	Total Room Number	Room	–	X	–	144	110	154	169
D	Occupancy Rate	%	–	X	–	82.5	68.2	74.0	58.8
E	Equiv. Occ. Room	Room	–	–	–	119	75	114	99
F	Cond. Floor Area/ Gross Floor Area	%	–	X	69	69	91	82	71
G	Cond. Floor Area/ Room	m^2/ Room	–	X	–	52.3	50.1	91.1	129.8
H	Gross Floor Area/ Room	m^2/ Room	–	X	–	76.4	54.8	111.6	183.9
I	Cost Equiv. Occ. Room	1000 Rp/ Room	T	B	–	1,949	2,354	3,844	6,283
J	Cost/ Cond. Floor Area	1000 Rp/ m^2	T	B	23	31	32	31	28
K	Cost/ Gross Floor Area	1000 Rp/ m^2	T	B	16	21	29	26	20
L	Total Energy/ Equiv. Occ. Room	1000 kWh/ Room	T	B	–	37	47	139	136
M	Total Energy/ Cond. Floor Area	kWh/ m^2	T	B	181	601	637	1,131	614
N	Total Energy/ Gross Floor Area	kWh/ m^2	T	B	124	412	582	923	433
O	Electr. Energy/ Equiv. Occ. Room	1000 kWh/ Room	E	B	–	24	26	22	68
P	Electr. Energy/ Cond. Floor Area	kWh/ m^2	E	B	150	392	355	182	309
Q	Cost J/ Energy Unit M	Rp/ kWh	–	B	127	52	50	27	46

ET = Energy Type
T = Total
E = Electrical
Equivalently Occupied Rooms = D x C

DS = Data Source
X = Existing Condition
B = Data from Bills

APPENDIX D

OFFICE BUILDING

AUDIT REPORT

THE PHILIPPINES

This report is one of approximately twenty audit reports prepared by the Philippine group focusing mainly on office buildings. While not as detailed as the Intercontinental Hotel report (Appendix E), these studies provide an excellent, concise overview of the building's energy use patterns and conservation opportunities. For purposes of confidentiality, the building's name has been removed from this report for publication.

OFFICE BUILDING

PRELIMINARY ENERGY AUDIT REPORT

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EXECUTIVE SUMMARY

An audit team from the Office of Energy Affairs (OEA) conducted an energy audit of an office building in line with OEA's on-going Project on Energy Conservation in Buildings. This report is the outcome of an extensive data collection and building inspection made possible with the assistance and cooperation of the building administration staff.

This report focuses on three major aspects of energy analysis, namely, the structural and architectural systems (or the building envelope design), lighting and electrical systems, and the air-conditioning systems. The data gathered by the audit team were analyzed using computer simulations and manual computations, on which recommendations for energy conservation were based.

The energy conservation opportunities, or ECOs, are classified under three major energy-consuming components: office equipment, lighting and electrical systems, and air-conditioning systems. Below is a summary of the energy cost-saving measures recommended.

Recommendations	Potential Benefits
OFFICE EQUIPMENT	
• Turn off office equipment (computers, typewriters, etc.) when not in use.	Minimize office equipment energy wastage along with less cooling load for the air-conditioning equipment.
ELEVATOR SYSTEM	
• Consider inclusion of elevator in building energy conservation program through consultation with elevator operating and maintenance personnel as well as with manufacturer.	More energy cost savings through more efficient elevator operation.
LIGHTING SYSTEM	
• Reduce lighting operating hours by 1-½ hours.	Annual energy savings of 168,280 kWh or annual energy cost savings of 277,660 pesos.*
• Install high-efficiency reflectors and remove diffusers wherever the consequent glare can be tolerated.	Improvement of illuminance levels in workplace.
• Reduce or switch off lights in areas not requiring higher levels.	Energy savings derived from the number of lights switched off or reduced.
• Implement a lighting maintenance program and motivate personnel to conserve energy.	Attain optimum efficiency of lighting system.

* The conversion rate used, as of June, 1990, was 22.885 Philippine pesos to 1 U.S. Dollar.

ELECTRICAL SYSTEM POWER FACTOR

• Repair defective power factor correction capacitors.	Avail of bonus for high PF.

AIR-CONDITIONING SYSTEM

• Reset thermostat setpoint to 25.55°C.	Annual energy savings of 31,548 kWh or annual energy cost savings of 52,054 pesos.
• Reduce air-conditioning equipment operating time.	Annual energy savings of 61,691 kWh or annual energy cost savings of 101,790 pesos.
• Operate the chiller at full load capacity, recalibrate all air-conditioning system controls, check chiller manufacturer's data, check air handling units' condition and proper maintenance of equipment.	Efficient operation of equipment since maintenance is considered an essential element of energy conservation.

BACKGROUND

The ASEAN-USAID Buildings Energy Conservation Project

The U.S. Government through its Agency for International Development is sponsoring a project called the ASEAN-USAID Buildings Energy Conservation Project in the ASEAN region. The project aims to appraise the energy use patterns and characteristics as well as potential energy savings in local existing buildings in the Philippines through computer simulations, and subsequently recommend a framework for setting cost-effective "Building Energy Use Standards" to be incorporated in the National Building Code.

The project involves both public and private sectors in various aspects of its implementation to ensure the development of practical and acceptable guidelines or policies on energy conservation in buildings.

Part of the work program of this project is the conduct of preliminary energy audits in 30 buildings that were previously surveyed during the first year of the project implementation. The aim of the preliminary energy audits is to further identify energy conservation potentials in the building sector and to quantify these potential savings. The results of the audits will be submitted to the administrator/manager of the building audited. All recommendations will also be consolidated and will serve as inputs to the "Building Energy Use Standards" that will be formulated.

This report deals with the energy audit of an office building conducted on October 21, 1988. The report includes all the findings in the various energy-consuming facilities of the building as well as the pertinent recommendations to improve the building energy utilization efficiency.

Office Building: Profile

The office building is a 14-story building, including the basement. It has a gross floor area of 25,711 m^2, with 19,860 m^2 or approximately 77% of the gross area comprising the conditioned office space.

The building is L-shaped with its frontage facing the southwest and southeast direction. Adjacent to the building are vacant lots; therefore, the building is not in direct contact with other buildings. Nearby buildings are of similar height as the building. The building's rear, facing the northeast and northwest orientations, faces a business area with buildings of smaller height.

As in a typical office building, greater occupancy loads occur during weekdays during office hours from 8:00 in the morning to 5:00 in the afternoon.

METHODOLOGY

The Preliminary Survey

A visit to the office building for an energy audit was made by the audit team. The audit is actually a follow-up to the energy survey conducted on September 23, 1987. Data required for building energy usage simulation runs were obtained during the previous visit. Results of the simulation runs using the utility program ASEAM2.1 were submitted to the administrator last December, 1987.

A walkthrough of the various energy-consuming facilities in the building was conducted. During the walkthrough, observations were made and random interviews with building occupants were conducted regarding operating practices. Observations on room temperatures, lighting levels, equipment layout, and energy-consuming equipment/appliances operating conditions were also taken.

Based on the energy audit findings and ASEAM2.1 simulation results, the audit team has come up with recommendations to conserve energy in the building.

ANALYTIC TOOL

The ASEAM-2 Program

A Simplified Energy Analysis Method, Version 2.1 (ASEAM2.1) is a modified bin method program for calculating the energy consumption of a building. It uses as part of its database the floor, wall and fenestration areas, the air-conditioning, the lighting and electrical equipment, and other specifications for the subsequent software calculations and simulation. If the annual total energy requirements from the program output report differs by not more than 10% from the actual kWh/yr bill of the building, then it is accepted as representative of the overall building characteristics in terms of cooling load (watts), energy consumption (kWh/yr) as well as the building envelope (U-values, shading coefficient, etc.).

AUDIT FINDINGS AND RECOMMENDATIONS

Structure

Findings:

The building is L-shaped with the longer sides exposed to the northeast and southwest orientations. Service areas and mechanical equipment rooms on each floor are situated at the building's rear facing the northeast. Since the building has no adjacent buildings, placement of the service areas and equipment rooms act as buffer zones in the northeast direction, thereby reducing the amount of direct solar heat gain entering the building.

Reinforced concrete construction is used throughout the building as external walls which are painted cream and gray. Lighter-colored or reflective exterior building colors such as white, beige, or silver could be used to reflect more direct sunlight, thereby reducing the air-conditioning load.

Windows are the clear glass type for all fenestration areas; the northeast, northwest, southeast and southwest orientations. The windows on the southeast and southwest orientations are floor to ceiling fixed clear glass windows. These windows are recessed and adequately shaded by vertical fins running down the length of the building from the twelfth floor to the second floor. Indoor shading devices vary from floor-to-ceiling venetian blinds, to single and double draperies. These devices lessen the amount of solar heat gain, but on the other hand, they also limit the amount of daylighting entering the office areas.

Doors leading from conditioned areas to the non-conditioned areas could be kept closed to reduce infiltration of warm air into the cooled spaces. As observed, doors facing non-conditioned areas such as elevators, lobbies, corridors, and canteen kitchen from the conditioned offices and dining area are kept open. When asked about this, employees cited as reason the lack of adequate interior illumination or daylighting and/or extremely low temperatures in their respective offices.

The roof is a concrete slab provided with an insulation blanket. It is medium colored and has a low heat transmission value of 0.14.

Lighting

Findings:

The entire office space is lighted by fluorescent lamp fixtures. Almost all of the fixtures have two fluorescent tubes in place, each with a rating of 40 watts. In addition, these fixtures are also provided with diffusers designed to minimize glare.

The office lighting layout allows almost uniform illumination of all areas irrespective of the kind of task in the workplace. In some office areas it was observed that the manner of partitioning has allowed some lights to be concentrated in non-working areas. This limitation is a usual characteristic of the typical lighting layout which does not make use of task lighting as a primary design consideration.

In general, the illuminance readings taken in the office areas show much lower illuminance levels when compared to the Illuminating Engineering Society (IES) recommended values. The following is a tabulation of the illuminance (lux) readings for the different areas in the building.

Area	*Illuminance (Lux)* *Actual*	*IES Recommended*
Office	110-320	320-1076
Hallways, Corridors	50-80	215
Canteen	140-180	110-1076

Almost all of the corridor spaces, stairwells, and even some comfort rooms utilize only daylighting for illumination during the daytime or when enough sunlight is available. Glass windows without any shading mechanism such as draperies or venetian blinds allow the most daylight. It was observed that these sunlit spaces are not air-conditioned so that additional cooling load due to daylighting is minimized. As a result, substantial energy savings in lighting and air-conditioning are realized.

Recommendations:

As mentioned above, a good deal of energy is already saved through the extensive use of daylighting instead of electric lighting in such areas as corridors and hallways. Still, more lighting energy can be conserved by simply turning off unnecessary lights during lunchtime and at coffee breaks. If this measure is practiced religiously, turning off, say, 90% of the lights at an equivalent of 1-½ hours a day could easily translate to an energy savings of about 15% of the total lighting energy usage! This amounts approximately to a cost savings of 277,659 pesos annually.

It is also recommended that high-efficiency reflectors be installed in the fixtures, particularly in those work areas where illuminance levels are very low. As much as 100% more light could be directed back to the workplace, thereby improving the illuminance levels.

Another practicable energy conservation measure can be made by removing the diffusers wherever the consequent glare can be tolerated. An obvious drawback of this measure—aside from the glare—is that the lamps will then be visually exposed—a possible detriment to the general appearance of the office space. A compromise between what is pleasing to look at and energy reduction should be found.

As a rule, it is good practice to reduce the lighting energy consumption such as by diminishing operating hours and/or reducing the lighting system connected load as is practicable. This will not only reduce the lighting energy consumption, but will also reduce the cooling energy required.

Further recommendations are as follows:

- Implement a lighting maintenance program. Clean lamps regularly to assure maximum efficiency; clean those exposed to dirt, dust, grease, or other contaminants more frequently. Clean fixtures can produce as much as 50% more light than dirty ones.
- Reduce or switch off lights in areas not requiring higher levels: stockrooms, corridors, unused conference rooms, parking lots, etc.
- Motivate personnel to conserve lighting energy. Use letters, memos, posters, and personal contact to campaign for lighting energy conservation. Stress:
  - The use of lighting only when it is needed.
  - The importance of switching off lights when they are not needed.

Electrical System Power Factor

The metered power factor has been high due to the installation of power factor (PF) correction capacitors. For the past six months, the PF of the air-conditioning system has been relatively low, averaging 82.5% to 87.4% since three capacitor units are not working, according to the maintenance staff. A tabulation of the metered PF for the year 1988 is presented in Table D-1.

It is clearly shown by Table D-1 that the system PF of the air-conditioning load has been left uncorrected for the past six months. As a result, the monthly metered PF for the load is much lower than when the connected capacitors were still working. It is known that the local utility company penalizes very low PFs while giving an equivalent bonus to those users with high PFs by awarding a much lower billing factor (e.g., 0.951 for 0.96 PF or higher).

In order to avail again the bonus for high PFs, it is recommended that the installed PF correcting capacitors be recommissioned as soon as possible to serve the air-conditioning supply system.

Office Equipment

It is recommended that office equipment (computers, typewriters, etc.) be turned off when not in use. Unwarranted usage of this equipment will not only result in wasted electrical energy, but will also result in an additional cooling load for the air-conditioning equipment if the office equipment is situated in an air-conditioned space. In other words, the air-conditioning equipment has to do more work than is necessary to remove the heat generated by the "idling" office equipment.

Elevators

The building utilizes several passenger elevators for all the floors. Elevator traffic is busy for almost the whole duration of office hours.

As a built-in measure, the elevators are designed to stop only at every other floor. For example, one elevator stops only at even-numbered floors while another elevator stops only at odd-numbered floors. Such a mode of operation allows a reduction in the possible number of elevator stops, thus reducing the associated energy consumption.

Recommendations:

As in other building systems, it is advisable to have an understanding of the operations of the particular elevator system in use—how much power is being consumed by the equipment—before exploring the opportunities for energy conservation. A meeting, therefore, with the technical people operating and maintaining the elevators is suggested. Because of the highly technical nature of the elevator, their opinion must be solicited on how to include elevators in the energy conservation scheme.

Since the building is being served by several elevators, it is advisable to schedule the operation of a unit mix for rush hours, and for low traffic hours. This can be done automatically or manually. The equipment manufacturer should be consulted on this.

Also, certain programmable controls can be installed to limit the floor stops further for operation of each elevator unit for energy conservation. Again, the elevator manufacturer must be consulted on this.

Air-Conditioning System

Findings:

Each floor of the building, from the ground to the 11th floor, uses two constant volume air handling units (AHUs) which provide a constant volume of air at temperatures that vary according to the load. The canteen located on the 12th floor is served by a 7.46 kW(10hp) AHU utilizing chilled water from the central plant. The AHUs maintain the rooms as 25°C(77°F). The central air-conditioning system operates from 6:30 A.M. to 4:30 P.M. Monday to Friday, which is the regular working period. During weekends, no air-conditioning is provided.

The cold supply air from the AHU is distributed through insulated ducts and discharged through ceiling diffusers while the return air passes through a common ceiling plenum.

The thermostat of each AHU is placed in the return air path in the machine room. It is connected to a three-way valve which controls the chilled water flow to the cooling coils of the AHU. A problem with such systems with one thermostat per AHU (also called single-zone system) is that some areas are undercooled. This problem is solved by installing damper control in the AHU, although the mechanism for controlling the damper of the AHU serving the mezzanine is not functioning due to rust. (Note: this was the only AHU seen by the audit team).

The cooling plant equipment consists of two 450-ton centrifugal chillers, a four-cell cooling tower, one 93.25 kW chilled water pump, and two 55.95 kW condenser pumps (one standby). The operation of the chillers depends upon the outside temperature. This means that during the summer months two chillers are operating simultaneously to meet the cooling load. During the conduct of the audit, only one chiller was operating at 90% capacity. This is good, given that chillers operate more efficiently at higher loads (80 - 100%).

An energy conservation measure already effected is the shutting off of the chiller, cooling towers, and condenser pump during lunchtime. Computations show that the savings generated by this measure is about 473.25 kWh/day, or 135,721.33 kWh/yr. This measure will be most effective when all unnecessary lights are turned off and no windows are opened during the one-hour lunch break, to prevent buildup of cooling load which will be carried by the central plant at startup at 1:00 P.M.

Recommendations:

A thorough assessment of the motor load performance characteristics for the purpose of isolating energy conservation opportunities is not expected since the survey conducted was not a detailed energy audit. The following recommendations, therefore, are based only on the survey observations and general considerations.

- Reset Thermostat Setpoint. The thermostat setpoint should be reset to 25.55°C(78°F), which is the recommended thermal comfort level. This can be done by adjusting the thermostat located in the return air path of the AHU until a temperature of 25.55°C is attained in the conditioned space. To minimize complaints from occupants, they should be advised to wear lighter clothing.

  The projected savings derived from resetting the thermostat setpoint, as computed by computer simulations, is 31,548 kWh/yr.

- Reduction of Air-Conditioning Operating Time. Study the possibility of reducing the operating time of the centrifugal chiller, cooling towers, and condenser pump by 15 to 30 minutes before 4:30 P.M., while operating the AHUs and chilled water pumps. Generally, the temperature of the cooling water is enough to carry the load before shutdown.

Projected savings: (See Attachment D for computations).

A.1 Switch off chillers, cooling towers, and condenser pump 15 minutes before 4:30 P.M. (assume COP = 4.15)
Savings in kWh/yr : 30,845.63
Percent of total : 0.77

A.2 Switch off chillers, cooling towers, and condenser pump 30 minutes before 4:30 P.M. (assume COP = 4.15)
Savings in kWh/yr : 61,691.52
Percent of total : 1.53

Further recommendations are as follows:

- Continue to Operate the Chiller at Full Load Capacity. As a rule, it is good to operate the compressor at its full-load capacity at which its motor is most efficient. During the summer months, try to delay as much as possible the simultaneous operation of two 450-ton chillers as this is likely to result in a low kW/ton refrigerating effect. One method of solving this problem is to consider the purchase of a small chiller in the 150 - 250 ton class. Instead of operating another 450-ton chiller when one 450-ton chiller operating at full capacity can no longer supply the necessary cooling energy, a small backup chiller will be operated parallel with one 450-ton chiller. The combined operation of a small chiller and one 450-ton chiller will give a much higher kW/ton than two 450-ton chiller operating simultaneously.
- Recalibrate All Air-Conditioning System Controls. Thermostats should be locked to prevent resetting by unauthorized persons.
- Check Chiller Manufacturer's Data. It is recommended that the efficiencies of the chillers be verified by checking the water temperatures in and out of condensers and chillers against design specifications, and by checking the amperage on compressor motor against manufacturer's data, and then making the necessary adjustments to operate the chiller efficiently.
- Check Air Handling Units' Condition. Check alignment of motor and fan, and when belts are used for power transmission, see to it that all are equally tensioned. When belts are frayed, loose, or need replacement, the entire set should be replaced.
- Properly Sized Motors. Energy savings could also be affected by replacing oversized fan motors with motors that properly match actual loads. Check if the existing motors are underloaded. If so, technically evaluate whether energy savings could be realized if existing oversized motors are replaced with properly sized motors.
- Proper Maintenance of Equipment. Dirty or poorly maintained equipment may continue to operate, but only by consuming greater amounts of energy. Therefore, maintenance is considered an essential element of energy conservation.
  - Cleaning of Filters. The manually-serviced type air filter requires periodic cleaning or replacement. The usual indication that cleaning or replacement is required is either a decrease in air flow through the filter or an increase in resistance across the filter. Dirty filters not only lower the power consumption of the fan, they will also lower the overall cooling capacity of the AHUs.
  - Cleaning of Coils. The efficient operation of both cooling and heating coils depends largely upon the cleanliness of the heat transfer surfaces. The coils can be cleaned with detergents and high pressure water using portable units.
  - Fan Maintenance. Thoroughly clean the fan (or blower) blades and check for damages in the blades that may cause out-of-balance running and excessive noise. Lubrication of bearings will reduce frictional losses. Adjust tension of belt drives whenever necessary.

- Check Strainer Screens in Pumping Systems. Regular cleaning of strainer screens keeps pressure losses in liquid systems to a minimum, thus saving pumping energy. It may be possible to replace fine-mesh strainer baskets with a much larger mesh, without endangering the operation of the system. This again will reduce pressure loss in the system and save energy.
- Check cooling tower bleed-off periodically to ensure that water and chemicals are not being wasted.

- Turn-off unnecessary equipment.

Table D-1. Metered Power Factor

% Power Factor Lighting System	A/C System	Month
93.1	86.1	10
92.9	86.5	9
94.3	86.1	8
94.6	85.5	7
93.7	82.5	6
93.9	87.4	5
93.7	94.0	4
93.8	94.2	3
94.5	93.7	2
95.2	96.0	1

ATTACHMENT A

ASEAM2.1 Report: Peak Load Summary

Space: Building
Floor Area: 213,783 ft^2
Volume: 1,859,320 ft^3

	COOLING	
Time of Peak:	Dec hour = 16	
Outside Temp:	92.5 °F	
	Sensible (Btu/hr)	**Latent** (Btu/hr)
Glass Solar	1,162,283	
Glass Conduction	313,397	
Wall Conduction	104,225	
Roof Conduction	10,684	
Opaque Solar	229,203	
Door Conduction	0	
Misc. Conduction	60,286	
Occupants	353,488	369,500
Lights	916,990	
Equipment	62,994	
Misc. Sensible	36,275	
Infiltration	206,878	
Total	3,456,704	
Total Load/Area (Btu/hr-ft^2)	16.2	

Note:

The auditorium was simulated in a separate run.

The external glass doors' conduction is 0 because the glass doors are treated as windows.

Only the sensible component of the infiltration load is counted. The corresponding latent load could be twice this amount making infiltration a major cooling load component.

ATTACHMENT B

ASEAM2.1 Report: Peak Load Summary

Space: Auditorium
Floor Area: 4,900 ft^2
Volume: 78,400 ft^3

	COOLING	
Time of Peak:	Jun hour = 16	
Outside Temp:	97.5 °F	
	Sensible (Btu/hr)	**Latent** (Btu/hr)
Glass Solar	12,917	
Glass Conduction	6,145	
Wall Conduction	13,306	
Roof Conduction	13,230	
Opaque Solar	18,473	
Door Conduction	0	
Misc. Conduction	1,022	
Occupants	46,000	47,500
Lights	63,093	
Equipment	560	
Misc. Sensible	0	
Infiltration	7,535	
Total	192,280	
Total Load/Area (Btu/hr-ft^2)	39.2	

Note:

The auditorium was simulated separately because its operating/occupancy schedule is different from that of the rest of the building.

Only the sensible component of the infiltration load is counted. The corresponding latent load could be twice this amount making infiltration a major cooling load component.

ATTACHMENT C

ASEAM2.1 Report: BLDG-END USE * Building Annual Energy by * * End Use and Fuel Type *

	Electric (kWh)
Heating Energy	
	0
Cooling Energy	
Centrifugal Chiller	877,718
Domestic Hot Water Energy	
	0
Building Miscellaneous	
Lights	1,121,856
Equipment	43,734
System Miscellaneous	
Fans	628,567
Plant Miscellaneous	
Cooling Tower	239,735
Pumping	612,324
Misc. Lights/Equip.	33,569
Elevators/Pumps	214,579
FM Station	69,080
Aux. Air-Con/EDP	141,912
Consumption Totals (kWh/yr)	4,024,483

ATTACHMENT D
AIR-CONDITIONING SYSTEM COMPUTATIONS

A.1 Switch off chillers, cooling towers, and condenser pump 15 minutes before 4:30 P.M.

Daily savings:

Chiller: 1 unit x 380 kW x .25 hr	95.000 kWh
Cooling tower: 2 units x 25 hp x .746 kW/hp x .25 hr	9.325 kWh
Condenser pump: 1 unit x 75 hp x .746 kW/hp x .25 hr	13.987 kWh
	118.312 kWh

Yearly savings:

118.312 kWh/day x 5 days/wk x 365/7 wks/yr	30,845.63 kWh
Percent of total: 30845.63/4,024,483 x 100	0.77 %

A.2 Switch off chillers, cooling towers, and condenser pump 30 minutes before 4:30 P.M.

Daily savings:

Chiller: 1 unit x 380 kW x .50 hr	190.000 kWh
Cooling tower: 2 units x 25 hp x .746 kW/hp x .50 hr	18.650 kWh
Condenser pump: 1 unit x 30 hp x .746 kW/hp x .50 hr	27.975 kWh
	236.625 kWh

Yearly savings:

236.625 kWh/day x 5 days/wk x 365/7 wks/yr	61,691.52 kWh
Percent of total: 61691.52/4,024,483 x 100	1.53 %

ATTACHMENT E

LIGHTING ENERGY SAVINGS COMPUTATIONS

A.1 Reduction of lighting operating time by 1 ½ hours/day for at least 90% of the lighting load.

Simulated lighting usage/yr	1,121,856 kWh
Operating hours/day	9 hrs
Proposed cutdown on hrs/day	1.5 hrs
Actual total lighting load (including ballasts)	L

Lighting usage w/o cutdown on hrs:
L x 9 hrs/day = 9L

Lighting usage w/ cutdown on hrs:
0.9L x (9 - 1.5) hrs/day + 0.1L x 9 hrs/day = 7.65 L

$$\% \text{ Savings} = \frac{9L - 7.65L}{9L} \times 100\% = 15\%$$

Usage savings = 15/100 x 1,121,856
= 168,278.4 kWh/yr

@ P 1.65/kWh,

Cost savings = P 1.65/kW x 168,278.4 kWh/yr
= P 277,659.36/yr

APPENDIX E

HOTEL INTERCONTINENTAL MANILA

AUDIT REPORT

THE PHILIPPINES

This report is one of eight detailed audit reports prepared by the Philippine group focusing on hotels. This report is an excellent in-depth study of the building's energy use patterns. It also presents detailed calculations of energy consumption and the potential savings through energy conservation opportunities.

HOTEL INTERCONTINENTAL MANILA

AUDIT REPORT

Prepared by

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BACKGROUND

The ASEAN-USAID Buildings Energy Conservation Project

The U.S. Government through its Agency for International Development is sponsoring a project called the ASEAN-USAID Buildings Energy Conservation Project in the ASEAN region. The project aims to use computer simulations to appraise energy use patterns and characteristics, as well as the potential energy savings, in existing buildings in the Philippines, and subsequently to recommend the framework for setting cost-effective "Building Energy Use Standards" to be incorporated in the National Building Code.

The project involves both public and private sectors in various aspects of its implementation to ensure the development of practical and acceptable guidelines or policies on energy conservation in buildings.

A technical committee and project staff compose the project management structure. The technical committee, represented by both public and private sector organizations, provides technical guidance and support in the formulation and implementation of building energy conservation policies. The project staff, on the other hand, is responsible for the day-to-day operation of the project, performing all energy surveys/audits, computer simulations, and research work.

The Audit Team

The project staff is divided into four subgroups assigned to deal with several aspects of energy conservation. Two of these subgroups are now working in close association to undertake a study on air-conditioning in buildings and to analyze, assess, and develop policies which will be the final output of the project.

Specifically, the group is tasked to:

- Identify ways in which cooling systems can be configured and installed in local buildings to reduce energy use;
- Utilize computer tools to evaluate performance of air-conditioning and control equipment;
- Prepare and gather base-line data on building energy use;
- Compile existing building energy audit results; and,
- Conduct detailed energy audits of selected buildings.

The two subgroups compose the audit team that conducted the detailed energy audit of the Hotel Intercontinental Manila last April 12, 14, and 18, 1988. The subgroups are the Assessment, Analysis and Policy Studies Group and the Air-Conditioning Equipment Group.

Selection of Buildings for the Detailed Energy Audit

The audit team has conducted energy surveys of several buildings within Metro Manila in order to gather base-line data on the trend of energy usage in local buildings. From the set of buildings surveyed, six buildings of the following classifications—hospital, office, hotel and supermarket—were selected for a detailed energy audits. The latest techniques in energy auditing were applied to identify energy conservation measures which are then assessed using available computer programs. An economic feasibility analysis of each energy conservation opportunity (ECO) identified was also performed.

A set of criteria was formulated by the audit team as a basis in the selection of buildings for the detailed energy audit. These are as follows:

- The annual energy consumption of the building should be more than 3.8 million kilowatt-hours or 1 million fuel oil equivalent liters of energy, inclusive of liquid fuels and electricity (as per requirement of Rule VII of Batas Pambansa (BP) Blg. 73 as amended by BP Blg. 872 which requires all commercial, industrial, and transport establishments consuming the aforementioned amount of energy to submit quarterly energy consumption reports to the Bureau of Energy Utilization, (now Office of Energy Affairs)).

- The window-to-wall ratio should be between 0.2 to 0.6.
- The air-conditioning system should be centralized.
- The building's cooling energy requirement should make up 50% of the total energy consumption of the building (based on ASEAM-2 output on breakdown of energy consumption).
- All equipment should be accessible for testing and inspection.
- All pertinent documents and data needed for evaluation should be available.
- The staff should be willing and cooperative.
- A potential for energy conservation should exist (based on the energy survey and ASEAM-2 output).
- An energy management program should exist.

Hotel Intercontinental Manila: Profile

The Hotel Intercontinental Manila is one of more than 80 Intercontinental Hotels all over the world. The hotel is centrally located in Makati, Metro Manila's financial and commercial district. It has 390 air-conditioned guestrooms that offer accommodations for single, double, or triple occupancy.

There are seven meeting and function rooms that can accommodate up to 1,500 people for banquets, receptions, meetings, exhibits, and shows. Other hotel facilities include two specialty restaurants, the Jeepney Coffee Shop and LaTerrasse; a cocktail lounge; bars; a pool; snack bar; and a discotheque.

A shopping arcade is located on the ground floor and includes souvenir shops, travel agencies, car rentals, a photo shop, and a flower shop. A beauty parlor and a barber shop are also provided on the second floor. As in other five-star hotels, room service is provided 24 hours a day.

METHODOLOGY

The Preliminary Survey

A visit to the Hotel Intercontinental Manila for an energy survey was made by the audit team on March 2, 1988. Data required to fill in the input forms of a computer program, ASEAM-2, were obtained (e.g., conditioned and unconditioned floor areas, construction materials, walls, windows, electrical equipment, air-conditioning equipment, and others). The computer program simulates the building energy usage throughout a year.

Prior to computer simulation, and even before the ASEAM-2 input forms are filled in, the building is "zoned." This is an important step in any building energy analysis program. Zoning requires a building to be divided into small areas with similar thermal and system characteristics. A zone is defined to be at a uniform space temperature, has one operating schedule, and served by one air-conditioning system.

The data gathered from the preliminary survey indicate that the Hotel Intercontinental Manila building has satisfied the set of criteria for the selection of buildings for the detailed energy audit. Initial findings show that the hotel, which was constructed during the late 1960s, has a window-to-wall ratio of 0.446. It uses a centralized air-conditioning system that consumes about 50.7% of its annual energy consumption of 6.989 million kilowatt-hours.

Furthermore, the availability of pertinent documents and cooperative staff to facilitate the conduct of the detailed energy audit were contributing factors in considering Hotel Intercontinental Manila for the detailed energy audit.

The Detailed Energy Audit

The detailed energy audit involved a comprehensive building inspection to determine exactly where and at what times energy was being consumed and where opportunities for conservation exist. The audit entailed several procedures for data collection. Among these are the following:

- Inventory of building structural features as well as mechanical and electrical equipment installed;
- Conduct of interviews and random surveys of the building occupants;
- Actual head count of building occupants at certain time intervals; and
- Actual measurements of important equipment operating parameters.

To facilitate the conduct of the detailed energy audit, the team was divided into three subgroups assigned to deal with the several audit procedures on three major energy-consuming systems in the building: the air-conditioning system, the electrical system, and architectural and structural systems.

