Institutionalization of a Benchmarking System for Data on the Energy Use in Commercial and Industrial Buildings

ASIA-PACIFIC ECONOMIC COOPERATION

Energy Working Group

Expert Group on Energy Efficiency and Conservation

Prepared by

Asia-Pacific Sustainable Development Center
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TECH Support Services

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ABBRIVIATIONS AND ACRONYMS

Btu	British thermal unit
CBECS	Commercial Buildings Energy Consumption Survey
DEMMTR	Demand metering
ESCO	Energy Service Company
EUI	Energy use index
GJ	Gigajoule
kBtu	Thousand Btu
kWh	kilowatt-hour
LNWKRKSF	Log of worker density
LSFLDGRM	Floor area allocated per lodging room
mmBtu	Million Btu
ORNL	Oak Ridge National Laboratory

1.0 INTRODUCTION

Benchmarking can be viewed as the first step in understanding and setting goals for energy efficiency improvements in commercial and industrial buildings. This report describes the institutionalization of a benchmarking system for data on energy use in commercial and industrial buildings which has been developed under the guidance of the APEC Expert Group on Energy Efficiency and Conservation. Following a brief description of the background of the study, the internet site which has been developed to allow users access to the benchmarking data is described. An analysis is then presented of 240 U.S. hotels to identify the main determinants of energy use intensity. Next, the survey of APEC member economies which was conducted to gather additional data is presented. This is followed by an analysis of non-U.S. hotel data which was undertaken to determine if key conclusions of energy use for U.S. hotels also applies to non-U.S. hotels. Finally, this report concludes with a review of procedures which can be followed for establishing energy efficiency targets.

Beneficiaries of the project include (1) policymakers and technical staff in APEC member economies who will have a better basis for decision making on local or economy-wide energy conservation programs; (2) private commercial and industrial businesses that can use the benchmarking database to estimate energy savings and cost-effectiveness of energy conservation investments; and (3) manufacturers of energy-efficient equipment for commercial and industrial buildings and providers of energy-efficiency services that may use benchmark information as a basis for targeting equipment improvements or service strategies towards less-efficient building types.

2.0 BACKGROUND

A priority recommendation from the 1994 Energy Efficiency and Conservation (EE&C) Experts Group Energy Audit Workshop was for APEC member economies to develop energy benchmarking data as a way to help target opportunities for energy conservation and increased competitiveness. This recommendation was subsequently discussed at the Fifth Energy Efficiency and Conservation Experts Group Meeting, and a pilot project was initiated to demonstrate its feasibility and benefits. The pilot phase focused on two types of commercial buildings (offices and hotels) and two industries (paper and metal castings), and was limited to the use of existing or easily available data within the member economies. Thus, building energy benchmark data consisted of a simple energy use index equal to total annual energy delivered to the building divided by the gross floor area. This provided a good first indication of how the energy efficiency of a given building compared with the rest of the buildings in the database.

Two EWG projects were initiated to build on the products and findings of the pilot phase and to institutionalize the benchmarking system. Project EWG 01/97 examined the issues and provided recommendations for institutionalization based on input received from APEC participants in the benchmark workshop held on 31 October 1998 in Honolulu. The project final report entitled "Recommendations for Institutionalizing the APEC Energy Benchmark System" was completed in December, 1998.

The objective of this project (EWG 02/98) is to institutionalize the existing APEC energy database by making it publicly available on the Internet, with features for downloading and inputting data. A second objective is to use U.S. hotel data to define the additional data needed to explain more of the differences in energy use between buildings and to develop credible energy targets. This project is being undertaken by the Asia-Pacific Sustainable Development Center (APSDC) located at the East-West Center in Honolulu, Hawaii, TECH Support Services, Oak Ridge, Tennessee, and the Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee.

3.0 INTERNET SITE FOR EXISTING ENERGY BENCHMARK DATA

The existing database includes 1750 offices, 409 hotels, 274 hospitals, 70 paper mills, 94 iron foundries, and 5 cement plants. Data were submitted from 9 APEC member economies using a standard Excel file format on 3.5 inch computer disks. Use of the Internet will make the full database and results of analysis readily available to the full range of beneficiaries listed above. A user can select sets of data to review by facility type and member economy and download data that is needed for offline analysis. Standard charts and tables that result from analysis are also available so that individual facilities can be compared to others in the database. Users without convenient access to the Internet will still be able to obtain data in the Excel format on request, either by mail or e-mail.

3.1 Policies and Procedures

Data Input: Although expansion of the database is not a major focus of this project, additional data has been received, and will likely continue to be submitted. Capabilities allow new data to be submitted, updating the standard charts and tables after data have been reviewed and added to the total database, and edited and aggregated data to be distributed back to users through the Internet. New data will only be added to the aggregate database by the Internet manager. Policies and procedures will be established for data checking and quality, schedules for updating the total database and results of analysis, and identification of database changes.

When energy benchmark data is needed to develop a database for a new facility type or to complete a database previously initiated, the requests for data will be listed on the Internet Web page and E-mailed to each member economy.

Collection and Distribution Format: It is recommended that Excel 97 or 5.0/95 Workbook files remain the basic format for data submission. Formatted Excel files (without data) for each facility type and instructions for inputting data will be available for downloading on the Web page. When data to be submitted are entered on the Excel data file, each participant would E-mail the Excel file to the address specified. The completed data file may also be mailed on 3.5" disk. Data checking and quality control procedures will be completed before new data are added to the total database for each facility type.

For distribution, energy benchmark data for each facility type and for each member economy will be available on the Web page for review and downloading. Those that want to examine all the data submitted, or perform their own analysis, will then be able to perform those tasks on their own computers, off-line.

Data Analysis: Results of analysis of the existing database will be displayed on the Web site as charts and tables that can be printed from the site or downloaded for use off-line. The results to be displayed on the Web site include:

- a plot and linear regression results of annual energy use versus the key determinant of energy use; such as gross floor area for buildings or metric tons of product for industry;

- a graph of cumulative distribution of the percentage of facilities within each energy use index (EUI) bin, and

- a table of high, medium, and low ranges of EUI values for each facility type.

