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Revised Building Energy Code of Thailand: Potential Energy and Power Demand Savings

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Abstract

The government of Thailand legislated a law called Energy Conservation Promotion Act (ECP Act) in 1992. A set of bye-laws identifying designated buildings (DBs) and detailing mandatory requirements for energy conservation for DBs were enacted in 1995. An Energy Conservation Promotion Fund (ENCON Fund) was created by the ECP Act to facilitate implementation of activities sanctioned by the act. The ENCON Fund has been used to fund energy audits carried out by consultants on all DBs that number around 1,800. Presently the requirements and procedures for energy conservation in buildings, embodied in a building energy code, are under revision. The revised code continues to adopt system performance requirements for building envelope, lighting, and air-conditioning. Moreover, the new code accounts for different patterns of use of DBs, provides credit for use of solar energy, and introduces a new option of whole building energy compliance. The formulation of overall thermal transfer value enables the OTTV of a building to be used, together with performance indexes of lighting and air-conditioning systems, to estimate the annual energy consumption of the building. The new code is intended to apply in full extent to very large new commercial buildings only, while smaller new buildings will be subjected only to envelope performance requirements. As a part of the effort to convince building developers, the public, and the relevant authorities on the potential benefits of the code, the authors develop building models from data obtained from energy audit reports to calculate energy and power demand savings of different categories of commercial buildings. The results are then used to estimate savings on energy and electric power demand from future new buildings, whose expected energy and power demand figures are taken from the report of the Load Forecast Working Group, a panel tasked to forecast future electric load for Thailand power system development.

1. INTRODUCTION

The soaring price of oil at present time attests to the finiteness of natural resources. It has been remarked that energy conservation can reduce energy use with no adverse impact on the environment and can lead to sustainability.

Thailand was a net energy importing country ever since it began its first Economic and Social Development Plan to embark on a new phase of coordinated economic development in 1964. From 1990, the economy expanded at a fast pace with the corresponding rise in energy consumption, giving rise to an elasticity of energy consumption growth over GDP growth of 1.12. From 1985 to the present, per capita consumption of oil and natural gas has increased six folds, while per capita consumption of electricity has increased five folds, [1] and [2]. The interest in energy conservation for commercial buildings arose from the situation of oil price hike and shortage. When ASEAN countries (in Southeast Asia) initiated joint activities with dialog countries in the early and mid 1980s, research and development in energy conservation in commercial buildings was a subject designated for cooperation.

A US-ASEAN cooperation program led to development of building energy codes for Indonesia, Malaysia, Philippines, and Thailand, and a review of the formulation of the Overall Thermal Transfer Value (OTTV) of Singapore, [3]. The OTTV has been adopted as the measure of thermal performance of building envelope in the Singaporean Building Energy Code (BEC) that had been implemented on a mandatory basis as a part of the Bye-Law of Building Control Act. The Singaporean BEC was modeled after Standard 90-1980, [4], of the American Society for Heating Refrigerating and Air-conditioning Engineers (ASHRAE).

The use of building energy code on a mandatory basis in an effort to achieve efficiency of energy consumption in buildings is common, as reported by Janda and Busch, [5]. After the date of publication by Janda and Busch, many more countries have adopted BECs that include OTTV or other requirements on energy performance of building envelope. Close to ASEAN, Hong Kong Special Administrative Region (HKSAR) promulgated a mandatory BEC in 1998. Regulation on OTTV and building envelope performance requirement was made since 1995. [6] and [7]. Wong, etal, [8], reported enacting a law of the People’s Republic of China on Conserving Energy in 1998. Mandatory regulations on heating, ventilating and air-conditioning, building energy performance, managements and testing related to thermal performance are now applied in China. Further away geographically, Ivory Coast had developed and applied “the Ivorian Energy Efficiency Building Code” to all new buildings, except residential buildings of three stories or less, since 1993, [9]. The initiative was taken from the examples of the ASEAN countries and Jamaica. The Ivorian code utilized economic criterion in determining levels of energy efficiency requirements based on whole building targets. Although energy efficiency for air-conditioning was made mandatory earlier, the Mexican government passed a law requiring energy efficiency on building envelope in 2001, [10]. A new building is considered to meet the Mexican requirements on building envelope if the calculated heat flow through its building envelope is less than that of a hypothetical reference building of the same dimensions and orientation.

As has been reported in [11], the Energy Conservation Promotion Act of Thailand was promulgated in 1992. Requirements on energy conservation for large commercial buildings became mandatory in 1995 after a set of bye-laws on BEC was announced. The ENCON Fund created by the ECP Act, was also operational by the same date. However, energy conservation effort for commercial buildings has been considered to have achieved limited success. As a part of the effort to improve the situation, a project was launched in 2002 initially with the assistance of Danish International Development Agency (DANIDA) and later through funding from the ENCON Fund to revise the BEC. The new code is now scheduled to apply in full to very large new commercial buildings only. A new building with floor area exceeding 10,000 m^2 (ten thousand square meter), designated as very large buildings (NVLB) under Building Control Act, must comply with requirements on building envelope, lighting, and air-conditioning before its design is approved for construction. For a new building with an area between 2,000 and 10,000 m^2, designated as large building (NLB), its building envelope must comply with the requirements on building envelope. These are consistent with the present bye-law of the Building Control Act that requires that building design and electrical and mechanical designs of a very large building be submitted for construction permission. For a large building, the bye-law requires only building design to be submitted. The existing bye-law of the ECP Act heavily focuses on existing building and no mechanism for enforcement of energy conservation requirements for new buildings has been developed It is suspected that most buildings constructed during 1995 to present do not comply with the code. The present effort includes the development of a computer code for evaluation of the compliance of a building design and provision of a handbook to assist building designers The responsibility that a building design complies with the requirements of the code rests with the building designer and no other person will certify a design, consonant with the present practice on building safety compliance. A building control subcommittee has been appointed to prepare the draft of a bye-law of the Building Control act that requires the design of very large building and that of large building to also comply with the requirements of the ECP Act An item on energy conservation requirement will be added to the check list of requirements for a new building to comply so that authorizing officials could use it to check if a BEC qualified professional has signed to authenticate its compliance with BEC. These steps would ensure that the BEC requirements are fully implemented.

This paper first briefly reviews implementation of building energy code in Thailand. Then it examines features of the new code. The methodology used and the results of assessment of potential electrical energy and power demand savings from implementation of the new code are then presented. It is concluded by emphasizing that energy savings benefits could be obtained only if the code is implemented successfully.

