CITY LEVEL ENERGY DECISION MAKING:
A CASE STUDY OF BANGKOK

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Abbreviations and Acronyms

APEC	Asia Pacific Economic Corporation
DSM	Demand-Side Management
ECPA	Energy Conservation Promotion Act
GDP	Gross Domestic Products
GHG	Greenhouse Gas
GPP	Gross Provincial Products
GWh	Gigawatt hour
IUEP	Integrated urban energy planning
kWh	kilowatt hour
MAT	Metropolitan Area of Thailand
SPM	Suspended particulate matter
kboe	Thousand barrel of oil equivalent
PM10	Particulate matter 10 microns in diameter and smaller

I. Introduction

Almost half of the world's population are living in the cities, and most of the energy consumption and many of its environmental impacts occur at the city level. City energy use is important since it directly affects the wealth and health of the people living in the city. The use of energy more efficiently can both save money and reduce harmful pollution. The costs of using energy are greater than the costs of buying energy because there are many costs, such as those associated with health effects from using energy, that are external costs and not included in energy prices.

Integrated urban energy planning (IUEP) is an important first step in developing sustainable cities for future generations. The initial step in IUEP implementation is to collect city energy information. This information will help identify the energy-use areas that are most important to the city and help identify IUEP-based projects for the city. Few economies have detailed city energy data. However, at the minimum, data on energy use by fuel type in the city is required to identify IUEP projects. If detailed energy data is preferred and the actual data is not available, the use of surrogate data and the utilization of energy modeling techniques could be useful to estimate missing information.

The Asia Pacific Economic Corporation (APEC) Energy for Sustainable Communities program, which is part of the APEC Energy Working Group, has established four objectives for their sustainable city activities, including:

- To profile the energy sectors of APEC communities,
- To institutionalize IUEP into the planning processes of APEC communities,
- To identify and implement IUEP-based projects, and
- To train city officials on the principles of IUEP.

This study is mainly to support the first objective of the program. It illustrates the value of information for facilitating policy decisions on energy efficiency and conservation and it shows how city energy data could be collected at different levels of detail. This illustration will hopefully be useful to APEC communities in profiling their energy sectors. In addition to the main task of profiling the energy sector of a city, the other tasks of this study include: (1) reviewing the existing research on health impacts related to city energy use to understand more about the true cost of using energy; (2) examining the decision making structure regarding the use of energy in a city to identify the points of contact for future work on IUEP project implementation; and (3) examining the organizations that are working on energy research to reveal potential local partners for developing a proposal for IUEP project funding.

Many economies in Asia offer a unique opportunity for studying city energy use due to the concentration of population and economic activities in dominant metropolitan areas, which are often referred to as megacities. This study uses the metropolitan area of Thailand (MAT), which is centered around Bangkok, as a case study. The MAT is a good example for the study. It represents a case where energy consumption in one "megacity" accounts for about 45 percent of total energy consumption in the economy. The MAT is also facing the problem of health impacts from energy related air pollution. In addition, MAT represents the typical case of a "city" in Asia where decision making regarding energy use at the city level is not well defined.

II. Energy Information for Decision Making

Information is important in facilitating any decision. Detailed information is useful, but might not always be necessary for some levels of decision making. Receiving additional information oftentimes involves additional costs, and more tasks in data collection and/or estimation. Therefore, more detailed information on energy use should be acquired only if it adds real value to the decision making process.

The information required for decision making on energy projects can be separated into three levels of details:

First Level Information. The first level information refers to the information on energy consumption by end-use sector. For example, energy consumption can be disaggregated into:

- Transportation sector
- Commercial sector
- Industrial sector
- Residential sector
- Agricultural sector.

Second Level Information. The second level information refers to the information on energy consumption at sub-sector levels. For example, energy consumption can be disaggregated into:

- Transportation sector
  - Passenger transportation
  - Freight transportation
  - Fishery transportation
  - Others
- Commercial sector
  - Offices
  - Hospitals
  - Hotels
  - Education
  - Retail buildings
  - Others
- Industrial sector
  - Food
  - Textile
  - Chemical
  - etc.

