Potential Energy and Power Demand Savings from Application of New Building Energy Code in Thailand

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Abstract 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 funded energy audits carried out by consultants on all DBs that number around 1,800. In 2002, a project was launched with the support of the Danish Agency for International Development (DANIDA) to revise the building energy code, from which the requirements for energy conservation in the Bye-Laws have been based. The new code continues to adopt system performance requirements for building envelope, lighting, and air-conditioning. More over, the new code accounts for different patterns of use of DBs and building facilities. 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 to new large commercial buildings only. 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 reminds us again of the finiteness of natural resources. It also reminds us that energy conservation and energy efficiency can reduce costs of energy with no adverse impact on the environment. Unlike development of alternative energy sources, energy conservation can be implemented immediately with no gestation period, such as that required for an energy generating plant.

Thailand was a net energy importing country ever since it began its first Economic and Social Development Plan (NESDB) to embark on a new phase of coordinated economic development. During 1970s and early 1980s, it was found that imported commercial energy sources accounted for over 50% of total energy consumption, and import bill from oil accounted up to 60% of total import cost. When ASEAN was formed for economic (and political) cooperation among the Southeast Asian nations, energy cooperation became a core issue. When ASEAN initiated joint activities with dialog partners, that included Australia, Canada, and USA, energy conservation was a common subject in the joint activities.

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, [1]. 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, [2], 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, [3]. 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. [4] and [5]. Wong, etal, [6], 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, [7]. 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, [8]. A new building is considered to meet the Mexican requirements on building enveloped 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 [9], the Energy Conservation Promotion Act of Thailand was promulgated in 1992. Mandatory energy conservation for large commercial buildings became mandatory in 1995 after a set of bye-laws on BEC was announced. The Energy Conservation Promotion Fund (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 to revise the BEC. The new code is now scheduled to apply in full to large new commercial buildings only. A new building with floor area exceeding 10,000m^2 (ten thousand square meter) must comply with requirements on building envelope, lighting, and air-conditioning before its design is approved for construction. Even though the existing Bye-law have similar requirements, no mechanism of enforcement has been developed. No inspection of design has been undertaken for buildings constructed between 1995 and the present. It is suspected that most new buildings constructed in the period do not comply with the code. The present effort include the redevelopment of a computer code for evaluation of the compliance of a building design, provision of a handbook to assist building designers, and training of building professionals on how to comply with the requirements. The responsibility that a building design complies with the requirements of the code rests with the building designer, consonant with the present practice on building safety compliance. The building control committee is in the process of preparing the draft of a bye-law of the Building Control act that requires a building design to also comply with the requirements of the ECP Act. An item on energy conservation in the check list of requirements for a new building to comply will be added so that authorizing officials could use 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.

Since the code is scheduled to be implemented in earnest, it is deemed that an assessment of the energy and power demand savings benefits of the code would lend further weight to help convince all members of the society that the whole effort is worthy. This paper is intended the report some results of such assessment.

2. DEVELOPMENT AND APPLICATION OF BUILDING ENERGY CODE IN THAILAND

2.1 Components of existing Thai code.

Studies conducted during early 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, [10]. 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.

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 [11]. 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, 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 optimum targets, while the performance requirements were meant to be minimum requirements at the onset. 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. 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.

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 [12] and is conceptually identical to the formulation employed in the Singapore code, [13] and Hong Kong code, [14]. In the development of the new code, a new concept 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.

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 [15] 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 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 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 groups of buildings.

Building Category	Usage time	Number of hours per year
Office and education institute	8.00-17.00	2,340
Department store, restaurant, and hypermarket	10.00-22.00	4,380
Hospital, hotel, and hostel	24 hours	8,760

The new OTTV formulation takes the form

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

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 and in all codes 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.

Air-ha

3.2 Energy Performance Requirements

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

Outs

Application of Life-cycle Costing 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 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.

Building Envelope Extensive studies and consultations led to the results shown in Table 2 for the value of minimum performance requirement for the envelope of each building category.

Lighting System A building model was created for each type of building under consideration. Typical functional areas were identified for each building type

Table 2 Recommended 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< 45 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}

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 actually lead to lower power density requirement. Table 3 shows the recommended allowable value for each building category.