2. DEVELOPMENT AND APPLICATION OF BUILDING ENERGY CODE IN THAILAND

2.1 Components of existing Thai code.

Studies conducted during 1980s found that air-conditioning (for cooling) and electric lighting typically accounted for 60% and 20% respectively of the electricity consumption of a commercial building in Thailand, [12]. Furthermore, heat gain across building envelope due to external driving forces contributes 60% of the load of the cooling coils of the air-conditioning system. Such studies led to the inclusion of requirements on performance of building envelope, air-conditioning system and lighting system in the building energy code. The code uses OTTV as the measure of the performance of the envelope of a building. The code defines measures of and set *requirements for minimum performance of building envelope system, lighting system and air-conditioning system*. The Thai code does not include auxiliary equipment such as lifts or escalators, nor does it include office equipment in its scope. There are separate promotional activities for improving efficiencies of household appliances and office equipment undertaken by various agencies. During the time of the initial development of Thai BEC, professional ilumination and air-conditioning societies were not in existence. Developments on the requirements on lighting and on air-conditioning were contributed by individuals.

2.2 Implementation of Building Energy Code in Thailand.

In implementing the Ministerial Regulations that embody the building energy code, limited success has been observed. This unfortunate situation stems from the way the law was applied and the deficiency in the code itself.

Experiences Gained. Implementation of the Ministerial Regulations during the last nine years on over 1,800 buildings have taught that too much emphasis has been placed on retrofitting existing buildings. While economic and financial justification for replacement of existing equipment in existing building are unclear because the value of each equipment whose life has not expired could not be properly evaluated, the requirements of the Ministerial Regulations have been difficult to fulfilled. Disproportionate emphasis has been placed on standard items of equipment replacement or maintenance management by the authority [13]. While the cost of equipment replacement would be born by the proprietor of each building, the authority develops its own set of targets for replacement. This leads to divergence on energy efficiency improvement in a given building between the building proprietor and the consultant who conducts energy audit and whose energy audit report must be approved by the authority. However, the code requirements are mainly performance based. The code introduces and familiarizes building professionals to OTTV as a measure of thermal performance of building envelope and as a system performance requirement. This has helped create a knowledge base among the pool of building professionals.

Weaknesses in the Present Building Energy Code. The code does not provide direct linkage between energy performance of different systems in a building to energy consumption and energy cost of the building. Moreover, the code tends to mislead industry participants to taking the code requirements as ultimate targets, while the performance requirements were meant to be minimum requirements at the onset. In most cases, performance levels higher than those required by the code should offer higher benefit over cost. The detailed requirements in the existing code are also subject to review since its requirements were made based on technologies prevailing close to one decade ago.

3. FEATURES OF THE NEW BEC OF THAILAND

The new code continues to adopt system performance requirements and includes whole building energy compliance. Economic principle is used in setting minimum performance requirements.

3.1 Components of the New Code

The new code still utilizes OTTV as the measure of thermal performance of building envelope and power density of lighting as the measure of performance of lighting. But it distinguishes three different time and duration of use of commercial buildings and provides three separate OTTV formulations. It also recognizes different lighting requirements and specifies three levels of performance requirements, each for a category of commercial buildings. It now uses coefficient of performance of air-conditioning and plant system as measure of performance of air-conditioning where the existing code uses only rated performance of chiller of a central air-conditioning system as the performance measure. It also introduces whole building energy compliance as another path for compliance. The new code also utilizes an OTTV-based energy equation as the basis for whole building energy calculation. Another significant feature is the accreditation for use of solar energy.

New OTTV and Energy Relationship. The OTTV formulation of the existing code was meant for it to represent average heat gain through a given building envelope for a whole year. That is

old OTTV = heat gain through building envelope of a given building for the whole year/(number of hours of use of the building x total external area of the building).

Such formulation is described in [14] and is conceptually identical to the formulation employed in the Singapore code, [15] and Hong Kong code, [16]. In the development of the new code, a slight variation was employed. The OTTV would be used as a measure of annual average heat gain through building envelope *as sensed by the cooling coil of the air-conditioning system* of a building. It is meant to be used in the equation

Annual average cooling coil load (of an air-conditioning system)
= *(OTTV) (wall area) as external factor of load*
\+ *lighting, equipment, occupants and ventilation as internal factor of load.*

Computer code was used to simulate annual cooling coil load of a generic building model under different sets of conditions. The results were used to regress for OTTV formulation. With such postulate, it can then be used to calculate annual energy use in a given building through the relationship

Annual energy use of a space
= *annual cooling coil load of the space /COP*
\+ *annual direct use of energy of lighting and other equipment,*

where COP is the coefficient of performance of the air-conditioning system. The first term in the last equation accounts for air-conditioning energy. Reference [17] provides background justification to the concept used here. With the OTTV formulation developed this way, the formulation could be used to calculate reference annual energy use of a building design and that of a reference building. In this way the equation can be used in the whole building energy compliance procedure. The OTTV formulation would become an accurate measure of thermal performance of the envelope of a building. *The energy equation relates performance of wall, lighting and air-conditioning to reference annual energy consumption of the whole building.*

In order to utilize the energy relationship on different categories of commercial buildings, three patterns of use of a building are identified, daytime only, late daytime to nighttime, and day and night. Table 1 list commercial buildings identified to fall into each category of usage. The number of hours of use of each category is also shown.

Table 1 Usage duration and total hours per year of three categories of buildings.

Building Category	Usage time	Number of hours per year
Office and education	8.00-17.00	2,340
Department store, hypermarket, and miscellaneous	10.00-22.00	4,380
Hotel, hospital, condominium, and hostel	24 hours	8,760

The new OTTV formulation takes the form

$$\begin{aligned} \text{OTTV} &= (1\text{-WWR})\,(TD_{eq})\,(U_w) \\ &+ (\text{WWR})\,(\Delta T)\,(U_f) \\ &+ (\text{WWR})\,(\text{SHGC})\,(\text{SC})\,(\text{ESR}), \end{aligned}$$

where WWR = window area to overall wall area,
TD_{eg} = equivalent temperature difference of opaque wall,
U_w = thermal conductance of opaque wall,
ΔT = temperature difference for glazed window,
U_f = thermal conductance of glazing,
SHGC = solar heat gain coefficient of glazing,
SC = shading coefficient of shading device, and
ESR = effective solar radiation.

A set of values of TD_{eq} and ESR is given for each category of buildings.

Lighting The indicator of performance of lighting system used in the present code is *lighting power density (LPD, Wm^{-2})*. This continues to be used.

Air-conditioning Performance indicator for an air-conditioning system used is the coefficient of performance of the whole system except when absorption chillers are used.

Hot Water System Performance requirement is made on production of hot water generation. No requirement is made on its use.

Renewable Energy Accreditation is given to use of daylighting and photovoltaic power production

3.2 Energy Performance Requirements

Energy performance requirement of each system was determined from economic principle.