The figures and table listed above are explained and illustrated in the final report of project EWG 01/97.

3.2 Description of Internet Site

The APEC energy benchmarking web site allows the user easy access to the APEC database, procedures for data submittal, benchmarking distributions created from the APEC database, and site tools. In addition, the site will be linked to Oak Ridge National Laboratory's benchmarking web site for easy access to additional benchmarking tools. The site currently offers these six options to the user:

Download APEC Database

APEC Benchmarking

Data Submittal:
- Commercial Buildings
- Industrial Buildings

Submittal Instructions

Submit Data

Fact Sheet for Exemplary:
- Commercial Buildings
- Industrial Buildings

The APEC database is downloadable from the web site in an Excel format. A single download provides the data for all APEC building types. Benchmarking distributions created from the APEC database for offices, hotels, and hospitals are viewable from the web site. These distributions are supplemented by instructions on how they can be used to provide a building energy performance indicator or "rating" for the user's individual building.

Data submittal forms, electronic worksheets, and submittal instructions can also be accessed at the site. Fact sheets can be accessed and completed to provide descriptive details of both commercial and industrial buildings. Electronic worksheets in Excel format can be downloaded that will allow entry of building energy use data in a tabular format. A tabular summary of the user's buildings results should be provided in a format consistent with the APEC database. This will simplify incorporation of new data into the database. The APEC database and other downloadable files at the site will be updated periodically as additional data becomes available. An email link is also provided at the site to simplify submittal of new building data. The web site is located at: **http://eber.ed.ornl.gov/apec**

4.0 ANALYSIS OF U.S. HOTEL DATA

The U.S. Energy Information Administration's 1992 Commercial Buildings Energy Consumption Survey (CBECS) database was analyzed to determine the drivers of energy use in U.S. hotels. Hotels are large energy users and a conservation priority within several member economies of APEC. By identifying the strongest drivers of energy use in hotels, hotel energy use can be better understood. By identifying the relationship of these drivers to hotel energy use, hotel energy efficiency and conservation potential can be more accurately assessed. In addition, these results can be used to develop an improved methodology for rating or benchmarking the energy performance of hotels to their peers. This analysis of U.S. hotel energy use was undertaken to provide this knowledge to the member economies of APEC.

4.1 Approach

This analysis was performed by:

1) extracting data for the hotels/motels category from the CBECS database,
2) identifying a subset of hotel characteristics to be investigated for relationships to hotel energy use, and
3) performing a multi-variable linear regression analysis to identify and quantify common hotel characteristics with the strongest relationships to hotel energy use.

The primary analysis focused on buildings with a CBECS primary building activity defined as "lodging". In addition, those lodging buildings that were part of multi-building facilities having a primary facility activity other than "hotel/motel" were also excluded. The major primary facility activity that this excluded was college and university lodging which was expected to be substantially different from the commercial hotel building stock.

Buildings in the CBECS database are selected in a statistical sampling approach such that weights that are supplied with the database can be applied to each observation such that the sample is representative of the population of buildings in the United States. The primary analysis was done on a weighted basis so the results would be representative of the population of U.S. hotels and motels. The secondary analyses were performed on a non-weighted basis to give the larger buildings in the CBECS database more influence on the results. These may be more representative of what can be expected for Asia-Pacific hotels on which data are being collected because to date, their sizes have been more similar to the larger hotels contained in the CBECS database.

The 1992 CBECS database contains over 600 individual building variables that describe building function and use, building construction, heating and cooling equipment, fuels used, fuel end uses, existing energy-efficient technologies, electric demand patterns, and many other characteristics. From these, a subset of 81 was selected to examine for their influence on the energy use of U.S. hotels.

A step-wise, multi-variate linear regression analysis was performed to identify correlations between hotel energy use and building characteristics. The strongest relationships discovered identify the drivers that help explain differences in energy use intensity between hotels.

A primary or source energy basis was used for relating hotel total energy use to building characteristics. This was done because past work on U.S. buildings has shown when examined on a site energy basis, that a group of all-electric or electric-dominated buildings will have significantly different energy use intensities (energy use per unit floor area, per lodging room, or per number of workers) than a group of buildings where electric use is not a dominant part of building total energy use. Calculation of primary energy use was based on an electricity conversion of 10.3 kBtu/kWh.

4.2 Results

Hotels are represented in the CBECS database under the primary building activity described as “lodging”. Extracting lodging buildings from the 7,000+ buildings database provided a sample of 257 lodging buildings. Further investigation into the data set indicated that 184 of these buildings were part of multi-building facilities (a group of two or more buildings at the same site owned or operated by a single organization, business, or individual). In the CBECS database, these multi-building facilities are further broken down by principal activities at the facility. “College or university” and “hotel/motel” dominated the principal facility activities at multi-building facilities. Buildings at multi-building facilities having a principal facility activity other than “hotel/motel” were extracted from the data. A total of 158 buildings remained in the analysis.

The 81 variables selected for analysis of their relationship to hotel energy use are listed in Table 4.1. These variables represent building construction, occupancy, use, and operational characteristics, weather variations, building equipment types and controls including space heating, space cooling, refrigeration, and lighting, installed efficiency features, and other factors thought to have important influences on hotel energy use. Testing of several other variables that could have been important was attempted but could not be done in most cases due either to 1) an excessive amount of non-reported values, or 2) insufficient variable values to establish a relationship to hotel energy use. While the available variables in the CBECS database are extensive, there are some key variables known to have important influences on building energy use that are not directly included in the database. Two of them are hotel occupancy rates and installed lighting capacity or lighting density. While not directly included in the CBECS data set, their importance can still influence analysis results. This occurs because these important

Table 4.1. CBECS Building Characteristics Tested for Their Influence on Hotel Energy Use