- Residential sector
    - ♦ Downtown
    - ♦ Sub-urban
- Agricultural sector
    - ♦ Crop
    - ♦ Livestock
    - ♦ Forestry
    - ♦ Fishery
    - ♦ Others

Third Level Information. The third level information refers to the information on energy consumption at the end-use devices. A model could be constructed in more or less detail than the example below, depending on the availability of time and data (proxy variables and surrogate data). The disaggregation could also be different depending on the energy pattern in that city.

- Transportation sector
    - ♦ Passenger transportation
        - * Road
            - ◊ Automobiles
            - ◊ Motorcycles
            - ◊ Motortricycles
            - ◊ Taxies
            - ◊ Buses
        - * Rail
            - ◊ Trains
            - ◊ Trollies
        - * Waterway
            - ◊ Ferries
            - ◊ Water taxies
    - ♦ Freight transportation
        - * Road
            - ◊ Heavy Trucks
            - ◊ Medium Trucks
            - ◊ Light Trucks
        - * Rail
            - ◊ Trains
        - * Waterway
            - ◊ Boats
    - ♦ Fishery transportation
        - * Fish carriers
    - ♦ Others
        - * Miscellaneous carriers

- Commercial sector
  - ♦ Offices
    - ∗ Lighting
      - ◊ Lights
    - ∗ Cooling
      - ◊ Air conditioners
      - ◊ Fans
    - ∗ Miscellaneous
      - ◊ Miscellaneous appliances
  - ♦ Hospitals
    - ∗ Lighting
      - ◊ Lights
    - ∗ Cooling
      - ◊ Air conditioners
      - ◊ Fans
    - ∗ Cooking
      - ◊ Electric stoves
      - ◊ LPG stoves
      - ◊ Natural gas stoves
    - ∗ Water heating
      - ◊ Electric heaters
      - ◊ Fuel oil boilers
      - ◊ Diesel boilers
    - ∗ Miscellaneous
      - ◊ Miscellaneous appliances
  - ♦ Hotels
    - ∗ Lighting
      - ◊ Lights
    - ∗ Cooling
      - ◊ Air conditioners
      - ◊ Fans
    - ∗ Cooking
      - ◊ Electric stoves
      - ◊ LPG stoves
      - ◊ Natural gas stoves
    - ∗ Water heating
      - ◊ Electric heaters
      - ◊ Fuel oil boilers
      - ◊ Diesel boilers
    - ∗ Miscellaneous
      - ◊ Miscellaneous appliances

- Education
  - Lighting
    - Lights
  - Cooling
    - Air conditioners
    - Fans
  - Miscellaneous
    - Miscellaneous appliances
- Retail buildings
  - Lighting
    - Lights
  - Cooling
    - Air conditioners
    - Fans
  - Miscellaneous
    - Miscellaneous appliances
- Others
  - Lighting
    - Lights
  - Cooling
    - Air conditioners
    - Fans
  - Cooking
    - Electric stoves
    - LPG stoves
    - Natural gas stoves
  - Water heating
    - Electric heaters
    - Fuel oil boilers
    - Diesel boilers
  - Miscellaneous
    - Miscellaneous appliances

- Industrial sector
  - Food
    - Thermal use
      - LPG boilers
      - Kerosene boilers
    - Mechanical use
      - Gasoline engines
      - Diesel engines
      - Electric motors

* Other electric uses
  ◊ Lights
  ◊ Air conditioners
♦ Textile
* Thermal use
  ◊ LPG boilers
  ◊ Kerosene boilers
* Mechanical use
  ◊ Gasoline engines
  ◊ Diesel engines
  ◊ Electric motors
* Other electric uses
  ◊ Lights
  ◊ Air conditioners
♦ Construction
* Thermal use
  ◊ LPG boilers
  ◊ Kerosene boilers
* Mechanical use
  ◊ Gasoline engines
  ◊ Diesel engines
  ◊ Electric motors
* Other electric uses
  ◊ Lights
  ◊ Air conditioners
♦ Chemical
* Thermal use
  ◊ LPG boilers
  ◊ Kerosene boilers
* Mechanical use
  ◊ Gasoline engines
  ◊ Diesel engines
  ◊ Electric motors
* Other electric uses
  ◊ Lights
  ◊ Air conditioners