ANALYTICAL TOOLS

The ASEAM-2 Program

A Simplified Energy Analysis Method, Version 2.0 (ASEAM-2) is a modified bin method program for calculating the energy consumption of a building. As part of its database, the program uses the floor, wall and fenestration areas, the air-conditioning, the lighting and electrical equipment, and other specifications for the subsequent software calculations and simulation. For the Philippine audit project, if the annual total energy requirements from the program's summary annual output report has a difference of not more than 10% from the actual kWh/yr bill of the building, then it is accepted as representative of the overall building characteristics, in terms of cooling load (watts), energy consumption (kWh/yr), and the building envelope (U-values, shading coefficient, etc.).

The Carrier Program

Carrier Corporation's Hourly Analysis Program (HAP) evaluates loads and system operation on an hourly basis, utilizing a nine-step procedure. The first three steps consist of defining weather data, day and schedule data, and defining spaces. Once these basic data are defined, the energy analysis procedure begins. The fourth and fifth steps define air system characteristics and control. Then air system operation for average weather and load conditions are simulated. This analysis generates the hourly cooling and heating coil data as well as fan input power quantities. The sixth step defines the plant's capacity, control, and operating characteristics, together with the air systems served by the plant. In the seventh step, plant operation is simulated using average weather data and coil load data from the air system simulations. Results include hourly input power data for equipment components such as compressors, pumps, cooling tower fans, heating elements, and boilers. In the final input stage, all the energy-consuming systems in the building are defined, as are cost and currency parameters. The ninth step develops a cost calculation based on the hourly power data for all energy-consuming systems in the building.

The DOE-2 Program

DOE-2 is a building energy use analysis program which also uses the hourly method in performing its calculations. First, LOADS calculation computes the heat loss and gain to the building spaces, and the heating and cooling loads imposed upon the building HVAC systems. Then the SYSTEMS calculation determines energy demand of the building. Finally, the PLANT calculation is the third step calculates the energy requirements of primary equipment—such as boilers and chillers, cooling towers, and others—in the attempt to supply the energy demand of HVAC and domestic steam and hot water systems.*

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* For see a more detailed description of DOE-2, see Vol. II, Chapter 2. of this report

Comparison of Analytical Tools

The ASEAM-2 software has a limited capability for modeling architectural and mechanical systems. Although it only takes a few minutes to run the program, such relatively quick output results in a proportionate loss of accuracy.

Carrier, on the other hand, offers a more flexible scheduling of lights, people, and equipment with a run time approximately the same as ASEAM-2. Its hour-by-hour simulation is more accurate than ASEAM-2's monthly modified bin method.

DOE-2 is a much more complex utility program than ASEAM-2 and Carrier. Although it also utilizes an hourly analysis method of computation and simulation, DOE-2 is more accurate than Carrier since it provides more options for simulation including various correction factors. Thus, run time will take about one hour for a 15-zone building using a 16Mh, 386 cpm personal computer.

BUILDING DESCRIPTION

General

Hotel Intercontinental Manila was constructed in the late 1960s. It has 14 floors, including a basement, with a gross floor area of 27,985 m^2. Seventy-one percent of the gross floor area (about 20,000 m^2) comprises the conditioned areas, including guestrooms, function rooms, ballroom, lobby, shops, restaurants, and offices. The 390 guestrooms make up the bulk of the conditioned area and occupy the top ten floors with an area of 1,530 m^2 per floor.

The Site

Hotel Intercontinental Manila is located at the heart of busy Makati Commercial Complex, a major urban business and commercial district in Metro Manila. It is bounded on the northeast by a main road, Ayala Avenue, and a block away, on the southeast, by E. de los Santos Avenue (EDSA).

Nearby buildings, within a 500-meter radius of the hotel, consist mainly of a 15-story residential condominium across Ayala Avenue, a two-story shopping arcade, and a four-story commercial building on the southwest. At the rear of the hotel, along EDSA, is a three-story parking garage, and fronting the hotel is a parking lot.

The level of density of nearby construction is moderate, with only about ten buildings within a half-kilometer radius, and with ample clearances between structures. The hotel is not in direct contact with any adjacent buildings.

Form and Space Organization

In general, large hotels are characterized by a complex functional space mix: service areas, guestrooms, assembly areas, etc. The blend of these functional spaces yields an energy mix of both internally load-dominated service areas and externally load-dominated guestrooms.

Space organization, or how spaces are arranged or grouped together, plays a significant role in the control of thermal loads. The building plan can have a major effect on the energy requirements for maintaining specified comfort conditions.

It is noted that the so-called "back of the house," which includes most of the service areas and equipment rooms of Hotel Intercontinental, is located in the southeastern and southwestern exposure e.g., the fan room near the ballroom on the second floor, and the kitchen and storage areas on the ground floor. These are strategic locations for service areas because they act as unconditioned buffer zones for control of solar gain in adjacent conditioned spaces.

The hotel is basically rectangular in shape, from the third floor to the topmost level, and L-shaped on the ground and second floor levels. The building's longer side is oriented along the northeast-southwest axis, which admits reduced direct solar radiation from the east-west exposure.

Guestroom layout is of the double-loaded corridor type, with two rows of rooms on either side of a common hallway. This type of layout allows for provision of a glass area in each guestroom, intended for outside views and daylighting.

The rooms face two directions, one row on the northwest, and another row on the southeast. Guestrooms located on the northwest side, facing Makati Commercial Complex, are exposed to afternoon sun and consequently have greater solar heat gain than guestrooms exposed to the southeast, facing EDSA, which admit only morning sun.

Based on the hourly load calculation output of the Carrier program, a typical southeast guestroom has peak solar heat gain equal to 254.1 W/m^2, while a typical northwest guestroom has peak solar heat gain equal to 474.8 W/m^2, twice as much as the former. Moreover, solar gain by exposure of glass per square meter of glass area is computed to be 10.01 W on the northwest and only 3.68 W on the southeast. Peak load time occurs at 3:00 P.M. in July.

A marked difference in the heat build-up of the two types of guestrooms is evident. This can be attributed to varied intensity of of solar heat on different orientations. Proper orientation of building spaces is an important factor for an energy-efficient building.

Building Envelope

External Walls:

Solar energy enters a space through surfaces, such as external walls, which are exposed to the sun. This results in heat gain inside a space that affects the building's total cooling load. The wall construction system and materials used are two important elements in determining the amount of heat gain inside a conditioned space.

The type of external wall construction used throughout the hotel building is conventional, with the core built of 15-cm poured concrete. Exterior finishes are either plastered or glass washout, while interior finishes vary for different areas. The heat transmission value (U-value) for a typical wall construction is computed below.

Outside air film	0.25
10 mm. glass washout	0.03
12 mm. mortar	0.10
150 mm. concrete	2.40
20 mm. plaster	0.15
Inside air film	0.68
Total Resistance	3.61 hr-ft^2-°F/Btu
U-Value	0.277 Btu/hr-ft^2-°F
	or 1.57 W/m^2°C

External surface color also affects a building's energy performance. Light-colored surfaces have lower thermal absorptance values, and hence, allow less heat gain. For the hotel building, absorptance value of external walls is 0.30.

Windows:

Most solar heat gain comes from radiative heat gain through glass areas. In comparison, only a small portion is contributed by conductive heat gain through opaque walls. Among the envelope features, fenestration characteristics dominate the building's cooling requirements.

Thermal load calculations consider two types of load components associated with glass, namely, solar gain and conduction. In Hotel Intercontinental, glass solar gain and glass conduction contribute 25.6% and 13.1%, respectively, to the total cooling load requirement of the building (see Table E-13). The sum of the two glass load components constitutes a substantial 38.7% of the hotel's total cooling load. This can be attributed primarily to the glass type used, the shading coefficient of the window system, and the window area in the form of window-to-wall ratio.

Glass Type. Two types of glass elements are used in the building. The first is fixed 6 mm (1/4") thick glass with reflective coating located on the ground and second floors on the northwestern, southeastern, and part of the northeastern exposures of the building. The heat transmission value for this type of window is 4.6 W/m^2°C. The second type of glass is 5 mm (3/16") thick clear glass used in the guestroom windows, also with a heat transmission value of 4.6 W/m^2°C.

Windows are found to be tight-fitting, weather-stripped, and most are fixed in their frames. These factors allow for reduced air infiltration due to cracks or leakages.

Shading Coefficient. The shading coefficient is the ratio of the solar heat gain of fenestration to the solar heat gain of reference glass, which is a single sheet of clear glass. The shading coefficient depends in general not only on the type of glass but also on whether venetian blinds, shades, draperies, etc., are used on the windows. Values for a range of commonly used glass types can be found in the *ASHRAE Handbook of Fundamentals.*

Curtains of various weaves are used extensively on almost all windows. Taking this, and the glass type used, into account, the shading coefficient for the clear glass is 0.64, and for the reflective-coated glass it is 0.42.

Window-to-Wall Ratio. Window-to-wall ratio is the total glass area divided by the sum of the total fenestration area and the total opaque wall area of the building. Hotel Intercontinental has a window-to-wall ratio of 0.4458, an average value for most of the buildings surveyed by the team. A relatively large window area may account for the significant load due to heat gain through glass.

Roof:

The roof is a flat concrete slab provided with a 2 in. fiberglass insulation blanket. The computed heat transfer coefficient (U-value) is 0.477 W/m^2°C. The addition of an insulating material to the roof construction caused a significant reduction in the heat transmittance value of the roof system.

Total roof area is 3020 m^2, which is only 10% of gross floor area. The thermal absorptance value of the roof is a high 0.91 because the external surface is dark-colored. A light-colored finish is advantageous for maximum reflectivity or lower absorptance. This allows less heat gain into the conditioned space.

External/Internal Shading:

The effect of solar heat on fenestration may be significantly reduced by installing various shading devices, such as overhangs, horizontal and vertical architectural projections, awnings, louvers, and other types of sun baffles.

External shadings of the eggcrate type are used in the guestrooms. This form of shading is characterized by horizontal projections or overhangs, and vertical projections or fins on both sides of the window. This type combines the effect of an overhang, which works well on southerly orientations, and the effect of fins, which are effective on easterly and westerly orientations.

Precast sunshades with glass washout finish are connected to 75 cm. deep concrete overhangs. The sunshades, with a depth of 96 cm., sufficiently cover the window area against solar radiation.

Indoor shading devices for most windows consist of double draperies. Nearest to the glass areas is a thin white lacy curtain for outward vision and daylight when desired. A dark-colored close-weave curtain for blocking out sunlight and providing privacy lies over this. However, to most effectively reduce solar heat gain, drapery exposed to sunlight should have high reflectance and low transmittance. That means it is better to have the open weave drapery (the white curtain) on the room side.

Advantages gained through proper use of double draperies are: (1) extreme flexibility of vision and light intensity; (2) a lowered shading coefficient leading to lowered solar heat gain; and (3) an improved comfort condition, as the room side drapery is more nearly at room temperature.

Interior Partitions:

To offset infiltration and heat transmission between conditioned and unconditioned spaces, thermally-resistant materials must be installed as partitions, leakages in door openings must be minimized, and practical housekeeping measures must be adopted.

The hotel's wall partitions are constructed of 10 cm. (4 in.) concrete hollow blocks plastered and with paint finish. It was noted during the survey that some areas, like the restaurants and bars, use special types of wall finishing materials such as bamboo, stone, brick, etc. Heat transmission values (U-values) of wall partitions range between 1.36 and 2.32 $W/m^2{}^\circ C$.

Occupancy Schedule

Usage patterns, perhaps the most significant determinant in energy usage, differ for different types of buildings. Hotel Intercontinental is inherently energy intensive because it operates 24 hours a day.

Offices, function rooms, and shops have greater occupancy densities during the working days. Shops are open from 8:00 A.M. to 9:00 P.M. with peak hours usually in the morning. Lobbies, on the other hand, have a more diverse occupancy density for the 24-hour day. The ground floor lobby usually fills up with people during the afternoons and mid-mornings.

Restaurants are generally occupied during mealtimes. Even then, the hotel's restaurants occupancy seldom reach their maximum capacity, except for the Jeepney Coffee shop on the ground floor, which was observed to have a regular influx of patrons. The disco and ballroom have maximum occupancies during the week-end evening hours.

Internal heat gain due to occupants contributes 23.1% to the total cooling load of the building. A significant percentage of the building's cooling load due to people may be attributed to the nature of services offered by the hotel.

AUDIT FINDINGS AND RECOMMENDATIONS

General

Hotel Intercontinental's annual energy consumption is 349 kWh/yr m^2. This value typifies the average energy consumption of hotels in Metro Manila, which is 351 kWh/yr m^2, based on the energy surveys conducted by the ASEAN-USAID project staff on eight other hotels.

The air-conditioning system constitutes the largest installed power load, at 50.7% of the total electrical consumption per year. The air-conditioning system as an energy-consuming component contributes significantly to the annual electrical consumption of any building. Lighting follows next at 21.5%, and electrical equipment at 9.6%.

Each of these energy-consuming components will be discussed in more detail later.

Electrical System

Findings:

Distribution System. The main normal power is supplied by the utility grid, MERALCO, at 34.5 KV three-phase primary lines through two transformer banks, each with a rated capacity of 1500 KVA and which step down the primary voltage to 460 volts and 208 volts at the secondary terminals. A nominal voltage of 440 volts, 60 Hz, is utilized for large motor loads, which include the chiller compressor motors and other large motors. The 208 volt system serves the general lighting load and convenience outlets as well as small motor loads, such as refrigerators and shop equipment.

In general, the distribution system layout is adequate to serve the electrical power needs of the various building facilities. Line efficiency is assumed high, allowing only minimal line losses which are estimated to account for roughly 28,649 kWh/yr.

Indoor Lighting System. The lighting system consists mostly of incandescent lamp fixtures, as is typical of hotel buildings where the aesthetic and color-rendering properties of incandescent lighting are most appropriate. A comparatively smaller portion comprises 1 x 40 W and 2 x 40 W fluorescent lamp fixtures of the high power factor, rapid-start type. Understandably, incandescent lighting illuminates areas where guests and hotel customers stay and frequent, such as guestrooms, lobbies, restaurants and cafeterias, and ballrooms, while fluorescent fixtures light up the work areas, such as offices, service and maintenance areas, as well as non-air-conditioned spaces.

The total lighting input power for the air-conditioned space is estimated at 307.66 kW. Only 26.64 kW (or 8.66%) is attributed to fluorescent lamps; the remainder—281.02 (or 91.34%)—is attributed to incandescent lamps. Total lighting power density,* then is 19.17 W/m^2. This is not far below the standard electrical design value of 20 W/m^2. The actual average lighting W/m^2 for the different areas of the building are tabulated below.

Area	*Lighting W/m^2*	*Area Served in Percent of Total Net Air-Conditioned Area*
Lobbies/Hallways	15.65	8.93
Shopping Arcade	30.70	3.71
Offices	17.81	4.76
Restaurants/Cafes	15.88	11.48
Guestrooms	16.08	57.55
Function Rooms/Ballrooms	44.55	9.75
General Service Areas	9.47	3.82

Although in some areas the illuminance appears adequate, actual light measurements show illuminance levels at the working place or desk-top level that are lower than the IES (Illuminating Engineering Society) recommended values. This condition is especially true in such areas as offices, stairwells, the main kitchen, and hallways on the guestroom floors which are provided with fluorescent lighting. Good and adequate illumination is present in the lobbies, laundry, and most hallway areas.

The overall low illuminance level in some areas can be attributed to:

- The low light transmission characteristics of the plastic diffusers being used for fluorescent fixtures in the main kitchen and in office areas.
- Task lighting in the guestrooms and in the cocktail lounge LaTerrasse, using only incandescent lamp fixtures.
- Entirely incandescent lamp lighting in the restaurants and cafeterias, except in the basement dining area.
- Relatively high mounting heights of some fluorescent lamp fixtures in the basement hallways and utilizing only 1 x 40 W fluorescent lamp per fixture.
- Relatively dark ceiling and wall coloring.

On the other hand, marginally acceptable illuminance level in other areas can be attributed to:

- Absence of diffusers for open-type fluorescent lamp fixtures in the basement hallways.
- Utilizing 2 x 40 W fluorescent lamp fixtures instead of the 1 x 40 W type.
- Available daylighting.
- Lower fixture mounting height.

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* The area being considered is the building's net air-conditioned area

The actual measured and IES-recommended illuminance levels for the different areas in the building are tabulated as follows:

Area	Illuminance, lux Actual Measured	IES Recommended
1. Hallways:		
Basement	15 - 260	215
Shopping Arcade	1250 (with daylighting)	215
Guestroom Floors	30	215
2. Offices:		
Engineering	120 - 200	323 - 1076
Front Office	150 - 200	538
Food & Beverage	150 - 175	323 - 1076
Business Center	100 - 125	323 - 1076
3. Lobbies:		
Ground Floor	180 - 200	108 - 323
Second Floor (office areas)	100 - 300	108 - 323
Elevator Lobbies	125 - 150	108 - 323
4. Restaurants:		
Employees' Bistro	120 - 200	32 - 1076
LaTerrasse	40 - 60	32 - 1076
Prince Albert	10 - 20	32 - 1076
Fabrica de Cerveza	40	32 - 1076
Jeepney Stop	100 - 150	32 - 1076
5. Engineering Warehouse	180 - 280	54 - 538
6. Laundry	100 - 700	323 - 1076
7. Stairwell	80 - 120	215
8. Main Kitchen	180 - 200	323 - 1076

The indoor lighting system efficiency, when measured in terms of actual useful lumens received on the working plane, is quite low, with an estimated overall efficacy of 18.22 lumens/watt. With the majority of the lighting fixtures consisting of incandescent lamps with a mean efficacy of about 12 lumens/watt, and with only a small portion comprising fluorescent lamps with a nominal efficacy of about 61 lumens/watt, the overall mean lumens/watt is estimated as follows:

For fluorescent lamp fixtures:

$$\text{Total watts} = (26.64 \text{ kW} + 0.90 \times 25.40 \text{ kW})\frac{1}{1.20} = 41.25 \text{ kW}$$

For incandescent lamp fixtures:

$$\text{Total watts} = 281.02 \text{ kW} + 0.10 \times 25.40 \text{ kW} = 283.56 \text{ kW}$$

$$\text{Mean Efficacy} = \frac{61 \times 41.25 + 12 \times 283.56}{41.25 + 283.56} = 18.22 \text{ lumens/Watt}$$

where:

26.64 kW	=	actual input power due to fluorescent lamp fixtures in air-conditioned space
281.02 kW	=	actual input power due to incandescent lamp fixtures in air-conditioned space
25.40 kW	=	actual total lighting input power in non-air-conditioned space
0.90	=	portion of non-air-conditioned space lighting due to fluorescent lamp fixtures
0.10	=	portion of non-air-conditioned space lighting due to incandescent lamp fixtures
1.20	=	factor to account for ballast power losses (typically 20% of lamp wattage)

Indoor lighting system efficiency is also measurable by the ballast losses incurred. The total ballast losses is approximately 11.96 kW or about 3.6% of the total indoor lighting load, as presented in the Electrical System Loss Calculations section. Equivalent ballast energy consumption is estimated at 70,879 kWh/yr (P141,759/yr. @ P2/kWh)* or 14% of the total accumulated annual building electrical energy losses.

Building Convenience Outlets and Appliance Loads in the Air-Conditioned Space. Most of the appliance loads inside the air-conditioned space are due to household refrigerators and color television sets for the guestrooms, household refrigerators and freezers in the restaurant areas, and laundry equipment (which is the largest consumer concentrated in a single enclosed area).

Some lighting loads are also connected to receptacle outlets but these are already incorporated in the building total lighting load.

Estimates show that the appliance† and receptacle loads constitute 131.71 kW of the total building load. Its overall expression in terms of power density‡ is 8.20 W/m^2. A power density tabulation according to the different areas is given below.

Area	*Equipment W/m^2*	*Area Served Percent of Total Net Air-Conditioned*
Lobbies/Hallways	0.0 (or negligible)	8.9
Shopping Arcade	5.29	3.7
Offices	3.72	4.8
Restaurants/Cafeterias	1.59	11.5
Guestrooms	8.67	57.6
Function Rooms/Ballrooms	2.66	9.8
General Service Areas	62.79	3.8

Electrical Power Factor Characteristics. The monthly metered electrical power factor of the building electrical system has been consistently maintained at a high 99% or better, due to an installed power factor correcting capacitor bank. As a bonus, the billing power factor constant is reduced to 0.951, so that immediate monthly savings of P9,800 * per hundred thousand kWh is

* The conversion rate used, as of June, 1990, was 22.885 Philippine pesos to 1 U.S. Dollar.
† The terms appliance, convenience outlets/loads, and receptacle outlets/loads may be used interchangeably.
‡ The area considered is the building's net air-conditioned area.
* Taken at P2.0/kWh electrical energy cost which includes generation, demand, and other charges.

obtained.

Building Motor Loads. Table E-7 shows that motor loads compose approximately 76.9% of the building total load and require 73.6% of the building annual total electrical energy consumption. This indicates that the system is a major source of ECOs.

As expected, the air-conditioning equipment accounts for the largest proportion of motor input power, being rated at a total of approximately 823.61 kW, whereas other motors comprising exhaust fans and blowers, elevators, etc., only contribute about half as much at approximately 417.81 kW.

Based on the detailed analysis of the air-conditioning system using computer simulations, average yearly operating and loading characteristics of the relevant motors can be evaluated. Other motors not included in the air-conditioning system are evaluated in a less sophisticated and detailed manner, without benefit of computer simulation, and using only base-line and approximate values in order to come up with acceptable yearly energy usage estimates.

The entire motor usage calculations, including usage factor (UF), load ratio (LR) determination, and energy losses breakdown are presented in the Electrical System sub-section.

Further investigation of the motor operating characteristics, shown in Table E-7, reveals the prevalence of high motor LR characteristics, i.e., more or less 1.0 for those in the air-conditioning system. The highest LR values are registered by the chiller motors and fan coil units (FCUs), which are assumed to operate at full load continuously. Only the cooling tower fan motors have noticeably low LR values. Miscellaneous motors such as boiler feed pumps and air compressor have varying LR values, since they are assumed to operate at widely varying loads and have very low UF values, due to their intermittent usage over a 24-hour period. Water pumps and hot water pumps with varying LR values, but with UF values of 0.6042 and 0.3333, are assumed to operate at variable loads at different time intervals equivalent to a total of 14.5 and 8 hours at peak load daily, respectively.

As a method of analysis, the UF values may be taken as representative of the motor loading ratios, provided the motor operates almost continuously for 24 hours a day. Such a condition is true for the motors of the air-conditioning system, exhaust fans, and blowers as well as miscellaneous kitchen equipment and refrigerators which have almost equal UF and LR values.

Based on the UF values, in addition to actual LR determination, it can be seen that the fan motors of the air handling units are operating at underloaded conditions. Maintaining a lower fan cfm may actually be part of an energy conservation plan. Still, an energy conservation opportunity exists here, as these motors are usually oversized. A similar case is evident in the cooling tower fan motors' loading performance. These motors were found to have very low computed LR values—at 0.3425—which shows that these are also oversized.

Motor losses contribute roughly 84.3% to total energy losses incurred (see Table E-11). This figure implies that a good deal of energy savings can be realized just by reducing the losses. Again, the larger portion of these losses (55.4%) comes from the air-conditioning motor equipment.

Building Load Demand and Energy Usage Profile. Figures E-1 and E-2 show the load demand profile for the year 1987 as well as the first quarter report on the same data for the year 1988 (see Table E-10). Illustrated are the behaviors of the monthly kW demand and kWh consumption, and load factor. The highest peak demand kW at 1416 kW was registered during the month of June and the lowest at 1050 kW on January. The monthly usage averaged over eleven months (i.e., excluding the month of February, when usage is too low) is 582,436 kWh. This average can now be used to obtain a yearly reference usage value, i.e., 6,989,236 kWh/yr, which is used to validate the simulated yearly usage of 6,989,083 kWh/yr, (see Table E-12) with a percentage error of only 0.002.

The efficiency of maximum demand use is measured by the parameter Load Factor (LF). In an ideal situation, the LF value is 1.0 and this means that, for the period (i.e., one month) at which the peak demand was taken, the load demand was constant at the value equal to the maximum demand. This, therefore, is an optimized situation, wherein the demand charge costs do not have to cover wastages (see Figure E-5). Actual LF values taken for the whole year indicate a high of 0.705 during the month of January and a low of 0.540 during the month of October. The annual average LF is 0.632, which is equivalent to saying that the annual average maximum demand was in use 63.2% of the time. This is a relatively satisfactory value, though a lot of demand charge costs savings could still be obtained.

The energy usage breakdown is given in Table E-12 and illustrated graphically in Figure E-4. Based on this figure, it can be observed that the largest single energy-using component is the cooling plant—at 41.1% of the total. Lighting in the air-conditioned space is the next largest single energy-using component, with 21.5% of the total. Miscellaneous consumption, electrical equipment (in the air-conditioned space), and air-conditioning system auxiliaries constitute smaller percentages at 18.4, 9.6, and 9.5 of the total, respectively.

Electrical Usage Factor and Load Ratio Determination. In the absence of a complete set of electrical demand measurements and for the purpose of simple computational presentation, the term Usage Factor (UF) will be adopted to relate the annual electrical energy usage with the energy usage at rated input power and continuous operation (i.e., 24 hrs/day x 365 days/yr = 8760 hrs/yr for a hotel) of a particular connected load. More importantly, by using the UF, electrical system component energy losses can be estimated with acceptable accuracy while avoiding tedious computations. The mathematical expression is defined as follows:

$$UF = \frac{\text{Annual Energy Usage}}{\text{Rated Power Input x 8760}}$$

Load Ratio (LR), as used in this report, is understood to reflect the loading characteristic of an electrical energy consuming component by relating the actual power input with the rated power input. The mathematical expression is as follows :

$$LR = \frac{\text{Actual Power Input}}{\text{Rated Power Input}}$$

or:

$$LR = \frac{\text{Annual Energy Usage}}{\text{Rated Power Input x Total Operating Hours/yr}}$$

Usage Factor and Load Ratio Calculations.

Chillers

Chiller 1:

Operating Hours = 5840 hrs/yr
Rated Input Power = 332.95 kW
Rated COP = 4.5
Rated TR = 426 (derated from an initial 450 to account for equipment age)

From computer simulation reports, the following data were obtained:

Time Period = 2944 hrs/yr
Chiller Average Part Load Ratio (CAPLR) = 0.92
Chiller COP Factor * = 0.9037

* Note: To obtain average operating COP, the chiller COP is multiplied by the Chiller COP Factor defined by the equation: 0.222903 + 0.313387 x CAPLR + 0.463710 x $CAPLR^2$. (Source: DOE-2 Engineer's Manual)

Hence, calculation yields:

$$\text{Average Power Input} = \frac{12000 \text{ Btuh/ton} \times (\text{CAPLR} \times \text{Rated Tons})}{3413 \text{ Btuh/kW} \times (\text{COPfactor} \times \text{Rated COP})}$$

$$\text{Average Power Input} = \frac{12000 \times (0.92 \times 426)}{3413 \times (0.9037 \times 4.5)} = 338.85 \text{ kW}$$

$$\text{LR} = \frac{338.85}{332.95} = 1.018$$

Similarly,

Time Period = 2896 hrs/yr
Chiller Average Part Load Ratio = 0.894
Chiller COP Factor = 0.87368

$$\text{Average Power Input} = \frac{12000 \times (0.894 \times 426)}{3413 \times (0.87368 \times 4.5)} = 340.59 \text{ kW}$$

$$\text{LR} = \frac{340.59}{332.95} = 1.023$$

$$\text{Average LR} = \frac{1.018 \times 2944 + 1.023 \times 2896}{2944 + 2896} = 1.020$$

Chiller 2:

Operating Hours = 2190 hrs/yr
Rated Input Power = 243.26 kW
Rated COP = 2.9
Rated TR = 200

From simulation reports, the following data were obtained:

Time Period = 1104 hrs/yr
Chiller Average Part Load Ratio = 0.912
Chiller COP Factor = 0.8944

Hence,

$$\text{Average Power Input} = \frac{12000 \times (0.912 \times 200)}{3413 \times (0.8944 \times 2.90)} = 247.25 \text{ kW}$$

$$\text{LR} = \frac{247.25}{243.26} = 1.016$$

Similarly,

Time Period = 1086 hrs/yr
Chiller Average Part Load Ratio = 0.909

Chiller COP Factor = 0.8909

$$\text{Average Power Input} = \frac{12000 \times (0.909 \times 200)}{3413 \times (0.8909 \times 2.90)} = 247.41 \text{ kW}$$

$$LR = \frac{247.41}{243.26} = 1.017$$

$$\text{Average } LR = \frac{1.016 \times 1104 + 1.017 \times 1086}{1104 + 1086} = 1.016$$

For Chillers 1 and 2, therefore:

$$\text{Average } UF = \frac{1.020 \times 332.95 \times 5840 + 1.016 \times 243.26 \times 2190}{(332.95 + 243.26) \times 8760} = 0.500$$

Condenser Pumps

Average Measured Power Input/Unit = 18.10 kW
Rated Power Input/Unit = 21.19 kW
Operating Hours =
2 units at 5840 hrs/yr (Chiller 1 on)
1 unit at 2190 hrs/yr (Chiller 2 on)

$$LR = \frac{18.10}{21.19} = 0.854$$

$$UF = \frac{2 \times 18.1 \times 5840 + 18.1 \times 2190}{2 \times 21.19 \times 8750} = 0.6762$$

Cooling Tower Fans

Operating Hours =
3 units at 5840 hrs/yr (Chiller 1 on)
2 units at 2190 hrs/yr (Chiller 2 on)
Total Usage of Cooling Plants = 2,873,160.93 kWh/yr

Cooling Tower Fans Usage = 2,873,160.93 – (Chillers Usage + Condenser Pumps Usage)
= 2,873,160.93 – [(1.02 x 332.95 x 5840 + 1.016 x 243.26 x 2190) + (0.854 x 2 x 21.19 x 5840 + 0.854 x 21.19 x 2190)]
= 97,586.01 kWh/yr

$$LR = \frac{97{,}586.01}{3 \times 13.01 \times 5840 + 2 \times 13.01 \times 2190} = 0.3425$$

$$UF = \frac{97{,}586.01}{3 \times 13.01 \times 8760} = 0.2854$$

Fan Coil Units (FCUs)

Rated Input Power (total) = 11.0 kW
Actual Input Power (total) = 11.0 kW
Operating Hours = 24 hrs/day (approx. at peak load)

$$LR = \frac{11.0}{11.0} = 1.0$$

$$UF = \frac{11.0 \times 8760}{11.0 \times 8760} = 1.0$$

Air Handling Units (AHUs)

AHU Motor No.	*Rated kW Output (1)*	*Rated kW Input (2)*	*Operating Hrs/Day (3)*	*Daily Rated Energy Usage (2) x (3)*
1	3.730	4.60	6	27.60
2	5.595	6.66	14	93.24
3	11.190	13.01	19	247.19
4	5.595	6.66	9	59.94
5	11.190	13.01	20	260.20
6	5.595	6.66	10	66.60
7	14.920	17.05	22	375.10
8	7.460	8.78	11	96.58
9	5.595	6.66	14/7	13.32
10	2.238	2.76	75/7	29.57
11	5.595	6.66	11	73.26
12	7.460	8.78	10	87.80
13	7.460	8.78	9	79.02
14	2.238	2.76	11	30.36
	Total:	112.62		1539.78 kWh/day

From the DOE-2 computer simulation outputs: The air system fans (AHUs and FCUs combined total) yearly usage is 379,358.00 kWh/yr. Yearly AHU fans usage is therefore:

379,358.00 – FCU's Usage = 379,358.00 – 11.0 x 8750

= 282,998.00 kWh/yr

LR = Varies

$$UF = \frac{282{,}998.00}{112.62 \times 8760} = 0.2869$$

Chilled Water Pumps

Rated Input Power = 2 x 21.19 kW

Operating Hours =
2 units at 5840 hrs/yr (Chiller 1 on)
1 unit at 2190 hrs/yr (Chiller 2 on)
Actual Energy Usage = 287,425.00 kWh/yr (Source: DOE-2 output reports)

$$LR = \frac{287,452.00}{2 \times 21.19 \times 5840 + 21.29 \times 2190} = 0.978$$

$$UF = \frac{287,425.00}{2 \times 21.19 \times 8760} = 0.7742$$

Lighting (Air-Conditioned Space)

Rated Input Power = 307.665 kW
Actual Energy Usage = 1,498,908.89 kWh/yr
Operating Hours = 24 hrs/day

LR = Varies

$$UF = \frac{1,498.908.89}{307.665 \times 8670} = 0.5562$$

Electrical Equipment (Appliances/Convenience Outlets Within Air-Conditioned Space)

Rated Input Power = 131.71 kW
Actual Energy Usage = 667,538.97 kWh/yr
Operating Hours = 24 hrs/day

LR = Varies

$$UF = \frac{667,538.97}{131.71 \times 8760} = 0.5786$$

Miscellaneous Consumption

Lighting (Non-Air-Conditioned Space)

Rated Input Power = 25.4 kW
Operating Hours = 20 hrs/day (approx. equiv.)
Actual Energy Usage = 25.4 x 20 x 365 = 187,274.2 kWh/yr

LR = Varies

$$UF = \frac{187,274.2}{25.4 \times 8760} = 0.8418$$

Elevators

Rated Input Power = 256.96 kW
Operating Hours = 24 hrs/day

LR = Varies

UF = 0.1833 (Source: W.S. Fleming and Associates, Typical Load Profiles.)