CBECS Variable Name	Characteristic	CBECS Variable Name	Characteristic
CLIMATE5	Climate zone	SWITCH5	Able to switch main heating fuel
SQFT5	Square footage	PRUSED5	Propane used in 1992
NFLOOR5	Number of floors	RFGEQP5	Commercial refrig./freezer equip present
YRCON5	Year construction was completed	WCTNK5	Centralized storage tank water heater
HT15	Main energy used for heating	WCSPC5	Water heat drawn from space heat equip.
HT25	Secondary energy used for heating	FACIL5	Multibuilding facility or complex
COOL5	Energy used for cooling	GENER5	Non-emergency generating capability
COOK5	Energy used - commercial cooking	LTOHRP5	Percent lit during operating hours
HEATP5	Percent heated in 1992	BULB5	Incandescent bulbs used
COOLP5	Percent cooled in 1992	FLUOR5	Fluorescent lights used
WKHRS5	Total weekly hours open	CFLR5	Compact fluorescent bulbs used
TOTWK5	Number of workers (all shifts)	HID5	High-intensity discharge lights used
NWKER5	Number of workers	SREF5	Specular reflectors used
WLCNS5	Wall construction material	DAYCTL5	Daylighting controls
RFCNS5	Roof construction material	TMCK5	Time clocks or timed switches used
BLDSHP5	Building shape	VAV5	Variable air volume (VAV) system
BLDLEN5	Building length	ECN5	Economizer cycle
BLDWID5	Building width	RIN5	Roof or ceiling insulation
ATTWLL5	No. ext. walls attached	WIN5	Exterior wall insulation ture
GLSSPC5	Percent glass on exterior	TRG5	Tinted or reflective glass
LTOHRP5	Percent lit during operating hours	AWN5	Shadings or awnings
NGSUPL5	Natural gas supplied	OPNWIN5	Most windows can be opened and closed
FKSUPL5	Fuel oil supplied	BLDDSM5	Bldg. participated DSM, past 3 years
STSUPL5	Steam supplied	AUDIT5	Energy audit ever performed
HWSUPL5	Hot water supplied	MAINT5	Regular preventive maintenance program
VACP5	Percent vacant		
OFCP5	Percent office		
RETLP5	Percent retail/service		
FDRM5	Space used commercial food preparation		
COMPRM5	Computer room with separate A/C		
HWTRM5	Space requiring large amounts hot water		
PCTERM5	PCs/computer terminals in building		
PCTRMC5	Number of PCs/computer terminals cat.		
OWNER5	Building owner		
WKHRS5	Total weekly hours open		
HCUSE5	Heat/cool equip. in use extra hours		
LTUSE5	Lighting equip. in use extra hours		
HDD655	Heating Degree-Days (Base 65 F)		
CDD655	Cooling Degree-Days (Base 65 F)		
HTPMPH5	Heat pump used for heating		
FURNAC5	Furnaces that heat air used		
SLFCON5	Self-contained units used		
STHW5	Steam or hot water piped in		
BOILER5	Boilers used		
PKGHT5	Packaged heating units used		
CHWT5	District chilled water piped in		
CHILLR5	Central chillers used		
ELHT15	Electricity used for main heating		
ELHT25	Electricity used for secondary heating		
ELCOOL5	Electricity used for cooling		
ELWATR5	Electricity used for water heating		
ELCOOK5	Electricity used for commercial cooking		
NGHT15	Natural gas used for main heating		
NGHT25	Natural gas used for secondary heating		
STHT15	District steam used for main heating		
LODGRM	Number of lodging rooms		
SFLDGRM	Floor area per lodging room (derived variable)		
NWKERKSF	Number of workers per sqft (derived variable)		

factors often have strong relationships to other variables included in the CBECS database and this analysis.

The building characteristics found to have the strongest relationships to primary energy use in hotels are the number of lodging rooms, floor area, and the number of workers. This is not unexpected, because all are indicators of building size and occupancy, two dominant influences on energy use in most buildings. A plot of hotel total energy use as a function of gross floor area is shown in Figure 4.1. Plots of energy use as a function of lodging rooms and number of workers are very similar. Note that most U.S. hotels are smaller and that there are only a few hotels at the highest values of floor area (the lodging rooms and numbers of workers plots are similar).

Figure 4.1. U.S. Hotel Energy Use Versus Floor Area
Total Energy Use (source mmBtu)

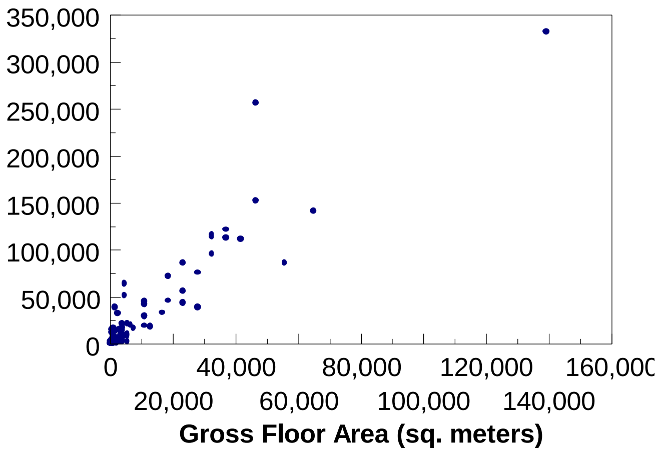
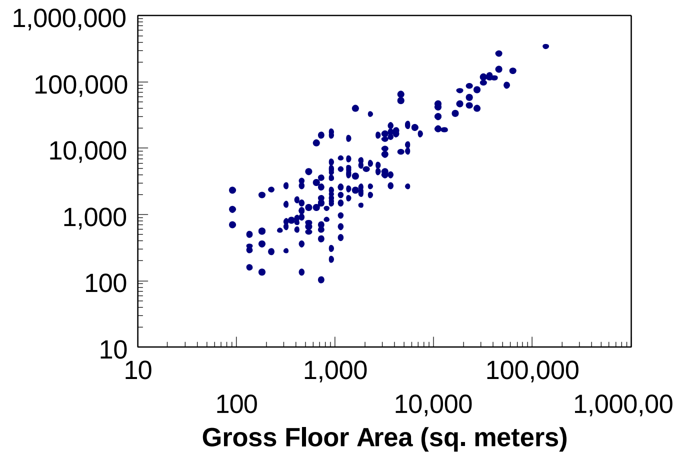


Figure 4.2. U.S. Hotel Energy Use Versus Floor Area
Total Energy Use (source mmBtu)



Correlations were determined on a logarithmic basis to prevent the larger hotels from dominating the relationship between total energy use and each variable. The same energy use versus floor area plot is shown on a log-log basis in Figure 4.2. Note that there is now more symmetry in the distribution of the data, a desirable feature for statistical analyses. The coefficient of determination, R^2, which indicates the correlation between total energy use and each variable, is 0.55 for the number of lodging rooms, 0.48 for floor area, and 0.46 for the number of workers. The correlation between these variables and hotel total energy use are near equivalent and therefore, any one could be used as the primary normalization variable.