Application of Life-cycle Costing to New Buildings. For a building at the design stage, the choice of building construction, systems and equipment to be used is relatively free of constraint. *It is logical that mandatory energy performance requirements or a mandatory building energy code applies to building not yet constructed.* Total cost throughout the life of a building should be used as basis for choice of building systems. Life-cycle costing accounts for initial cost, energy cost, other operating and maintenance cost (including labor), life of each component forming the system; discount rate, inflation and escalation of some cost items such as energy cost, and salvage value of each component when its life is expired. . The first two items dominate in our case.

In the application of life cycle costing principle to determine minimum performance requirements of each building system, extensive examples of alternative systems of different performance were developed and their life cycle costs evaluated. The results were used in consultation with expert groups to decide on minimum performance requirements of each system.

Building Envelope Thermal properties and life cycle costs of typical opaque walls, with and without insulation, in combination with coated and uncoated glazing, single and double layer, were compiled and presented to a panel of experts and stakeholders comprising building designers and developers. Annual costs of energy associated with the use of a combination of opaque wall and glazing were derived from energy simulations. A series of consultations led to the results shown in Table 2 for the value of minimum performance requirement for the envelope of each building category. At a value of window area to overall wall area close to 0.35, it was demonstrated that a certain combination of opaque wall and glazing offers lower life cycle cost and the resultant OTTVs when applied to each building category fall within the values in Table 2.

Table 2 Minimum allowable energy performance for building envelope.

Building type	Requirement
Wall	
Office or school,	O-OTTV < 50 Wm^{-2}
Department store, hypermarket, and restaurant	S-OTTV < 40 Wm^{-2}
Hotel, hospital, and hostels	H-OTTV < 30 Wm^{-2}
Roof	
Office and school,	O-RTTV < 15 Wm^{-2}
Department store or hypermarket, and restaurant	S-RTTV < 12 Wm^{-2}
Hotel, hospital, and hostel	H-RTTV < 10 Wm^{-2}

Lighting System A building model was created for each type of building under consideration. Typical functional areas were identified for each building type. The level of illuminance or light flux per area was chosen in accordance with typical design for each functional area. Life cycle costing was applied to show that higher performance level for lighting lead to lower power density requirement and lower life cycle cost. Table 3 shows the recommended allowable value for each building category.

Table 3. Allowable rated power density for lighting.

Category of building	Allowable rated power(W/m^2 of utilized area)
Office and education	14
Department store, hypermarket, and miscellaneous	18
Hotels, hospitals, condominium, and hostel	12

Air-conditioning System The same concept was applied to air-conditioning system. For a large air-conditioning system, the main equipment that consumes 65% of power is the chiller. The recommended values for coefficient of performance for large electric chillers are shown in Table 4. For unitary air-conditioners, requirement on coefficient of performance is made for each set.

Table 4. Recommended performance requirements for chillers.

Category and size	Minimum performance, COP (kW/TR)
Air-cooled water chiller	
Up to351.7 kW$_{th}$ (100 TR)	2.70 (30.1)
Over 351.7 kW$_{th}$ (100 TR)	2.93 (1.20
Water-cooled water chiller	
Less than 527.5 kW$_{th}$ (200 TR)	3.90 (0.90)
From 527.5 kW$_{th}$ and less than 703.3 kW$_{th}$ (250 TR)	4.69 (0.75)
From 703.3 kW$_{th}$ and less than 879.2 kW$_{th}$ (300 TR)	5.25 (0.67)
From 879.2 kW$_{th}$ and less than 1,758.3 kW$_{th}$ (500 TR)	5.40 (0.65)
Over 1,758.3 kW$_{th}$	5.67 (0.62)

Note TR = ton of refrigeration, 1 TR = 3.517 kW$_{th}$.

The air-handling system, condenser water cooling system, and chilled water transport system taken together had been recommended a rated minimum coefficient of performance of 7.03 (0.5 kW/TR). Figure 1 illustrates the requirements.

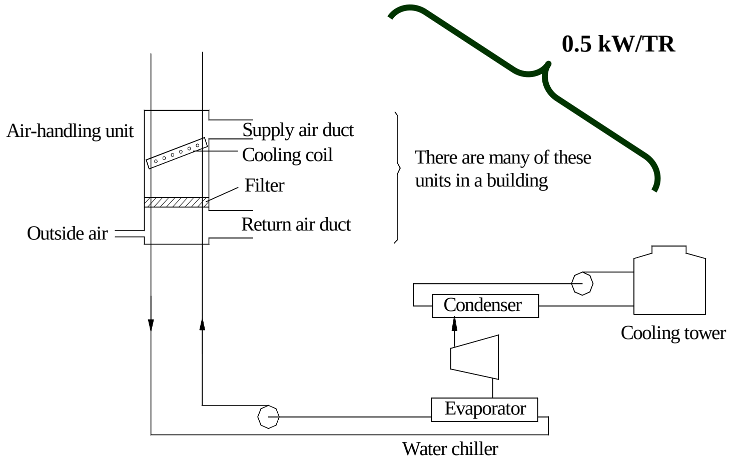

Figure 1. Requirements on other part of the air-conditioning system.

Absorption chillers It was envisaged that only waste heat was and would be used to run absorption chillers in Thailand. There was no need to account for the energy use in the whole building energy compliance procedure. Minimum coefficients of performance were set at 0.65 for single effect and 1.1 for double effect chillers respectively. Rating condition was chosen to comply with international standard, but adjusted to suit higher thermal environment in Thailand.

Hot Water System No requirement was made on hot water use. Minimum efficiency of hot water generation required for each type appears in Table 5. Heat pumps are increasingly used for hot water generation where ventilation air as heat source is pre-cooled by the operation.

Table 5 Required minimum efficiency of hot water generation.

Type	Condition	Minimum performance
Boiler		Efficiency, %
Oil-fired steam	Higher heating value of fuel	85
Oil-fired hot water		80
Gas-fired steam		80
Gas-fired hot water		80
Heat Pump	Inlet water temperature 30 C, ambient air 30 C	Coefficient of performance
	Outlet water temperature 50 C	3.5
	Outlet water temperature 60 C	3.0

Note Gas refers to both natural gas and liquefied petroleum gas.

Renewable Energy Accreditation is given for use of solar energy through application of daylighting and photovoltaic power generation.

Daylighting It has been reported that daylight illuminance from sky on any vertical façade exceeds 5 klux and 10 klux at frequencies of 90% and 75% respectively. Daylight illuminance is expected to be sufficient on a work plane extending from the window to a distance of up to 1.5 times the height of window, as measured from the height of work plane. The row(s) of luminaries designed to serve this space along the row(s) of window(s) and up to 1.5 times such height is discounted from calculation of power density of lighting for the building if

1) the row(s) of luminaries is separately switched from the rest of the space, and
2) the product of visible transmittance of glazing and shading coefficient of external shading device exceeds 0.3, and
3) the value of visible transmittance of the glazing exceeds the value of its solar heat gain coefficient.