Hot Water Pumps

Rated Input Power = 30.01 kW
Operating Hours = 24 hrs/day

LR = Varies

UF = 0.3333 (Source: W.S. Fleming and Associates, Typical Load Profiles.)

Water Pumps

Rated Input Power = 21.94 kW
Operating Hours = 14.5 hrs/day (approx. equiv. at full load)
Actual Energy Usage = 21.94 x 14.5 x 365 = 136,137.7 kWh/yr

LR = Varies

$$UF = \frac{136,137.7}{21.94 \times 8760} = 0.6042$$

Boiler Feed Pumps

Rated Input Power = 4.44 kW
Operating Hours = 5 hrs/day (approx. equiv. at full load)
Actual Energy Usage = 4.44 x 5 x 365 = 8103.00 kWh/yr

LR = Varies

$$UF = \frac{8103.00}{4.44. \times 8760} = 0.2083$$

Air Compressor

Rated Input Power = 13.01 kW
Operating Hours = 3 hrs/day (approx. equiv. at full load)
Actual Energy Usage = 13.01 x 3 x 365 = 14,245.95 kWh/yr

LR = Varies

$$UF = \frac{14,245.95}{13.01 \times 8760} = 0.125$$

Exhaust Fans and Blowers

Rated Input Power = 41.33 kW
Operating Hours = 16.3 hrs/day (approx. equiv. at full load)
Actual Energy Usage = 41.33 x 16.3 x 365 = 245,892.80 kWh/yr

LR = Varies

$$UF = \frac{245,892.80}{41.33 \times 8760} = 0.6792$$

Miscellaneous Kitchen and Refrigeration Equipment

Rated Input Power = 50.15 kW
Operating Hours = 9.95 hrs/day (approx. equiv. at full load)
Actual Energy Usage = 50.15 x 9.95 x 365 = 182,132.30 kWh/yr

LR = Varies

$$UF = \frac{182{,}132.30}{50.15 \times 8760} = 0.4146$$

Electrical System Loss Calculations.

Formulas

Ballast Losses

Ballast Power Losses = 20 % of Total Lighting Input Power
Ballast Energy Losses = Ballast Power Losses x UF x Operating hrs/yr

Line Losses

Line Energy Losses = Percentage Factor x Total Energy Usage

Line energy losses for motor loads are typically 1% to 4% of the aggregate motor usage (full-load conditions) in an industrial work area. Considering that the lighting and appliance power distribution system in a hotel building is characterized by an overall low demand factor aside from a higher power factor, this percentage factor may therefore be reasonably reduced to say, 0.3%.

Thus, for the Lighting and Appliance Distribution System:

Line Energy Losses = 0.003 x Total Lighting and Appliance Usage

The typical hotel building being characterized by a much smaller aggregate motor connected load and a less extensive motor cable system, the percentage factor may be reasonably diminished to say, 0.5%.

Thus, for the Motor Distribution System:

Line Energy Losses = 0.005 x Total Motor Usage

The ensuing loss calculations are just rough estimates and may only be taken to estimate the range of magnitudes of existing line losses.

Motor Losses

Rated Power Losses = (1 − Rated Efficiency) x Rated Power Input

Energy Losses = Rated Losses x UF x CF x Operating hrs/yr

Note: For motors with undetermined LR values, CF is assumed to be unity, i.e., CF = 1.

Equation of CF:

$CF = 0.56 \times LR^2 + 0.44$ (typical loss-loading relation) where:

UF	=	Usage Factor
CF	=	Loss Factor (used to adjust computed losses due to loading variations)
LR	=	Actual, mean, or estimated loading ratio of motor for a certain time period

Loss Calculations.

Ballasts

Air-Conditioned Space:

Total Fluorescent Lamp Input Power = 34.81kW (approx.)

UF = 0.5662

Ballast Power Losses = 0.20 x 34.81 = 6.962kW

Ballast Energy Losses = 6.962 x 0.5662 x 8760

= 33,921.04 kWh/yr

Non-Air-conditioned Space:

Total Fluorescent Lamp Input Power = 25.0 kW

UF = 0.8438

Ballast Power Losses = 0.20 x 25 = 5.00 kW

Ballast Energy Losses = 6.962 x 0.5662 x 8760

= 33,921.04 kWh/yr

Total Ballast Energy Losses = 33,921.04 + 36,958.44

= 70,879.48 kWh/yr

Line Losses

Lighting and Appliance Branch Circuits and Feeders

Breakdown of Lighting and Appliance Usage

Load Component	*kWh/yr*
Lighting (Air-conditioned space)	1,498,908.89
Elect. Equipment/Appliance (Air-conditioned space)	667,538.97
Lighting (Non-air-conditioned space)	187,274.20
Misc. Kitchen and Ref. Eqpt.	182,132.20
Total:	2,535,854.26

Lighting and Appliance System Line Losses : 0.003 x 2,535,854.26 = 7,607.56 kWh/yr

Motor Branch Circuits and Feeders

Breakdown of Motor Load Usages

Load Component	*kWh/yr*
Air-Conditioning system:	3,539,943.96
Misc. Motors:	
Elevators	412,677.80
Hot Water Pumps	87,600.00
Water Pumps	116,117.45
Boiler Feed Pumps	8,103.00
Air Compressor	14,245.95
Exhaust Fans and Blowers	245,892.80
Total:	4,424,581.00

Motor Equipment

For the chillers, chilled water pumps, cooling tower fans, and condenser pumps, approximate energy losses are calculated as follows:

$$UF = \frac{\text{Actual Energy Usage/yr}}{\text{Rated Input Power x 8760/yr}}$$

Therefore:

$$\text{Actual Energy Usage} = \text{UF x Rated Input Power x 8760}$$
$$= k\,[\,P_1 T_1 + P_2 T_2\,]$$

$$k = \frac{\text{UF x Rated Input Power x 8760}}{[P_1 T_1 + P_2 T_2]}$$

Thus, for an energy-using component with several sets of equipment units, say two, operating at different time periods:

$$\text{Total Energy Losses} = k \times CF_i \times (1 - n_i)\, P_i T_i,\ i = 1,2$$

$$= \frac{\text{UF x Rated Input Power x 8760}}{P_1 T_1 + P_2 T_2} \left[CF_1 (1 - n_1) P_1 T_1 + CF_2 (1 - n_2) P_2 T_2 \right]$$

If $n_1 = n_2 = n$; and $CF_1 = CF_2 = CF$, then:

$$\text{Total Energy Losses} = \text{UF x CF x Total Rated Input Power x 8760 x } (1-n)$$

where:

k	=	constant of proportionality
P_1, P_2	=	Rated Input Power values drawn by specific motor equipment when Chiller 1 is on and when Chiller 2 is on, respectively.

T_1, T_2	=	Time duration values when Chiller 1 and Chiller 2 are on, i.e., 5840 and 2190 hrs/yr, respectively
n_1, n_2	=	Rated efficiencies of P_1 and P_2, respectively
n	=	Rated efficiency
CF_1, CF_2	=	Loss factors of P_1 "and" P_2, respectively
CF	=	Loss factor.

Chillers

$$CF_1 = 1.023 \text{ and } CF_2 = 1.018$$

$$\text{Energy Losses} = \frac{0.50 \times (332.95 + 243.26) \times 8760}{332.95 \times 5840 + 243.26 \times 2190} \times$$

$$[1.023 \times (1 - 0.95) \times 332.95 \times 5840 +$$

$$1.018 \times (1 - 0.92) \times 243.26 \times 2190]$$

$$= 145{,}532.81 \text{ kWh/yr}$$

Cooling Tower Fans ($n_1 = n_2 = n_3 = n = 0.86$)

$$CF_1 = CF_2 = CF_3 = CF = 0.506$$

$$\text{Energy Losses} = 0.2854 \times 0.506 \times 3 \times 13.01 \times 8760 \times (1 - 0.86)$$

$$= 6{,}912.50 \text{ kWh/yr}$$

Condenser Pumps ($n_1 = n_2 = n = 0.88$)

$$CF_1 = CF_2 = CF = 0.848$$

$$\text{Energy Losses} = 0.6762 \times 0.848 \times 2 \times 21.19 \times 8760 \times (1 - 0.88)$$

$$= 25{,}545.67 \text{ kWh/yr}$$

Air Handling Units

The following tabulation can be derived from Table E-1.

AHU Motor No.	*Measured kW Output* (1)	*kW Losses* (2)	*Operating Hrs/Day* (3)	*Output kWh/Day* (1)x(3)	*Losses kWh/Day* (2)x(3)
1	1.599	0.358	6	9.594	2.148
2	1.357	0.552	14	19.00	7.728
3	5.473	0.975	19	103.99	18.525
4	4.355	0.850	9	39.20	7.65
5	2.849	0.781	20	56.98	15.62
6	3.460	0.728	10	34.60	7.28
7	11.100	1.556	22	244.20	34.232
8	2.826	0.624	11	31.09	6.864
9	8.386	1.334	14/7	16.77	2.668
10	1.551	0.386	75/7	16.618	4.136
11	3.009	0.678	11	33.099	7.458
12	4.414	0.791	10	44.14	7.91
13	4.414	0.791	9	39.726	7.119
14	1.502	0.378	11	16.522	4.158
			Total:	705.529	133.496

UF = Rated Energy Usage = k(Actual Energy Output + Energy Losses)

$0.4114 \times 116.21 \times 8760 = k\,(705.529 + 133.496) \times 365$

Energy Losses $= k \times 133.496 \times 365$

$$= \frac{0.4114 \times 116.21 \times 8760 \times 133.496}{705.29 + 133.496}$$

$= 66{,}654.42$ kWh/yr

(where k = constant of proportionality.)

Fan Coil Units ($n = 0.84$)

Energy Losses $= 11 \times 8760 \times (1 - 0.84) = 15{,}417.6$ kWh/yr

Chilled Water Pumps ($n_1 = n_2 = n = 0.88$)

$CF_1 = CF_2 = CF = 0.976$

Energy Losses $= 0.7742 \times 0.976 \times 2 \times 21.19 \times 8760 \times (1 - 0.88)$

$= 33{,}662.73$ kWh/yr

Elevators ($n = 0.90$)

Energy Losses $= 0.1833 \times 256.96 \times 8760 \times (1 - 0.90) = 41{,}260.27$ kWhr/yr

Hot Water Pumps (n = 0.87)

Energy Losses = 0.3333 x 30.01 x 8760 x (1 – 0.87) = 11,390.66 kWh/yr

Water Pumps (n = 0.85)

Energy Losses = 0.6042 x 21.941 x 8760 x (1 – 0.85) = 17,418.58 kWh/yr

Boiler Feed Pumps (n = 0.84)

Energy Losses = 0.2083 x 4.44 x 8760 x (1 – 0.84) = 1296.27 kWh/yr

Air Compressor (n = 0.86)

Energy Losses = 0.125 x 13.01 x 8760 x (1 – 0.86) = 1994.43 kWh/yr

Miscellaneous Kitchen and Refrigeration Equipment (n = 0.83)

Energy Losses = 0.4146 x 50.15 x 8760 x (1 – 0.83) = 30,963.73 kWh/yr

Exhaust Fans and Blowers (n = 0.84)

Energy Losses = 0.6792 x 41.33 x 8760 x (1 – 0.84) = 39,344.78 kWh/yr

Recommendations:

Distribution System.

Distribution Imbalance. Distribution imbalances, such as voltage imbalance across the phases and line current imbalance, will cause inefficiencies in all motors connected to the distribution system. Hence, it is always important to check if system voltage imbalance or line current imbalance is present. If these defects are found to be occurring in the system, adequate steps should be taken to improve the balance of the loads on each panel. As a benchmark, it is acceptable to have the panelboard loading (amperes) balanced within 10% or lesser of each phase. Voltage imbalance tolerance, as a rule, is much smaller as compared to "allowable" current imbalance.

Under-Utilized Transformer Capacity. The hotel building's electrical loads are supplied via two transformers with a capacity of 1500 KVA each and are located in the same substation. From the utility billing receipts, it was found that the highest maximum demand registered was 1416 kW during June 1987 (see Table E-10) Since this value is less than the rated capacity of one transformer operating at a high power factor, the total transformer losses could be substantially reduced by connecting all loads to a single 1500 KVA transformer. The other transformer then becomes a standby unit and the losses associated with it are avoided.

Savings are calculated as follows:

Annual Savings = 1,500(1 – 0.984)0.20 x 8760

= 42,048 kWh/yr

where:

1500	=	KVA rating of the transformer to be taken off.
0.984	=	rated efficiency of the transformer (typical).
0.20	=	iron loss factor.
8760	=	operating hours per year.

Note that these values should be treated only as a partial guide. Further technical evaluation should be conducted in order to come up with actual measured data and supporting analysis.

Indoor Lighting System.

- Low illumination levels, especially in work areas, can initially be improved at minimal cost by:
  - Cleaning of lamps, diffusers and reflectors regularly as accumulation of dirt reduces the efficacy of the fixture.
  - Repainting of fixture reflectors, if necessary.
  - Repainting the ceiling with lighter finishes.
  - Cleaning walls regularly to avoid accumulation of light-absorbing dirt.
- Low illumination levels in the hotel spaces occupied or frequented by hotel guests and customers are due mostly to incandescent lighting. Therefore, further steps to increase these illumination levels could either result in more capital expenditures, such as by increasing the number of connected incandescent lamps; reducing the localized ambience provided by incandescent lighting; and more capital outlay for lamps with reduced color-rendering properties but higher efficacy, such as fluorescents. Hence, further study should be conducted in order to decide on a feasible compromise. To mention one possible solution, in such places where natural light is available, the incandescent fixtures should be controlled by a suitable lighting control mechanism, such as a manually or automatically operated light dimmer, so as to optimize the usage of sunlight by dimming the artificial lighting whenever sufficient daylight is available.
- Further optimization measures could be undertaken—especially in areas where fluorescent lighting is present—with minimal cost, by:
  - Removing all louvers and diffusers in areas where the illumination is low and the consequent glare can be tolerated, such as in the kitchen, service elevators, and storage areas.
  - Turning off lights during daytime in areas where their light is hardly noticeable, as in the shopping arcade (with incandescent lighting), particularly in the areas closest to the windows.
  - Checking if the ballasts of delamped fluorescent fixtures are still connected. For a two-lamp fixture, where one lamp is removed but the associated ballast still connected, energy still consumed by the ballast amounts to 20% of the lamp usage. It is important to cut the black and white leads of the relevant ballasts once these are found in order to effectively disconnect them from the circuit.

Small Appliance and Convenience Outlets. Employees should be encouraged to turn off electrical office equipment, such as copiers, typewriters, calculators, and water heaters when not in use. Avoid "idling" of shop and kitchen electrical machines and tools. Refrigerators should be located so as to allow sufficient air circulation at their back portions where the associated air-cooled condensers are installed. Regular cleaning routines for this equipment will allow further energy savings.

Electrical Power Factor Characteristics. The existing power factor (PF) correcting capacitor bank is—as is usual —installed at the main distribution panel. This, however, requires automatic sensing of the prevailing PF and automatic switching of the capacitors. This is due to the variable characteristic of the overall system PF which is dependent on the percent loading of the connected loads—specifically, the motors—and the turning on and off of the loads. Therefore, it is suggested that the automatic sensing and switching device, if there is one, be investigated. Without this device, turning off a large portion of the motor loads can cause over-correction of the system PF. This, in turn, leads to overvoltage that is both harmful to equipment and can cause momentary inefficiencies, which will accumulate with the passage of time.

Another way to achieve PF correction is to connect individual capacitors to each motor. This method ensures that the motor line losses will be considerably reduced, due to the PF improvement of the motor distribution system. Notice that although the system PF is improved by the installation of a capacitor bank at the main distribution panel, the PF of the motor distribution system is uncorrected—with comparatively higher line losses than if it were PF corrected. The only drawback to this method is the higher cost per capacitor KVAR as compared to the other method.

It is therefore suggested that, upon thorough technical evaluation, the value of avoiding overvoltage in the electrical system through capacitor automatic sensing and switching be seriously considered, and if such measures are not yet in effect, that relevant actions be undertaken. Furthermore, it may also be worth considering connecting individual capacitors to motors, particularly those with very low measured PFs.

Building Motor Loads. ECOs in motor loads may be found and isolated in the underloaded motors of the AHUs and cooling tower fans.

Table E-1 presents the findings on the AHUs and the cooling tower fan motors. Input powers (kW) for all the motors were measured at actual loading conditions, except for the cooling tower fan motors, due to their inaccessibility. Estimated input power for each cooling tower fan motor was obtained by multiplying the motor input kW rating by the computed average loading ratio (LR is 0.3425, see Table E-7). Motor nameplate HP ratings and typical efficiencies at full load, three-quarter load, and half-load were also tabulated. These data were then input to a computer program specifically developed to generate the motors' loss equations and from these, calculate the actual motor output powers, losses, percent efficiencies, and loadings. Tables E-1 and E-2 are reproductions of the software's output showing data needed for evaluation of motor losses and sizing. From these tables, the motors are identified only by their respective motor numbers. Thus, for proper identification as to the area served, Table E-8 should be consulted. Motor No. 15 is not the AHU motor in the pre-cooler area (which is not operational), but is, rather, a single motor unit representing each of the three cooling tower fan motors. In the absence of actual measurements, the assumption is that the three cooling tower fan motors have identical actual operating data to that of motor No. 15. Hence, operating hours of motor No. 15 in Table E-6 is the aggregate operating hours of the three cooling tower fan motors.

Using these processed data, the motors' typical efficiency vs. loading curves can be easily plotted, as in Figure E-6. Notice the shape of the curves. As the loading progresses from zero upwards, the losses increase as the variable losses increase in proportion to the percent loading. The characteristic is also illustrated by the equations below:

$$L = L_{100}\,(Ax^2 + B) \text{ : Motor Loss Equation} \qquad (1)$$

where:

L	=	losses at any load
L_{100}	=	losses at full load
A	=	constant (variable losses coefficient)
B	=	constant (fixed losses coefficient)
X	=	loading ratio = actual output power/rated output power

Further mathematical manipulation yields the equation of the efficiency vs. percent loading curves as follows:

$$\frac{100}{PE} = 1 + k\,(A_x \frac{PL}{100} + \frac{100B}{PL}) \text{ : Efficiency vs. Percent Loading Equation} \qquad (2)$$

where:

PE = actual efficiency (%)

k = L_{100}/rated output (kW)
PL = percent actual loading

Given the loss equation constants A and B and using Equations 1 and 2, simulation of the losses and efficiency at any load can be undertaken for the purpose of proper motor sizing and optimized loading.

Tables E-1 and E-2 present the processed data based on actual input power measurements (except for the cooling tower fan motors). However, the basis for further detailed technical evaluation (i.e., sizing of replacement motors) is the measured input power data of AHU motors multiplied by the factor C (0.924) to account for deviations from the measured actual input power data of each AHU motor. These are based on the computer simulation results of the motors' kWh/yr usage. This new set of input power data is then computer-processed, as presented in Tables E-3 and E-4. Utilizing the resulting data, calculations using a computer spreadsheet software package such as the Lotus 123 program are generated in a tabular format as seen in Table E-6. The procedure is to size the approximate replacement motor by dividing the present motor output (kW) by 0.746 (the conversion factor from kW to HP). As a rule, a replacement motor is sized according to the nearest higher HP rating, in anticipation of future increase in loads. Table E-6 shows the calculated sizes of the replacement motors. The kWh usage savings are derived by calculating the usage differences between the existing and the replacement motors. Those replacements with negative savings are canceled and the corresponding existing motors then considered properly sized, whereas those with positive values are considered for possible replacement. Those HP ratings are given in Table E-6.

Referring to Table E-6, motors numbered 2, 6, 8, 10, 11, 14 and 15 (3 units) are now preliminarily considered as candidates for replacement. Upon replacement with HP ratings of 2.0, 5.0, 5.0, 2.0, 5.0, 2.0, and 5.0 (3 units), respectively, estimated kWh savings of 2307.47 kWh/yr are obtained. These results, however, should be reinforced by further technical evaluations which use a more extensive set of actual measurements to come up with more conclusive results.

Building Load Demand and Energy Usage Profile:

Load Demand Rescheduling. Rescheduling the use of electrical equipment can lower the demand peaks. This action may not actually reduce the total energy used. But it will reduce the demand charge paid to the power company.

Theoretically, reduction in power demand reduces the required standby capacity, which in turn may postpone the utility company's need to install costly additional capacity to meet an increasing load on its systems.

A graph of load demand versus time before re-scheduling (see Figure E-5a) could assist in the evaluation of possible savings. It is therefore suggested that adequate monitoring and data recording equipment, such as submetering (see next recommendation below), be installed to obtain the load profiles of large electrical equipment, as well as that of the lighting system. If the overall plot shows some high cyclical peaks, usually some savings are possible by altering equipment usage during off-peak hours in order to shave off the peak demands.

A sample graphical analysis is shown in Figure E-5b. Just by leveling off the peak from a before-demand high of 1400 kW to 1100 kW after rescheduling will produce cost savings of:

(1400 - 1100)kW x (P12.60/kW demand per month) x 12 mos./yr.

= P45,360.00/yr.

Another simple but effective way of emphasizing the savings benefits attainable through the demand-saving scheme is by determining the annual savings that can be obtained per kW as in the following:

Cost savings = (P12.60/kW demand per month) x 12 mos./yr.

= P8,612.11 kW/yr.

A quick matter-of-fact analysis should easily point out how much more could be saved, just by learning to lower the usually neglected peaks by a few more kilowatts.

Install Submetering. Submetering is helpful in monitoring the loading behaviors of motors and other large equipment, as well as lighting systems. Appropriate demand control can then be achieved by referring to data acquired by submetering and subsequently performing the relevant peak-reducing schemes.

Air Conditioning System

Findings:

General Space. The function of air-conditioning is to provide the desired thermal comfort conditions for the occupants inside a building. The attainment of these conditions requires the consumption of electricity to operate the air-conditioning equipment. Due to the present energy crisis experienced in many countries, the study of more efficient designs for buildings becomes a continuous process even though energy conservation measures have been already implemented.

Indoor Design Temperature. To conserve energy, the suggested inside temperature of conditioned spaces is 25.6°C (78°F). Based on the actual measurements during the survey, the temperatures maintained in the public areas inside the hotel is already more or less 25.6°C. Temperatures maintained in the guestrooms, controlled by the thermostat and fan speed selector, depend on the occupants' preference.

Ventilation Requirements. Admission of outdoor air and exhausting a portion of recirculated air is necessary to maintain the quality of air inside the space. However, the amount of outdoor air admitted must be kept to a minimum in order to conserve energy.

It was observed that efforts have been made by the hotel's staff to reduce ventilation air. With the exception of the laundry's AHU, which uses 100% outdoor air, the outdoor air dampers of all AHUs are closed, thereby admitting somewhat lower quantities of ventilation air than those called for by the design.

Infiltration. During the conduct of the detailed energy audit, all windows and doors were checked for possible infiltration of outside air. The windows are generally tight-fitting, thereby preventing infiltration and reducing cooling energy.

Internal Loads. The primary sources of internal loads are people, lights, and equipment operating in the conditioned spaces. Hotel Intercontinental has conditioned areas of 23.7 m^2/person for guestrooms (based on 68% average occupancy), 14.3 m^2/person for lobbies, and 2.4 m^2/person for the remaining function areas such as restaurants, offices, etc. Lighting and equipment densities are 19.17 W/m^2 and 8.21 W/m^2, respectively.

External Loads. The external loads are composed of the heat gains through windows, walls, and roofs. External, as well as internal, shading devices are utilized to limit the solar transmission through windows. The walls and roof are of light color to decrease solar absorption.

The hotel's space conditions discussed previously were used in the calculation of the cooling load. The cooling load is the rate at which heat must be removed from the conditioned spaces inside the building in order to maintain the desired thermal comfort conditions. The load was estimated through the three computer programs, ASEAM-2, Carrier, and DOE-2 (see Table E-13).

The percentages of the cooling load components are important as guides in energy conservation, since they indicate the potential areas where cooling energy can be reduced. However, reduction of cooling load has its limitations or restrictions. For example, heat gain through glass is the biggest component but use of additional external shading devices presents, at the least, an architectural problem, and internal shading such as curtains in the guestrooms are not readily controlled.

Reduction in lighting has a great impact since it affects both cooling and electrical consumption. Use of exhaust fans in unconditioned spaces and exhaust hoods in some heat-emitting devices will reduce excessive heat build-up, decreasing loss of cooling energy through the partitions (next to conditioned areas) and increasing comfort and therefore efficiency of the employees in these areas.

Air Distribution System. For the public areas (restaurants, lobbies, offices, and others), the hotel uses a conventional constant volume AHU which provide a constant volume of air at temperatures that vary according to the load. Fan coil units are used in the guestrooms, function rooms, and some offices to provide the necessary cooling.

For the cooling load variations, each AHU is equipped with a thermostat, located in the return air path in the machine room and connected to a water-regulating valve, which controls the amount of chilled water flowing through the cooling coils. Temperatures in the zones are well controlled since a single AHU serves only one zone, that is, a space with a single load profile. Adjusting the thermostat for single AHU will only affect the zone served by that AHU.

Fan coil units found in the hotel have varied capacities and fan motor ratings, ranging from about 0.023 to 0.373 kW (1/32 to 1/2 HP). Each FCU has a thermostat and a 3-speed fan control located in the room or space it serves.

Typical among buildings in the Philippines, the air-conditioning system in the hotel has no humidity control.

An interesting survey finding was the large discrepancy between measured and rated power of the motors used to drive the fans of the AHUs. Compared to other buildings, the overall fan $W/m^3/hr$ is low, probably because the AHUs are located near the areas they serve. However, all of the motors were observed to be operating at loads which are less than the rated load. An example is the motor serving the laundry AHU. Its measured power is 1.7 kW. This is 70% lower than the rated motor capacity of 5.6 kW. Thus, either the AHU motors are oversized or the filters and coils are dirty and clogged.

It is known that, in an installed fan and duct system, the fan power and flow rate decrease as the pressure increases. Usually the pressure is increased by restricting the air flow, e.g., use of VAV dampers, clogged and dirty AHU filters and coils. That is why some air-conditioners maintenance personnel sometimes intentionally allow AHUs to get dirty to obtain energy savings from the reduced motor power until the occupants complain about the increased temperatures resulting from the reduced effectiveness of the air distribution system.

This strategy, however, results in "hidden" energy wastage, due to reduced motor efficiencies. Generally, motor efficiency decreases as actual load is reduced, relative to rated load. This inefficiency is a major drawback to reducing motor power by allowing reduced air flow from dirt buildup. Alternative strategies to achieve both energy efficiency and some temperature control (reduce overcooling of the spaces) are by adjusting the thermostats and/or trying to raise the chilled water temperature.

The amount of cooling energy required in a space depends on the total cooling load and number of hours of operation. A decrease in either of the two will reduce consumption of the air-conditioning equipment, which accounts for about 50.7% of the total building electrical consumption. Table E-14 presents cooling energy requirements in percentages.

It was found that instrumentation used for monitoring the air temperatures and chilled water temperatures and pressures entering and leaving the AHUs need replacement. These instruments are important in determining whether the system is performing efficiently and for identifying inefficiencies.

Cooling Plant Equipment. For hotels and other buildings with daily 24-hour operating schedules, a common problem encountered is over-designed cooling plant equipment. In a machine room, it is common to find multiple chillers of equal capacity, whereas one unit would be enough to handle the maximum cooling load of the building, making the others act as standby units. During periods when the cooling load decreases, the chiller will unload or reduce its capacity. However, at this unloaded condition, the chiller operates at very low efficiency and might even surge, causing damage to the compressor.

The design of the cooling plants for the Hotel Intercontinental solved this problem. For the air-conditioning requirements of the hotel, three centrifugal chillers with rectangular induced-draft cooling towers are utilized. One chiller has a capacity of 450 tons, while the other two are 200 tons each. The 450-ton chiller is usually operated from 8:00 A.M. to 10:00 P.M., the period of maximum cooling load occurrence. A 200-ton chiller is operated from 10:00 P.M. to 3:00 A.M., shut off from 3:00 A.M. to 5:30 A.M., and operated again from 5:30 A.M. to 8:00 A.M. With this operating strategy, the average operating ratio of the chillers is about 87%, which is about the optimum for centrifugal chillers.

The cooling plant equipment, including the monitoring instruments, are well-maintained. Each chiller has working flowmeters (not usually found in buildings' cooling plant installments), thermometers, and pressure gages for the chilled water and condenser water system, voltage and current measuring instruments for the chiller, and other chiller gages which are important in checking the proper system operation.

It was also noted that the hotel Engineering Staff are conscious of energy savings. Scheduling equipment operation based on demand, such as turning off of AHUs and chillers, is one of their energy conserving measures.

Recommendations:

Using the data gathered from the preliminary and detailed energy audit, computer programs were used to determine the annual energy consumption of Hotel Intercontinental. Knowledge of the breakdown of energy consumption is crucial to identifying potential areas for ECOs.

Relative to other buildings, the percentage consumption of the air-conditioning is low. However, further reduction of energy consumption can still be obtained. The following is a list of the ECOs identified. Several computer simulations using DOE-2 were made to analyze the effects of these ECOs on the total energy consumption of the building.

Air Distribution System/Cooling Plant Equipment

- *Rehabilitate Instrumentation in the Air Distribution System.* Entering and leaving chilled water temperatures and pressures, and entering and leaving air temperatures, are important parameters that must be monitored to check the system performance (air and water sides) and sources of losses. Losses in chilled water lines due to corrosion and faults in the insulation can be detected if a few thermometers and pressure gages are strategically installed (e.g., near the fan coils on certain floors). Computer simulations show that losses could have occurred in the air distribution ducts or chilled water lines. The installation of monitoring instruments would verify these losses.

- *Retrofit With High Efficiency Chillers.* Since the chiller is the largest single energy consumer in the building, improvement in its performance will have a significant effect on energy consumption. Good design, installation, and proper maintenance will make a chiller operate at optimum. However, the improvement of efficiency in chillers has its limits.

  Newer chillers have higher efficiencies than those currently installed in the hotel. Still, a considerable amount of investment is needed for a retrofit. The existing baffle-type (wood slats as tower fills) cooling towers can also be replaced by PVC cellular fill types which are commonly used in newly-constructed buildings. This type of cooling tower is compact and efficient. It can provide lower condenser water temperatures as required by the new chillers, thereby increasing overall plant efficiency. The estimated savings per year was based on the following:

  - The chillers were replaced with those of COP = 5.0.
  - The existing cooling towers were replaced with PVC cellular-type towers of the same size, with two-speed fans.