Table 3. Recommended allowable rated power density for lighting.

Category of buildings	Allowable rated power (W/m^2 of utilized area)
Offices or educational building	14
Department stores, hypermarket, and restaurant	18
Hotels, hospitals, 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 chillers are shown in Table 4.

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)	(1.30) 2.70
Over 351.7 kW_{th} (100 TR)	(1.20) 2.93
Water-cooled water chiller	
Less than 527.5 kW_{th} (200 TR)	(0.90) 3.91
From 527.5 kW_{th} and less than 703.3 kW_{th} (250 TR)	(0.75) 4.69
From 703.3 kW_{th} and less than 879.2 kW_{th} (300 TR)	(0.67) 5.25
From 879.2 kW_{th} and less than 1,758.3 kW_{th} (500 TR)	(0.65) 5.40
Over 1,758.3 kW_{th}	(0.62) 5.67

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.

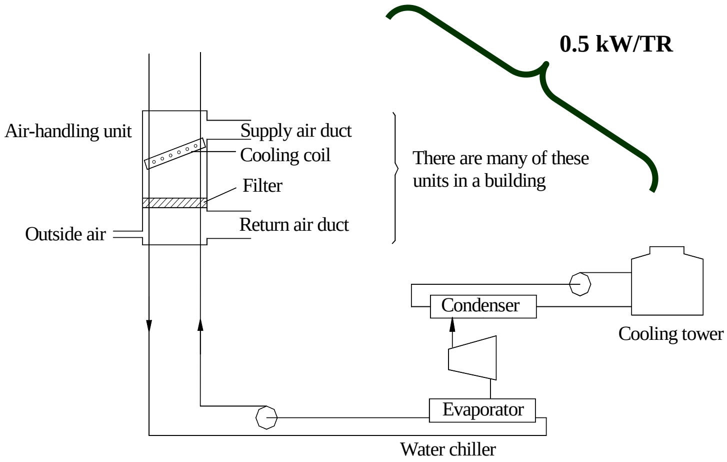

Figure 1. Requirements on other part of the air-conditioning system.

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

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

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 5. 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.

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 andsize.

The rated energy requirement of the reference building model is to be calculated from the following formulation

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

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 to new very large buildings (NVLB) only. 'Very large buildings' in the terminology of the building control law refers to commercial buildings with total usable area (all covered area except car park) of 10,000 m^2 or more. For such buildings, it is required that lighting, electrical, and mechanical (air-conditioning system) designs and layouts are submitted together with its building plans for a building design to be approved. Moreover, the purpose of the use of the building must be declared. For an NVLB, 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 commercial building is extracted. The data are then use to find values of parameters relevant to energy use for lighting, air-conditioning, and other end-uses of each building type. These parameters are used to either form a building model of each building type, 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 reference models. The OTTV, RTTV, lighting power-density and performance parameters of the air-conditioning model of each reference 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. 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 model. This case is called the "economic" case. We also calculate energy and power demand savings for the code complying case and for the economic case for each type of building. We identify the number and size of very large building from the energy audit database. Each of our base case model represents the buildings in each category. From the code complying model and the economic model, we identify total savings the code complying case and the economic case could give. We assume the year 2007 as the year that NVLBs must comply with BEC. Load growth from VLBs beyond the year 2007 is identified as load due to NVLBs. The NVLBs must comply with the new BEC. The difference between the load growth and the load from code complying NVLBs represents savings emanating from implementation of the new BEC. We show also that the economic case offers even more savings. We calculate annual savings and cumulative savings from code complying $NVLB_5$ and economic NVLBs for year 2010 and 2016. These are the reference years in Thailand Power Development Plan.

4.1 Energy Audit Base 5

This is the database of information extracted from energy audit reports of designated buildings (DBs). The present bye-law's define DBs as those commercial customers of the electric utilities that require 1,000 kW or more of power or are connected to the distribution supply with transformers of capacity 1,250 kVA or higher. Such customers may own one or more buildings. A school or an educational institute may have many buildings, each of a few hundred square meters and requiring less than 100 kW, but all buildings together requires over 1,000 kW, would be classified as a DB.