For most building types, floor area is traditionally the primary normalization variable for comparing building energy use and past work of this type has been based on it. In the analysis of secondary influence or “drivers” of total energy use in hotels, floor area was selected as the variable of choice to remain consistent with previous work. For the hotel industry, however, the number of lodging rooms is a dominant primary normalization variable. This analysis could just have easily used lodging rooms as the primary normalization variable.

The linear regression model used for identification of the key secondary influences or drivers of total energy use in hotels was:

$$\log (EUI) = C_0 + C_1*(sqft) + C_2*lodgrm + C_3*nwker + ...$$

EUI is the total energy use intensity (kBtu/sqft) of each hotel on a source energy basis. The C_0 constant represents the intercept for the model and the C_1, C_2, C_3 , and others are constants that are multiplied by each analysis variable. These constants represent the slope of the linear relationship that is determined between energy use intensity and each respective analysis variable.

The final regression model proposed for representing the energy use intensity in hotels is:

$$\log (EUI) = 7.37 - 0.385 * \log (SFLDGRM) + 0.824 * DEMMTR$$

$$+ 0.329 * \log (NWKERKSF).$$

Statistical results supporting the model are provided in Table 4.2. The model coefficient of determination, 0.38, indicates that these three variables can explain 38% of the variations in hotel energy use remaining after floor area normalization. The model is limited to the three variables most capable of explaining the variations in hotel energy use after floor area normalization because additional variables add little improvement to the model. Two of the three model variables were derived because they were not specifically included in CBECS.

Table 4.2. Model Statistical Analysis Results

Variable	Model Parameter Estimate	Standard Error
INTERCEPT	7.372376	0.02308440
LSFLDGRM	-0.385360	0.00380600
DEMMTR	0.823981	0.00568127
LNWKRKSF	0.328873	0.00306105

Root MSE 0.86425 R-square 0.3796

The impact of the explanatory variables on energy use intensity is in line with expectations. As the floor area allocated per lodging room (LSFLDGRM) increases, total energy use intensity decreases as indicated by the negative model coefficient. This is expected since hotels with larger rooms would have lower occupancy, an important influence on hotel energy use. The presence of electricity demand metering (DEMMTR) itself does not of course cause the energy use intensity of a hotel to increase as indicated by it’s positive model coefficient. Instead, this variable is strongly correlated to one or more characteristics at the building that impact total energy use intensity. Building size is the likely characteristic because the data show, as expected, that demand metering is rarely used on smaller hotels and almost always present on larger ones. It could also be related to the fact that larger buildings are normally on electric rate schedules where electric kWh costs are much lower than for their smaller counterparts. Thus, the incentive to reduce electric use is not as great. The third driver, the log of worker density (LNWKRKSF), increases hotel energy use as worker density increases. Worker density is likely an indicator of occupancy rates and the amount and level of services provided to guests. As these increase, hotel energy use would certainly be expected to increase as supported by these results.

4.3 Applying the Results to Energy Benchmarking

Average EUI's for group of buildings are frequently used as comparators for judging the energy performance of an individual building. While useful, they can be very misleading in many and perhaps most cases. This occurs because group averages are susceptible to strong influence by individual buildings in the group having excessive EUI's. And groups almost always have one of more of these excessive users that pulls the group average to well above the group median. Thus, most buildings in a group are more efficient than the "average" building. Groups where 65 to 70% or more of the observations fall below average are not uncommon. In this case, two-thirds of the group show up as better than average leading many to conclude they have buildings better than the norm when if fact the opposite may be true. For this reason, distributional benchmarking provides a much better indicator of building energy performance than a group average (Sharp 1996).

A simple distribution of EUIs, while better than an average, is still not good enough for credible building performance rating. There are secondary drivers (also referred to as factors or influences) that cause the energy use of specific buildings to be higher than their peers that are not related to the energy efficiency of the building. Hotel floor area per lodging room is a major one as identified by this analysis. If not normalized for, hotels with higher floor areas per lodging room (an indicator of lower occupancy) which causes their EUI to be lower, will get a better performance rating than the building actually achieves. Likewise, a hotel with higher lodging density (less floor area per lodging room) would be unfairly penalized by an unnormalized performance rating. Other secondary influences of energy use inappropriately affect the performance rating as well.

Figure 4.3. Secondary Influences Can Cause Inaccurate Performance Ratings

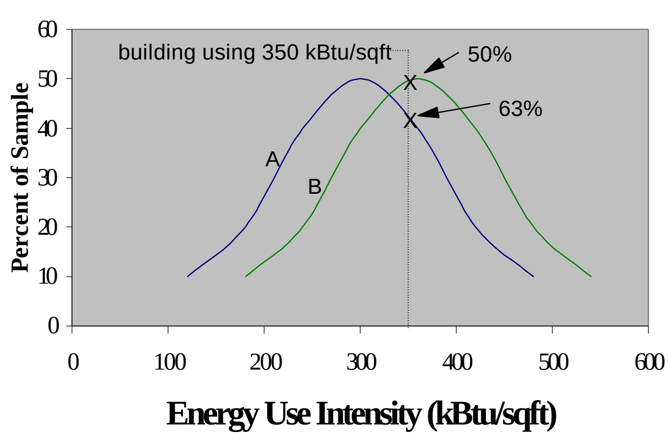


Figure 4.3 illustrates how the results of this analysis could be used to normalize for the strongest and