  Replacement of two chillers (both the 450-ton and the 200-ton) is estimated to have a payback period of about 8 years. An alternative is to replace the smaller and less efficient 200-ton chiller and have a lower payback period. Using a COP of 4.45 for the 200-ton chiller, computer simulations show a payback period of about 4.5 years.

Possible replacement of chillers can be done in conjunction with cogeneration using an appropriate liquid absorption refrigeration unit. This will also result in the elimination of the use of cooling towers.

- *Consider Variable Air Volume System.* The variable air volume system provides a variable volume of air at a constant discharge temperature. When the space demands peak cooling, maximum air flow is supplied. As the space cooling requirement decreases, the air flow to the space is reduced proportionately to a specified minimum flow rate. Air volume is controlled by VAV boxes which throttle the air flow in the air distribution ducts. Each VAV box has its own thermostat.

  New designs are already moving towards VAV systems, for they offer significant fan savings. AHU fans can have variable speed drives, inlet vane, or discharge damper control. Variable speed drives are the most efficient but most expensive to purchase. Discharge damper control is the least efficient and least expensive to purchase. Inlet vane control is in the middle both for efficiency and cost. No estimate of payback period was made because the building plans for the duct layout or air distribution system was unavailable during the audit.

- *Consider Variable Speed Chilled Water System.* Most of the time the chilled water pumps operate at loads lower than design. Substantial savings can be obtained by using variable speed controllers for pump motors. However, they are known to be expensive and require careful matching of the motor and drive.

- *Investigate Rescheduling of Chillers.* Since the 450-ton chiller has a higher rated COP (that is, at design load), it may even be economical to use it for longer periods if the management finds the investment for new chillers to be too costly. Computer simulations show savings of about 45,954 kWh/yr, assuming the part-load performance of the chillers are simulated accurately.

Boiler System

The hotel's thermal energy requirements (aside from cooking) are provided by the boilers. There are two firetube boilers installed in the hotel basement. Each has a rated capacity of 2950 kgs/hr of steam (based on 10.3 bars, 200 bhp rating). Normally, only one boiler is operating. On average, the boilers operate 16.5 hours per day.

Steam is raised at 6.2 barg and is used mainly in the calorifiers which supply the hot water requirements of the hotel. Industrial fuel oil (IFO) is used as fuel and, in 1987, the total IFO consumption was 503,323 lits.

The results of the combustion tests conducted during the energy audit are shown in Tables E-17, E-18, E-19, and E-20.

Table E-18 summarizes the observed average surface temperature of the boiler. Note that the surface coating of the boiler is aluminum oxide paint.

Based on the data shown in Table E-18, the radiation heat loss from the boiler is about 0.44% of the fuel gross heating value. See Table E-19 for the summary of computations for radiation-convection heat loss.

The efficiency of the boiler was evaluated using the indirect method (i.e., Heat Loss Method). Table E-20 summarizes the computed efficiencies of Boiler No. 1 at various operating loads.

Other Observations/Recommendations:

The boiler operates at very high excess air levels. No combustion monitoring is being done. Hence, the operators are not aware of such uneconomical operation. Adjustments were made during the combustion testings but the lowest percent O_2 level obtained was only 7.5%. Reducing the air supply further resulted in unstable and smoky flames. The high excess air level is also manifested in the flue gas temperature, which at the observed level, is considered dangerous from the standpoint of corrosion. Locally available IFO contains a minimum of 3% sulfur. To avoid cold end corrosion, 200°C flue gas temperature is generally considered optimum in IFO fired units. Acid dewpoint is about 175-185°C.

The computed efficiencies are still high even if the excess air levels are high due to the relatively low flue gas temperatures.

The burner is an air-atomized unit that utilizes compressed primary air for atomization. However, it was observed that the atomizing air pressure is lower (5 ps.) than that of the fuel. In this case, proper fuel atomization is not ensured.

The fuel should be preheated further to 100-105°C, the usual preheat temperature requirement for locally available IFO, to obtain the correct viscosity to facilitate efficient atomization.

BFW leakages and its frequent overflow from the BFW Tank should be eliminated.

Significant savings would accrue if the management would procure a gas analysis kit to continuously monitor the combustion conditions. Savings will be generated through proper maintenance of combustion conditions with the use of the analyzer. A simple chemical type analyzer (Bacharach Fyrite) used for O_2 and CO gas analysis will cost about P20,000.00. Table E-21 summarizes the potential savings if combustion conditions are maintained at optimum level.

Electrical Demand Profile, 1987
Hotel Intercontinental Manila

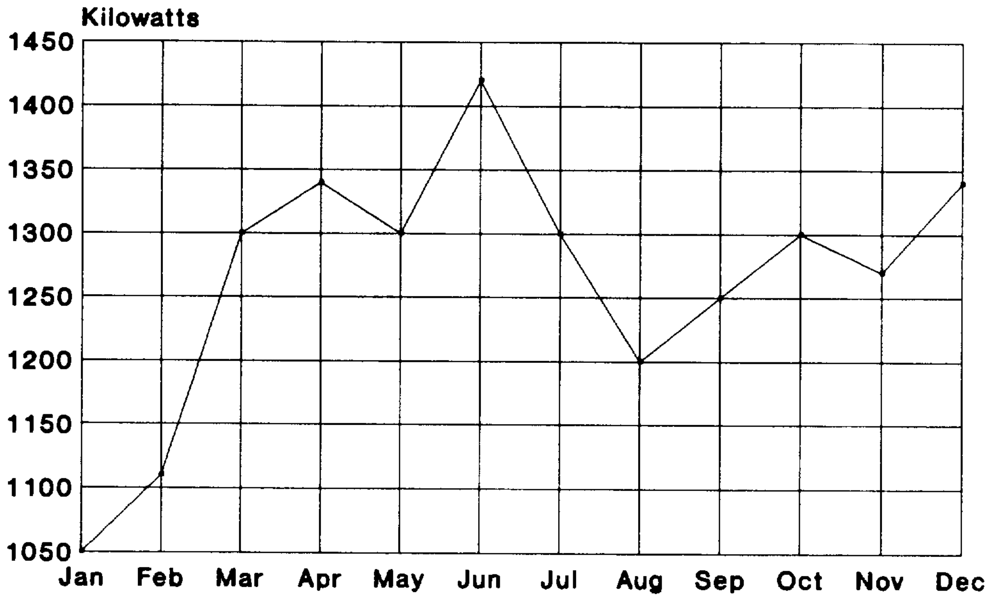

Figure E-1

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Electrical Usage Profile, 1987
Hotel Intercontinental Manila

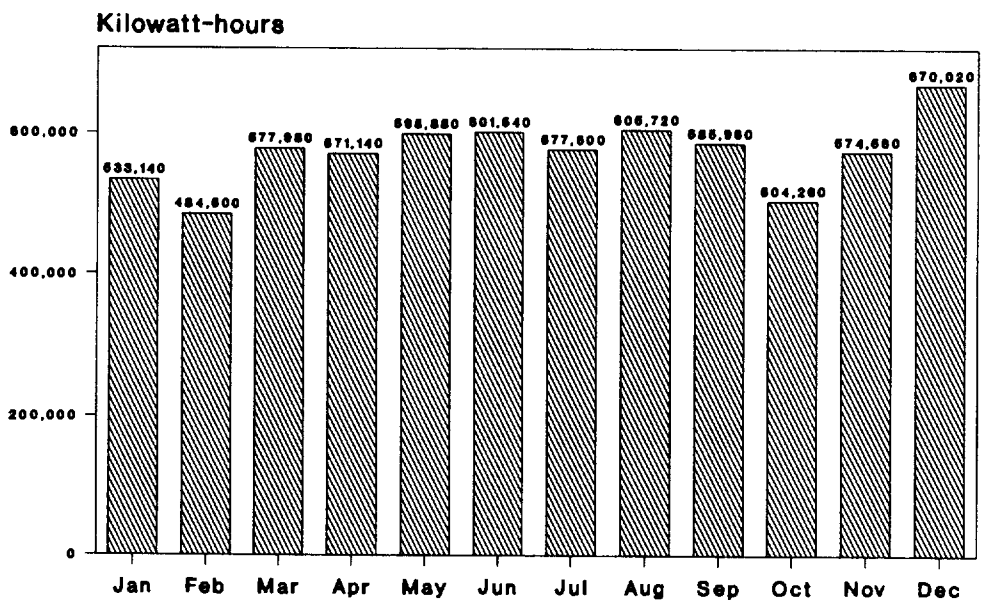

Figure E-2

e02eluse.cc.5/90

Electrical System Losses Breakdown
Hotel Intercontinental Manila

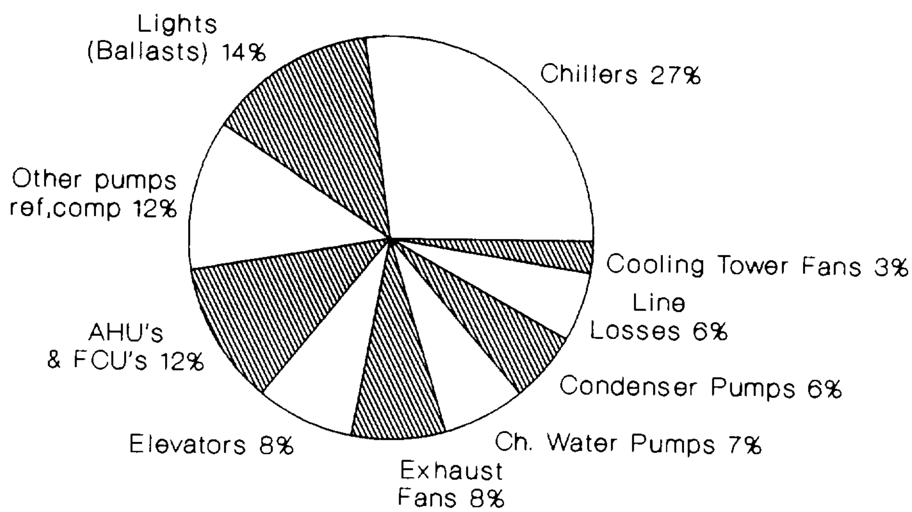

Figure E-3

e03eloss.cc.6/90

Electrical Usage Breakdown
Hotel Intercontinental Manila

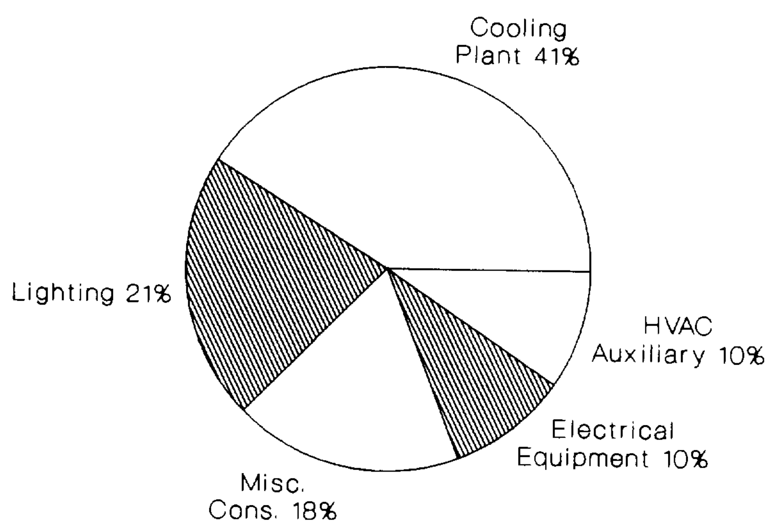

Figure E-4

e04elbdn.cc.6/90

Probable Daily Demand Curve Before Re-Scheduling

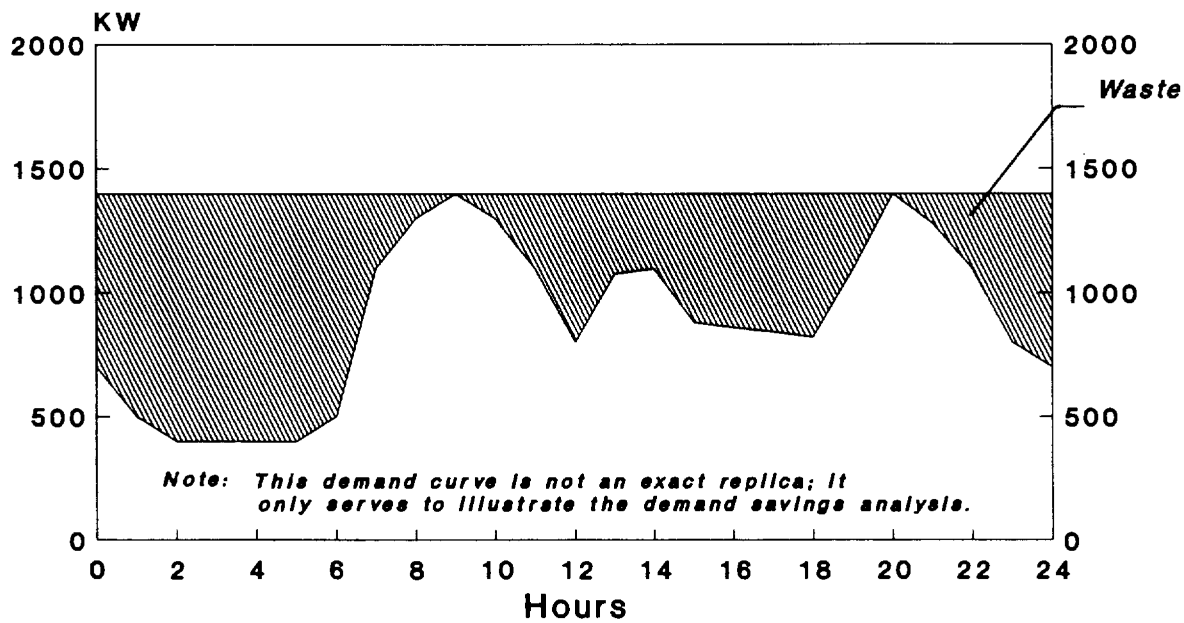

Figure E-5a

Sample Re-Scheduled Daily Demand Curve

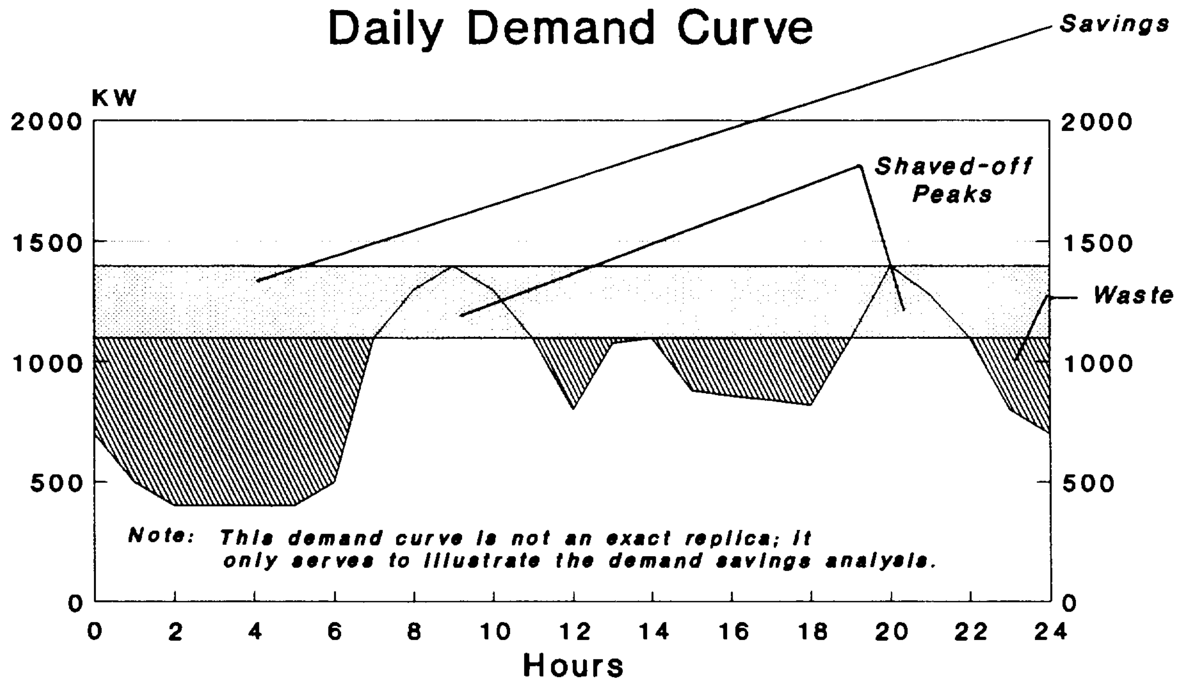

Figure E-5b

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Motor Efficiency vs. Percent Loading

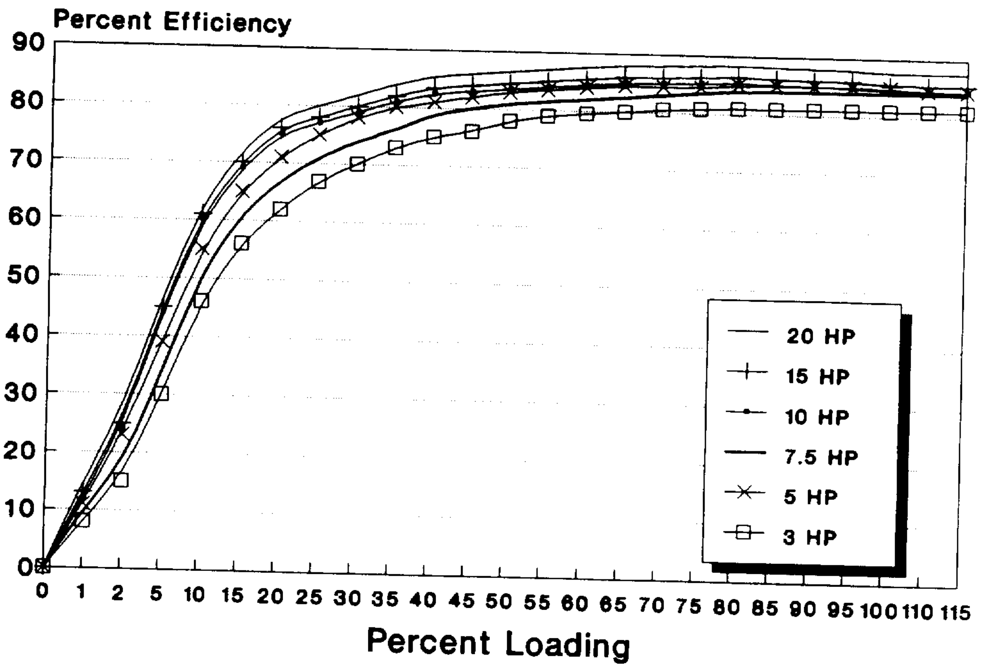

Figure E-6

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Table E-1. - Motor Data

Unit No.	HP Rating	Actual Kilowatts Input	Output	Losses	Percent Loading	Percent Efficiency
1	5.0	1.957	1.599	0.358	42.88	81.73
2	7.5	1.909	1.357	0.552	24.26	71.09
3	15.0	6.448	5.473	0.975	48.91	84.87
4	7.5	5.205	4.355	0.850	77.83	83.66
5	15.0	3.630	2.849	0.781	25.46	78.48
6	7.5	4.188	3.460	0.728	61.83	82.61
7	20.0	12.656	11.100	1.556	74.40	87.71
8	10.0	3.450	2.826	0.624	37.88	81.90
9	15.0	9.720	8.386	1.334	74.94	86.28
10	3.0	1.937	1.551	0.386	69.29	80.06
11	7.5	3.687	3.009	0.678	53.79	81.62
12	10.0	5.205	4.414	0.791	59.61	84.80
13	10.0	5.205	4.414	0.791	59.61	84.80
14	3.0	1.880	1.502	0.378	67.10	79.88

Table E-2. - Motor Efficiencies and Losses Equation Constants

Unit No.	HP Rating	Percent Efficiencies 4/4 Load	3/4 Load	1/2 Load	Loss Constants A	B
1	5.0	85.00	85.00	83.00	0.5596	0.4404
2	7.5	84.00	83.50	81.00	0.5123	0.4877
3	15.0	86.00	86.00	85.00	0.6106	0.3894
4	7.5	84.00	83.50	81.00	0.5123	0.4877
5	15.0	86.00	86.00	85.00	0.6106	0.3894
6	7.5	84.00	83.50	81.00	0.5123	0.4877
7	20.0	87.50	87.50	86.50	0.6050	0.3950
8	10.0	85.00	85.00	84.00	0.6138	0.3862
9	15.0	86.00	86.00	85.00	0.6106	0.3894
10	3.0	81.00	81.50	77.50	0.5082	0.4918
11	7.5	84.00	83.50	81.00	0.5123	0.4877
12	10.0	85.00	85.00	84.00	0.6138	0.3862
13	10.0	85.00	85.00	84.00	0.6138	0.3862
14	3.0	81.00	81.50	77.50	0.5082	0.4918

Table E-3. - Motor Data

Unit No.	HP Rating	Actual Kilowatts Input	Output	Losses	Percent Loading	Percent Efficiency
1	5.0	1.809	1.462	0.347	39.20	80.84
2	7.5	1.764	1.219	0.546	21.78	69.08
3	15.0	5.959	5.026	0.934	44.91	84.33
4	7.5	4.810	4.010	0.800	71.68	83.37
5	15.0	3.355	2.586	0.769	23.11	77.09
6	7.5	3.871	3.175	0.696	56.75	82.03
7	20.0	11.697	10.247	1.450	68.68	87.60
8	10.0	3.188	2.583	0.605	34.63	81.01
9	15.0	8.983	7.742	1.242	69.18	86.18
10	3.0	1.790	1.424	0.366	63.63	79.54
11	7.5	3.408	2.755	0.652	49.25	80.86
12	10.0	4.810	4.062	0.748	54.46	84.45
13	10.0	4.810	4.062	0.748	54.46	84.45
14	3.0	1.737	1.378	0.359	61.58	79.32
15	15.0	4.4546	3.630	0.826	32.44	81.46

Table E-4. - Motor Efficiencies and Losses Equation Constants

Unit No.	HP Rating	Percent Efficiencies 4/4 Load	3/4 Load	1/2 Load	Loss Constants A	B
1	5.0	85.00	85.00	83.00	0.5596	0.4404
2	7.5	84.00	83.50	81.00	0.5123	0.4877
3	15.0	86.00	86.00	85.00	0.6106	0.3894
4	7.5	84.00	83.50	81.00	0.5123	0.4877
5	15.0	86.00	86.00	85.00	0.6106	0.3894
6	7.5	84.00	83.50	81.00	0.5123	0.4877
7	20.0	87.50	87.50	86.50	0.6050	0.3950
8	10.0	85.00	85.00	84.00	0.6138	0.3862
9	15.0	86.00	86.00	85.00	0.6106	0.3894
10	3.0	81.00	81.50	77.50	0.5082	0.4918
11	7.5	84.00	83.50	81.00	0.5123	0.4877
12	10.0	85.00	85.00	84.00	0.6138	0.3862
13	10.0	85.00	85.00	84.00	0.6138	0.3862
14	3.0	81.00	81.50	77.50	0.5082	0.4918
15	15.0	86.00	86.00	85.00	0.6106	0.3894

Table E-5. - Existing Motors

Motor No.	Rated HP	Measured Input/kW	Output kW1	Percent Efficiency	Output x (1.0/.746)
1	5.0	1.809	1.462	80.84	1.96
2	7.5	1.764	1.219	69.08	1.63
3	15.0	5.959	5.206	84.33	6.98
4	7.5	4.810	4.010	83.37	5.38
5	15.0	3.355	2.856	77.09	3.83
6	7.5	3.871	3.175	82.03	4.26
7	20.0	11.697	10.247	87.60	13.74
8	10.0	3.188	2.583	81.01	3.46
9	15.0	8.983	7.742	86.18	10.38
10	3.0	1.790	1.424	79.54	1.91
11	7.5	3.408	2.755	80.86	3.69
12	10.0	4.810	4.062	84.45	5.45
13	10.0	4.810	4.062	84.45	5.45
14	3.0	1.737	1.378	79.32	1.85
15	15.0	4.456	3.630	81.46	4.87

Table E-6. - Replacement Motors

Motor No.	Rated HP	Input kW	Output kW	Efficiency Percent	Usage Hrs/Day	Savings kWh/Day
1	2.0	1.858	1.462	78.70	6.00	-0.2921(cancel)
2	2.0	1.549	1.219	78.70	14.00	3.0104
3	7.5	6.198	5.206	83.99	19.00	-4.5493 (cancel)
4	7.5	4.810	4.010	83.36	9.00	-0.0018 (cancel)
5	5.0	3.362	2.856	84.95	20.00	-0.1368 (cancel)
6	5.0	3.732	3.175	85.08	10.00	1.3923
7	15.0	11.889	10.247	86.19	22.00	-4.2253 (cancel)
8	5.0	3.050	2.583	84.70	11.00	1.5232
9	15.0	8.984	7.742	86.18	2.00	-0.0015 (cancel)
10	2.0	1.785	1.424	79.75	10.71	0.0485
11	5.0	3.246	2.755	84.88	11.00	1.7838
12	7.5	4.870	4.062	83.42	10.00	-0.5952 (cancel)
13	7.5	4.870	4.062	83.42	9.00	-0.5357 (cancel)
14	2.0	1.732	1.378	79.56	11.00	0.0553
15	5.0	4.321	3.630	84.00	60.00	8.0867

Daily Total: 15.80 kWh/Day
Yearly Total: 5765.69 kWh/Year
Cost Savings: 11531.39 Pesos/Year

Table E-7. - Electric Motor Data

Motor Equipment	No. of Units	Rated Out-Put (HP)	Approx. Full-Load Eff. (%)	Rated Input Power (kW)	Equiv. Usage Factor (UF)	Load Ratio (LR)	Oper. Hours/ Day
Chiller 1	1	424	95	332.95	0.500 (for Units 1&2)	1.020	5840H/yr
Chiller 2	1	300	92	243.26		1.016	2190H/yr
Chilled Water Pumps	2	2x25	88	2x21.19	0.7742	0.978	2 Units at 5840H/yr 1Unit at 2190H/yr
Cooling Tower Fans	3	3x15	86	3x13.01	0.2854	0.3425	3 Units at 5840H/yr 2 Units at 2190H/yr
Condenser Pumps	2	2x25	88	2x21.19	0.6762	0.854	2 Units at 5840H/yr 1 Unit at 2190H/yr
Water Pumps (Total)*	-	25	85	21.94	0.6042	Varies	24.0
Hot Water Pumps (Total)*	-	35	87	30.01	0.3333	Varies	24.0
Exh. Fans and Blowers (Total)	-	46.54	84	41.33	0.6792	Varies	24.0
Elevators	6	6x50	90	6x41.44	0.1833	Varies	24.0
	1	10	90	8.29	-	Varies	24.0
Boiler Feed Pumps	1	5	84	4.44	0.2083	Varies	24.0
Aircomp.	1	15	86	13.01	0.125	Varies	24.0
Fan Coil Units (Total)	-	-	84	11.00	1.0	1.00	24.0
Misc. Kitchen and Ref.	-	31.05	83	50.15	0.4146	Varies	24.0
Air Handling Units	14	Varies	Varies	112.62	0.2869	Varies	Varies

* Approximate - not based on nameplate data.

Table E-8. - AHU Fan Motors Data

Motor No.	Area Served	Rated HP	Output kW	Normal Operation Hrs/Day or (Hrs/Wk)
1	Cafeteria	5.0	3.730	6
2	Laundry	7.5	5.595	14
3	Le Boulevardier	15.0	11.190	19
4	Where Else	7.5	5.595	9
5	Coffee Shop	15.0	11.190	20
6	Prince Albert	7.5	5.595	10
7	Ground Floor Lobby	20.0	14.920	22
8	Second Floor Lobby	10.0	7.460	11
9	Business Shops	7.5	5.595	(14)
10	Admin. Offices	3.0	2.238	(15)
11	Shopping Arcade	7.5	5.595	11
12	Bahia	10.0	7.460	10
13	Skytop	10.0	7.460	9
14	Barber/Beauty Shop	3.0	2.238	11
15	Pre Cooler	20.0	14.920	Not operational

Table E-9. - Estimated Average Total Electrical Load Demand

Load Component	Rated Load Demand (Input kW) [1]	Usage Factor [2]	Average Demand (Input kW) [1] x [2]
Chillers	576.21	0.5000	288.10
Chilled Water Pumps	42.38	0.7742	32.81
Cooling Towers Fans	39.03	0.2854	11.14
Condenser Pumps	42.38	0.6762	28.66
FCUs	11.00	1.0000	11.00
AHUs	112.62	0.2869	32.31
Lighting	307.66	0.5562	171.11
Elect. Equipment	131.71	0.5786	76.20
Miscellaneous:			
Lighting	25.40	0.8417	21.38
Elevators	256.96	0.1833	47.10
Hot Water Pumps	30.00	0.3333	10.00
Water Pumps	21.94	0.6042	13.26
Boiler Feed Pumps	4.44	0.2083	0.93
Air Compressor	13.01	0.1250	1.63
Exhaust Fans and Blowers	41.33	0.6792	28.07
Misc. Kit. Ref. Equipment	50.15	0.4146	20.79
Total:	1706.22		794.49

Note: Breakdown based on the computer output results and manual calculations.

Table E-10. - Monthly Electrical Usage Parameters

Year	Month	Metered kWh	Max.Demand kW	Load Factor	HUOD
1987	January	533,140	1050	0.705	507.75
	February	484,500	1116	0.603	434.14
	March	577,980	1296	0.619	445.97
	April	571,140	1344	0.590	424.96
	May	598,880	1296	0.642	462.10
	June	601,540	1416	0.590	424.82
	July	577,600	1296	0.619	445.68
	August	605,720	1200	0.701	504.77
	September	585,960	1248	0.652	469.52
	October	504,260	1296	0.540	389.09
	November	574,560	1272	0.627	451.70
	December	676,020	1344	0.699	502.99
		Average:	1264.05	0.632	455.29
1988					
	January	416,860	1200	0.482	69.71
	February	640,300	1296	0.686	75.28
	March	626,240	1344	0.647	78.07

where:

$$\text{Load Factor} = \frac{\text{Actual Monthly kWh}}{\text{Max. Demand x Total Hrs/Month}} = (\text{LF})$$

$$\text{HUOD} = \frac{\text{Actual Monthly kWh}}{\text{Max. Demand}} = \text{Equiv. Hours Use of Demand}$$

Table E-11. - Breakdown of Estimated Energy Losses

Load Component	Annual Energy Losses	% of Total Energy Losses	% of Bldgs. Total Energy Use	Cost Equiv. (at P2/kWh*)
Lighting (Ballast Losses)	70,879.48	13.75	1.01	141,758.96
Line Losses	28,648.5	5.57	0.41	57,297.00
Motors:				
Chillers	145,532.81	28.24	2.08	291,065.62
Cooling Tower Fans	6,912.50	1.34	0.10	13,825.00
Condenser Pumps	25,545.67	4.96	0.37	51,091.34
AHUs	45,047.14	8.74	0.64	90,094.28
FCUs	15,417.60	2.99	0.22	30,835.20
Chilled Water Pumps	33,662.73	6.53	0.48	67,325.46
Elevators	41,260.27	8.01	0.59	82,520.54
Hot Water Pumps	11,390.66	2.21	0.16	22,781.32
Water Pumps	17,418.58	3.38	0.25	34,837.16
Boiler Feed Pumps	1,296.27	0.25	0.02	2,592.54
Air Compressor	1,994.43	0.39	0.03	3,988.86
Misc. Kitchen & Ref.	30,963.73	6.01	0.44	61,927.46
Exhaust Fans & Blowers	39,344.78	7.64	0.56	78,689.56
	524,410.86 kWh/yr	100.00 Percent	7.37 Percent	1,030,630.30 Peso/yr

* Note: Includes generation, demand, and other energy charges.