Opaque wall sections are allowed to intersperse glazed windows. Width of wall section(s) of up to the window width is allowed. Figure 2 illustrates the configuration of windows with interspersing wall section(s), height of window above work plane, and accredited luminaries.

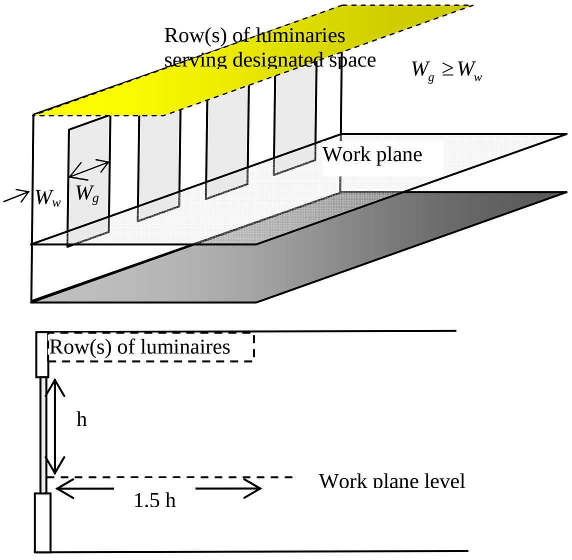

Figure 2 Configuration of an accredited daylighted space.

Photovoltaic (PV) power generation Accreditation is given to expected electricity to be generated from photovoltaic power system. This can be used to discount whole building energy use calculated from a relationship to be presented in the next section. For a given PV system with system efficiency η_s, expected annual electricity generated is calculated from

$$E_{pv} = 9*365*\eta_s*ESR,$$

where *ESR* is effective solar radiation. Its value for a given inclined plane in any direction is obtainable from Table 6.

Table 6 Values of effective solar radiation for calculation of electricity from PV generation.

Inclination angle degree	Direction							
	North	North east	East	South east	South	South west	West	North west
0	437.4	437.4	437.4	437.4	437.4	437.4	437.4	437.4
15	405.0	421.7	433.6	440.0	441.6	438.9	431.5	419.5
30	359.0	390.2	413.0	425.5	428.6	423.0	408.4	385.6
45	306.7	348.3	379.6	397.2	401.5	393.2	372.6	341.6
60	255.4	301.6	337.6	358.4	363.5	353.2	328.6	293.3
75	212.4	255.6	291.2	312.7	317.7	306.5	281.1	246.7
90	185.1	215.8	244.5	263.1	267.4	256.8	234.6	207.6

3.3 Whole Building Energy Compliance

If one or more of the three systems of a proposed building design cannot comply with the corresponding system performance requirement, then the developer can submit the proposed building design to be assessed under the whole building energy compliance procedure.

Rated Energy Requirement of a Proposed Building Design. The rated energy requirement of the proposed building design is calculated from the following relationship

$$\begin{aligned} E_{pa} \quad = \quad & \sum_{\substack{i=1 \\ i\neq j}}^{n} \left[\frac{A_{wi}\left(OTTV_i\right)}{COP_i} + \frac{A_{ri}\left(RTTV_i\right)}{COP_i} \right. \\ & + \left. A_i \left\{ \frac{C_l\left(LPD_i\right) + C_e\left(EQD_i\right) + 130C_o\left(OCCU_i\right) + 24C_v\left(VENT_i\right)}{COP_i} \right\} \right] n_h \\ & + \sum_{i=1}^{n} A_i\left(LCD_i + EQD_i\right) n_h \end{aligned}$$

The first summation in the expression above accounts for rated air-conditioning energy for a year, and the second summation accounts for the energy consumed directly by lighting and other equipment. The summation includes all air-conditioned zones and unconditioned spaces, and accounts for the corresponding area of each space. No air-conditioning energy is contributed from unconditioned spaces. The values of coefficients of thermal power contribution to the load of the air-conditioning systems by lighting, equipment, occupants and ventilation: C_l, C_e, C_o, and C_v are given in Table 7. The rated energy requirements of a building accounts for energy use during the nominal operating hour, n_h, of the given building category only. The number of operating hours of each building category is also given in Table 1.

Table 7 Values of coefficients of thermal power contribution of each type of building.

Building Category	C_l	C_e	C_o	C_v
Office and School	0.84	0.85	0.90	0.90
Department store, hypermarket, and miscellaneous				
Hotel, hospital, condominium, and hostel	1.0	1.0	1.0	1.0

Rated Energy Requirement of the Reference Building. A reference building model of the same shape, same floor area, same envelope area and same orientation is set up when the whole building energy compliance option is required. The model possesses air-conditioned zones and unconditioned spaces identical to those of the proposed building design. Each zone and each space comprises equipment power density (EQD), density of occupancy (OCCU), and ventilation rate (VENT) identical to those in the zones and spaces of the proposed building design. However, the OTTVs of the walls and RTTVs of the roofs in all facades of the reference building uniformly comply with required values of OTTV and required values of RTTV of building of that category. Lighting power density in each zone and space takes on a common lighting power density value LPD_c that complies with the relevant minimum performance requirements of the relevant category of building. The coefficient of performance of each air-conditioning system serving a space *i*, COP_{ci}, complies with the required standard performance of the given type and size. The rated energy requirement of the reference building model is to be calculated from the following formulation

$$\begin{aligned} E_{pc} = & \sum_{\substack{i=1 \\ i\neq j}}^{n} \left[\frac{A_{wi}(OTTV_c)}{COP_{ci}} + \frac{A_{ri}(RTTV_c)}{COP_{ci}} \right. \\ & + \left. A_i \left\{ \frac{C_l(LPD_c) + C_e(EQD_i) + 130C_o(OCCU_i) + 24C_v(VENT_i)}{COP_{ci}} \right\} \right] n_h \\ & + \sum_{i=1}^{n} A_i(LPD_c + EQD_i) n_h \end{aligned}$$

The proposed building design is considered to comply under whole building energy requirement when E_{pa} is less than or equal to E_{pc}.

4. ASSESSMENT OF POTENTIAL ENERGY AND POWER DEMAND SAVINGS

The new code is scheduled to apply in full to new very large buildings (NVLB). For a new large building (NLB), only its envelope is subject to the requirements of the new BEC. For both types of buildings, it is required that the purpose of the use of a new building must be declared. For an NVLB or NLB, submitted information for construction permission is complete for assessment of compliance with the new BEC.