most dominate secondary influences of hotel energy use intensity as identified in this work. In the figure, curve A is the unnormalized frequency distribution (histogram) of EUIs for CBECS hotels where demand metering is present (occurs at most hotels) at the typical lodging room density for CBECS hotels (350 sqft per lodging room). Using the EUI model, Curve B approximates the same curve normalized for a lodging room density of 250 sq ft per lodging room (one-third of CBECS hotels are at or below this value, a range corresponding to the potential for high guest densities). The EUI model indicates the typical hotel with a lodging room density of 250 sq ft (and demand metering) has a total source energy use of 350 kBtu/sqft. As a result, it would get a rating of 50 or 50% on the normalized distribution. On Curve A, the unnormalized distribution, it would receive a rating of 63 or 63% indicating two-thirds of all hotels are more energy efficient when if fact only one-half are more efficient. The influences of other secondary drivers can combine with lodging density impacts to make this situation worse. As a result, it is necessary to normalize rating systems based on simple EUIs alone. The EUI modeling results can be used to develop normalized distributions for all the important secondary drivers of hotel energy use as identified in this analysis. This methodology is being used by two new building energy performance rating systems in the United States.

5.0 SURVEY TO COLLECT ADDITIONAL HOTEL DATA

It was necessary to survey APEC member economies of the Expert Group on Energy Efficiency and Conservation to collect the additional data because it is only theywho know the particular hotels and the hotel contact. Methods to collect and submit the data depended on whether it was an addition to data already submitted or completely new data.

5.1 Additions to Existing Data

The existing APEC database contains 161 hotels submitted by seven member economies, not including the U.S. Each member economy that had previously submitted hotel data was requested to collect the additional three characteristics data found to be an important determinant of energy use for U.S. hotels. The suggested procedure was to contact each hotel and ask the hotel manager or operator for the information. It was also suggested that, if a visit to the hotel is required, this would be a good opportunity to show the manager how that hotel's EUI compares with others in the database. A cumulative percentage distribution chart was offered for that use, on request.

In order to ensure a proper match with existing data; the EE&C Contact was asked to prepare a table or spreadsheet with a row for each hotel and with column headings for:

- building number (previously assigned by the member economy),
- location,
- gross floor area (in square meters),
- number of workers (on main shift),
- district steam or hot water (Yes or No), and
- energy source for space heating (such as: electricity, gas, oil).

A formatted Excel form for entering the above data was also provided for convenience and a file or printout of all hotel data submitted for each economy was offered on request. The additional data could be returned by E-mail or FAX.

The district steam/hot water and space heating energy type information was collected based on results of the preliminary CBECS hotel analysis for "lodging" only building types. Refinement of the data set, as described in Section 4.2, produced results indicating these two variables, while still important, should be supplemented by lodging room quantity information which was found to be more important.

5.2 New Hotel Data

Member economies that wanted to submit entirely new hotel data would have to submit the entire data set. For this case, the EE&C Expert Group contact was asked to contact the U.S. analyst maintaining benchmark data to receive a formatted Excel data form file and instructions for entering the hotel data.

5.3 Results of Data Survey

Complete data sets were received on 56 hotels from three member economies, as summarized in Table 5.1 below.

Table 5.1. Hotel Energy Data for Three Economies

	Hong Kong, China	Singapore	Chinese Taipei
Number of Hotels, and Year of Energy Use	26, 1998	25, 1993	5, 1994
Gross Floor Area Range (m^2)	3,120 – 64,212	2,604 – 87,082	30,887 – 277,704
Number of Workers, Range	29 – 750	50 – 250	258 – 1,200
Number of Workers Per Thousand m^2	6.6 – 17.4	2.5 – 19.2	0.9 – 10.3
Energy Use Index Range (GJ/ m^2)	0.5 – 2.6	0.8 – 4.7	0.1 – 2.0

NOTE: 14 of the Hong Kong hotels also had complete data sets for the year 1990.

Response from the survey was also received from the Chile and the Republic of Korea. Chile could not collect data for the project at this time, but will try to include a data collection project for next year. The Republic of Korea reported difficulty in trying to expand a data set that was originally submitted in 1994.

All additional hotel data received was added to the APEC energybenchmark database and is available on the Internet site described in Section 3.2. If the Internet is not convenient, benchmark data will be suppliedas an Excel file on 3.5" disk upon request to any of the authors of this report.

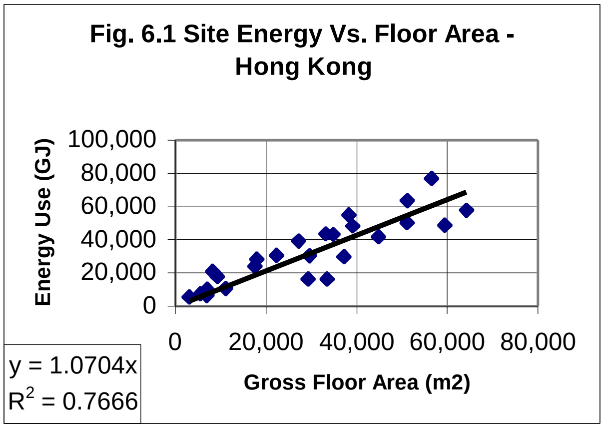
6.0 ANALYSIS OF NON-U.S. HOTEL DATA

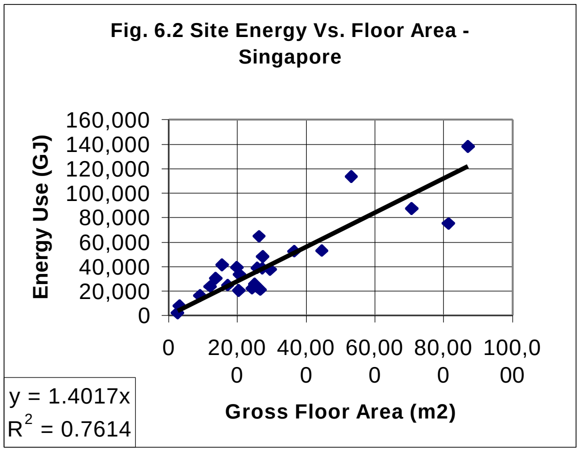
The analysis of the CBECS database for U.S. hotels and motels determined that the key determinants of energy use per unit of floor area (the EUI) were:

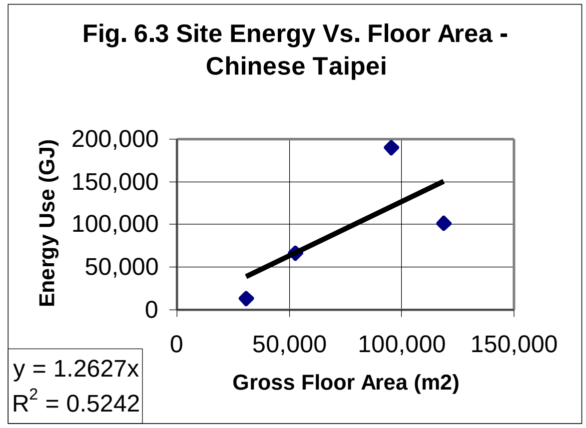
- The number of lodging rooms per gross floor area,
- The presence of an electric demand meter, and
- The number or workers on the main shift.

The use of electric demand metering was not considered important for APEC benchmarking because it is almost always present in the larger hotels. The importance of the number of lodging rooms per gross floor area was not discovered until the database was narrowed from "lodging" to "hotel/motel", but it is believed that two of the remaining three variables may be sufficient because of their interrelationship. Thus, the objective of this analysis is to determine if the number of workers is an important determinant of energy use for non-US hotels as it was shown to be for US hotels.

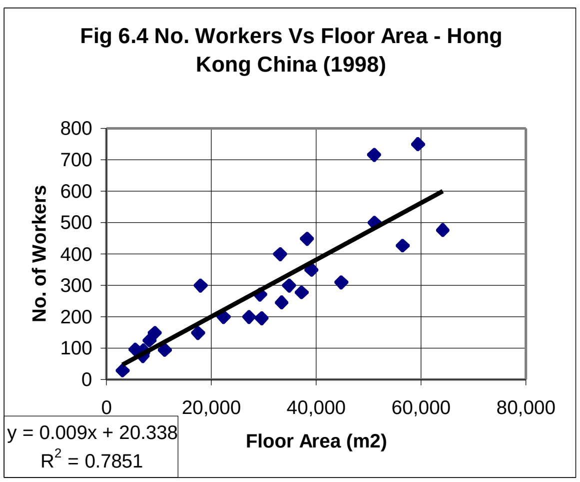
Figures 6.1, 6.2, and 6.3 show a linear regression of total site energy use versus gross floor area. The plots confirm that a linear model of energy use versus floor area is valid and the high values of R^2 indicate that floor area explains a large percentage of the variation of energy use between hotels.

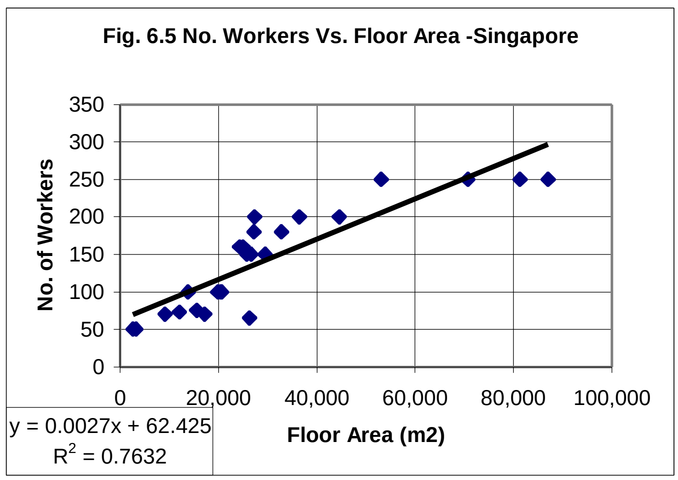






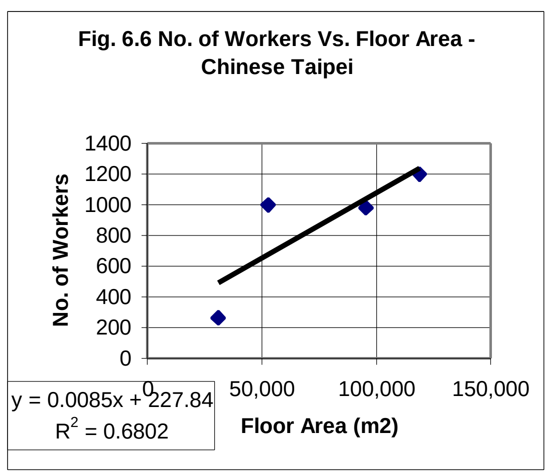
The number of workers also appears to be strongly related to gross floor area, as shown in Figures 6.4, 6.5, and 6.6; and, as would be expected, site energy use also has a strong linear correlation with the number of workers.





The importance of the other two variables, gross square meter per lodging room and the presence of an electric demand meter, or the ranking of the three variables cannot be determined without additional data.

As in the U.S. hotel analysis, linear regression analysis of EUI as a function of worker density was used to determine if worker density can help explain the variation in energy use after floor area normalization.



Resulting models are:

Hong Kong China	ln(EUI) = -1.176+ 0.579*ln(No. Workers/m^2);	R^2 = 0.225
Singapore	ln(EUI) = 0.421 – 0.0113*ln(No. Workers/m^2);	R^2 = 0.0002
Chinese Taipei	ln(EUI) = -2.070 + 0.842*ln(No. Workers/m^2);	R^2 = 0.209

The results are comparable to the model developed in Section 4.0, for a one variable case. Correlations exceed 0.20 in two cases indicating that worker density alone can help explain a significant portion of the variation in EUI. In addition, for these two cases, increasing worker density corresponds to increasing EUI as found in the U.S. hotel results. The results for Singapore are inclusive. Either no relation exists or the data are insufficient to enable its determination.