Table E-12. - Breakdown of kWh/yr Usage

Load Component	kWh/yr	Percent of Total
1. Cooling Plant (Chillers, Cooling Tower Fans, Condenser Pumps)	2,873,160.93	41.11
2. HVAC Auxiliaries (AHUs, FCUs, Chiller Water Pumps)	666,783.03	9.54
HVAC Total =	(3,539,943.96)	(50.65)
3. Lighting (Air Conditioned Space)	1,498,908.89	21.45
4. Electrical Equipment (Air Conditioned Space)	667,538.97	9.55
Non-HVAC Total =	(2,166,447.86)	(31.00)
5. Miscellaneous Consumption		
Lighting (Non-Air-conditioned Space)	187,274.20	2.68
Elevators	412,677.80	5.90
Hot Water Pumps	87,600.00	1.25
Water Pumps	116,117.45	1.66
Boiler Feed Pumps	8,103.00	0.12
Air Compressor	14,245.95	0.20
Exhaust Fans & Blowers	245,892.80	3.52
Misc. Kitchen & Ref.Eqpt.	182,132.20	2.61
Line Losses	28,648.50	0.41
Misc. Consumption Total =	(1,282,691.30)	(18.35)
Grand Total =	6,989,083.10 kWh/yr	

Table E-13. - Cooling Load Summary

Load Component	Sensible (Watts)	Latent (Watts)	Percent of Total
Glass Solar Gain	264,374		25.6
Glass Conduction	135,334		13.1
Wall Transmission	31,600		3.0
Roof Transmission	13,669		1.3
Loss to Unconditioned Space	58,584		5.7
Underground Surfaces	936		0.1
Lighting	191,669		18.6
Other Electric	57,298	2,083	5.7
People	113,256	125,470	23.1
Cooling Infiltration	12,932	26,420	3.8
Totals	879,652	153,973	100.0
Total Cooling Load (Watts)	1,033,625		

Note: The above loads exclude outside ventilation air loads, heat gain in machine rooms and return air plenums, fan heat load, and losses in supply air and chilled water distribution system.

Table E-14. - Space Cooling Summary

Space	Peak Cooling kW	Mo.	Hour	Cooling GJ/yr	Energy %
Employee's Dining	50.65	Sep	1700	300.587	1.039
Laundry	264.01	Sep	1600	2752.400	9.516
Ground Floor Shops	99.81	Apr	1500	1119.292	3.870
Ground Floor Lobby	123.44	Apr	1500	2608.687	9.019
Boulevardier	141.10	Apr	1500	2339.954	8.090
Prince Albert	92.67	Sep	1700	924.980	3.198
Jeepney Coffee Shop	124.49	Apr	1500	2308.836	7.982
Euphoria Disco	238.47	Sep	1800	2036.175	7.040
Beauty/Barber Shop	47.20	Apr	1500	495.813	1.714
Second Lobby	67.98	Apr	800	806.491	2.788
Administration	61.08	Apr	1500	478.958	1.656
Ballroom	248.08	Jun	1800	544.224	1.882
Bahia	199.52	May	1700	1867.345	6.456
Skytop	170.42	Jun	1800	1374.837	4.753
Offices/Function Rooms	56.33	Apr	1500	463.833	1.604
Special Suite	3.59	Jun	1600	403.124	1.394
Managers Suite	3.50	Jun	1600	390.605	1.350
SE Guest Rooms	1.39	Apr	1500	3129.598	10.820
NW Guest Rooms	1.44	Apr	1500	4052.868	14.012
24-Hr Offices	28.28	Apr	1500	526.326	1.820
				----------	--------
Total:				28,924.033	100.0

Table E-15 - Estimated Annual Energy Savings

Item Description	Annual Energy Savings kWh/yr	Percent Savings*
High Efficiency Chillers	544,804	7.8
Variable Air Volume	232,759	3.3
Variable Speed Chilled Water Pumping	114,200	1.6
All ECO Combinations**	949,742	13.6

* Basis: 6,989,236.36 kWy/yr total electrical consumption.

** Note: the savings obtained when implementing a combination of ECOs is not necessarily equal to the sum of that for individual ECOs.

Table E-16 - Annual Component Electrical Energy Consumptions*

Component	Consumption kWh/yr	Percent of Total
Cooling Plants[1]	2,873,161	41.2
A/C Auxiliaries[2]	666,783	9.5
A/C Total	3,539,944	50.7
Lighting	1,498,909	21.5
Electrical Equipment[3]	667,539	9.6
Misc. Consumption[4]	1,271,584	18.2
Non-A/C Total	3,438,032	49.3
Total kWh/yr	6,977,965	100.0

Notes: * These are the computer simulation results (DOE-2) used as the basis of estimated savings per year in the ECO runs (% error = 0.1611%; Basis = 6,989,236.36 kWh/yr electrical consumption).

1. Includes chiller, cooling tower fans, and condenser pumps.

2. Includes air system fans and chilled water pumps.

3. Electrical equipment found inside conditioned areas.

4. Includes elevators, domestic water pumps, and other electrical energy-consuming equipment not found inside conditioned areas.

Table E-17. - Combustion Test Results

Firing Mode	Percent of O_2 Flue Gas	Flue Gas Temperature, °C
High Fire	7.5	187.2
High Fire	8.0	187.8
High Fire	8.5	183.3
Low Fire	12.0	181.7

Notes: Only Boiler No.1 was operating during the time of the audit.

Fuel Flow Rate: 2.82 lits/min.

Ambient air conditions: 39°C DPT, 25.5° WBT.

BFW Temperature: 90°C.

Fuel Oil Temperature: 90°C.

Steam Pressure: 6.2 barg.

Table E-18. - Boiler Surface Temperature

Surface	Temp.,°C
Laterals	64.4
Front	76.0
Rear	96.0

Note: Boiler Dimensions:
Diameter: 1.651 m
Length: 5.258 m

Table E-19. - Boiler Radiation-Convective Heat Loss

Radiation	Heat Losses (kJ/hr)
Lateral Surface	23,657.497
Front Surface	2542.169
Rear Surface	4527.919
Total Radiation Heat Losses	30727.584
Fuel Heat Input	6,977,295.360
Radiation Heat Loss, %GHV	0.440

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Table E-20 - Efficiency of Boiler No. 1

Firing Mode	Flue Gas $\%O_2$	Flue Gas Temp.°C	Boiler Eff. %	Steam Economy kg Steam/Lit Fuel
High Fire	7.5	187.2	82.05	14.31
High Fire	8.0	187.7	81.66	14.26
High Fire	8.5	183.3	81.55	14.25
Low Fire	12.0	181.7	77.94	13.75
Optimum	2.9	200.0	83.82	14.50

Table E-21. - Potential Savings: Optimum Combustion Conditions

Old. Eff.	New. Eff.	%Fuel Savings	Approx. LOE	Annual Savings kPesos
82.05	83.82	2.1	10570	29.8
81.66	83.82	2.6	13086	36.9
81.55	83.82	2.7	13590	38.3
77.94	83.82	7.0	35233	99.4

Note: The figures were arrived at using the following data and assumptions:

- 503323 lits IFO annual consumption.
- 2.9% O_2 in flue gas.
- 200° flue gas temperature.
- P2.82/lit IFO cost.
- Combustion/bumer are provided and are in good operating condition.

Table E-22. - Boiler Efficiency: Boiler No. 1

Site:	**Manila Intercon**	**Date: May 1988**
Location	**Makati, Metro Manila**	**Engr.: ASEAN-US Staff**
	Firing Mode:	**High Fire**

Test Data		**Fuel Analysis**	
Flue Gas $\%O_2$	7.500	%C	85.000
Flue Gas CO	0.000	%H	11.200
Flue Gas Temp.(C)	187.200	%O	0.000
Amb. Air Temp.(C)	39.000	%N	0.000
Abs. Humidity	0.015	%S	3.000
P/H Air Temp.(C)	39.000	%Ash	0.800
Fuel Temp.(C)	90.000	Fuel $\%H_2O$	0.500
Stm. Press (barg)	6.206	Fuel HV, kJ/kg	43262.000
BFW Temp.(C)	90.000	Rad. Loss, %GHV	0.440
Stoich.Air, kgs	13.788	%Excess Air	52.853
Fuel Input, kgs	1.005	Air Input, kgs	21.075
H_2O in Fuel, kgs	0.005	H_2O in Air, kgs	0.316
Total Input, kgs	22.396	Total Output, kgs	22.397

Flue Gas Analysis

Gas	**%Vol. (Dry)**	**%Vol.(Wet)**
CO_2	10.076	9.119
CO	0.000	0.000
O_2	7.500	6.787
N_2	82.290	74.467
SO_2	0.133	0.121
H_2O		9.506
Total	100.000	100.000

Summary of Boiler Heat Losses

Flue Gas Sensible Heat, %	8.857
Ash Sensible Heat, %	0.003
Inc. Combustion, %	0.000
Comb. H_2O Latent Heat, %	7.301
Radiation Heat Loss, %	1.792
Total Losses, %	17.953
Boiler Efficiency, %	82.047
Steam Economy, kg.Steam/kg.Fuel	14.815

Table E-23. - Boiler Efficiency: Boiler No. 1

Site:	**Manila Intercon**	**Date: May 1988**
Location	**Makati, Metro Manila**	**Engr.: ASEAN-US Staff**
	Firing Mode:	**High Fire**

Test Data		**Fuel Analysis**	
Flue Gas %O_2	8.000	%C	85.000
Flue Gas CO	0.000	%H	11.200
Flue Gas Temp.(C)	187.200	%O	0.000
Amb. Air Temp.(C)	39.000	%N	0.000
Abs. Humidity	0.015	%S	3.000
P/H Air Temp.(C)	39.000	%Ash	0.800
Fuel Temp.(C)	90.000	Fuel %H_2O	0.500
Stm. Press (barg)	6.206	Fuel HV, kJ/kg	43262.000
BFW Temp.(C)	90.000	Rad. Loss, %GHV	0.440
Stoich.Air, kgs	13.788	%Excess Air	58.569
Fuel Input, kgs	1.005	Air Input, kgs	21.863
H_2O in Fuel, kgs	0.005	H_2O in Air, kgs	0.328
Total Input, kgs	23.196	Total Output, kgs	23.197

Flue Gas Analysis

Gas	%Vol. (Dry)	%Vol.(Wet)
CO_2	9.699	8.801
CO	0.000	0.000
O_2	8.000	7.259
N_2	82.172	74.565
SO_2	0.128	0.116
H_2O		9.257
Total	100.000	100.000

Summary of Boiler Heat Losses

Flue Gas Sensible Heat, %	9.187	
Ash Sensible Heat, %	0.003	
Inc. Combustion, %	0.000	
Comb. H_2O Latent Heat, %	7.359	
Radiation Heat Loss, %	1.791	
Total Losses, %	18.340	
Boiler Efficiency, %		81.660
Steam Economy, kg.Steam/kg.Fuel		14.758

Table E-24. - Boiler Efficiency: Boiler No. 1

Site:	Manila Intercon	Date: May 1988
Location	Makati, Metro Manila	Engr.: ASEAN-US Staff
	Firing Mode:	High Fire

Test Data		Fuel Analysis	
Flue Gas $\%O_2$	8.500	%C	85.000
Flue Gas CO	0.000	%H	11.200
Flue Gas Temp.(C)	183.300	%O	0.000
Amb. Air Temp.(C)	39.000	%N	0.000
Abs. Humidity	0.015	%S	3.000
P/H Air Temp.(C)	39.000	%Ash	0.800
Fuel Temp.(C)	90.000	Fuel $\%H_2O$	0.500
Stm. Press (barg)	6.206	Fuel HV, kJ/kg	43262.000
BFW Temp.(C)	90.000	Rad. Loss, %GHV	0.440
Stoich.Air, kgs	13.788	%Excess Air	64.747
Fuel Input, kgs	1.005	Air Input, kgs	22.715
H_2O in Fuel, kgs	0.005	H_2O in Air, kgs	0.341
Total Input, kgs	23.396	Total Output, kgs	24.062

Flue Gas Analysis

Gas	%Vol. (Dry)	%Vol.(Wet)
CO_2	9.322	8.483
CO	0.000	0.000
O_2	8.500	7.734
N_2	82.054	74.664
SO_2	0.123	0.112
H_2O		9.007
Total	100.000	100.000

Summary of Boiler Heat Losses

Flue Gas Sensible Heat, %	9.235	
Ash Sensible Heat, %	0.003	
Inc. Combustion, %	0.000	
Comb. H_2O Latent Heat, %	7.422	
Radiation Heat Loss, %	1.789	
Total Losses, %	18.449	
Boiler Efficiency, %		81.551
Steam Economy, kg.Steam/kg.Fuel		14.753

Table E-25. - Boiler Efficiency: Boiler No. 1

Site:	**Manila Intercon**	**Date: May 1988**
Location	**Makati, Metro Manila**	**Engr.: ASEAN-US Staff**
	Firing Mode:	**High Fire**

Test Data		**Fuel Analysis**	
Flue Gas %O_2	12.000	%C	85.000
Flue Gas CO	0.000	%H	11.200
Flue Gas Temp.(C)	181.700	%O	0.000
Amb. Air Temp.(C)	39.000	%N	0.000
Abs. Humidity	0.015	%S	3.000
P/H Air Temp.(C)	39.000	%Ash	0.800
Fuel Temp.(C)	90.000	Fuel %H_2O	0.500
Stm. Press (barg)	6.206	Fuel HV, kJ/kg	43262.000
BFW Temp.(C)	90.000	Rad. Loss, %GHV	0.440
Stoich.Air, kgs	13.788	%Excess Air	127.516
Fuel Input, kgs	1.005	Air Input, kgs	31.370
H_2O in Fuel, kgs	0.005	H_2O in Air, kgs	0.471
Total Input, kgs	32.845	Total Output, kgs	32.846

Flue Gas Analysis

Gas	%Vol. (Dry)	%Vol.(Wet)
CO_2	6.682	6.200
CO	0.000	0.000
O_2	12.000	11.134
N_2	81.229	75.369
SO_2	0.088	0.082
H_2O		7.215
Total	100.000	100.000

Summary of Boiler Heat Losses

Flue Gas Sensible Heat, %	12.229	
Ash Sensible Heat, %	0.003	
Inc. Combustion, %	0.000	
Comb. H_2O Latent Heat, %	8.054	
Radiation Heat Loss, %	1.772	
Total Losses, %	22.057	
Boiler Efficiency, %		77.943
Steam Economy, kg.Steam/kg.Fuel		14.239

Table E-26. - Boiler Efficiency: Boiler No. 1

Site:	**Manila Intercon**	**Date: May 1988**
Location	**Makati, Metro Manila**	**Engr.: ASEAN-US Staff**
	Firing Mode:	**High Fire**

Test Data		**Fuel Analysis**	
Flue Gas $\%O_2$	2.900	%C	85.000
Flue Gas CO	0.000	%H	11.200
Flue Gas Temp.(C)	200.000	%O	0.000
Amb. Air Temp.(C)	39.000	%N	0.000
Abs. Humidity	0.015	%S	3.000
P/H Air Temp.(C)	39.000	%Ash	0.800
Fuel Temp.(C)	90.000	Fuel $\%H_2O$	0.500
Stm. Press (barg)	6.206	Fuel HV, kJ/kg	43262.000
BFW Temp.(C)	90.000	Rad. Loss, %GHV	0.440
Stoich.Air, kgs	13.788	%Excess Air	15.202
Fuel Input, kgs	1.005	Air Input, kgs	15.884
H_2O in Fuel, kgs	0.005	H_2O in Air, kgs	0.238
Total Input, kgs	17.127	Total Output, kgs	17.128

Flue Gas Analysis

Gas	**%Vol. (Dry)**	**%Vol.(Wet)**
CO_2	13.546	11.956
CO	0.000	0.000
O_2	2.900	2.560
N_2	83.375	73.591
SO_2	0.179	0.158
H_2O		11.734
Total	100.000	100.000

Summary of Boiler Heat Losses

Flue Gas Sensible Heat, %	7.463	
Ash Sensible Heat, %	0.003	
Inc. Combustion, %	0.000	
Comb. H_2O Latent Heat, %	6.914	
Radiation Heat Loss, %	1.803	
Total Losses, %	16.183	
Boiler Efficiency, %		83.817
Steam Economy, kg.Steam/kg.Fuel		15.045

APPENDIX F

CHARN ISSARA SHOPPING ARCADE

AUDIT REPORT

THAILAND

This report is one of five excellent energy audits conducted by the Thailand investigative team. The five audits focused on the buildings' air-conditioning systems and used DOE-2 for the analysis. The building types covered by the other audits were: office, hotel, hospital, and academic library.

PROGRESS REPORT

ASEAN-USAID PROJECT
ON
ENERGY CONSERVATION IN BUILDINGS

AIR-CONDITIONING SYSTEM
CHARN ISSARA SHOPPING ARCADE, BANGKOK, THAILAND

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ABSTRACT

Shopping arcades in tropical countries require air-conditioning systems both for the comfort of the occupants and to keep dust and dirt out of shops.

Investigation of the energy consumption and air-conditioning loads of a typical first-class shopping arcade in Bangkok showed that the air-conditioning system accounted for about 60% of the total energy consumption. The investigation also showed that considerable amounts of energy could be conserved, without sacrificing comfort, by taking the following steps:

- Using a variable air volume system to supply air according to the air-conditioning load requirement.
- Using an air-to-air heat exchanger to reduce heat load of the fresh air intake.
- Raising the leaving chilled water temperature as high as possible.

Since most of the time the enthalpy of the outside air is much higher than that of the exhaust air, considerable energy could be conserved by using the cool and dry exhaust air to reduce the enthalpy of the warm and humid outside air brought into the air-conditioning system.

OBJECTIVE AND SCOPE OF WORK

Introduction

The rapid growth in the economy of Thailand has led to a rapid increase in the number of large, air-conditioned commercial buildings. Air-conditioning equipment consumes more than 70% of the total electrical energy consumption of commercial buildings. They also contribute immensely to the electricity peak load. Thus, energy conservation in air-conditioning is a significant developmental strategy, the ASEAN-USAID Project on Buildings Energy Conservation focus on air-conditioning equipment and systems in Thailand is quite timely.

Objective

This research aims to assess the performance of air-conditioning equipment in use in the major cities of Thailand, and to explore possible approaches to increasing efficiencies of the air-conditioning systems in buildings. The activities of the research project included the use of PC-DOE-2.1B in parametric analysis and actual physical evaluation of the air-conditioning equipment under different control sequences.

Scope of Work

The scope of work includes the following subjects:

Baseline Information on Air-Conditioning Use:

This study was made in collaboration with the daylighting research group to acquire the baseline information on the configuration and type of air-conditioning equipment in use. In addition, the study included a survey and energy audit of buildings as a continuation of an earlier study.

The study also furnishes information on the relative number of each class of air-conditioning equipment and the typical construction of the air-conditioned space for which the equipment is used, and identifies a number of buildings which might be classified as typical.

This activity aims to provide baseline information for use in DOE-2 analysis and for use in evaluating air-conditioning performance. The study evaluates configurations and conditions of existing air-conditioning systems, determines the potential for energy conservation and electrical load reduction, and provides recommendations for energy conservation based on the above evaluations.

Expected results from this research will be:

1. A set of baseline information on air-conditioning equipment and building construction.

2. Radiation and weather data for the local area.
3. The training of a technician who will be experienced in the parametric study of air-conditioning system performance.
4. A parametric study of air-conditioning equipment for each major city, available for policy consideration.
5. A physical evaluation of the air-conditioning equipment performance.

BUILDING SELECTION

Reasons for the selection of the Charn Issara Shopping Arcade for this research are as follows:

- There are many shopping arcades in Thailand and many more will be built.
- Shopping arcades are a type of building which needs to have an air-conditioning system for the comfort of its occupants.
- Charn Issara Shopping Arcade is a typical shopping arcade in Thailand and it uses a typical air-conditioning system.

BUILDING DESCRIPTION AND DATA COLLECTION FORMS

Building Description

General:

Charn Issara Shopping Arcade and Office Condominium was built in 1985. The first four storys house an arcade with total floor area of 4,800 m^2 and an atrium in the center. The atrium is surrounded by corridors and shops. The shops face the atrium. The fifth floor is a trade exhibition center. The 6th to 26th floors are offices.

Shops are air-conditioned mainly by small split-type air conditioners. The cost of operating the air conditioner is the responsibility of the owner of the shop. The atrium, corridors, and some of the shops are air-conditioned by the central air-conditioning system, which consists of three air-cooled water chillers. Each air-cooled water chiller has 1,200,000 Btu/hr cooling capacity. Chilled water is circulated by three sets of centrifugal pumps, each of which has a pumping capacity of 240 gpm. There are eight air handling units and eight fan coil units supplying 66,000 cfm of cooled air to the air-conditioned spaces. Air handling units are controlled by two-way motorized valves with proportional thermostats. Offices are air-conditioned by split-type air conditioners.

Building Envelope:

Walls. Exterior walls are four-in. hollow brick with plaster on both sides and tinted glass.

Doors. Main entrance doors are nine-mm. thick tinted glass.

Roof. The roof is a four-in. thick concrete slab and is insulated with two-in. thick fiberglass insulation.

Ceiling. The ceiling is constructed with nine-mm. thick gypsum board with a metal stud frame.

Floor. The floor is a four-in. thick concrete slab.

Data Collection Forms

The PC-DOE 2.1 B program consist of four parts: load input, system input, plant input, and economics. Data collection forms, using ASEAM-2 input forms as a guideline, provide the framework for the field surveys.

Load Input:

1. Information about building shading obstructions.
2. People schedule.

3. Lighting schedule.
4. Lighting fixture type.
5. Lighting load or task lighting.
6. Equipment schedule.
7. Equipment load.
8. Zone number, sizes, locations, construction materials, and locations (exterior and interior).
9. Glass type.
10. Ground and roof construction materials.

System Input:

1. Reset control temperature setting.
2. Design zone volumetric air flow.
3. Design zone outside air flow.
4. Design zone exhaust air flow.
5. Zone temperature setting.
6. Zone thermostat type, throttling range.
7. Supply air temperature setpoint.
8. Supply air temperature control.
9. Outside air control.
10. System fan control.
11. Fan schedule.
12. Static pressure for fan, efficiency and brake horse power.
13. Total and sensible cooling coil capacity.
14. Coil bypass factor.
15. Return air routing.

Plant Input:

1. Type, size, quantity, run period schedule, electric input ratio, and performance curve.
2. Temperature and capacity control setpoint.
3. Cooling tower design wet bulb temperature, fan control, and type of cooling tower.
4. Pump type, flow rate capacity, efficiency, and brake horse power.

FIELD SURVEY TASKS AND DATA COLLECTION

General

To analyze the building energy consumption using PC-DOE-2.1B, it is necessary to collect all data required by the program. A considerable amount of time was spent getting details of the building envelope. The building envelope includes walls, windows, doors, roof, and bottom floor. All these isolate the space inside from the outside environment. Since heat load makes up a significant amount of the total energy consumption, it was very important that the building envelope be examined in great detail to find areas where it could be improved. Mechanical and electrical systems were also analyzed as part of the field survey. These systems include air-conditioning equipment, piping, ducting, fans, pumps, lighting, and power systems. All systems were checked for method of control, operating efficiency, maintenance scheduling, leaks, insulation, and discussions were held with workers or employees who influenced their energy consumption. The field survey included acquiring information on structural and architectural features, as well as mechanical and electrical equipment. Whenever possible, interviews were conducted with the workers and employees associated with the building's various functions in order to gain more insight into the overall operation.

Steps to Collect the Data

Modeling the building's energy consumption requires that certain data be collected. Steps to collect the data are described below:

Pre-Survey Information:

In this step, the building's drawings—which include the architectural, structural, mechanical, electrical, sanitary (plumbing), and elevator systems—are obtained. The building's existing energy bills are also obtained and analyzed. The researcher contacts the person who takes care of the building's facilities, such as the chief engineer, to ask about equipment, operation, and maintenance schedules.

Field Survey Tasks:

This step consists of several items as described below:

Load Input.

1. Review the building's drawings and perform field visit.
2. Survey the building envelope, including walls, windows, roof, floors, etc.
3. Assign zone spaces in the building.
4. Measure space and construction materials in zones.
5. Measure temperature and check the thermostat setpoints in zones.
6. Count occupants and activities.
7. Measure electrical system, including lighting and power, in the zones.
8. Assign occupancy schedule of zones.
9. Measure infiltration in zones.

System Input.

1. Consider type and configuration of air-conditioning system in the building and zones.
2. Measure leaving temperature of cooling equipment and check the cooling coil temperature setpoint.
3. Check total consumption of fan power in zones.
4. Check total supply air to spaces or zones.
5. Check temperature rise of discharge air from fan.
6. Check air control method, fan control method, and motor drive.
7. Check scheduling of fans.
8. Check the optimizer.

Plant Input.

1. Consider chiller type, cooling capacity design coefficient of performance, entering and leaving water setpoint, part load ratio of the machine, and power consumption.
2. Check number, sequencing, and load management of chillers.
3. Check scheduling of machines.
4. Check chilled water pumps and condenser water pumps for capacity, consumption, number, and operation.
5. Check cooling towers for design wet bulb temperature, fan control, and type.
6. Check cooling towers for number and mode of operation.

Final Check for Complete Data Collection:

This step will review and finalize all data to compile into loads, system, and plant forms.

Data Summary of the Building and Its Operation

The analysis is limited to the air-conditioning systems in the shopping arcade and to the central air-conditioning system using air-cooled water chillers.

Total air-conditioned floor area: 4,800 m^2.

Air-conditioning equipment:

- 3 x 100 tons air-cooled water chillers
- 3 x 240 gpm. centrifugal chilled water pumps
- 8 air handling units and 8 fan coil units with a total supply air of 66,000 cfm.

EVALUATION OF ENERGY CONSERVATION OPPORTUNITIES

Air-conditioning systems and equipment of the Charn Issara Shopping Arcade were simulated to find opportunities for energy conservation.

Supply Air of Air Handling Units

Analysis of the load suggests that the minimum supply of air to the air handling units should be 68,400 cfm. The survey showed that the existing supply of air to the air handling units to be 66,000 cfm. No energy could therefore be saved by adjusting the speed of the blowers of the air handling units to supply the minimum amount of air to the space.

Fresh Air Intake

Survey data showed that fresh air intake into the building was 7,660 cfm. This amount of fresh air was considered to be the minimum amount for ventilation for the 4,800 m^2 total floor area of the building. The existing amount of fresh air was therefore kept constant throughout.

Variable Air Volume System

A simulation was run in which the supply air volume of the air handling units was controlled to meet the cooling loads by discharge air dampers or inlet guide vanes. Comparing the energy consumed by the existing air-conditioning system with a variable air volume system using discharge air dampers or inlet guide vanes for controlling air quantity showed that much energy could be saved using the variable air volume system. Investment in a variable air volume system is considerable, but still economically feasible.

Air-to-Air Heat Exchanger

Fresh air taken into the building was 7,660 cfm. If this amount of warm and humid fresh air could exchange heat to the cool and dry exhaust air, the cooling load needed to cool fresh air would be greatly reduced.

Raising Leaving Chilled Water Temperature

Theoretically, the coefficient of performance of the refrigeration system will increase with an increase in the evaporating temperature. However, in the central air-conditioning system, the power to pump chilled water and the power to blow air through the cooling coils must be added to the power of the refrigeration system. If the water temperature is increased, more water and more air will have to be passed through the cooling coils for the same cooling loads.

Analysis of the Charn Issara Shopping Arcade air-conditioning system showed little change in power consumption when the leaving chilled water temperature was varied between 45°F and 52°F. The power consumption was lowest when the leaving chilled water temperature was 49°F.

RESULTS

[The original report contains all of the tables and figures listed below. For the sake of brevity, only one table, summarizing the findings of Tables 1 and 2, is presented at the end of this report.]

CONCLUSION

Comparison of various conditions against the base case condition showed that:

- By installing discharge air dampers in the existing air-conditioning system, cooling energy saving would be 964.66 MBtu/yr, electrical energy saving 120,055 kWh/yr and money saving 182,483 Baht/yr.* Equivalence at 12% interest rate would be 1.79 years and IRR would be 65.18.
- By installing inlet guide vanes in the existing air-conditioning system, cooling energy saving would be 1,443.48 MBtu/yr, electrical energy saving 205,708 kWh/yr, and money saving 312,676.16 Baht/yr. Equivalence at 12% interest rate would be 1.57

* The conversion rate used, as of June, 1990, was 25.86 Thai Bahts to 1 U.S. Dollar.

years and IRR would be highest at 73.85.

- By installing an air-to-air heat exchanger in the existing air-conditioning system, cooling energy saving would be 2,841.73 MBtu/yr, electrical energy saving would be 316,637.50 kWh/yr, and money saving 481,289 Baht/yr. Equivalence at 12% interest rate would be 2.11 years and IRR would be 55.92.
- By installing discharge air dampers and an air-to-air heat exchanger in the existing air-conditioning system, cooling energy saving would be 3,082.90 MBtu/yr, electrical energy saving 365,351 kWh/yr, and money saving 553,814.55 Baht/yr. Equivalence at 12% interest rate would be highest at 2.59 years and IRR would be 46.32.
- By installing inlet guide vanes and an air-to-air heat exchanger in the existing air-conditioning system, cooling energy saving would be 3,202.60 MBtu/yr, electrical energy saving 412,564.78 kWh/yr, and money saving would be highest at 627,698.47 Baht/yr. Equivalence at 12% interest rate would be 2.57 years and IRR would be 46.62.

By comparing plant cooling and electrical energy inputs per year of various air-conditioning systems at various chilled water temperatures, it was determined that the optimum leaving chilled water temperature would be 49°F.

Economic comparison of various conditions showed that it was best to invest in installation of inlet guide vanes and an air-to-air heat exchanger to the existing air-conditioning system. The system with inlet guide vanes and an air-to-air heat exchanger would need the least cooling energy and electrical energy consumption. The cooling energy would be reduced by approximately 49%, while electrical energy consumption would be reduced by approximately 29%.

Table F-1. Comparison of Various Conditions Against the Base Case

Equipment Required	Supply Air CFM	Fresh Air CFM	Cooling Energy Savings (MBtu/yr)	Electrical Energy Savings (kWh/yr)	Money Saving (Baht/yr)	Operating Cost (Baht/yr)*	Investment Cost (Baht)	Equivalence At IR.12% (yr)	IRR
--	68,400	7,660	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Discharge Damper	Variable	7,660	964.66	120,055.00	182,483.60	25,000.00	240,000.00	1.79	65.16
Inlet Guide Vane	Variable	7,660	1,443.48	205,708.00	312,676.16	25,000.00	388,000.00	1.57	73.85
Air-to-Air Heat Exchanger	68,400	7,660	2,841.73	316,637.50	481,289.00	75,000.00	718,000.00	2.11	55.92
Discharge Damper and Air-to-Air Heat Exchanger	Variable	7,660	3,082.90	364,351.68	553,814.55	100,000.00	958,000.00	2.59	46.32
Inlet Guide Vane and Air-to-Air Heat Exchanger	Variable	7,660	3,202.60	412,564.78	627,098.47	100,000.00	1,106,000.00	2.57	46.62

* Operating cost of added equipment.

APPENDIX G

HOLIDAY INN CITY CENTRE

AUDIT REPORT

MALAYSIA

This report is an example of the auditing work conducted by the Malaysian team. The auditors used ASEAM-2, a software tool appropriate to an intermediate level of analysis.