The existing bye- laws also required that each DB conducted an energy audit, to be assisted by a registered consultant. The cost of the energy audits has been born by the ENCON Fund. Up to 1,800 DBs have been audited. Each audit report must be approved. The Department for Alternative Energy Development and Energy Efficiency 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 of pertaining to over 1,500 individual DBs in theis database. Data from Audit Base 5 is sorted for six categories of types of commercial buildings. Table 5 exhibits the summary information on the six types of DBs: office, hotel, hospital, department store (This category includes retail store and hypermart), school or educational institute and miscellaneous (This. includes restaurants and other entertainment places).

Table 5 Summary information related to energy indexes of each type of DBs.

	Item	Unit	Office
1	AC energy/AC area,	$kWhm^{-2}.Y^{-1}$	115.20
2	Light energy/used area ,	$kWhm^{-2}.Y^{-1}$	12.87
3	Other energy/used area,	$kWhm^{-2}.Y^{-1}$	58.71
4	Total energy/used area,	$kWhm^{-2}.Y^{-1}$	102.93
5	AC area/total area		0.28
6	AC energy/total energy		0.41
7	Lighting energy/total energy		0.22
8	OTTV	Wm^{-2}	55.54
9	RTTV	Wm^{-2}	33.86
10	AC performance -split type	kW/RFT	1.51
11	-window type	kW/RFT	1.83
12	-package type	kW/RFT	1.38
13	-chillers	kW/RFT	1.02

Table 5 (continued)

Item	Hotel	Hospital	Dept store	School	Misc.
1	143.18	162.14	184.93	76.22	216.54
2	27.02	24.07	56.20	11.05	26.02
3	27.95	25.83	76.74	6.29	43.16
4	148.44	115.98	268.66	37.28	117.53
5	0.65	0.41	0.68	0.27	0.32
6	0.64	0.56	0.52	0.53	0.43
7	0.19	0.22	0.22	0.32	0.20
8	51.40	57.21	45.25	55.61	60.58
9	23.35	31.01	20.86	29.09	27.53
10	1.64	1.59	1.48	1.51	
11	1.76			2.03	
12		1.30	1.06		
13	1.09	0.75	0.71	1.07	

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 5 is applicable to recent new buildings.

4.2 Building models

Creating models of VLBs 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 5. Table 6 list values of some physical parameter for a model of *department store* of usable area of 20,000 m^2.

Table 6 Values of physical parameters for the model of department store.

Item	Values
5-storey, height 6m/floor, dim 80x50m	
Total area of roof, Ar (m^2)	4,000
Total wall area, Aw (m2)	7,800
Total used area, At (m2)	20000
Total area of air-conditioned space, Afac	15000
Un-conditioned area, Au (m2)	5000
Ratio of wall area to A/C floor area,	0.52
Ratio of roof area to A/C floor area,	0.27

Table 7 list values of important energy related parameters of the building model for three cases. For the base case, values of OTTV, RTTV, and air-conditioning performance are taken from energy audit reports (Table 5). Audit Base 5 contains energy consumption parameters such as air-conditioning energy ($kWhY^{-1}$) air-conditioned area (m^2), lighting ($kWhm^{-2}Y^{-1}$), total energy index ($kWhm^{-2}Y^{-1}$), etc. These values from summary audit information are used to adjust input parameters of the model in Table 7 such as lighting power density, equipment power density, so that the resultant values of output parameters from the model shown in Table 8 match with those from Table 5

Table 7 Values of input parameters for a model of department store, for three cases: base, code compliance, and economic.