Results of analysis lead to the following recommendations:

- That the relationships between hotel energy use intensity and number of workers be utilized to improve APEC hotel energy performance benchmarks.
- Collect data on all three variables during application of the benchmarking tool or when implementing a hotel data collection project.
- When an individual member economy has collected enough data (at least 10 hotels per normalization variable), utilize regression analysis and develop a normalized benchmarking tool for that economy.

7.0 PROCEDURE FOR ESTABLISHING ENERGY EFFICIENCY TARGETS

There are several possible methods to establish a quantitative energy efficiency target for a particular building type, and selection depends on the intended purpose and use of the target and the amount of resources that can be budgeted for its development. Examples include:

1. Energy codes for new or existing buildings. Codes are usually developed from energy simulations of "typical" buildings, have prescriptive and performance compliance paths, and must assume that a building is built and operated as designed. Targets may be set as compliance with the code or as some percentage better.
2. Identification of exemplary buildings. Buildings that are known to be energy efficient through design, retrofit, or operation can be used to develop targets based on energy use and/or on the application of specific energy systems and operations. This requires detailed knowledge about the building and the reasons for having low energy use. The EWG Project 01-98 surveyed member economies for nominations of exemplary buildings, but there was no response. It was assumed that data is not available and that significant resources would be required to collect it.
3. Setting target relative to existing buildings. This method usually requires collection of energy use and characteristic data for existing buildings of a particular type. One can use distribution curves to show how a particular building compares with others in the

database; or define a range, such as the best 25% of the buildings, as the energy efficiency target. Identification of exemplary buildings can also be used to establish the range on the curve to be used as a target.

To date, APEC energy benchmarking development has used method 3, above, based on guidelines set by the Expert Group on Energy Efficiency and Conservation. The guidelines included:

- A measure of efficiency was needed to which individual facilities could be compared,
- A key objective was to identify high energy users for setting priorities and motivating facility manager to take action,
- Start with the simplest, whole facility EUI, and
- Build database on individual facilities with actual energy use (i.e., no simulations or sector averages).

7.1 Efficiency Targets From EUI Database

Most of the APEC energy benchmark database contains the minimum data necessary to calculate the EUI. This data is still applicable and should be used until additional determinants of energy use are identified and collected. This is because gross floor area has been shown to be the most important normalization variable for explaining the variation in energy use between buildings of the same type.

An example of using energy benchmark data to set an energy efficiency target is the U.S. Environmental Protection Agency's (EPA) Energy Star Buildings Program. It uses a 0 – 100 scale and issues an Energy Star Label to buildings that score 75 or greater after adjustments for climate and other building characteristics. The 0 – 100 scale is the same scale as the cumulative percentage distribution of buildings within EUI bins, except that the percentage value at each bin is subtracted from 100 to make higher values correspond to higher efficiency. That is, a percentage value of 65 means that the building being rated has a lower EUI (and higher energy efficiency) than 65% of the buildings in the database. A "score" of 75 corresponds to an EUI value for which only 25% of buildings are of equal or higher efficiency. The energy efficiency "target" may be considered to be the "score" of 75 or the corresponding value of the adjusted EUI.

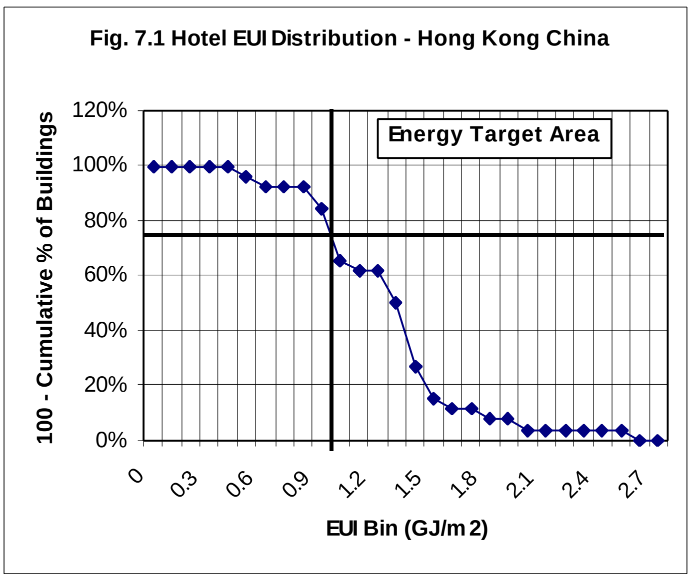
The APEC energy benchmark database only has one variable, the gross floor area, for normalizing the energy use of buildings. This simplifies the procedure for establishing an efficiency target and allows the method to be illustrated with the type of chart used previously to report results of benchmark analysis. The procedure consists of the following steps:

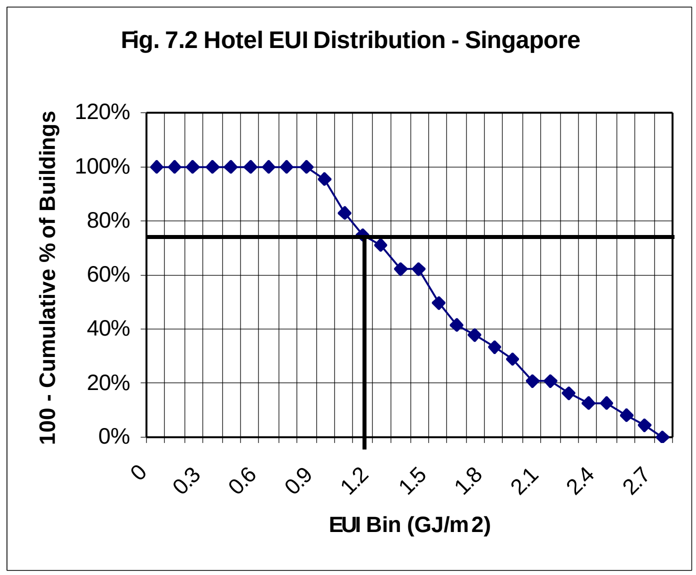
1. Collect annual consumption of electricity and each other fuel type, and the gross floor area for a sample of buildings of the same type. Divide total energy use by gross floor area to obtain the EUI value. The formatted Excel data file used to collect and maintain the APEC database is a convenient tool for entering the needed data.