PRELIMINARY ENERGY AUDIT REPORT

HOLIDAY INN CITY CENTRE

KUALA LUMPUR, MALAYSIA

Preformed by:

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February 27, 1988

INTRODUCTION

The energy audit is a study which determines how, when, and where energy is used in an existing building and identifies opportunities for conservation.

OBJECTIVES

The objectives of the commercial audits performed are as follows:

- Evaluate the existing configuration and condition of the building energy systems and determine the potential for energy conservation and/or electrical load reduction;
- Evaluate the existing operating and maintenance practices for potential energy conservation and electrical load reduction; and
- Provide recommendations for cost-effective energy conservation based on the above evaluation.

METHOD OF ANALYSIS

Data Collection

Before starting the study in detail, it was first necessary to understand how the building uses energy. To do this, utility bills of the building were analyzed, and compiled into an energy history. Examination and analysis of the utility bills before, during, and after an energy audit were also useful. Once the energy history was established and analyzed, a comprehensive building inspection was undertaken to determine where conservation measures were needed. In addition, interviews were conducted with maintenance engineers and employees associated with various functions to gain insight into overall building operations. A large part of inspection time was spent examining the building envelope, including walls, windows, doors, roof, and floors. Since cooling makes up a significant amount of the total energy consumption, it was very important to examine the building envelope in detail to find areas where it could be improved. Building mechanical and electrical systems also were examined and analyzed. These systems included cooling equipment, piping and ducting, fans, domestic hot water, steam boiler, and lighting. All systems were checked for control methods, operating efficiency, maintenance scheduling, leaks, insulation, and other factors which influenced energy consumption.

Energy Conservation Opportunities (ECO) Analysis

Using the information gathered from the energy history and building inspections, a list of energy and cost-saving opportunities and recommendations was developed. Many of the cost-effective energy conservation measures required little or no capital outlay because significant savings could be obtained through minor operational changes. Future changes would be broader in scope and more capital intensive. All calculations in this study were performed by the ASEAM Version 2.0 computer simulation program developed by W. S. Fleming & Associates, Inc. Costs are estimated in 1987 Malaysian Ringgit.

BUILDING DESCRIPTION

General

The building consisted of a four-story podium block with parking floors and a 14-story hotel tower (see Figures G-1 and G-2). It is joined to an adjacent building at the northeast corner. The building's facades are oriented to the northeast, southwest, and northwest, with the front facing the southeast. The building has approximately 130,000 ft^2 of floor area and was commissioned in 1980.

Building Envelope

Walls:

The exterior walls were brickwork and finished by rough cast plaster, marble, and tiles. The walls outside the hotel guest rooms were a dark color.

Windows:

All windows contained single-pane glass. The hotel guest rooms, function rooms, and shops had internal shading. The first floor facades on the southeast were shaded by overhangs.

Doors:

The main entrance was an automatic sliding door of single-pane glass. Internal doors were of the swinging type and were made of wood.

Roof:

The roofing material was eight-inch concrete slab and finished with rubber insulation.

Floor:

The floor material was six-inch concrete slab and finished by cement, tile, marble, and carpet, except for staff canteen, food store, and housekeeping areas.

Air-Conditioning System

The refrigeration plant of the main air-conditioning system serving the hotel guest rooms consisted of two Mitsubishi centrifugal chiller units, with one normally in operation and one on standby. Chilled water from the operational unit was circulated to individual cooling coils found in each guest room of the hotel. Conference rooms and restaurant areas were also served by the chilled water plant. The chillers work on R-12, and typically operated at 80% of the full load capacity; at night the load imposed was less.

Lighting

The building used two types of lighting.

Fluorescent:

- 4 x 2 : 4 fluorescent tubes, 2-foot
- 2 x 4 : 2 fluorescent tubes, 4-foot
- 3 x 4 : 3 fluorescent tubes, 4-foot

The fluorescent lights were used in offices, the staff canteen, toilets, kitchen, and car-parks.

Incandescent:

The building used different intensities of fixtures, i.e., 25W, 40W, 60W, 80W, and 100W. The incandescent lights were used in hotel guest rooms, room corridors, front lift lobby, function rooms, the restaurant, bar, coffee house, and the hotel lobby.

ELECTRICITY BILL

Monthly bills were supplied by the National Electricity Board of Malaysia (NEB). The building used Tariff E1 – Medium Voltage General Industrial Tariff. The NEB charge for each unit was M$ 0.16/US$ 0.06. The NEB also charged for each kilowatt of maximum demand per month. The charge was M$12.00/US$ 4.65 and the minimum charge was M$ 500/US$ 194. The building owner was also required to pay a Connected Load Charge when using supplies at medium or high voltages. The chargeable maximum demand (MD) was the shortfall between 75% of the declared MD and the actual MD measured in any one month. The charge for the monthly connected load was M$ 4/US$ 1.55 for each kW of chargeable MD.

ENERGY END-USE

The building's electricity consumption for the first nine months in 1987 was M$ 894,906/US$ 346,796. The energy consumption totaled 3,809,150 kWh which cost M$ 707,544/US$ 274,189, of which M$ 99,880/US$ 38,706 was the maximum fee. LPG (liquefied petroleum gas) was largely used for cooking. The consumption was 150 cylinders per month which cost M$ 57.80/US$ 22.40 per cylinder. Diesel was used for hot water and the steam boiler. The consumption was 8,900 litres, at M$ 0.56/US$ 0.22 per litre.

BASE CASE

The base case simulation result showed only a slight difference when compared with actual bills, not including the maximum demand fee. This is shown below:

Total electricity consumption for the first nine months from actual bill	= 3,797,900 kWh
Total electricity consumption for the first nine months from base case	= 3,452,981 kWh
Percentage of variation	= 10%

The distribution of electricity consumption was analyzed from the result of this base case. The last two months showed slightly higher electricity use compared to other months. Possible causes included the following:

- Higher than anticipated appliance electricity usage;
- Variation in building electricity use;
- Increased use of the five lifts because of maintenance work; and
- Increased infiltration rates because of inefficient use of entrance/exit doors.

RECOMMENDATIONS

The following is a list with brief descriptions of Operation and Maintenance (O&M) procedures and ECOs identified during our study which, if implemented, could save a significant amount of energy. The O&M items can generally be performed by maintenance staff or maintenance contractors.

Building Envelope

Keep Boundary Doors Closed:

Both doors that separate conditioned space from the outside environment or unconditioned space, and doors that mark the boundary between areas kept at different temperatures should always be closed. Doors for food stores, control rooms, and meeting rooms were always open, and this increases the rate of infiltration. The use of revolving doors should be investigated.

Lighting

Use High-Efficiency Ballasts:

Fluorescent lighting was widely used in administration offices, corridors, staircases, toilets, and car-parks. The electricity consumption can be reduced if present ballasts are replaced with high-efficiency ballasts, i.e., 8W.

Reduce Number of Light Fixtures at Windows:

The front staircase, back staircase, and office corridor have daylighting access. The number of light fixtures can be reduced to 30% of the present installed capacity.

Replace Incandescents with SL Lamps:

The lamps in hotel guest rooms and corridors can be replaced with SL lamps without affecting output or color. This can be described as below:

present incandescent	replace with	SL lamp
GLS 40W		SL 9W
GLS 60W		SL 13W
GLS 100W		SL 25W

The replacement of incandescents in hotel guest rooms could reduce the installed capacity by 62.5%. This is shown below:

Total wattage for 255 guest rooms with different categories which use incandescent	=126,030 Watts
Total wattage for 255 guest rooms with different categories which use SL lamps	= 47,242 Watts
Wattage of reduction	= 78,788 Watts
Percentage of reduction	= 62.5%

The number of lamps replaced will be 2,207. 1,258 of these are SL 9W; 653 are SL 13W and 298 are SL 25W. Total investment for this replacement is:

Total investment @ M$ 30/each	= 2,209 x 30
	= M$ 66,270
	= US$ 25,682

The replacement of incandescent lamps in corridors would reduce the installed capacity by 77.5%. This is shown below:

Total wattage for hotel corridors which use incandescents	= 7,680 Watt
Total wattage for hotel corridors which use SL lamps	= 1,728 Watt
Wattage of reduction	= 5,952 Watt
Percentage of reduction	= 77.5%

The number of SL 9W lamps replaced will be 192. The investment for this replacement is:

Total investment @ M$ 30	= 192 x 30
	= M$ 5,760
	= US$ 2,232

Air-Conditioning System

Increase Thermostat Setting:

Set all thermostat setting temperatures to 24°C.

Optimize Operating Time:

The operating time of cooling systems could be optimized by starting the air handing units (AHUs) one-and-one-half hours before daily activities begin, and by turning it off during the last half-hour of occupancy. This can be done for function rooms, meeting rooms, and administration offices.

Optimize Refrigeration System Operation:

Details of Recommendation. Considerable cost savings could be achieved by optimizing the operation of the refrigeration chiller unit. It is recommended that the two chiller units be provided with an optimizer unit that would cause the units to operate at peak efficiency. After monitoring the load imposed by the chiller unit in operation, and adjusting the setpoints accordingly, the optimizer would ensure low electrical usage.

Principle of Optimization. The coefficient of performance factor is a measure of the efficiency of operation of any chiller unit.

$$COP = \frac{\text{cooling produced (refrigeration load)}}{\text{electrical power required (by chiller compressor motor)}}$$

COP varies not only with the amount of load, but also with the temperature of the chilled water produced and the temperature of the condenser water circulated. COP increases with the temperature at which chilled water can be circulated to the air handling plant. A good operational control should provide a higher COP, and, therefore, reduce the power requirements of the compressor motor. The optimizer would monitor all the factors affecting COP and other related parameters, and could reset the machine to operate at a revised condition, resulting in the best COP factor possible.

Cost Saving Calculation. It is estimated that the recommended optimizer control system would save 12% of chiller energy, assuming that the chiller operated at approximately 260 amps, and at a power factor of 0.9.

Power consumed	= 3 x 415 x 260 x 0.9 = 168 kW
Annual energy consumed at an average of 80% of normal operation	= 0.8 x 168 x 8 760 = 1,177,344 kWh
Annual operating costs at M$ 0.16 per kWh	= M$ 188,375 = US$ 73,000
Estimated saving @ 12%	= M$ 22,605 = US$ 8,760

Resource/Investment Required. Approximately M$ 60,000/US$ 23,252 would be required for the following work:

- installation of a limited monitoring system to determine load variation of the chiller during a typical day;
- interlocking of the optimizer with the chiller electronic operating and safety controls; and
- testing, balancing, and recommissioning the system.

Payback Period.

$$\text{Simple payback period} = \frac{\text{investment required}}{\text{annual cost savings}}$$

$$= \frac{60{,}000/22{,}605}{}$$
$$= 2.65 \text{ years}$$

Installation of a speed control device is also recommended. It would regulate the capacity of the compressor refrigeration unit to meet the exact requirements of the hotel's building load.

Equipment

Turn Off Kitchen and Office Equipment:

Workers should be encouraged to keep electricity-consuming kitchen equipment off when not in use. Staff should minimize use of office equipment such as the copiers, typewriters, and computers.

Refrigerator: Clean Condenser Coils:

Clean coils and fans to increase heat transfer efficiency. The energy consumption of refrigerators and freezers is directly related to the temperature at which they are kept. If possible, temperature settings should be increased as much as possible while maintaining food-storage quality. Every degree can mean large savings.

ENERGY CONSERVATION OPPORTUNITIES (ECOs)

Single ECOs (SECOs)

Three potential SECOs are identified:

SECO #1. Replace incandescent lamps in hotel guest rooms with SL lamps.

SECO #2. Replace incandescent lamps in guest room corridors with SL lamps.

SECO #3. Increase thermostat settings.

Multiple ECO (MECO)

Two potential MECOs are identified:

MECO #1. Replace incandescent lamps in hotel guest rooms and increase thermostat settings.

MECO #2. Replace incandescent lamps in guest room corridors and increase thermostat settings.

The results are shown in Tables G-1 and G-2.

COMMENT

Submeters should be installed to track the energy use of the large consumers, i.e., chillers, pumps, and AHUs, thereby discovering any unpredicted large increase in electricity consumption. With sufficient recorded submetering, immediate action could be taken when excess consumption was noted. At a minimum, submetering should be installed for each cooling tower, for each chiller installation, and for the individual AHUs. Daily kWhs should be recorded by the maintenance department and evaluated by the maintenance officer. At a minimum, the chiller log-forms must contain the following:

- entering/leaving chiller water temperature;
- entering/leaving condenser water temperature;
- condenser pressures;
- chiller pressures; and
- amps.

Daily boiler logs containing information on temperature and efficiency would provide useful information for the calculation of possible energy savings. The maintenance department should review the manuals, and if necessary, update them. The maintenance department must be sure that the staff is familiar with the manuals and schedules, and that they follow them as closely as possible. Plant cooling instruments must be maintained properly, and this is not being done at the present time. Training should be given on the proper use of equipment, and on the basic principles of building energy conservation.

CONCLUSION

The ECO implementation would reduce the total energy consumption for the building. Of course, the ECO with the lowest payback period should be implemented first, and the evaluation of the ECO with longer payback period should await consequent re-examinations. If modifications were made to the existing mechanical installations, the above-mentioned energy savings would be affected.

Sectional View of Holiday Inn, City Centre, Kuala Lumpur

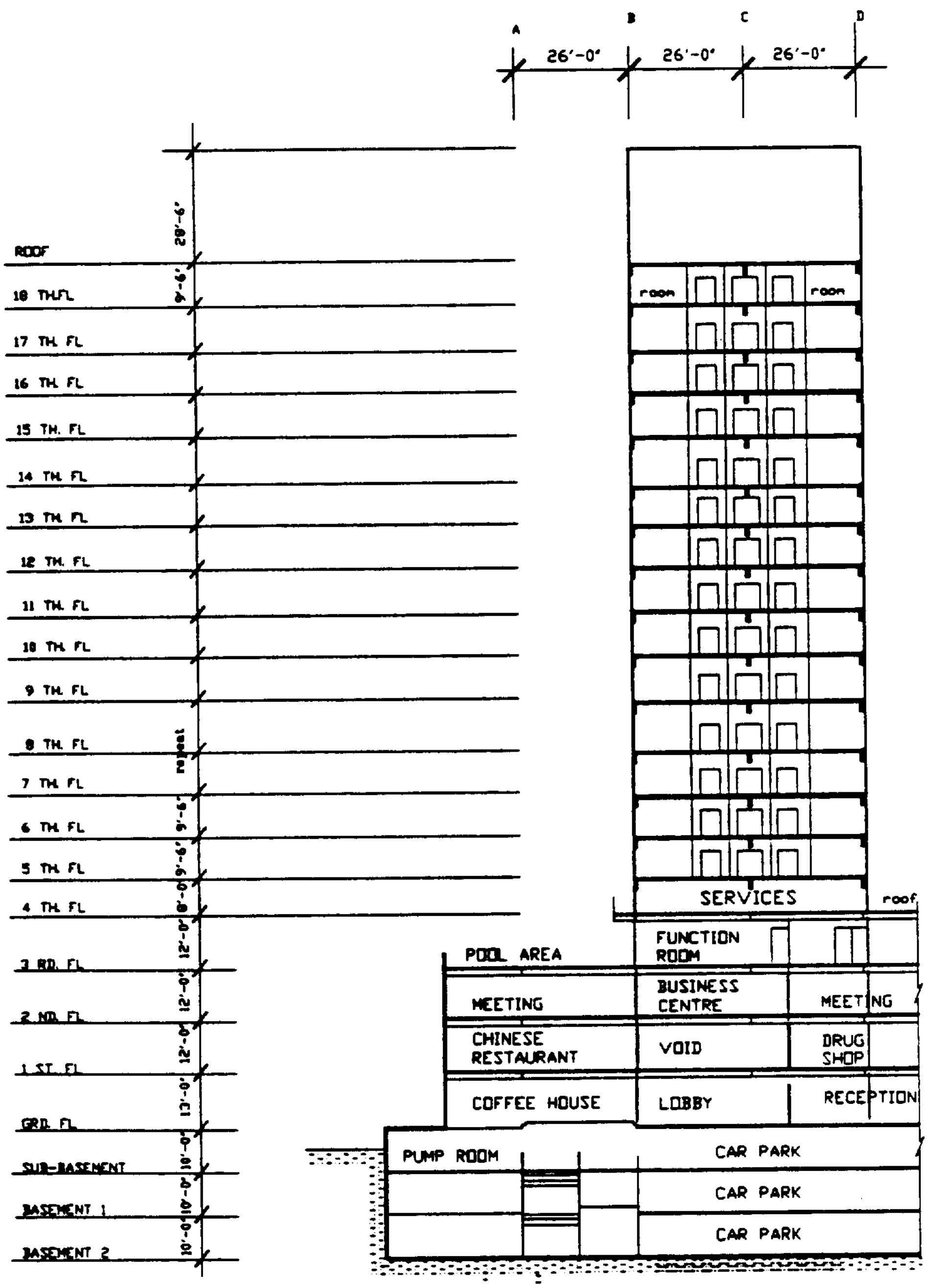

Figure G-1.

Site Plan of Holiday Inn, City Centre, Kuala Lumpur

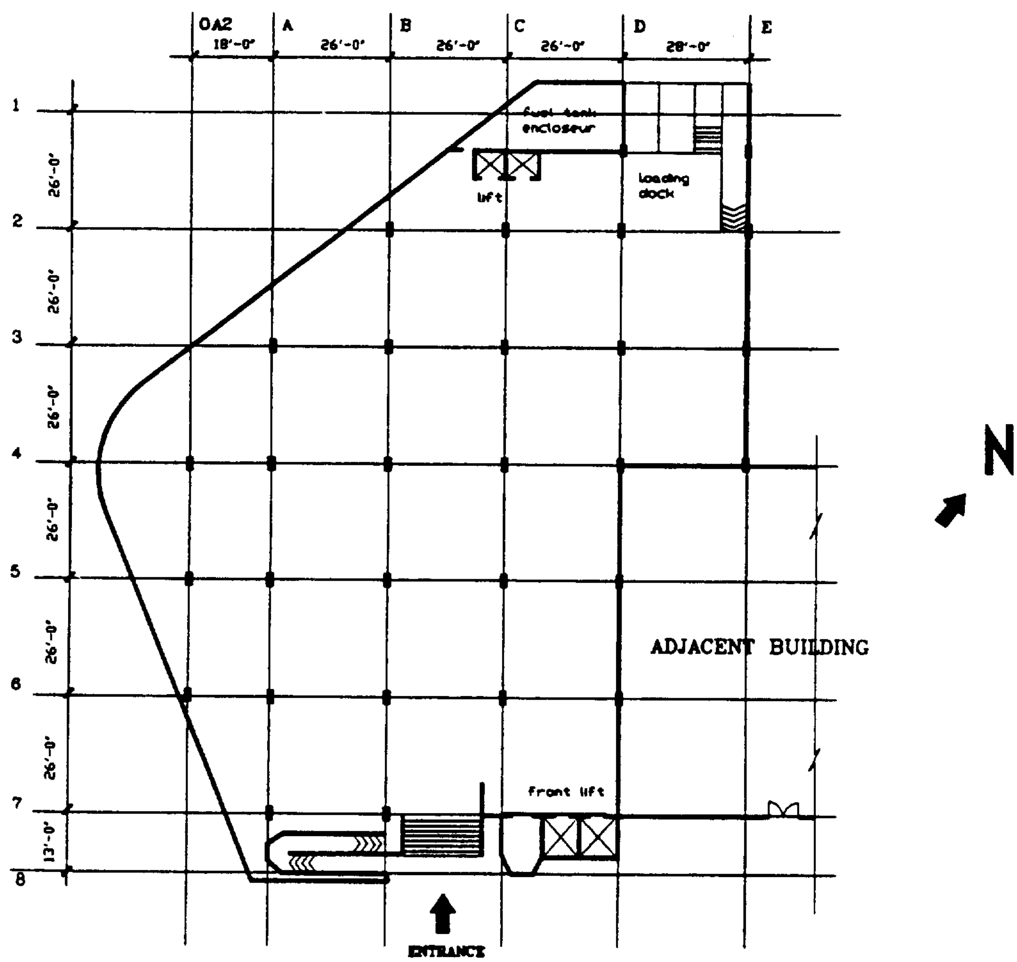

Figure G-2.

Table G-1 - ASEAM Run Results

Run No.	ECO No.	Saving M$/US$	Saving %*
1	SECO #1	578,668/22,423	8
2	SECO #2	7,258/2,812	1
3	SECO #3	20,913/8,103	3
4	MECO #1	81,7291/31,670	2
5	MECO #2	28,542/11,062	4

$$\text{* Energy saving, \%} = \frac{\text{cost saving}}{\text{total dollar cost (base case)}}$$

Table G-2 - List of Payback Periods for ECOs

ECO No.	ECO Description	Saving M$/US$	Saving %	Payback yrs*
1	Replace incandescent lamps in guest rooms with SL lamps	57,866/22,423	8	1-2
2	Replace incandescent lamps in guest room corridors with SL lamps	7,258/2,812	1	0-1
3	Increase thermostat setting temperature	226,053/8,759	3	no-cost
4	Installed optimizer control system for chillers	226,053/8,759	12	2-3

$$\text{*Payback period} = \frac{\text{investment}}{\text{annual saving}}$$

APPENDIX H

LIGHTING STUDY

SINGAPORE

This report concisely summarizes the results of an extensive lighting survey conducted for over 300 buildings in Singapore including a number of different building types. The report also documents the policy discussion regarding future lighting standards and shows how existing lighting conditions compare to standards in Singapore, Malaysia, and Thailand.

SINGAPORE LIGHTING STUDY

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PURPOSE OF REPORT

This report is the final report of Subproject 1.1 – Lighting Survey and is a summary of the principal researcher's findings and recommendations arising from discussions with the Lighting Subcommittee of the Singapore Public Works Department (PWD), Energy Conservation Committee.

LIGHTING SUBCOMMITTEE TASKS

At the first meeting of the Lighting Subcommittee, on 24th July 1984, the following objectives and procedures were agreed:

Objectives

The objectives of this Subcommittee are:

- To review present provisions of lighting loads in buildings.
- To examine current lighting design and installations.
- To examine the viability of the introduction of natural lighting as a means of energy saving in building design.
- To devise a method of calculation of the availability of daylight in buildings.
- To recommend a revision of building regulations to include daylighting.

Procedure

The procedures laid down by the Subcommittee to achieve the above objectives are:

- To conduct a survey of major buildings in Singapore and to evaluate the present practice of lighting design and installation.
- To run the DOE 2.1B program on several building forms and to evaluate energy saving due to the introduction of daylighting.
- To draft calculation procedures and building regulations for daylighting.

SCOPE OF REPORT

The areas covered in the report include:

- A review of the programme of surveys undertaken in Singapore, including details of buildings visited and the format of survey data.
- Results of the survey data, including details of lighting power densities for various types of activity, associated levels of illuminance achieved for these activities, and measures of lighting efficacy.
- Analysis of results to indicate distribution of values with respect to prevailing regulatory limits and accepted design standards in Singapore.
- Comparison of results from survey data with existing and proposed standards for other ASEAN countries.
- Proposals for revisions to regulatory standards in Singapore.
- Appraisals of the impact of such revisions with particular reference to compliance and design implications.

THE FIELD SURVEY

To establish a significant database from which it would be possible to judge the current design practice and level of regulatory compliance, a total of 100 buildings was proposed. The buildings were selected for inclusion in the survey based on the following criteria:

- All building types contained in para 2.8 of Handbook on Energy Conservation (PWD).
- Buildings with good lighting design and installation.

- Energy-efficient buildings.

Assistance was sought from Subcommittee members from PWD and the Public Utilities Board in identifying appropriate buildings. At this stage of the survey, of the building types included in current regulations, primarily offices, shops and circulation spaces were chosen.

The data collection method and survey record was based on a previous survey carried out by the Department of Building Science, National University of Singapore (NUS), the record sheet being taken as the pro forma, and developed into the final survey form.

The survey was carried out between August 1984 and September 1985 by students of the School of Architecture, NUS, under the supervision of Mr. J.F. Pickup, Senior Lecturer in the Department of Building Science, NUS. Preliminary reporting of the results was made to the Main Committee in 1986. The survey work was funded by the ongoing lighting research programme in the Department of Building Science, NUS.

In 1986, it was agreed to extend the range of building types to include schools. A survey of 10 schools was carried out in June 1986 with the assistance of the Ministry of Education. In view of the extensive availability of daylight in the school buildings, the survey form was modified to include measurements of daylight illuminance.

In 1987, the survey was further extended as part of the ASEAN US Cooperation Programme Phase 3, Research Activity S1.1. The criteria for the additional work was:

- Extension of existing data base.
- Verification of results from previous surveys.
- Inclusion of additional activity types (industrial).

This work was carried out by students of the School of Architecture, NUS, acting as part-time research assistants under the supervision of Mr. Peter Woods, Senior Lecturer in School of Architecture. The survey work was funded from the ASEAN US Cooperation Programme budget for Research Topic area S.1.

For this survey, additional data were collected with respect to daylight illuminance and distribution of interior surface luminances.

Summary of Field Survey Visits

Table H-1 gives details of numbers of buildings visited and spaces surveyed, broken down by activity type in each phase of the survey. Note that the total number of buildings visited is not the summation of each column because some buildings, spaces with more than one activity type were surveyed.

Field Survey Results

For each location, the following has been calculated from the survey results:

- Lighting power density (including an allowance for lighting circuit).
- Illuminance levels on the working plane (average).

For offices and shopping centers, installed efficacy values have been calculated to allow a comparison with possible target values. Table H-2 summarizes the results for the major building activities surveyed.

POWER DENSITY LIMITS

Criteria for Power Density Limit Revision

The Lighting Subcommittee took as its basis for evaluating the impact of existing regulations and proposing future revisions the following criteria:

(1) Existing regulatory standards.

(2) Performance of existing buildings.

(3) Proposed standards in other ASEAN countries.

(4) Current technical performance of equipment.

(5) SISIR code standards for illuminance.

(6) Assessment of availability of appropriate equipment.

(7) Implications for lighting quality.

Compliance with Power Density Standards

Surveyed values for power density have been compared with both current Singapore regulations as stated in the Handbook on Energy Conservation and standards proposed in comparative documents for Malaysia and Thailand. Both are draft proposals and possibly subject to modification. They are, however, indicative of intentions. Table H-3 summarizes the comparison.

MEASURED ILLUMINANCE LEVELS

There is no published standard for illuminance design level pertinent to the buildings surveyed, except by implication that good design practice would comply with other suitable international standards.

The Code of Practice for Artificial Lighting C.P. 38 1987 has now been published. Table H-4 compares surveyed values with the levels recommended in the code.

DISCUSSION OF RESULTS

For each of the main activities, the implications of the survey results are listed below. A summary of the discussion on the results by the Subcommittee follows with recommendations to the Energy Conservation Committee.

Offices

Summary of Results:

The existing regulatory limit of 20W/m^2 has been achieved by 65% of the sample surveyed. For the 136 cases, the average value was 19 W/m^2. By comparison with the proposed standards in other ASEAN countries, 30% of the sample surveyed:

- 49% would comply with draft Malaysian standard of 18 W/m^2.
- 40% would comply with draft Thailand standard of 16 W/m^2.

Current equipment available and in use in Singapore is demonstrably capable of meeting the SISIR code illuminance target within a power budget of 16 W/m^2 (efficacy > 33 lm/W, achieved by 16% of sample). A disturbing trend illustrated by the survey is the number of cases where the task illuminance was substantially lower than the SISIR code recommendations, 40% of sample below 300 lux (67% of the sample have an efficacy lower than 25 lm/W). This would seem to arise because of low design standards and poor maintenance.

Subcommittee Discussion of Office Results:

Two issues were raised: the need for greater distinction between large and small offices, and the availability of suitable lamps, luminaires, and control gear to meet the recommendation. The argument for the former is that small offices do not utilize the lamp output as effectively as large offices. Hence, in any power density limit, this should be acknowledged with a slightly more generous budget. The arguments against such a distinction are:

- The difficulty in defining 'small office' for the purposes of a regulation and setting a limiting size.
- Typical planning of office floors tends to locate small offices at the perimeter, where they usually enjoy a significant amount of daylight. It is acknowledged that internal decor, blinds, and external obstructions might mitigate against this advantage.

- Where small offices occur remote from windows in deep plan locations, partitions normally have extensive glazing for visual relief. This means the lighting of a small office tends to perform in like that of a larger space.

These latter arguments were taken by the Subcommittee to be more persuasive than having distinctions in the Handbook for different office sizes.

With regard to the question of equipment availability, the Subcommittee is indebted to Mr. John F. Pickup, NUS, for a series of calculations of the performance of typically available lamps, luminaires, and control gear. His observations follow:

Example

An office 4m x 4m x 2.85m high using two modular recessed prismatic luminaires with three 1200mm 40-watt standard fluorescent tubes in each. Reflectance of ceiling is 0.7 and of walls, 0.5, with a utilization factor of 0.3.

The installed luminous efficacy, including average (locally made) (10 watts loss) ballasts and 1200mm 40-watt standard fluorescent tubes, is 17 lm/W. Using 36-watt tri-phosphor fluorescent tubes with low-loss (6.5W) ballasts, the installed efficacy is 21.2 lm/W.

An area of 4m x 4m (room index = 1.0) and providing 300 lux would correspond to six fluorescent tubes and two luminaires. Using average ballasts and lamps, the power density is 18.75 W/m^2. Using tri-phosphor tubes and low-loss ballasts, the power density becomes 16 W/m^2.

Polished aluminum reflectors with louvres, giving a better utilization factor of say 0.35, could permit two lamps only per luminaire and a resulting power density of 10.6 W/m^2.

On this basis, a regulatory limit of 16 W/m^2 was thought reasonable.

Recommendations by Subcommittee for Offices:

- Lower power density limit to 16 W/m^2.
- Promote SISIR code task illuminance requirements.
- Promote target efficacy of 33 lm/w or greater.
- Education Programme: Design Methods (Task/Ambient), Programmed Maintenance, and Lighting Quality.

Shopping Centers

Summary of Results:

The existing regulatory limit of 30 W/m^2 has been achieved by 69% of the sample surveyed. For the 45 cases, the average value was 29 W/m^2. By comparison with the proposed standards in other ASEAN countries, of the sample surveyed:

- 47% would comply with the lower draft Malaysian standard of 23 W/m^2.
- 42% would comply with the lower draft Thailand standard of 22 W/m^2.

There is a wide variation in illuminance levels, although 40% of the sample exceed the SISIR code value of 500 lux (sample average is 436 lux).

Subcommittee Discussion of Shopping Centers Results:

The question of the value of retaining any limit for shopping centers was raised in light of the wide divergence of lighting standards. The main argument for retention was that having no limit might be interpreted as suggesting that energy conservation in shopping areas was considered unimportant by the authorities. With regard to the revision of the limit, the increased acceptance of new merchandising techniques based on display lighting and the availability of new low-powered sources was put forward as being a trend which would automatically reduce power consumption.

Recommendations by Subcommittee for Shopping Centers:

- Retain a power density limit for shopping centers and reduce to 23 W/m^2.
- Promote SISIR code task illuminance requirements.
- Education Programme: Disseminate new lighting trends for merchandising (particularly low wattage lamps for accent and display lighting).

Circulation

Summary of Results:

The existing regulatory limit of 10 W/m^2 has been achieved by 56% of sample surveyed. For the 81 cases, the average value was 16 W/m^2. By comparison with the proposed standards in other ASEAN countries, of the sample surveyed:

- 77% would comply with the draft Malaysia standard of 17 W/m^2.
- 75% would comply with the draft Thai standard of 15 W/m^2.

The illuminance distribution centers on the lower SISIR code recommendation. The sample average is 135 lux compared with the recommendation of 150 lux.

Subcommittee Discussions of Circulation Results:

The Subcommittee felt that the original regulation limit of 10 W/m^2 was probably too severe, given that in many buildings the distinction between the circulation spaces and other activities is not always clear in the lighting design. Clearly there was no justification for lowering the limit and it would not be wise to raise it. The Subcommittee also felt that "circulation areas" should be taken to include lobbies, corridors, and stairs, without separate categorization.