The methodology we will use is as follows. Relevant data from an energy audit database for each type of and each of the two sizes commercial building is extracted. The data are then used to find values of parameters relevant to energy use for lighting, air-conditioning, and other end-uses of each building type and each size. These parameters are used to either form a building model of each building type and size, or are used to adjust other parameters so that each building model possesses features that are consistent with the values of these parameters. The resulting models are called base case models. The OTTV, RTTV, lighting power-density and performance parameters of the air-conditioning system of each base case model are then changed to comply with those required by BEC. The annual energy (kWh) and peak power demand (kW) of each model using code complying parameter values are now obtained as if these are energy values of a code complying building. This is called the ‘code’ case. We also use our prior experience to change OTTV, RTTV, and other parameters to higher performance levels that offer even lower life cycle costs than those of the code complying models. This case is called the “economic” case. We also calculate energy and power demand savings of the code complying case and of the economic case for each type and size of building. We identify the number and size of very large buildings (VLBs) from the energy audit database. From data obtained from the power distribution utilities, we identify energy consumption of very large buildings (VLBs) and large buildings (LBs) of each building type. Subtracting consumption of very large buildings we then obtain energy consumption of each type of LBs. We assume the year 2007 as the year that NVLBs and NLBs must comply with BEC. Load growths from VLBs and LBs beyond the year 2007 are identified as loads due to NVLBs and NLBs. We consider two scenarios of energy savings, the code or standard case and the promotion case. We calculate annual savings and cumulative savings for both scenarios for the year 2016, which is the last year of the present power development planning period.

4.1 Energy Audit Base 5

This is the database of information extracted from energy audit reports of designated buildings (DBs). The present byelaws of ECP Act define DBs as those commercial customers of the electric utilities that require 1,000 kW or more of electric power or are connected to the distribution supply with transformers of capacity 1,250 kVA or higher. A customer in this category may own one large or many small buildings and is connected to the utility with one meter.

The existing bye-laws also required that each DB conducted an energy audit, to be assisted by a registered consultant. The costs all energy audits have been born by the ENCON Fund. Up to 1,800 DBs have been audited. Each audit report must be approved by the Department for Alternative Energy Development and Energy Efficiency. The Department compiles information from the audit reports into databases. One of the more detailed database is coded Audit Base 5. There are over 1,500 entries pertaining to over 1,500 individual DBs in this database. Data from Audit Base 5 is sorted for eight types of commercial buildings.

Summary Information from Audit Base 5 Table 8 exhibits summary information on the eight types of DBs.

Table 8 Summary information related to energy indexes of each type of DBs.

	Item	Unit	Office	Hotel	Hospital	Dept	School	Misc.	Condo	Hyper
1	AC energy/AC area,	kWhm^{-2}.Y^{-1}	115.20	143.18	162.14	184.93	76.22	216.54	168.06	165.43
2	Light energy/used area ,	kWhm^{-2}.Y^{-1}	12.87	27.02	24.07	56.20	11.05	26.02	12.23	84.77
3	Other energy/used area,	kWhm^{-2}.Y^{-1}	58.71	27.95	25.83	76.74	6.29	43.16	16.65	136.17
4	Total energy/used area,	kWhm^{-2}.Y^{-1}	102.93	148.44	115.98	268.66	37.28	117.53	66.05	359.63
5	AC area/total area		0.28	0.65	0.41	0.68	0.27	0.32	0.26	0.72
6	AC energy/total energy		0.41	0.64	0.56	0.52	0.53	0.43	0.58	0.39
7	Lighting energy/total energy		0.22	0.19	0.22	0.22	0.32	0.20	0.22	0.24
8	OTTV	Wm^{-2}	55.54	51.40	57.21	45.25	55.61	60.58	49.97	36.26
9	RTTV	Wm^{-2}	33.86	23.35	31.01	20.86	29.09	27.53	17.37	22.91
10	AC performance -split type	kW/RFT	1.51	1.64	1.59	1.48	1.51	NA	0.20	0.20
11	-window type	kW/RFT	1.83	1.76	NA	NA	2.03	NA	NA	1.45
12	-package type	kW/RFT	1.38	NA	1.30	1.06	NA	NA	NA	NA
13	-chillers	kW/RFT	1.02	1.09	0.75	0.71	1.07	NA	NA	2.08

Theses are office, hotel, hospital, department store, school or educational institute, miscellaneous (This. includes restaurants and other entertainment places.), condominium and hostel, and hypermarket. Energy audits have been conducted since early 1996. It is expected that the database includes information from reports conducted up to 2003. The date of report submission and ages of buildings are unavailable. We assume that the information in Table 8 is applicable to recent buildings.

Number of Very Large Buildings The database also contains information on the area of each building audited. From such information, the number and other information of existing VLBs are obtained as shown in Table 9. Most VLBs are situated in the Metropolitan area (Bangkok and three surrounding provinces) served by the Metropolitan Electricity Authority (MEA), while few are situated in remaining part of Thailand served by the Provincial Electricity Authority (PEA).

Table 9 Number of very large buildings (VLBs) of each type of buildings.

Building type	Energy kWhm^{-2}	Area m^2	Region		
			MEA	PEA	Total
Office	146.4	41,019	183	2	185
Hotel	173.3	37,749	65	65	130
Hospital	148.8	31,918	37	42	79
Department store	556.0	29,530	52	30	82
School	93.9	19,810	3	6	9
Miscellaneous	139.6	59,701	11	15	26
Condominium	118.3	26,697	40	4	44
Hypermarket	394.6	26,021	50	20	70

From the identified VLBs, summary information similar to those in Table 8 were also extracted and used to form a model for each of the eight types of VLBs.

4.2 Building Models

Creating models of commercial buildings is the second step in the assessment process. The energy relationship described in Section 3.1 and the equation shown in Section 3.3 are used as bases for forming the models. Diversity factors that account for diversity of lighting use, equipment use and space use are utilized for adjusting the energy outputs from the models to match with those from Table 8. Table 10 list values of some physical parameters for a model of *department store* of usable area of 29,530 m^2. This model represents a very large department store building.

Table 10 Values of physical parameters for the model of department store.

Item	Values
5-storey, height 6m/floor, dimension 80mx50m	
Total area of roof, Ar (m^2)	5,906
Total wall area, Aw (m2)	7,685
Total usable area, At (m2)	29,530
Total area of air-conditioned space, Afac	25,369
Un-conditioned area, Au (m2)	4,161
Ratio of wall area to A/C floor area,	0.30
Ratio of roof area to A/C floor area,	0.23

Table 11 lists values of relevant energy parameters of the building model for three cases. For the base case, values of OTTV, RTTV, lighting power density, air-conditioning performance parameters, and others are extracted from Energy Audit Base 5 for the case of VLBs. These values from summary audit information are used to adjust input parameters of the model such as lighting power density, equipment power density, so that the resultant values of output parameters from the model match with those from the database.

Table 11 Values of input parameters for a model of department store, for three cases: base, code compliance, and economic.