2. Select the best subset of the sample of buildings to be used to define the efficiency target. For this example, the target will be set by the best 25% of buildings in the sample and data was collected for 32 buildings.

3. One may only want to determine the EUI value at which only 25% of buildings in the sample are lower. For the sample size of 32, the best 25% is equal to eight buildings. Sort the table of data by EUI. The energy efficiency target is the EUI value for the eighth building. The EUI of any building can then be compared to the target EUI to determine the percentage reduction in energy use needed to reach the target.

4. It is believed that a building owner will be more interested, and motivated, in seeing how the building "scores" relative to others in the sample. For this case, complete a histogram analysis on the EUI data with cumulative percentage specified as output. The resulting table will show the number of buildings within each EUI bin (the frequency) and the cumulative percentage of buildings at each EUI value. Subtract each cumulative percentage value from 100 and plot the distribution curve of cumulative percentage versus EUI bins, as shown in Figures 7.1 and 7.2 using data submitted by Hong Kong and Singapore. 7.1 and 7.2 using data submitted by Hong Kong and Singapore.





A "score" of 75 means that the building outperforms (has a lower EUI) 75% of the buildings in the sample. The dark horizontal line at 75% on Figure 7.1 indicates the "target" and the corresponding EUI value is where that line crosses the distribution curve. In Hong Kong, a hotel needs an EUI value of 1.0 GJ/m2 or less to reach the target; in Singapore, the EUI target value is about 1.1. The shape of the distribution curve affects the percentage reduction in energy use to change from one score to another. For example, to change from a score of 50 to the target of 75 requires a 26% improvement in Hong Kong and a 19% improvement in Singapore.

7.2 Energy Targets Using Multiple Building Characteristics

As described in Section 4, there are other determinants of energy use that can be used to account for the remaining variation in energy use between buildings after normalization for floor area. The procedure demonstrated in this project for hotels can be applied to any other building type that is included in the CBECS database. The procedure consists of the following steps:

1. Using the CBECS database, or any other database containing building characteristics to be tested for statistical significance, perform the step-wise, multi-variant linear regression analysis as described in Section 4. This will identify the building characteristics with the strongest correlation to energy use and the coefficients for the model, or equation, representing the energy use intensity.
2. Normalizing energy use for differences in floor area is done by using the EUI as the independent variable of the model. One must now develop a method to adjust the EUI to account for differences between buildings for each of the other variables in the model. One method is to identify a typical value for each variable as a default and to calculate an adjustment factor to the EUI for buildings being rated that differ significantly from the default values. This type of calculation is best performed in the background using a spreadsheet macro or table of adjustment factors.
3. Design the rating tool so that a user can enter the required data for each variable and receive results for the building being rated. Results may be displayed as "pass/fail", a score between zero and 100, the percentage of buildings in the database that use less energy per square meter, or the percentage reduction of energy use required to meet the efficiency target.

Examples of a benchmark "tool" using multiple variables include those developed by T. Sharp of Oak Ridge National Laboratory for office buildings and K-12 school buildings that are located on the Internet at:

http://eber.ed.ornl.gov/commercialproducts/cbenchmk.htm

The U.S. EPA Energy Star Label for Buildings rating tool is located at:

http://www.epa.gov/labelbuilding

8.0 RECOMMENDATIONS

The energy benchmark database, Web site, and tools for efficiency targets have no intrinsic value except as a way to convince building owners or operators to evaluate their buildings and take steps to improve energy efficiency. The potential and the technology exist to reduce energy use in non-residential buildings by an average of at least 25% with cost effective projects, and external financial and technical resources are available as needed. The real challenge is to educate and motivate the owners and operators of public and private buildings to take action. Energy efficiency benchmarking, energy targets and rating systems, and use of the Internet to make these databases and tools widely available help to get the building owner's attention; but long term deployment strategies and programs for energy efficiency need to be implemented in a way to get retrofit projects started.

The U.S. is stressing the deployment of existing technologies and practices through programs such as the DOE Rebuild America and the EPA Energy Star Buildings, but any successful deployment program must be tailored to fit the existing culture, policy, and procedures within each member economy. It is believed that planning and implementation assistance can be made available to any economy, but the economy must take the lead and ownership of programs for long term, sustained improvement.

The following recommendations include work needed to maintain and improve the energy benchmark system and to design and implement energy efficiency programs in existing buildings.

<u>Internet Site</u> This project established an Internet site and populated it with the existing APEC energy benchmark database for buildings and industry and associated forms, instructions, and output charts. The following activities are recommended:

- Test the value of the Internet site and the benchmarking database within one or more member economies. Activities could include integrating use of benchmarks and targets in existing energy efficiency programs; and publicizing the Internet site to building owners and operators, energy auditors, ESCOs, and others involved in retrofit of buildings. An interested member economy could submit a proposal for APEC funding.

- Maintain and improve the Internet site during the next year and, if appropriate, resolve the issue of long term financing.

<u>Collect and Analyze Additional BuildingData</u> Research sponsored by the U.S. DOE and EPA is underway to identify the additional determinants of energy use for other building types. Offices was the first sector completed, and this project addressed hotels. A listing of the additional data needed for each building type should be placed on the Internet site as the analysis of the U.S. database proceeds. Member economies could then request the added data during planned data collection projects, and the new data could be added to the Internet database. Analysis of the data would proceed as soon as enough buildings have been submitted.

<u>Tools for Ratings and Energy Efficiency Targets</u> An interactive tool that provides a “score” or a target for improvement for a building should be developed in a format that meets the needs of participating member economies and made available on the Internet site; either on the ORNL server or linked to a server of the member economy. Example Internet sites were identified in Section 7.2.

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