Recommendations of Subcommittee for Circulation Areas:

- Retain power density limit at 10 W/m^2.
- Promote SISIR code illuminance requirements.

Schools

Summary of Results:

The existing regulatory limit of 20 W/m^2 has been achieved by 100% of sample surveyed. For the 44 cases, the average value was 10 W/m^2. By comparison with the proposed standards in other ASEAN countries, of the sample surveyed:

- 100% would comply with the lower draft Malaysian standard of 17 W/m^2.
- 100% would comply with the lower draft Thai standard of 16 W/m^2.

The distribution of illuminance levels in the sample suggests a general design level of around 400 lux. The SISIR code recommends 300 lux. The normal luminaire encountered in the survey is a surface-mounted open trough fitting which, in combination with the efficient fluorescent lamps used, accounts for the high efficacy performance. This standard design is of concern to the Subcommittee as it may not meet an adequate standard for control of discomfort glare.

Subcommittee Discussion of Schools Results:

This concentrated mainly on lighting quality and the need for varying standards for different age groups. This was also coupled with a discussion on lecture theatre design. The Subcommittee felt that it should express its concern over possible glare problems in current school lighting schemes. With respect to different standards for each age group, the development of the use of extensive audio-visual material, particularly in tertiary institutions, suggested no real reason for having higher limits. Where high levels of task illuminance were necessary, as in laboratories or machine rooms, the use of appropriate task lighting would be a preferred solution to excessive ambient illuminance.

Recommendations by Subcommittee for Schools:

- Lower power density limit to 15 W/m^2.
- Promote SISIR code task illuminance and limiting glare indices.

Production Areas

Summary of Results:

There is no existing regulatory limit for production areas. Of the 17 cases surveyed, the average value was 24 W/m^2. By comparison with the proposed standards in other ASEAN countries, 30% of the sample surveyed, would comply with the draft Malaysian standard of 20 W/m^2. The sample, though small, demonstrates an extremely wide range of illuminance and power density levels. There would seem to be no reason why a power density limit for production areas cannot be specified given that the illuminance recommendations in the SISIR code are similar to those for offices. Such a power density limit would have to recognize the particular space dimensions in production areas (ceiling heights) and obstructions to the task.

Subcommittee Discussions of Production Area Results:

It was raised very early in the project that industrial buildings should be included in the Regulations. The problem identified, even from the small sample surveyed, is the wide range of current conditions. Some installations are being specified at much higher standards than the Singapore Code, particularly for U.S. firms operating in Singapore. The Subcommittee felt that a single but fairly liberal limit should be made for production areas.

Recommendations by Subcommittee for Production Areas:

- Institute a power density limit of 20 W/m^2.
- Promote SISIR Code Task Illuminance requirements.
- Education Programme: Design Methods (Task/Ambient) and Programmed Maintenance.

SUMMARY OF RECOMMENDATIONS

The main findings and recommendations by the Lighting Subcommittee have been summarized in Table H-5.

Illuminance

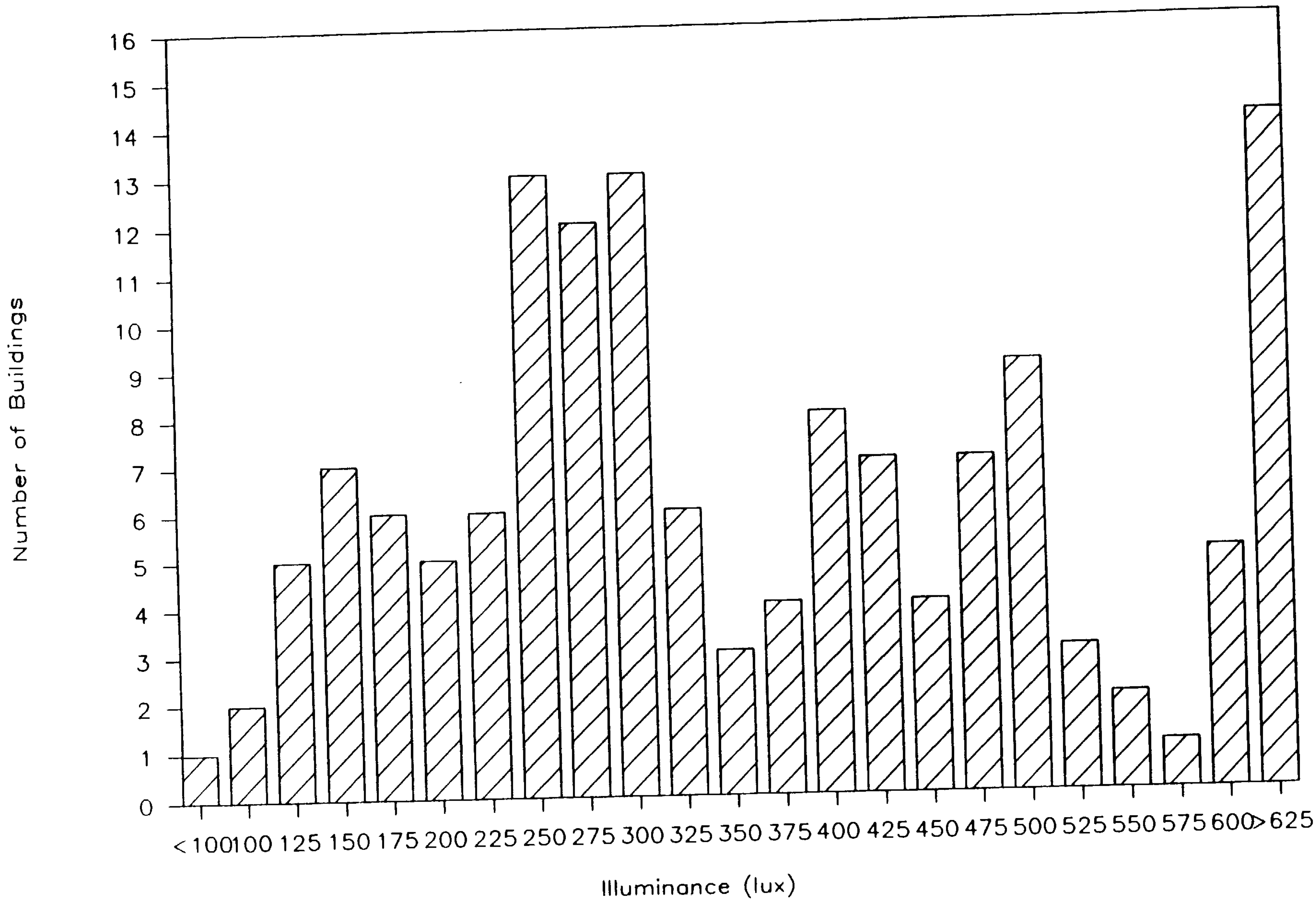

Figure H-1.

Power Density

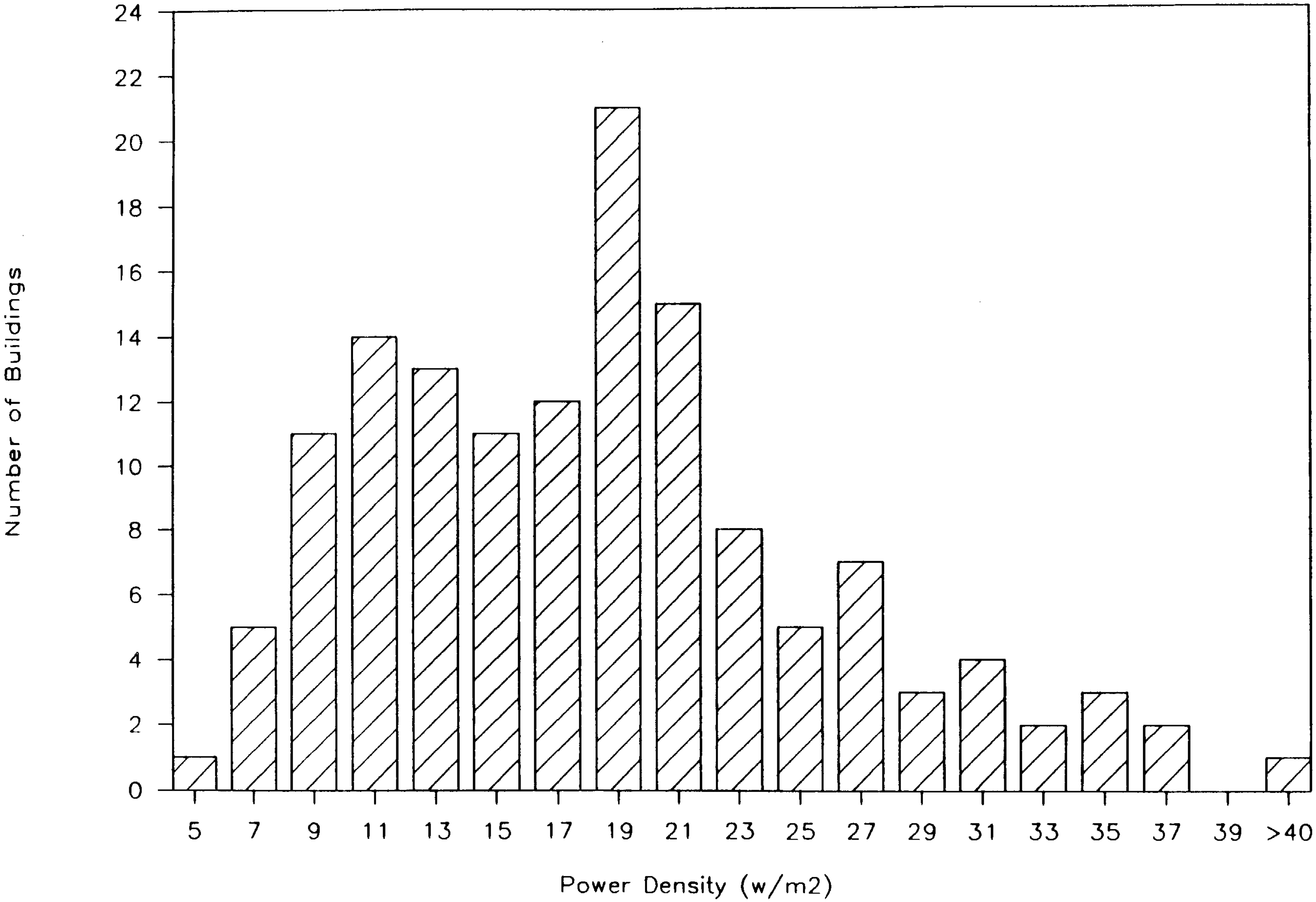

Figure H-2.

Efficacy

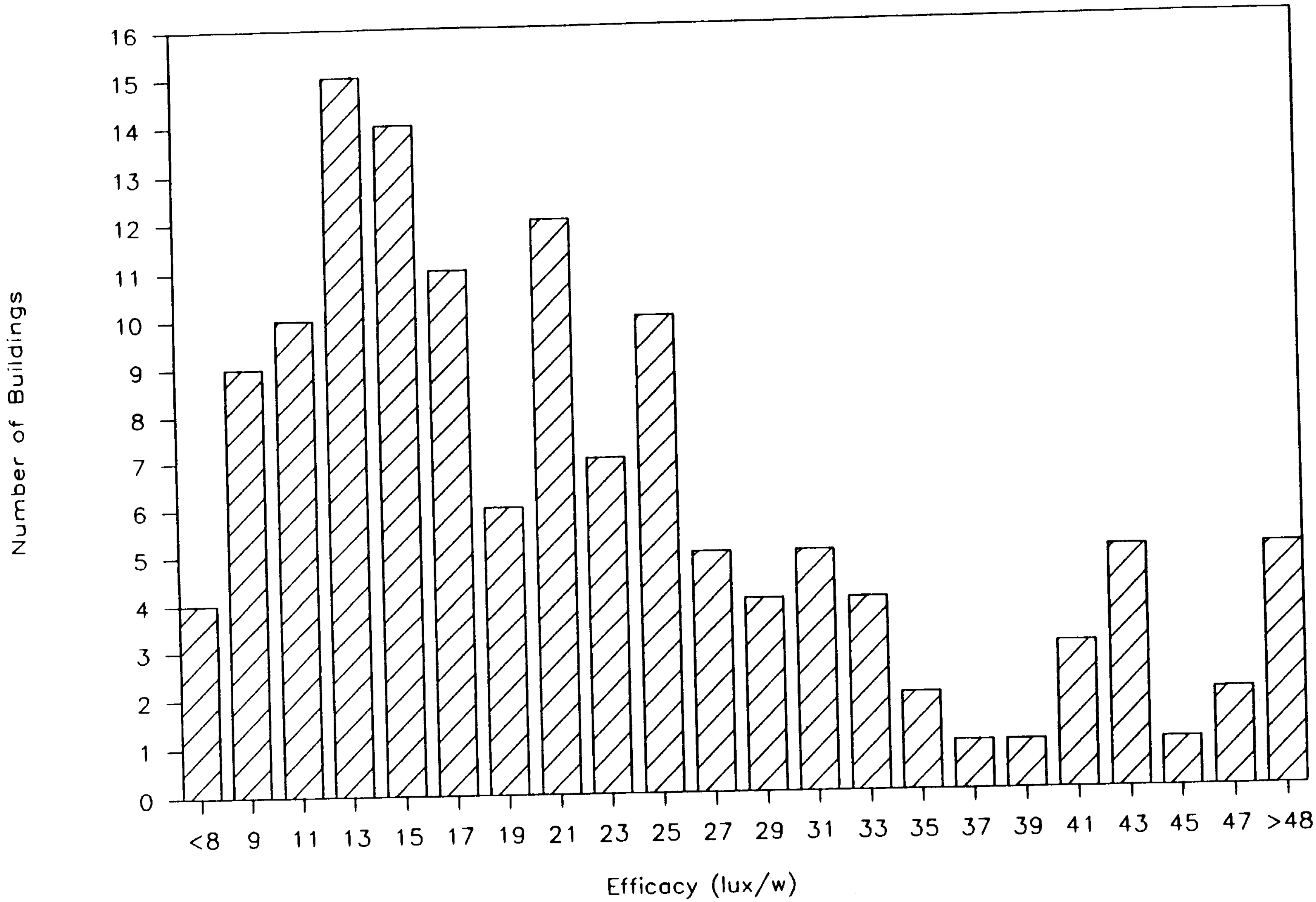

Figure H-3.

Table H-1. Summary of Survey Locations

Activity Type	1st Survey Period (1984/85) Buildings	Locations	2nd Survey Period (1986) Buildings	Locations	3rd Survey Period (1987) Buildings	Locations
Office	44	68	-	-	21	63
Shops/Dept Stores	23	44	-	-	3	3
Circulation Space	58	84	-	-	1	2
Schools	-	-	10	44	-	-
Auditoria/Cinema	13	14	-	-	-	-
Industry	-	-	-	-	7	22
Restaurant/Kitchen	15	15	-	-	-	-
Ticketing/Reception	5	5	-	-	4	4
Hotel	9	9	-	-	-	-
Indoor Sports	3	3	-	-	-	-
Conference/Meeting	2	2	-	-	6	7
Computing	-	-	-	-	2	3
		244		44		104

Table H-2. Summary of Survey Results

Activity (no. of cases)	Power Density (lm/w) Average	Max	Min	Std. Dev.	Working Plane Illuminance (Lux) Average	Max	Min	Std .Dev.
Offices (136)	19	60	5	8	366	946	94	167
Shopping (45)	29	79	11	15	436	1,140	128	235
Circulation (81)	16	48	1	11	134	518	13	111
Classrooms (44)	10	13	5.6	1.4	400	865	115	125
Production Areas (17)	24	59	3.7	14	520	887	169	224

Table H-3. Comparison of Power Density Standards and Survey Results

Activity	Singapore Regulations (Current)	Draft Malaysian Standard	Draft Thailand Standard	Survey Mean Values
Offices	20	18	16	19
Shops	30	26 - 23	22 - 23	29
Circulation	10	17	15	16
Classrooms	20	17 - 20 - 22	16 - 18	10
Production areas	-	-	-	24

Table H-4. Activity Type/Illuminance Standards

Activity	SISIR Code Recommended Level	Mean Survey Value	Percentage Above SISIR Standard	Percentage Below SISIR Standard	Sample Size
Office	300(550)750	366	750 = 4.5%	300 = 40%	136
Shops	300(500)750	436	750 = 9.0%	300 = 33%	45
Circulation	100(150)200	134	200 = 17%	100 = 47%	81
Classrooms	200(300)500	400	500 = 17%	200 = 9%	44
Production areas	300(500)750	497	750 = 19%	300 = 25%	17

Table H-5. Recommended Changes to Power Density Limits (W/m^2)

Type of Building	Maximum Lighting Load		
	Current	Recommended	Comment
Offices	20	16	Revision readily achievable, but concerted effort necessary to ensure illuminance standards are met.
Classrooms	20	16	Revision easily achievable but concern over glare from current luminaire choice.
Lecture Theatres/ Auditorium	25	16	
Shops/Supermarkets Dept stores	30	23	Retain limit. Revised level will be met by general changes in merchandising strategies.
Restaurants	25	20	Availability of efficient sources of color rendering and appearance desirable for restaurants allows for reduction.
Circulation lobbies/ stairs	10	10	Current survey evidence suggests existing limit is sufficiently stringent.
Car Parks	5	5	
Production	-	20	Introduction of a limit is recommended. Task lighting should be recommended.

APPENDIX I

ASEAN COMMERCIAL BUILDING ENERGY SURVEY FORM

ASEAN COMMERCIAL BUILDING ENERGY SURVEY FORM

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ASEAN Commercial Building Energy Survey

Parts One through Five of this questionnaire are intended to be completed by the building owner, manager, and/or operator. Part Six is more detailed. It may require a trained building survey team to visit your building to assist the owner, manager, and/or operator to answer the questions.

Please CIRCLE THE APPROPRIATE NUMBER or LETTER or BOX that correctly answers the questions, or write in your response where indicated. Please do not estimate. If you are unable to answer a question, please route the questionnaire to the person who can complete the missing information. Please indicate if the information is not available by writing in "not available".

PART ONE: GENERAL INFORMATION

1.1. **Name of Building:**

1.2. **Address:**

1.3. **Name of Respondent:**

1.4. **Position:** **Tel. No.:**

1.5. **Building Type (or, predominant building function)**

a. Office/Professional Building
b. Shopping Center/Mall/Retail/Service (Dry Goods Retail)
c. Food Sales (Groceries)
d. Food Services (Restaurants)
e. Hotel/Motel/Dormitory
f. Hospital/In-patient Health Services
g. Clinic/Out-patient Health Services
h. Skilled Nursing/Other Residential Care (Nursing Home)
i. Education (Schools, Universities)
j. Assembly Building
k. Public Order and Safety
l. Industrial Processing and Manufacturing
m. Agricultural Purposes
n. Laboratory
o. Refrigerated Warehouse or Storage
p. Non-refrigerated Warehouse or Storage
q. Religious Facility
r. Residential
s. Other (Please specify:) ____________________
____

1.6. **Number of Floors** (excluding car parks) ____________________

1.7. **Building Size** (exclude car parks; include service and circulation areas)
Please circle whether areas are supplied in m^2 or ft^2.

a. Total area per floor (typical): ________________ (m^2 or ft^2)
or
Total building area: __________________ (m^2 or ft^2)

b. Conditioned area per floor (typical; include air-conditioned and ventilation-only areas): ___________ (m^2 or ft^2)
or
Total building conditioned area: ___________ (m^2 or ft^2)

c. Car parks: ____________ (m^2 or ft^2)

1.8 **Energy Use** (including all end-uses; annual data is the minimum, monthly is preferred)

a. Fuel types used: ☐ Electricity ☐ Gas ☐ Fuel Oil ☐ Other (specify): ___________
b. Annual energy use_________ kWh; ___________ BTU; ___________ gallons
c. Annual energy cost__________________ ($ or other monetary units)
d. Annual elec. demand cost, if any__________ ($ or other monetary units)
e. Maximum of the billing-period peak electric demand ________ kW
f. Don't know

Source of data:

☐ Utility Company
☐ Bills
☐ Other (specify) _______________

or

Monthly:

Is there more than one of any one meter type (electric, gas, etc.)?
☐ Yes ☐ No

If so, record the data by meter on a separate sheet; include what area or equipment the meter supplies.

- *List readings taken from the main meter (or meters if there are gas or other meter types) for the past 12 months, for all energy types*
- *If demand charges exist, also list demand readings (kW) for the same period.*
- *If other fuel is used, list the fuel type and units (litres, BTU, etc.).*
- *If building operator does not have the information, obtain accounting numbers and appropriate permission from the building operator to get this billing history from the utility &/or other fuel supplier(s).*
- *Always obtain copies of the bills if possible.*

Year & Month	Electricity (kWh)	Elect. Cost	Electric Demand (kW)	Elect. Demand Cost	Other Fuel Energy	Other Fuel Cost

1.9 **Age of building**

1.9.1. Initial Construction: when was the construction completed for the major or largest portion of the building?

____________________ Year?

If you do not know the building age precisely, provide your best estimate of the period during which the major portion of construction was completed:

- ☐ 1900 or before
- ☐ 1901-1920
- ☐ 1921-1945
- ☐ 1946-1960
- ☐ 1961-1970
- ☐ 1971-1973
- ☐ 1974-1979
- ☐ 1980-1983
- ☐ 1984-present
- ☐ Don't know

1.9.2 Major Renovations or Additions: when was such construction completed (if any)? What percentage of the building or building subsystem was renovated? If an addition occurred, what percentage of the original building was it?

________ Year _______ Percent Renovated (for the building)
________ Year _______ Percent Renovated (for the mechanical system)
________ Year _______ Percent Renovated (for the lighting system)

If you do not know the renovation/addition age precisely, provide your best estimate of the period during which the major portion of construction was completed:

- ☐ 1900 or before
- ☐ 1901-1920
- ☐ 1921-1945
- ☐ 1946-1960
- ☐ 1961-1970
- ☐ 1971-1973
- ☐ 1974-1979

☐ 1980-1983
☐ 1984-present
☐ Don't know

1.10 **Building Architect and Engineers of Record**

Please list the architects and engineers who designed the building. List the architects and architectural firm, and the mechanical and electrical engineers or engineering firms.

Architect: Name ____________________
Address ____________________
Telephone ____________________
Do not know ☐

Mechanical Engineer: Name ____________________
Address ____________________
Telephone ____________________
Do not know ☐

Electrical Engineer: Name ____________________
Address ____________________
Telephone ____________________
Do not know ☐

PART TWO: ENERGY DECISION INFORMATION

In this section, we are interested in how energy is regarded in your building and in the people who are responsible for energy policy and energy decisions.

2.1 Overall, has the number of energy-conserving activities in your building increased, decreased, or remained the same since 1980? *Please circle one number in response.* Or since ___________? Supply later date if more applicable.

1 Increased overall
2 Decreased overall
3 Remained the same
4 Don't know.

2.2 On a scale of 1 (highly important) to 4 (not important at all), how would you rate the importance of each of the following factors for motivating energy conservation activities in your building? *Please circle a number as your response to each factor; the same rating can be given to two or more factors.*

Motivating Factors	Importance				Not Applicable
	Highly			Not at all	
Expectations of rising energy prices	1	2	3	4	9
Utility demand charges or rate structures	1	2	3	4	9
Cost-control policy for building	1	2	3	4	9
Tax incentive (credits)	1	2	3	4	9
Awareness of successful experiences of similar buildings	1	2	3	4	9
Availability of information on building energy costs	1	2	3	4	9
Availability of outside funds (grants, private capital, etc.)	1	2	3	4	9
Exposure to marketing of energy conservation products	1	2	3	4	9
Changes in building code requirements	1	2	3	4	9
High energy costs	1	2	3	4	9
Other *Please specify:*	1	2	3	4	9

2.3 For energy matters, who is PRIMARILY RESPONSIBLE for setting general objectives, selecting specific actions to reduce energy use, financing capital projects, and the daily management of energy conservation activities for your building? *Circle all that apply.*

Responsible Persons(s)	Setting General Objectives	Selecting Specific Actions	Financing Capital Projects	Daily Management
Governing body (Board of Trustees/Directors/Supervisors)	1	1	1	1
Chief Executive Officer (CEO)	1	1	1	1
Other administrator *Please specify title:*	1	1	1	1
Chief financial officer	1	1	1	1
Building manager	1	1	1	1
Building engineer	1	1	1	1
Energy committee	1	1	1	1
Private consultant	1	1	1	1
Other *Please specify:*	1	1	1	1
No designated individual	1	1	1	1

2.4 For energy matters, what INFORMATION sources do you use in setting general objectives, selecting specific actions to reduce energy use, financing capital projects, and in daily management of energy conservation activities in your building? *Circle all that apply.*

Information Source	Setting General Objectives	Selecting Specific Actions	Financing Capital Projects	Daily Management
Experience of other buildings	1	1	1	1
Financial status of building	1	1	1	1
Manufacturers of energy conservation produces	1	1	1	1
Attending conferences	1	1	1	1
Technical and trade publications	1	1	1	1
Professional societies (e.g., ASHRAE)	1	1	1	1
Contacts with other professionals (e.g., engineers)	1	1	1	1
Personnel in government energy offices	1	1	1	1
Utility companies	1	1	1	1
Consultants and auditors	1	1	1	1
Other *Please specify:*	1	1	1	1

2.5 Do you have a written energy plan (excluding audits) for controlling energy costs in your buildings?

1 Yes
2 No
3 Don't know

ASEAN Commercial Building Energy Survey

PART THREE: ENERGY USE

In this section, we are interested in the energy consumption in your building, now, and in the past. We are also interested in the actions you have taken, or plan to take, to improve the energy performance of your building.

3.1 What is your estimate of the energy performance of this building (compared with your estimate of typical energy performance for other buildings of its type)? The building is:

1 Very energy efficient
2 More efficient than average
3 Average energy efficiency
4 Less efficient than average
5 Much less efficient than average
6 Don't know

3.2 What features do you think make this building more (or less) energy efficient than others:

1 Design or structural features *Please specify:*

2 Building envelope features
3 Air-conditioning features
4 Lighting systems features
5 Controls
6 Operations and maintenance
7 Operator training
8 Others *Please specify:*

3.3 How important is the cost of energy (compared with other costs) in determining how the building is operated?

1 Very important (a major factor)
2 Important (a significant factor)
3 Average factor
4 Not important (a minor factor)
5 Don't know

3.4 Overall, has total annual energy consumption (NOT COSTS) changed in your building since 1980? Or in a later year, if more appropriate.
Please specify year if different from 1980: ________

1 Increased overall
2 Decreased overall
3 About the same (GO TO QUESTION 4.6)
4 Don't know (GO TO QUESTION 4.6)

3.5 If there has been a change in total energy consumption NOT DUE to energy conservation measures, why do you think it has occurred? *Circle a response for each of the 4 items.*

	Reason	Yes	No	Direction of Change	
				Up(+)	Down(-)
1	Change in building functions	1	2	+	-
2	Change in building operations	1	2	+	-
3	Change in occupied square footage	1	2	+	-
4	Change in building codes	1	2	+	-

3.6 We are interested in finding out what ENERGY CONSERVATION OPPORTUNITIES (ECOs), including no-cost/low-cost measures, you have taken or plan to take. Please refer to Part Seven, **Additional ECOs for Building Energy Audits**, for other ECOs. Please specify any "Other" measures used in the appropriate subset of Part Seven, and also here. *Please circle all that apply.*

Energy Conservation Measures (ECOs)	Date of Installation		Planned
	1973-1979	1980-1987	1988-1992
BUILDING ENVELOPE Solar Barriers	1	1	1
Insulation	1	1	1
Windows (reflective films)	1	1	1
Windows (all other ECOs)	1	1	1
Other openings	1	1	1
Manual adjustments	1	1	1
CONTROLS - AIR-CONDITIONING Time clocks	1	1	1
Computer-based energy management systems (EMS)	1	1	1
Other *Please specify:*	1	1	1
CONTROLS - ELECTRICAL/LIGHTING Time clocks	1	1	1
Computer-based energy management systems (EMS)	1	1	1
Other *Please specify:*	1	1	1
MECHANICAL (AIR-CONDITIONING) Air-Conditioning	1	1	1
Distribution system (pipes/ducts)	1	1	1
Distribution system modifications (other ECOs)	1	1	1
Domestic (service) hot water	1	1	1
Manual adjustments	1	1	1
Energy recovery devices	1	1	1
Fuel conversions	1	1	1
Cogeneration	1	1	1
Other *Please specify:*	1	1	1
ELECTRICAL/LIGHTING Lighting conversion	1	1	1
Lighting modifications	1	1	1
Manual adjustments	1	1	1
Other electrical applications	1	1	1
RENEWABLE RESOURCES Conversion to renewable resources	1	1	1
Other *Please specify:*	1	1	1

3.7 If you have used any of the ECOs listed above in Question 3.6, which TWO ECOs have saved the most energy for your building?

1 ____________________

____

2 ____________________

____

3.8 If you have had problems in implementing energy conservation measures, please describe the kinds of problems you have had:

Technical (e.g., maintenance staff cannot handle added duties, equipment, operations and maintenance, installation):

____

____

Financial (e.g., limited capital to invest, not considered cost-effective, waiting for existing equipment to complete its useful life, budget):

____

____

Managerial (e.g., building owner will not agree, staffing approvals):

____

____

Information (e.g., about products, benefits, etc.):

____

____

Building occupants (e.g., interfere with building operations, or tenant perceptions of comfort):

____

____

Other *Please specify:*

____

____

3.9 Have you identified possible actions for improving the energy performance of your building **that you do not plan to take**? If so, please list them:

1 ______________________________

____

2 ______________________________

____

3 ______________________________

____

4 ______________________________

____

3.10 What prevents you from taking these actions?

Technical

____

____

Financial

____

____

Managerial

____

____

Information

____

____

Building occupants

____

____

Other *Please specify:*

____

____

3.11 What financing arrangements have been used by your building to purchase energy-saving capital equipment since 1980, and what financial arrangements are you considering for any planned energy investment? *Circle all that apply.*

Source	Use	Planning
Internal funds	1	1
Commercial loans	1	1
Lease/lease purchase	1	1
Savings-based financing	1	1
Tax exempt bonds	1	1
Grants	1	1
Other *Please specify:*	1	1

3.12 Is an energy monitoring or accounting report, which periodically tracks and analyzes energy use and/or energy costs (e.g., monthly, quarterly, annually) prepared for your building?

1 Yes
2 No
3 Don't know.

If YES, to whom are the results reported? *Circle all that apply.*

1 Energy committee
2 Building manager
3 Building engineer
4 Governing body (Board of Trustees/Directors/Supervisors)
5 Chief financial office
6 Chief executive officer (CEO)
7 Other administrator *Please specify title:*

____

____

8 Maintenance/custodial staff
9 Other *Please specify:*

____

____

ASEAN Commercial Building Energy Survey

PART FOUR: TYPE OF BUILDING OWNERSHIP

In this section, we are interested in the nature of the current ownership of the building, the size and type of organization that owns the building, and its experience with building energy conservation. We are also interested in the ownership of the building when it was constructed.

4.1 Type of current building owner:

1 Government

a. National
b. Regional
c. Local

2 Other institutional

d. Religious
e. Charitable
f. Hospitals
g. Other

3 Private company
4 Individual
5 Other *Please specify:*

____

____

4.2 Current Mode of Ownership (*circle one major category, and as many subparts as apply*).

1 Owner/Resident (Owner occupies building)

a Entire building
b Part (*give approximate percentage of floor space*) ______%

2 Owner/Nonresident (Owner leases building)

a Owner is responsible for energy utility costs
b Owner is responsible for building operations
c Owner is responsible for maintenance

d Tenant is responsible for energy utility costs
e Tenant is responsible for building operations
f Tenant is responsible for maintenance
g Tenant is responsible also for installing some energy using building systems:

1) Lighting systems?
2) Cooling systems?