Item	Base	Code	Econ
Envelope			
OTTV (W.m^{-2})	43.6	40.00	20.60
RTTV (W.m^{-2})	17.6	12.00	12.00
Air-conditioning			
Chiller, COP	4.95	5.41	6.39
Other part, COP	5.02	7.03	8.79
System, COP	2.49	3.06	3.70
Lighting			
Lighting power density in A/C area, LPD$_a$ (W.m^{-2})	27.30	18.00	14.00
Diversity factor lighting in A/C area, D$_{fla}$	0.80	0.80	0.80
Lighting in un-conditioned space, LPD$_u$ (Wm^{-2})	6.26	6.26	5.00
Equipment			
Equipment power density in A/C area, EQD$_a$ (W.m^{-2})	19.50	19.50	18.00
Diversity factor for equipment in A/C space, D$_{feu}$	0.90	0.90	0.90
Equipment power density for un-cond space, EQD$_u$ (W.m^{-2})	5.00	5.00	5.00
Occupancy			
Occupancy in A/C space (Wm^{-2})	20.00	20.00	20.00
Diversity of occupants in A/C area, D$_{foa}$	0.80	0.80	0.80
Ventilation (l.m^{-2}.s^{-1})	1.00	1.00	1.00
Night (off-time) light & security power, P$_n$ **(**W/m^{-2}**)**	2.95	2.56	2.56
Lighting (Wm^{-2})	2.25	2.00	2.00
Equipment (Wm^{-2})	0.70	0.56	0.56
Work hours, N$_{oh}$	4380	4380	4380
Night (off-time) hours, N$_{nh}$	4380	4380	4380

For the 'code' case, values of OTTV, RTTV, lighting power density, and others correspond to those required by the BEC. In the 'economic' case, insulation is applied economically to opaque wall to reduce the OTTV to 20.6 Wm^{-2}. Efficient fluorescent lamps and electronic ballasts are assumed used in this case to give a lighting power density of 14 Wm^{-2}. High performance chillers with well-planned air and water delivery systems are also assumed used so as to render coefficient of performance of air-conditioning system of 3.7.

Table 12 presents summary results from the model. For the department store model, the 'code case' shows significant savings due mainly to substantial improvement in lighting. Air-conditioning system also improves and contributes to the overall savings. The 'economic' case improves over the 'code' case to some extent. For department store, the OTTV is generally small. As shown in the case here, implementation of BEC will not lead to significant improvement of its OTTV.

Table 12 Values of energy output parameters from the model for the three cases.

Item	Base	Code	Economic
Power demand, kW	4036.0	2987.5	2813.9
Total kWh/used area	555.9	394.3	367.9
AC kWh/AC area	200.3	152.0	121.0
Light kWh/used area	129.6	63.2	44.7
Others kWh/used area	254.1	254.1	254.1

Information from a load shape study published by the National Energy Policy Office, [18], was used to construct load shape of the load for our department store model. The result is shown in Figure 3.

The load shape for the 'code' case shows substantial reduction in electric power demand when compared to that of the base case. This result clearly illustrates that energy efficiency due to implementation of BEC, and promotion program to pull it beyond code level accrue benefits both in terms of electric energy savings and electric power demand savings. The latter savings will reduce requirements for additional power generating plant. For a developing economy where electric load grows at substantial level annually, this can lead to significant national savings.

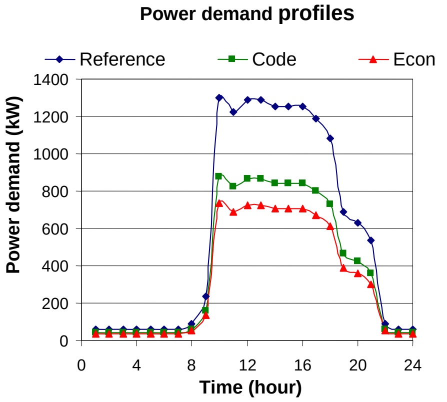

Figure 3 Resultant load shapes for the department store model for three cases: base, code compliance, and economic.

Summary Energy Consumption from Models Sixteen models, each similar to that of the foregoing example, were formed. Eight models for eight types of VLBs and eight models for eight types of LBs were used to produce results shown in Table 13. The results will be used for assessment of macro-level savings. Power demand for each building type, for each case, and for both VLBs and VBs are also obtained from the models but not shown here.

Table 13 Values of energy consumption index from building models.

Building type	Large buildings, kWh/m^2			Medium buildings, kWh/m^2		
	Base	Code	Econ	Base	Env	Econ
Office	146.4	98.7	82.3	102.9	98.4	69.3
Hotel	173.2	117.0	101.7	148.4	138.1	102.9
Hospital	148.8	123.9	112.0	116.0	108.3	89.7
Dept store	556.0	394.3	368.0	268.7	256.9	168.3
School	94.0	79.3	67.2	37.3	35.0	25.0
Misc	139.7	117.2	100.0	117.5	97.9	67.5
Condo	118.4	105.3	92.7	66.0	62.4	52.0
Hyper	394.7	300.9	248.7	359.6	322.3	221.3

Note Env refers to the case where building envelope only complies with requirements.

4.3 Energy and Power Demand of Existing Buildings

The database, Audit Base 5, contains information on buildings audited from 1996 to around 2004. We assume the database contains energy information pertaining to year 2001, that we take as our reference year. From the number of VLBs and base case energy consumption identified and as shown in Table 9, we calculate total base case energy consumption of each type of these VLBs. The database of MEA and PEA contains information on aggregate energy consumption of each type of VLBs and LBs for year 2001. The total consumption of each type of VLBs obtained is used to subtract from the aggregate consumption from MEA and PEA database to obtain energy consumption of each type of LBs for year 2001. These base case results are shown in Table 14.

The value of power demand obtained from the department store model such as that given in Table 12 is taken as proportionate to energy consumption from the building model. This proportion is used with value of energy consumption of the department store group to obtain power demand for this group of VLBs. The same procedure is used to obtain power demand of other types of VLBs and LBs.

Table 14 Energy consumption and power demand of base case VLBs and LBs in 2001, with energy and power demand of MEA, PEA and EGAT.

Item	**Year 2001**		
EGAT Energy Generation, GWh	**103869**		
EGAT Power Demand, MW	**16126**		
MEA			
Energy Demand, GWh	**35323**		
Power Demand, MW	**6229**		
Building type	**VLBs**	**LBs**	**Total**
Office	1099.0	2349.4	3448.4
Hotel	425.2	536.9	962.0
Hospital	175.8	522.0	561.9
Department store	82.1	522.0	1082.6
Education	5.6	451.9	457.5
Misc	58.6	376.0	434.6
Condominium	126.4	396.6	522.9
Hypermart	513.4	0.0	513.4
Total, GWh	2486.0	5154.8	7983.4
Total, MW	594.9	972.3	1567.2
PEA			
Energy Demand, GWh	**60963.2**		
Power Demand, MW	**9456.3**		
Building type	**VLBs**	**LBs**	**Total**
Office	12.0	1492.3	1504.3
Hotel	425.2	837.2	1262.4
Hospital	199.5	500.8	700.3
Department store	16.4	775.7	792.2
Education	11.2	699.1	710.2
Misc	158.3	398.7	557.1
Condominium	12.6	223.4	236.1
Hypermart	205.4	0.0	205.4
Total, GWh	1040.6	4927.3	5967.9
Total, MW	164.8	1002.8	1167.6

Sums of power demand values of all groups are reported at the last row where total energy consumptions appear one row above, both for MEA and PEA areas, in Table 14. Energy and power demand of the whole service areas of MEA and PEA are shown in the table for comparison.