Envelope	Ref	Code	Econ
OTTV ($W.m^{-2}$)	45.25	45.00	20.60
RTTV ($W.m^{-2}$)	20.86	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 fin A/C area, LPDo ($W.m^{-2}$)	27.30	18.00	14.00
Diversity factor for A/C area lighting, Dflo	0.80	0.80	0.80
Lighting cost for office ($B.m^{-2}.Y^{-1}$)	23.50	30.57	
Lighting in un-conditioned space, LPDu (Wm^{-2})	6.26	6.26	5.00
Equipment			
Equipment power density for A/C area, EQDo ($W.m^{-2}$)	19.50	19.50	18.00
Diversity factor for equipment in A/C space, Dfeo	0.90	0.90	0.90
Equipment power density for un-cond space, EQDo ($W.m^{-2}$)	5.00	5.00	5.00
Occupancy			
Occupant-A/C space ($W.m^{-2}$)	20.00	20.00	20.00
Diversity of occupants in A/C area, Dfoc	0.80	0.80	0.80
Ventilation ($l.m^{-2}.s^{-1}$)	1.00	1.00	1.00
Night (off-time) light & security power, Pn (W/m^{-2})	2.95	2.56	2.56
Light	2.25	2.00	2.00
Equipment	0.70	0.56	0.56
Work hours, Noh	4380.	4380.	4380.
Night (off-time) hours, Nnh	4380.	4380.	4380.

Table 8 Values of energy output parameters from the model for the tree cases.

Item	Reference	Code	Economic
Power demand, kW/used area	62.52	42.14	35.28
Total kWh/used area	267.0	177.8	142.1
AC kWh/AC area	178.0	132.3	88.2
Light kWh/used area	56.3	35.9	26.4
Others kWh/used area	59.3	59.3	55.3

Information from a load shape study published by the National Energy Policy Office [16], was used to construct load shape of the load for our department store model. The result is shown in Figure2.

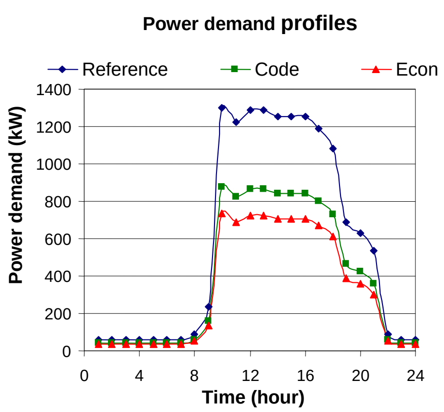

Figure 2 Resultant load shapes for the department store model for three cases: base, code compliance, and economic.

Input values to the model for the code compliance case and the economic case are also shown in Table 1. The resultant output values for these two cases are shown in Table 8 and illustrated in the load shapes in Figure 2.
The number of very large commercial buildings for each type of building is identified from Audit Base 5. The results are shown in Table 9.

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

Building type	Region		
	MEA	PEA	Total
Office	183	2	185
Hotel	65	65	130
Hospital	37	42	79
Dept store	52	30	82
School	3	6	9
Misc.	11	15	26

4.3 Energy and Power Demand of Very Large Buildings

Reference Consumption and Power Demand before Iimplementation of New BEC The database, Audit Base 5, contains information of buildings archived since 1996 to around 2003. We assume the database contains energy information for year 2001, that we take as our reference year. From the number of VLBs identified, we calculate energy consumption of each type of these VLBs. These results are shown in the column under the heading "Ref" in Table 10.

Table 10 Energy consumption and power demand of very large buildings in 2001, along with energy and power demand of MEA, PEA and EGAT generation.

EGAT En Gen, GWh	103869		
EGAT Power, MW	16126		
MEA			
Energy Demand, GWh	35322.8		
Power Demand, MW	6228.6		
Very large buildings	**Ref**	**Code**	**Econ**
Office	1099.0	583.1	523.9
Hotel	425.2	226.2	202.1
Hospital	175.8	94.8	82.7
Dept & Hyper	560.6	352.9	287.1
Education	5.6	4.0	3.6
Misc	58.6	51.0	49.1
Total, GWh	2324.7	1312.0	1148.6
Total, MW	582.6	328.8	287.9
PEA			
Energy Demand, GWh	60963.2		
Power Demand, MW	9456.3		
Very large buildings	**Ref**	**Code**	**Econ**
Office	12.0	6.4	5.7
Hotel	425.2	226.2	202.1
Hospital	199.5	107.7	93.9
Dept & Hyper	323.4	203.6	165.6
Education	11.2	7.9	7.3
Misc	79.9	69.6	67.0
Total, GWh	1051.2	621.3	541.7
Total, MW	182.2	107.7	93.9