3 Corporate/Franchise Owner (Owner occupies building, but decisions frequently are made at corporate levels distant from location where building is located).

4 Developer/Speculator (Owner expects to sell the building to occupant/tenants or to future landlord).

4.3 The current building owner has owned the building since what year?

1 Since____________________*Please specify year purchased.*

2 Don't know

4.4 What is the size of the current owner's organization?

1 Less than 5 people
2 Six to 50 people
3 Fifty-one to 200 people
4 More than 200 people
5 Don't know

4.5 Does the current building owner have experience in owning and operating other buildings?.

1 Yes If YES, how many other buildings? *Circle one.*

a One building
b Two—five buildings
c Six or more buildings
d Do not know

2 No
3 Do not know

4.6 When the building was constructed, what was the mode of ownership? *Circle the appropriate answers, including one major ownership category, and as many subparts as apply.*

1 Same ownership since construction
2 Different owner, but same mode of ownership as currently
3 Don't know original mode of ownership
4 Different mode of ownership *Specify which type:*

1 Owner/Resident (Owner occupies building)

a Entire building
b Part *Give approximate percentage of floor space:* ______%

2 Owner/Nonresident (Owner leases building)

a Owner is responsible for energy utility costs
b Owner is responsible for building operations
c Owner is responsible for maintenance

d Tenant is responsible for energy utility costs
e Tenant is responsible for building operations
f Tenant is responsible for maintenance

g Tenant is responsible also for installing some energy using building systems:

1) Lighting systems
2) Cooling systems

3 Corporate/Franchise Owner (Owner occupies building, but decisions frequently are made at corporate levels distant from location where building is located)

4 Developer/Speculator (Owner expects to sell the building to occupant/tenants or to future landlord)

4.7 When the building was constructed, what financing arrangements were used? *Circle all that apply.*

Source	Used	Planned
Internal funds	1	1
Commercial loans	1	1
Lease/lease purchase	1	1
Tax exempt bonds	1	1
Grants	1	1
Other *Please specify:*	1	1

4.8 What mode of construction contract was used to construct the building? *Circle one.*

1 Design-bid-build:

Design services are completed under one contract. Design documents are put out to bid to more than one contractor, and the building is constructed by the successful bidder.

2 Design-build:

A single contract is made to both design and construct the building. This eliminates a separate bid process.

3 Negotiated construction contract:

Can be same as other modes, but the construction phase differs greatly. Various parts of the construction are let to individual contractors based on past experience or reputation without accepting or reviewing multiple bids.

4 Fast-tracked and multiple-bid package projects:

The building shell may be designed and constructed with little or no knowledge of the mechanical, electrical, and/or lighting systems that are to be installed and used *after* the erection of the shell.

5 Package project:

Factory-built building may be completely provided with systems, appliances, and finishes so that all systems are integrated and coordinated for on-site construction.

6 Other *Please specify:*

---

7 Don't know ☐

ASEAN Commercial Building Energy Survey

PART FIVE: PERSON COMPLETING THE QUESTIONNAIRE

For the person primarily responsible for completing this survey, please answer the following questions.

5.1 How long have you worked at this building? ________ (years)

5.2 How long have you held your current position? _______ (years)

5.3 What degrees and certificates have you earned?

____

____

5.4 Where did you work immediately prior to coming to this building?

____

____

5.5 How many people do you supervise?__________

5.6 How many of these are engineers? __________

5.7 What is the title (position) of your immediate supervisor? _______

____

5.8 If we have questions, whom should we contact for clarification? Contact person:

____

Title:

____

Address:

____

____

____

____

Phone: ____________________

5.9 Would you like to receive information regarding the findings of this survey? Please check the line below and we will arrange to send the survey results as soon as they are complete.

_________ I would like to receive the summary results of the survey.

5.10 Is their anything else you would like to comment on in regard to this questionnaire or energy use in general?

THANK YOU FOR YOUR HELP!

WE APPRECIATE THE TIME YOU SPENT HELPING US.

ASEAN Commercial Building Energy Survey

PART SIX: BUILDING CHARACTERISTICS

NOTE: *Parts One through Five must also be completed. If you have completed Parts One through Five already, please make a copy for your records and return Parts One through Five using the pre-addressed envelope enclosed.*

6.1 **Photographs**: Attach photos of building exterior here. If possible, include (and label) at least two elevations: one North or South, one East or West.

6.2 **Access to sunlight and breezes:**

6.2.1 Density of nearby construction. What is the level of density of construction in nearby area?

- ☐ Very dense urban environment, with no open space, other than streets
- ☐ Moderately dense urban or suburban environment, with some open spaces between buildings
- ☐ A few buildings nearby, but more than half of the space near the building is open space
- ☐ Building is freestanding, few or no buildings nearby

6.2.2 Adjacent buildings. This building is in direct contact with other buildings on:

- ☐ One side
- ☐ Two sides
- ☐ Three sides
- ☐ There are no adjacent buildings

6.2.3 Does the building site or its surroundings contain obstructions that reduce the possible use of breezes for natural ventilation? In your estimate, the access to breezes for natural ventilation is:

☐ Good ☐ Fair ☐ Poor

6.2.4 Nearby buildings, if they exist, are generally

- ☐ Taller than sample building
- ☐ Not as tall
- ☐ About same height
- ☐ Heights vary from shorter to taller

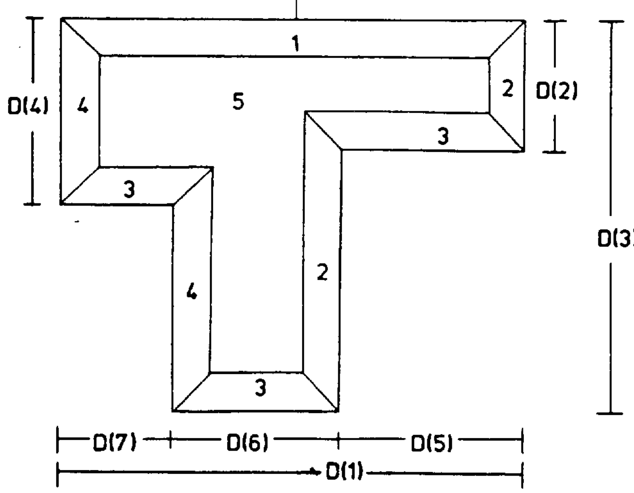
6.2.5 Does the building site or its surroundings contain objects that block sunlight from reaching the building? In your estimate, surrounding objects (trees, buildings, etc.) provide shade on average for daylight hours for:

- ☐ All of the building including the roof
- ☐ More than one-half of the building
- ☐ More than one-quarter of the building
- ☐ No shade is provided

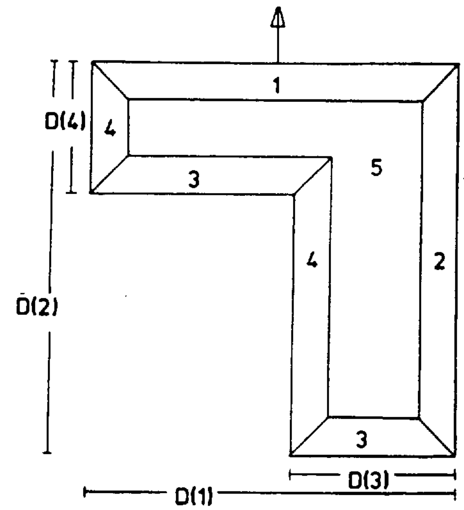
6.3 **Shape, Dimensions and Orientation:**

6.3.1 Which **shape** (of those on the next two pages) best describes this building? Circle the applicable drawing. *If your building has a very unusual shape that did not fit any of the shapes provided, please draw a sketch of the shape of the building. Use the blank area on the bottom of page 19. Please indicate dimensions for Question 6.3.2 on the sketch you make. Please also indicate the north direction on the sketch.*

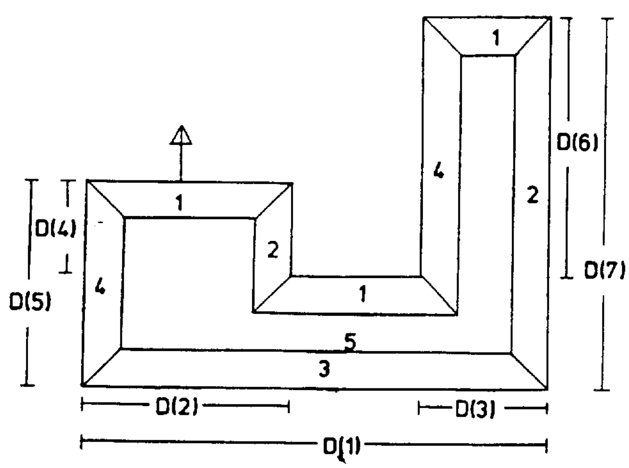
T—Shaped Building



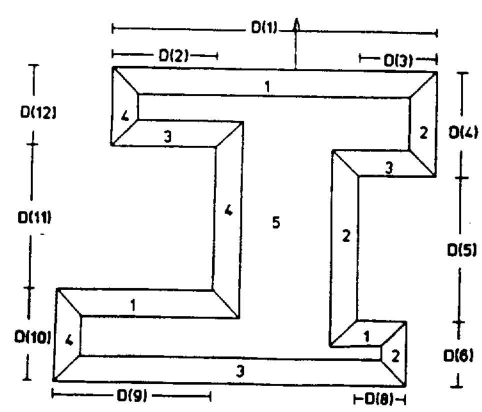
L—shaped Building



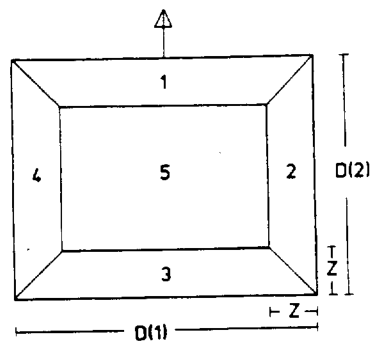
U—Shaped Building



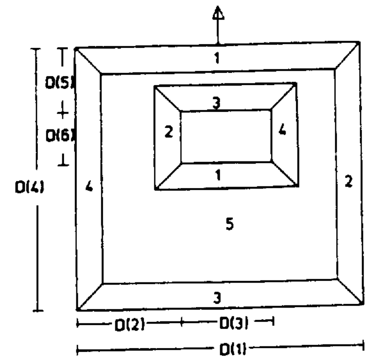
I—Shaped Building



Rectangular Building



Rectangular Building with Courtyard



6.3.2 **Dimensions:** (numbers refer to shape drawings). *Please circle which units used*

D(1) = ____________________ (metres or feet)

D(2) = ____________________ (metres or feet)

D(3) = ____________________ (metres or feet)

D(4) = ____________________ (metres or feet)

D(5) = ____________________ (metres or feet)

D(6) = ____________________ (metres or feet)

D(7) = ____________________ (metres or feet)

D(8) = ____________________ (metres or feet)

D(9) = ____________________ (metres or feet)

D(10) = ____________________ (metres or feet)

D(11) = ____________________ (metres or feet)

D(12) = ____________________ (metres or feet)

Z (depth of
perimeter zones) = ____________ (metres or feet)

Floor-to-ceiling height = ________ (metres or feet)

Floor-to-floor height = _________ (metres or feet)

6.3.3 **Orientation:** Toward which direction does the arrow (on the building shape drawing) most closely point?

☐ North ☐ East ☐ South ☐ West
☐ Northeast ☐ Southeast ☐ Southwest ☐ Northwest

6.4 **Number of floors of car parks** enclosed within this structure:

Above grade _______ Total area _______ (m^2 or ft^2) *Circle which units used.*

Below grade _______ Total area _______ (m^2 or ft^2) *Circle which units used.*

6.5 **Areas of Conditioned and Unconditioned Spaces**

- *Use the following tables.*
- *Circle any areas that are currently vacant.*
- *For zone numbers, refer to shape drawings; include applicable areas of all floors in each zone.*
- *Watts per fixture includes the ballast(s).*
- *Include both task and ambient lighting.*

Lighting Fixture Types (use these codes):

1x4: 1 tube fluorescent, 4 foot **2x4**: 2 tube fluorescent, 4 foot
3x4: 3 tube fluorescent, 4 foot **4x4**: 4 tube fluorescent, 4 foot

1x__: 1 tube fluor., ____ length **2x__**: 2 tube fluor., ____ length
3x__: 3 tube fluor., ____ length **4x__**: 4 tube fluor., ____ length

SFL: screw-in (or "compact") fluorescent
EEI: energy-efficient incandescent
SI: standard incandescent
HID: high intensity discharge (high pressure sodium, metal halide, or mercury vapor)
Other (specify)

Type of Fixture Mounting (use these codes):

RGD: recessed with glass diffuser
RPD: recessed with plastic diffuser
SUS: suspended
ATT: attached
Other (specify)

Lighting Control Type (use these codes):

CB: circuit breaker or switch in remote panel
WS: wall switch in local area
OS: occupancy sensor
SCH: scheduled automatic control
DL: daylighting control

Type of Area	Zone Number(s)	Area (m^2)	Lighting					O.A. Vent. Rate*			
			Type of Fixture and Mounting	Watts per Fixture	Number of Fixtures	Total Watts	Control Type	Rate	Check Which Units Used		
									ACH	CFM	m^3/h
PUBLIC SERVICE AREAS:											
Lobby											
Restrooms											
Corridors/Stairways											
Gymnasium											
Multipurpose/Auditorium											
Shower Room											
Swimming Pool (indoor)											
Laundry											
Pharmacy											
Bar											
Dance Floor											
Public Service--not listed											
Subtotals	----		----	----			----	----	--	--	--
OFFICE AREAS:											
Office											
Bank floor											
Bank teller area											
Conference											
Accounting (Countroom)											
Drafting											
Office--not listed											
Subtotals	----		----	----			----	----	--	--	--

*Outside air ventilation rate.

Type of Area	Zone Number(s)	Area (m^2)	Lighting					O.A. Vent. Rate*			
			Type of Fixture and Mounting	Watts per Fixture	Number of Fixtures	Total Watts	Control Type	Rate	Check Which Units Used		
									ACH	CFM	m^3/h
RETAIL AREAS:											
Sales--display											
Sales--cashier											
Fitting											
Mall											
Retail--not listed											
Subtotals	----		----	----			----	----	--	--	--
STORAGE AREAS:											
Conditioned Storage											
Refrigerated Storage											
Enclosed Loading Dock											
Storage--not listed											
Subtotals	----		----	----			----	----	--	--	--
DINING/FOOD: PREPARATION AREAS:											
Dining Room											
Cafeteria/Lunch Room											
Food Display, Sales, & Light Preparation											
Kitchen											
Meat Room											
Produce Preparation											
Dining/Prep--not listed											
Subtotals	----		----	----			----	----	--	--	--

*Outside air ventilation rate.

Type of Area	Zone Number(s)	Area (m^2)	Lighting					O.A. Vent. Rate*			
			Type of Fixture and Mounting	Watts per Fixture	Number of Fixtures	Total Watts	Control Type	Rate	Check Which Units Used		
									ACH	CFM	m^3/h
EDUCATION AREAS:											
Classroom											
Library seating											
Library stacks											
Vocational Shop											
Education Area--not listed											
Subtotals	----		----	----			----	----	--	--	--
HOSPITAL/MEDICAL AREAS:											
Animal/Kennel											
Autopsy/morgue											
Central Sterile Supply											
Clinic Operatory											
Emergency Suite											
Intensive Care Unit											
Nursing Units											
Patient Rooms, incl. baths											
Surgical Suite, incl. prep., delivery & recovery											
Treatment & Diagnosis, incl. examination, therapy, radiation											
Hospital/Med.--not listed											
Subtotals	----		----	----			----	----	--	--	--

*Outside air ventilation rate.

Type of Area	Zone Number(s)	Area (m^2)	Lighting					O.A. Vent. Rate*			
			Type of Fixture and Mounting	Watts per Fixture	Number of Fixtures	Total Watts	Control Type	Rate	Check Which Units Used		
									ACH	CFM	m^3/h
EQUIPMENT/PROCESS AREAS:											
Computer (machine room, raised floor only)											
Laboratory											
Duplication Room											
Shop/Repair Area											
Mechanical Equip. Room											
Electrical Equip. Room											
Mechanical/Electrical Equipment Room											
Elevator shafts											
Equip./Process--not listed											
Subtotals	----		----	----			----	----	--	--	--
UNCONDITIONED AREAS:											
Car Parks											
Attic											
Mechanical Equip. Room											
Electrical Equip. Room											
Mechanical/Electrical Equipment Room											
Security Area											
Loading Dock											
Unconditioned Areas --not listed											
Subtotals	----		----	----			----	----	--	--	--

Type of Area	Zone Number(s)	Area (m^2)	Lighting					O.A. Vent. Rate*			
			Type of Fixture and Mounting	Watts per Fixture	Number of Fixtures	Total Watts	Control Type	Rate	Check Which Units Used		
									ACH	CFM	m^3/h
LIVING AREAS:											
Conditioned Living Quarters											
Unconditioned Living Quarters											
Living Areas											
Hotel Guest Rooms, incl. bathrooms											
Living Areas--not listed											
Subtotals	----		----	----			----	----	--	--	--

*Outside air ventilation rate.

6.6.1 **Building Totals** (Area and Lighting)

		Area (m^2)			Number of Fixtures	Total Watts	
Totals (for Conditioned Area)	----		----	----			----
Totals (for Unconditioned Area)	----		----	----			----
Total Area (Excluding Carparks)	----		----	----			----

*Outside air ventilation rate.

6.6.2 **Lighting Schedule**: List the hours of operation of the lighting on the following days:

Day of Week	**Time Lights Turned On**	**Percent of Lights Turned On**	**Time Lights Turned Off**
Mondays to Fridays			
Saturdays			
Sundays			

6.7 CONSTRUCTION

6.7.1 **Walls**: What is the exterior wall **construction**?

- ☐ Brick or masonry
- ☐ Concrete, poured or filled blocks
- ☐ Concrete, hollow blocks
- ☐ Glass curtain wall
- ☐ Metal with insulation
- ☐ Metal without insulation
- ☐ Other (specify)__________

What is the exterior wall color?__________

Optional: Provide sketch of layers of wall construction

6.7.2 **Roof**: What is the roof **construction**?

- ☐ Metal deck
- ☐ Concrete deck
- ☐ Wood deck
- ☐ Corrugated Metal
- ☐ Other (specify)________

Does roof have **insulation**? ☐ Yes ☐ No

Optional: Provide sketch of layers of roof construction.

Roof is ☐ Flat ☐ Pitched. If pitched, what is slope?______

Roof **color**__________

Does roof have **skylights**? ☐ Yes ☐ No

If yes, what is glass type? (check all that apply)

- ☐ Tinted
- ☐ Reflective
- ☐ with Shading Films
- ☐ Single-glazed
- ☐ Double-glazed
- ☐ Other (specify)________

What is total skylight **area**?_______ (m^2 or ft^2) *Circle which units used.*

Are skylights operable? ☐ Yes ☐ No

Are skylights equipped with external **shading devices**?

☐ Yes ☐ No

6.7.3 Windows

What is glass type? (check all that apply)

- ☐ Tinted
- ☐ Reflective
- ☐ with Shading Films
- ☐ Single-glazed
- ☐ Double-glazed
- ☐ Other (specify)________

For each zone (from shapes), what is total **window area**?
(Include applicable areas of all floors in each zone.) *Circle which units used.*

Zone 1:________ (m^2 or ft^2)
Zone 2:________ (m^2 or ft^2)
Zone 3:________ (m^2 or ft^2)
Zone 4:________ (m^2 or ft^2)

What types of windows are used. *Check all those that apply.*

☐ Casement	______ (%)
☐ Awning	______ (%)
☐ Horizontal sliding	______ (%)
☐ Vertical sliding	______ (%)
☐ Jalousie	______ (%)
☐ Fixed	
☐ Other *(specify)*	______ (%)

Are windows operable? ☐ Yes ☐ No

Are windows typically left open? ☐ Yes ☐ No
If yes, when?_______________
What percent of window area is left open? ______ (%)

Are windows equipped with external **shading devices**?

Zone 1: ☐ Yes ☐ No
If yes, what type (see drawings)

- ☐ Horizontal device
- ☐ Vertical fin
- ☐ Vertical movable
- ☐ Fixed Eggcrate
- ☐ Movable Eggcrate
- ☐ Other (specify)________

What is depth of shading device? (from glass to outside surface):
______(m or ft) *Please circle which units used*

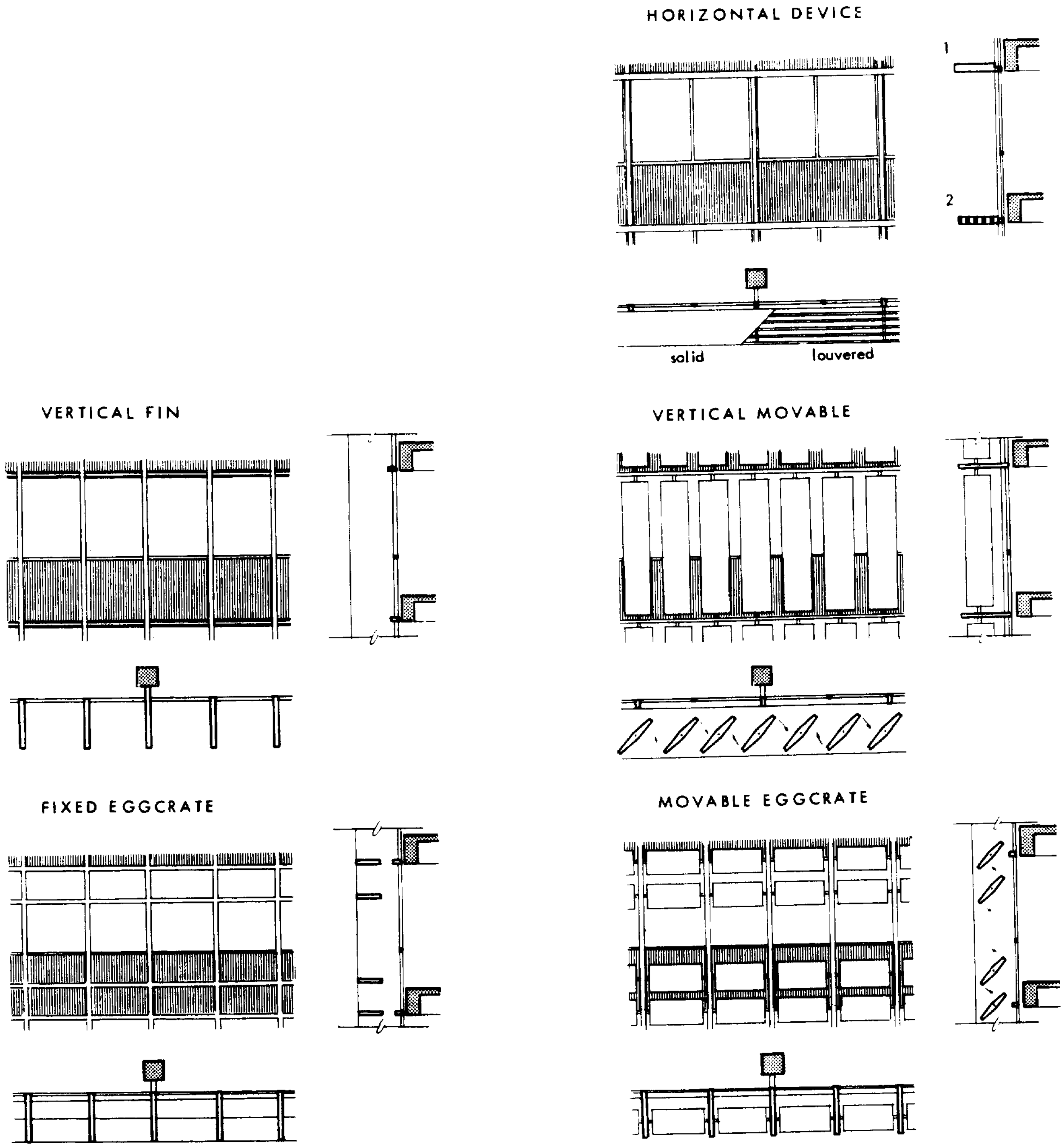
If not all windows in this zone have shading, what % of window area does have shading?______(%)

Zone 2: ☐ Yes ☐ No
If yes, what type (see drawings)

- ☐ Horizontal device
- ☐ Vertical fin
- ☐ Vertical movable
- ☐ Fixed Eggcrate
- ☐ Movable Eggcrate
- ☐ Other (specify)________

What is depth of shading device? (from glass to outside surface):
______(m or ft) *Please circle which units used.*

If not all windows in this zone have shading, what % of window area does have shading?______(%)



Standard types of shading devices.

Zone 3: ☐ Yes ☐ No
If yes, what type (see drawings)
☐ Horizontal device
☐ Vertical fin
☐ Vertical movable
☐ Fixed Eggcrate
☐ Movable Eggcrate
☐ Other (specify)________

What is depth of shading device? (from glass to outside surface):
______(m or ft) *Please circle which units used.*

If not all windows in this zone have shading, what % of window area does have shading?______(%)

Zone 4: ☐ Yes ☐ No
If yes, what type (see drawings)
☐ Horizontal device
☐ Vertical fin
☐ Vertical movable
☐ Fixed Eggcrate
☐ Movable Eggcrate
☐ Other (specify)________

What is depth of shading device? (from glass to outside surface):
______(m or ft) *Please circle which units used.*

If not all windows in this zone have shading, what % of window area does have shading?______(%)

6.7.4 **Doors**:
What is total **exterior door area**?__________(m^2 or ft^2)

Are doors typically left open? ☐ Yes ☐ No
If yes, when?_______________

6.8 Mechanical Systems

6.8.1 Air-Conditioning systems:

Complete the following table. Use these **System Type** codes:

CVRH: Constant volume with reheat
VAVR: Variable Air Volume with reheat
CBVAV: Ceiling-Bypass Variable Air Volume
FCU: Fan Coil Unit
WSHP: Water Source Heat Pump
AAHP: Air to Air Heat Pump
SZPU: Single-Zone Packaged Unit
WAC: Window Air Conditioner
Other: (specify)__________
None

Zones are from the shape drawings.

Use these **Cooling Energy Source** codes:

	No. of Units	Sizes	
		Capacities	Units Used
None	---	---	---
DX: Direct Expansion			
Cent: Centrifugal Chiller			
Recip: Reciprocating Chiller			
Abs: Absorption Chiller			
DBndl: Double-Bundle Chiller			
Tower: Cooling Tower Water			
Dist: District Cooling			
Other: (specify):______________			

Use these **Reheat Energy Source** codes:

	Size	
	Capacities	Units Used
None	---	---
Boil: Fuel-fired Boiler		
Res: Electric Resistance		
Chill: Chiller waste heat		
Dist: District Heat		
Other: (specify):______________		

System Number	System Type	Zone(s) Served	Thermo-stat Setting (°C)	System kW Input	Cooling Energy Source	Reheat Energy Source	No. of Fans	Fan Size	
								Capacities	Units Used
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Schedule: What are the hours of operation of the air-conditioning equipment on the following days:

Day of Week	Time A/C Turned On	Time A/C Turned Off
Mondays to Fridays		
Saturdays		
Sundays		

Is **subcooling** used as a dehumidification strategy? ☐ Yes ☐ No

If some part of the building uses a **very different schedule** from the building's predominant schedule, please indicate it below.

Functions: ____

Day of Week	Time A/C Turned On	Time A/C Turned Off
Mondays to Fridays		
Saturdays		
Sundays		

6.8.2 **Domestic Hot Water**:

What is the energy source?

	Size	
	Capacities	Units Used
☐ None	---	---
☐ Electric Resistance		
☐ Natural Gas		
☐ Fuel Oil		
☐ Fuel-Fired Boiler		
☐ District Heating		
☐ Other (specify):__________ ____________________		

6.9 Other Equipment

In the following table, list all energy-consuming equipment (other than lighting, air-conditioning, and domestic hot water) that is greater than 2 kW input, or is used more than 2 hours per day, or both. The zone numbers are from the shape drawings; include the applicable areas of all floors in each zone.

Equipment Description	Zone Number	# of Identical Units	kW per Unit	Total kW	Daily Operating Hours

6.10 **Occupancy and Schedule**

6.10.1 **Occupancy**: What is the average number of people in the building on the following days:

Day of Week	# of Employees	# of Visitors	Total
Mondays to Fridays			
Saturdays			
Sundays			

6.10.2 **Schedule**: What are the hours of building occupancy on the following days:

Day of Week	Time Occupancy Begins	Time Occupancy Ends
Mondays to Fridays		
Saturdays		
Sundays		

PART SEVEN: ADDITIONAL ECOs FOR BUILDING ENERGY AUDITS*

7.1 Architectural

1. Storm or Replacement Windows/Doors
2. Insulation, Wall, Roof, Attic, Floor
3. Weatherstripping and Caulking
4. Reduction of Glass Area
5. Heat Reflecting Window/Door Coatings
6. External Shading Devices
7. Other________________________________

7.2 Boiler Plant

1. Flue Dampers
2. Insulate Piping
3. Flue Gas Heat Recovery
    a. Preheat Combustion Air
    b. Preheat Make-up Water
    c. Preheat Domestic Hot Water
4. Turbulators
5. Convert to Higher Efficiency Boilers
6. Convert to Alternate Fuel(s)
7. Variable Speed Pumping
8. Insulate Domestic Hot Water Tank
9. Other________________________________

7.3 Chiller Plant

1. Heat Recovery From Condenser Water
2. Raise Chilled Water Temperature
3. Chiller Optimization
4. Variable Speed Pumping
5. Thermal Storage
6. Cooling Tower
    a. Replacement/Rehab
    b. Water Treatment
    c. Fan Speed Control
    7. Other________________________________

7.4 Lighting

1. Reduce Light Levels
2. Replace Lamps with High Efficiency Lamps
    a. Incandescent
    b. Fluorescent
3. Convert Incandescent to Fluorescent
4. Daylighting
5. Convert Exterior Lighting To High Efficiency
6. Solid-state Ballasts
7. Increase Fixture Efficiency
    a. Reflectors

*Note which zones these ECOs apply to during your field survey.

b. Lenses/Louvers

8. Controls
   a. Local Switching
   b. Occupancy Sensors
   c. Automated Schedule
9. Other____

7.5 **Air Handling Unit Systems**

1. Convert Constant Volume To Variable Volume
2. Insulate Ductwork
3. Reduce System CFM
4. Heat Wheels/Pipes or Run Around Loops for Cool Recovery
5. Return Air Recirculation
6. Reduce Make-up and/or Exhaust CFM
7. Supply/Exhaust Fan Timers
8. Isolate 24 Hours Areas
   a. Package Systems
   b. System Revisions
9. Other____

7.6 **HVAC Controls**

1. Schedule Start/Stop Times
2. Optimized Start/Stop Times
3. Economizer Cycle
4. Mixed Air Control
5. Night/Weekend Set Up
6. Discharge Temperature
7. Central Energy Management Control System
8. Cycle Fan System From Space Temperature
9. Other____

7.7 **Electrical**

1. Replace Low Efficiency Motors with High Efficiency Motors
2. Interlock Exhaust Fans with Lighting
3. Other____

7.8 **Laundry**

1. Dedicated System(s) for Laundry
2. Waste Water Heat Recovery
3. Alternate Fuels
4. Other____

7.9 **Kitchen**

1. Exhaust Fan Interlock with Operation
2. "Make-up" Air
3. Other____

7.10 **Solar**

1. Photovoltaic
2. Domestic Hot Water Systems
3. Space Cooling
4. Other___________________________

7.11 **Staffing**

1. Integrate Housekeeping Functions with Operational Functions
2. Revise Building Usage During Periods of Partial Occupancy
3. Other____

7.12 **Other**

Please indicate any other significant ECOs you may recommend that are not listed above.