Table 15 Energy consumption and power demand of base case VLBs and LBs in 2007.

Item	**Year 2007**		
EGAT Energy Generation, GWh	**158212**		
EGAT Power Demand, MW	**24344**		
MEA			
Energy Demand, GWh	**49469**		
Power Demand, MW	**8752**		
Building type	**VLBs**	**LBs**	**Total**
Office	1539.2	3290.3	4829.4
Hotel	595.4	751.9	1347.3
Hospital	246.2	731.0	786.9
Department store	115.0	731.0	1516.1
Education	7.8	632.9	640.7
Misc	82.0	526.6	608.7
Condominium	177.0	555.4	732.4
Hypermart	719.0	0.0	719.0
Total, GWh	3481.6	7219.2	11180.6
Total, MW	833.1	1361.7	2194.8
PEA			
Energy Demand, GWh	**98455**		
Power Demand, MW	**14853**		
Building type	**VLBs**	**LBs**	**Total**
Office	19.4	2410.0	2429.4
Hotel	686.6	1352.1	2038.8
Hospital	322.2	808.8	1131.0
Department store	26.5	1252.8	1279.3
Education	18.0	1129.0	1147.0
Misc	255.7	643.9	899.7
Condominium	20.4	360.9	381.3
Hypermart	331.7	0.0	331.7
Total, GWh	1680.6	7957.5	9638.1
Total, MW	266.2	1619.5	1885.7

The energy and power generation required on the Electricity Generating Authority of Thailand (EGAT), the generation utility, are also shown at the top of Table 14. The power and energy generation figures of EGAT already account for transmission losses.

For the year 2007, we assume that the energy and power demand of VLBs and LBs will grow proportionately to the load growth of MEA, PEA, and EGAT. We assume that the new BEC is implemented in 2007. All NVLBs and NLBs from the year 2008 onwards comply with the new BEC. The forecasted total loads and those of VLBs and LBs for the year 2007 are shown in Table 15.

Energy consumption from the VLBs and LBs grow substantially from those in the year 2001. These consumption and demand are all at the frozen efficiency levels of 2001. In MEA region, electricity consumption by VLBs and LBs accounts for 23% of the total. In PEA region, the proportion is 10%. For the whole system, the proportion is 13%.

4.4 Energy and Power Demand Savings

We consider two scenarios of energy and power demand savings as a result implementation of the new BEC. These are the Code Scenario and the Promotion Scenario.

Code Scenario In this scenario, NVLBs must comply fully with requirements of new BEC, while NLBs comply only with the envelope requirements. All existing VLBs and LBs consume energy at the base level. Table 16 shows these requirements on all commercial buildings.

Table 16 Requirements on NVLBs and NLBs for the Code Scenario**.**

Buildings	**Very Large**	**Large**
New	Envelope, lighting, air-conditioning, and hot water	Envelope only
Existing	Base	Base

Table 18 shows the results of energy and power demand savings for this case in the year 2016. In the table, the values in the columns under ‘Old base’ represent energy and power demand of existing or old VLBs and LBs, frozen since 2008, The values in the column under “New code’ correspond to those from NVLBs that comply with the full requirements of the code, while those under ‘New env case’ correspond to those from LBs that comply with the envelope requirements. The values under ‘Code savings’ for NVLBs and those under ‘Env savings’ for NLBs are energy and power demand savings from NVLBs and NLBs that comply with the new BEC.

Total system savings of energy and power demand appear in the upper right hand corner of Table 18, under ‘Savings for year 2016’ The savings on EGAT’s system are obtained from adjusted savings from MEA and PEA loads using a factor that accounts for transmission losses. Resulting energy saving is 2753.5 GWh and power demand saving is 292.9 MW. The cumulative energy savings from the year 2008 to the year 2016 is also shown to be 8274.2 GWh. Such savings would results from mandatory implementation of new BEC that requires minimal investment from the state.

This scenario would result from strict adherence to implementation of mandatory BEC by the state while building developers try to minimize initial investment costs. This is not very realistic.

Promotion Scenario In this scenario it is assumed that there are promotional programs by the state so that some developers of new buildings are convinced of life cycle benefits and costs and choose economic or lower life cycle costs options for the envelope, lighting, and air-conditioning systems. Most developers still comply only with the minimum requirements of BEC. Also, proprietors of some existing buildings decide to retrofit their buildings to achieve economic level when the lives of some building systems end. Table 17 summarizes the assumptions used in this case.

Table 17 Assumptions used in the 'Promotion' scenario.

Buildings	**Year**	**Very Large Buildings**	**Large buildings**
New	2010	85% Code 15% Economic	80% Envelope 20% Economic
	2016	60% Code 40% Economic	55% Envelope 45% Economic
Existing	2010	10% Economic	15% Economic
	2016	25% Economic	40% Economic

Table 19 shows the results for the year 2016. It is assumed that more economic options are chosen for large buildings than for very large buildings and that promotional programs are successful so that economic options are increasingly chosen, both for new buildings and for retrofitted buildings.

There are five columns of values under 'Very Large Buildings'. The values in the first column among these five represent energy and power demand of buildings existing from 2007 at frozen energy efficiency. The values in the second column represent those from new buildings (completed during 2008 and 2016) at base (or present) energy efficiency levels. The values in the third column represent savings in 2016 from 25% (as assumed in Tabl1 17) of existing buildings that have been retrofitted at economic level. The values in column four represent savings form 60% of new buildings that comply with the code. The values in the last column represent savings from 40% of new buildings that are constructed with systems rated at economic efficiency levels.

Those values in the five columns under 'Large Buildings' are similar to those in the previous five columns except that new large buildings either comply with the envelope requirements of the code or their systems are at economic efficiency levels.

Total energy and power demand savings for the year are 5724.7 GWh and 1121.5 MW respectively. These are equivalent to 2% of energy or power demand in that year. Cumulative energy savings from 2008 amounts to 21,208.7 GWh, which is about 7.5% of energy demand in 2016.

5 CONCLUSION

We have presented the components of the revised BEC of Thailand. We also have described steps in the assessment and presented results from assessment of energy efficiency benefits from implementation of the code. Two scenarios are used in the assessment. The first scenario is very basic and conservative. The second scenario is more optimistic. However, information from Audit Base 5 shows that there are still fewer very large buildings outside of Metropolitan Bangkok. The percentages of air-conditioned areas in buildings outside Bangkok are also relatively low for most types of buildings. Unfortunately, air-conditioning will increasingly penetrate into buildings and dwellings. Without serious energy conservation effort, the increasing level of energy consumption due in part to consumption by commercial buildings can threaten our energy sustainability.