The value of power demand obtained from the model as given in Table 8 is taken as proportionate to energy consumption from the building model. This proportion is used to scale the energy consumption of the department store group to obtain power demand for this group. Summation of power demand values of all group is reported at the last row in a column with heading of "Very large buildings" in Table 10. Energy and power demand of the group of very large buildings in the Metropolitan Electricity Authority (MEA) and of the group in the Provincial Electricity Authority (PEA) are shown for reference case, code complying case and economic case. For the present year of 2006 and the whole of 2007, we assume that the energy and power demand of VLBs will grow proportionately to the load growth of MEA, PEA, and EGAT. We assume that the new BEC is implemented in 2007. All NVLBs from the year 2008 onwards comply with the new BEC. All load and demand growths from VLBs beyond 2007 are due to NVLBs that comply with the new BEC. The forecasted loads for the year 2007 are shown in Table 11 as reference.

Table 11 Energy consumption and power demand of very large buildings in 2007, the last year before code compliance for new buildings.

EGAT En Gen, GWh	158212		
EGAT Power, MW	24344		
MEA			
Energy Demand, GWh	49469.0		
Power Demand, MW	8752.0		
Very large buildings	**Ref**	**Code**	**Econ**
Office	1539.2	816.6	733.7
Hotel	595.4	316.7	283.1
Hospital	246.2	132.8	115.9
Dept & Hyper	785.1	494.3	402.0
Education	7.8	5.5	5.1
Misc	82.0	71.5	68.8
Total, GWh	3255.7	1837.4	1608.6
Total, MW	816.0	460.5	403.1
PEA			
Energy Demand, GWh	98,455		
Power Demand, MW	14,853		
Very large buildings	**Ref**	**Code**	**Econ**
Office	19.4	10.3	9.2
Hotel	686.6	365.2	326.4
Hospital	322.2	173.9	151.7
Dept & Hyper	522.3	328.8	267.5
Education	18.0	12.8	11.8
Misc	129.0	112.4	108.2
Total, GWh	1697.6	1003.4	874.8
Total, MW	294.2	173.9	151.6

Energy consumption from the VLBs grow substantially from those in the year 2001. These consumption and demand are all at the frozen efficiency levels of 2001. The corresponding columns under 'code' and 'econ' are shown for reference purpose.

Energy and Power Demand Savings from New BEC We show the calculated savings first for the year 2010, three years after implementation of new BEC in Table 12.

Table 12 Energy and power demand savings for the year *2010* and cumulative energy savings from 2008.

EGAT En Gen, GWh	193530				**System savings**	
EGAT Power , MW	29808				**Code**	**Econ**
MEA				**GWh**	474.4	555.3
Energy Demand, GWh	58980.0			**MW**	100.8	117.8
Power Demand, MW	10436.0	**Cum savings, GWh**			1,245.3	1,457.9
Very large buildings	**Old**	**New ref**	**New code**	**New econ**	**Code savings**	**Econ savings**
Office	1539.2	295.9	157.0	141.1	138.9	154.9
Hotel	595.4	114.5	60.9	54.4	53.6	60.1
Hospital	246.2	47.3	25.5	22.3	21.8	25.0
Dept & Hyper	785.1	150.9	95.0	77.3	55.9	73.7
Education	7.8	1.5	1.1	1.0	0.4	0.5
Misc	82.0	15.8	13.7	13.2	2.0	2.5
Total, GWh	3255.7	626.0	353.3	309.3	272.7	316.7
Total, MW	816.0	156.9	88.5	77.5	68.3	79.4
PEA						
Energy Demand, GWh	123,066.4					
Power Demand, MW	18,498.7					
Very large buildings	**Old**	**New ref**	**New code**	**New econ**	**Code savings**	**Econ savings**
Office	19.4	4.8	2.6	2.3	2.3	2.5
Hotel	686.6	171.6	91.3	81.6	80.3	90.1
Hospital	322.2	80.6	43.5	37.9	37.1	42.6
Dept & Hyper	522.3	130.6	82.2	66.9	48.4	63.7
Education	18.0	4.5	3.2	2.9	1.3	1.6
Misc	129.0	32.2	28.1	27.0	4.2	5.2
Total, GWh	1697.6	424.4	250.8	218.7	173.5	205.7
Total, MW	294.2	72.2	42.7	37.2	29.5	35.0

In Table 12, the values in the column under 'Old' represent energy consumption and demand of existing or old VLBs, frozen since 2008, The values in the next column correspond to those from NVLBs that would have resulted if the mandatory BEC is not implemented. These are the load growths from VLBs up to the year 2010 from the load levels in 2007. The values in the next column under 'New code' correspond to consumption and demand of NVLBs that comply with the new BEC and the values in the next column are for economic case. The savings in energy and power demand from NVLBs that comply with the new BEC appear in the column under 'Code savings', and those from economic case appear in the last column. It is seen that total savings in energy and power demand are substantial and account for up to half of total NVLBs in each future year.

Total system savings of energy and power demand appear in the upper right hand corner of Table 12, under 'System Savings' The savings on EGAT's system are obtained from adjusted savings from MEA and PEA loads using a factor that accounts for transmission losses. The cumulative energy savings that account for energy savings from the year the new BEC is implemented on a mandatory basis to the given year of 2010 is also shown. For completeness similar results for the year 2016, the last year of the present Power Development Plan are shown in Table 13.

Table 13 Energy and power demand savings for the year *2016* and cumulative energy savings from 2008.

EGAT En Gen, GWh	282488				**System savings**	
EGAT Power , MW	43558				**Code**	**Econ**
MEA				**GWh**	1588.7	1857.5
Energy Demand, GWh	84882.0			**MW**	365.5	427.0
Power Demand, MW	15029.0	**Cum savings, GWh**			8893.7	10400.5
Very large buildings	**Old**	**New ref**	**New code**	**New econ**	**Code savings**	**Econ savings**
Office	1539.2	1101.8	584.6	525.2	517.3	576.6
Hotel	595.4	426.3	226.7	202.6	199.5	223.6
Hospital	246.2	176.2	95.1	83.0	81.1	93.3
Dept & Hyper	785.1	562.0	353.8	287.8	208.2	274.2
Education	7.8	5.6	4.0	3.7	1.6	1.9
Misc	82.0	58.7	51.2	49.2	7.6	9.5
Total, GWh	3255.7	2330.7	1315.3	1151.5	1015.3	1179.2
Total, MW	816.0	584.1	329.7	288.6	254.5	295.5
PEA						
Energy Demand, GWh	184,024					
Power Demand, MW	27,608					
Very large buildings	**Old**	**New ref**	**New code**	**New econ**	**Code savings**	**Econ savings**
Office	19.4	13.9	7.4	6.6	6.5	7.3
Hotel	686.6	491.5	261.5	233.7	230.1	257.9
Hospital	322.2	230.7	124.5	108.6	106.2	122.1
Dept & Hyper	522.3	373.9	235.4	191.5	138.5	182.4
Education	18.0	12.9	9.1	8.4	3.8	4.5
Misc	129.0	92.3	80.5	77.4	11.9	14.9
Total, GWh	1697.6	1215.3	718.3	626.2	497.0	589.1
Total, MW	294.2	252.6	149.3	130.2	103.3	122.5

Information from Audit Base 5 shows that there are very few very large office, outside of Metropolitan Bangkok. There are also very few very large education buildings throughout Thailand. But this trend may change as economy improves. Air-conditioning will increase its penetration to buildings located in urban areas in the provinces and the proportion of NVLBs could increase beyond what we assume here.

5 CONCLUSION

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 planning and execution for energy efficiency and development of renewable energy in Thailand that would lead to substantial gain in energy efficiency. When we view the progress in the execution of the work through the intervening years in perspective, it appears there were some obstacles that require serious redress. We anticipated that the obstacles be analyzed and new solution attempted. Unfortunately, it the present work by state towards improvement of energy efficiency in buildings in the country appears to have stalled. Even though the new building energy code has been developed and preparation for its implementation is underway, there is no clear sign that it would be implemented, nor that there would be coordination of effort to set clear direction of development and implementation. 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.

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