The promulgation of the ECP Act and the corresponding bye-law together with the establishment of the ENCON Fund gave rise to considerable expectation of systematic and progressive execution energy conservation activities. Unfortunately we have not witnessed efforts that match our expectations. Ten years have passed but we might be heading back towards the situation in the formative years in 1980s. This paper is intended to convince readers that the potential for savings is there, but it needs earnest implementation to achieve these savings.

Table 18 Energy and power demand of very large and large buildings in 2016 under 'Code' scenario.

Item	**Value**			
EGAT Energy Generation, GWh	**282488**	Savings in year 2016	**2753.5**	GWh
EGAT Power Demand, MW	**43558**		**292.9**	MW
		Cumulative savings from 2008	**8274.2**	GWh

MEA

Energy Demand, GWh	**84882**
Power Demand, MW	**15029**

Building type	**Very Large Buildings**			**Large Buildings**			**Total Savings**
	Old Base	New Code	Code Savings	Old Base	New Env case	Env Savings	
Office	1539.2	742.6	359.2	3290.3	2250.6	104.7	**463.9**
Hotel	595.4	287.9	138.3	751.9	500.7	37.5	**175.8**
Hospital	246.2	146.7	29.5	731.0	488.6	34.8	**64.3**
Department store	115.0	58.4	23.9	731.0	500.5	22.8	**46.8**
Education	7.8	4.7	0.9	632.9	424.9	28.2	**29.1**
Misc	82.0	49.3	9.4	526.6	313.9	63.1	**72.5**
Condominium	177.0	112.8	13.9	555.4	375.4	22.2	**36.1**
Hypermart	719.0	392.4	122.3	0.0	0.0	0.0	**122.3**
Total, GWh	3481.6	1794.9	697.5	7219.2	4854.7	313.3	**1010.8**
Total, MW	833.1	429.5	166.9	816.0	548.7	35.4	**114.2**

PEA

Energy Demand, GWh	**184024**
Power Demand, MW	**27608**

Building type	Old Base	New Code	Code Savings	Old Base	New Env	Env Savings	**Total Savings**
Office	19.4	11.4	5.5	2410.0	6263.7	291.5	**297.0**
Hotel	686.6	403.1	193.6	1352.1	3421.5	256.3	**450.0**
Hospital	322.2	233.2	46.9	808.8	2053.8	146.1	**193.0**
Department store	26.5	16.3	6.7	1252.8	3258.9	148.7	**155.4**
Education	18.0	13.2	2.4	1129.0	2879.7	191.0	**193.5**
Misc	255.7	186.6	35.7	643.9	1458.4	293.1	**328.8**
Condominium	20.4	15.8	2.0	360.9	926.8	54.7	**56.7**
Hypermart	331.7	219.8	68.5	0.0	0.0	0.0	**68.5**
Total, GWh	1680.6	1099.3	361.3	7957.5	20262.9	1381.4	**1742.7**
Total, MW	266.2	174.1	57.2	816.0	2077.8	141.7	**178.7**

Table 19 Energy and power demand of very large and large buildings in 2016 under the ‘Promotion’ scenario.

Item	Value			
EGAT Energy Generation, GWh	**282488**	Savings in year 2016	**5724.7**	**GWh**
EGAT Power Demand, MW	**43558**		**1121.5**	**MW**
		Cumulative savings from 2008	**21208.73**	**GWh**

MEA

Energy Demand, GWh	**84882**
Power Demand, MW	**15029**

Building type	**Very Large Buildings**					**Large Buildings**					**Total Savings**
	Old Base	New Base	Old Econ Savings	New Code Savings	New Econ Savings	Old Base	New Base	Old Econ Savings	New Env Savings	New Econ Savings	
Office	1539.2	1101.8	168.4	215.5	192.9	3290.3	2359.8	430.0	57.7	347.0	**1411.5**
Hotel	595.4	426.3	61.4	83.0	70.4	751.9	539.2	92.2	20.7	74.4	**402.1**
Hospital	246.2	176.2	15.2	17.7	17.4	731.0	524.3	66.3	19.1	53.5	**189.4**
Department store	115.0	82.3	9.7	14.4	11.1	731.0	524.3	109.2	12.6	88.1	**245.1**
Education	7.8	5.6	0.6	0.5	0.6	632.9	453.9	83.5	15.5	67.4	**168.2**
Misc	82.0	58.7	5.8	5.7	6.7	526.6	377.7	89.7	34.8	72.3	**214.9**
Condominium	177.0	126.7	9.6	8.4	11.0	555.4	398.3	47.3	12.2	38.1	**126.6**
Hypermart	719.0	514.7	42.7	73.4	48.9	0.0	0.0	0.0	0.0	0.0	**165.0**
Total, GWh	3481.6	2492.4	313.5	418.5	359.1	7219.2	5177.7	918.2	172.6	740.9	**2922.8**
Total, MW	833.1	596.4	75.0	100.1	85.9	1361.7	976.6	219.7	32.6	139.7	**551.3**

PEA

Energy Demand, GWh	**184024**
Power Demand, MW	**27608**

Building type	Old Base	New Base	Old Econ Savings	New Code Savings	New Econ Savings	Old Base	New Base	Old Econ Savings	New Env Savings	New Econ Savings	**Total Savings**
Office	19.4	16.7	2.1	3.3	2.9	2410.0	2069.6	315.0	50.6	304.3	**678.2**
Hotel	686.6	589.7	70.9	114.8	97.3	1352.1	1161.1	165.8	44.5	160.2	**653.5**
Hospital	322.2	276.7	19.9	27.8	27.4	808.8	694.5	73.4	25.4	70.9	**244.7**
Department store	26.5	22.8	2.2	4.0	3.1	1252.8	1075.8	187.1	25.8	180.8	**403.1**
Education	18.0	15.5	1.3	1.5	1.8	1129.0	969.5	149.0	33.2	143.9	**330.6**
Misc	255.7	219.6	18.1	21.2	24.9	643.9	553.0	109.6	50.9	105.9	**330.7**
Condominium	20.4	17.5	1.1	1.2	1.5	360.9	309.9	30.7	9.5	29.7	**73.7**
Hypermart	331.7	284.8	19.7	40.6	27.1	0.0	0.0	0.0	0.0	0.0	**87.4**
Total, GWh	1680.6	1443.2	135.4	214.2	186.0	7957.5	6833.5	1030.7	239.9	995.7	**2801.9**
Total, MW	266.2	228.6	32.4	51.3	44.5	1619.5	1390.8	246.6	48.8	202.7	**570.2**

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