- Residential sector
  ♦ Downtown [1]
  * Lighting
    ◊ Fluorescent lights

[1] Sub-sector level of the residential sector could be disaggregated by dwelling type such as townhouse, detached house, condominium, and apartment, if data is available.

        - Cooking
            - ◊ Electric stoves
            - ◊ LPG stoves
            - ◊ Natural gas stoves
        - Cooling
            - ◊ Air conditioners
            - ◊ Fans
        - Refrigeration
            - ◊ Refrigerators
        - Others
            - ◊ TVs
            - ◊ Radios
            - ◊ Clothes washers
            - ◊ Irons
    - ♦ Sub-urban
        - Lighting
            - ◊ Fluorescent lights
        - Cooking
            - ◊ Electric stoves
            - ◊ LPG stoves
            - ◊ Natural gas stoves
        - Cooling
            - ◊ Air conditioners
            - ◊ Fans
        - Refrigeration
            - ◊ Refrigerators
        - Others
            - ◊ TVs
            - ◊ Radios
            - ◊ Clothes washers
            - ◊ Irons
- Agricultural sector
    - ♦ Crop
        - Irrigation
            - ◊ Electric pumps
            - ◊ Diesel pumps
        - Land preparation
            - ◊ Diesel tractors
            - ◊ Gasoline tractors
        - Harvest
            - ◊ Electric equipment
            - ◊ Diesel equipment

- ♦ Livestock
  - * Irrigation
    - ◊ Electric pumps
    - ◊ Diesel pumps
  - * Land preparation
    - ◊ Diesel tractors
    - ◊ Gasoline tractors
  - * Harvest
    - ◊ Electric equipment
    - ◊ Diesel equipment
- ♦ Forestry
  - * Irrigation
    - ◊ Electric pumps
    - ◊ Diesel pumps
  - * Land preparation
    - ◊ Diesel tractors
    - ◊ Gasoline tractors
  - * Harvest
    - ◊ Electric equipment
    - ◊ Diesel equipment
- ♦ Fishery
  - * Fishing
    - ◊ Diesel boats
    - ◊ Gasoline boats

The first level information is generally easier to find than the second level, which is easier than the third level. This is especially true for national data. The first level information is the minimum information to have before any IUEP-based project could be designed. It is the first step information that helps identify the relative importance of an end-use sector to the city as compared to the other sectors and helps prioritize IUEP activities. For example, if the data shows that the agriculture sector is the smallest energy consumer in the city as compared to other end-use sectors, the agricultural sector should have lower priority than other end-use sectors in implementing energy efficiency projects. In this case, there is no need to collect the second level of energy data for the agricultural sector.

The first level of information, however, does not tell much about consumer behavior on energy use. More detailed information, at least at the second level, is thus needed for the end-use sectors that are large energy consumers and good candidates to be selected for implementing IUEP-based projects. For decision makers to implement energy efficiency measures, the third level information will be beneficial since it will show the potential savings of each end-use device.

Since most energy planning is conducted at the national level, the data is compiled and reported at the national level. Data at the city level, in many cities, even for the first level of information, does not exist. However, detailed energy consumption at the city level can be estimated by using modeling techniques and/or by basing estimates on reasonable assumptions. The existence of a national energy model offers a shortcut to the construction of a city energy model. However, the focus of energy issues is different at the city level than the national level. Therefore, some modifications are necessary to utilize a national-level model for the analysis of city energy issues. Some examples include:

- A city energy model normally requires more details on the energy-consuming or end-use sectors and less details on the energy-producing sectors, as compared to a national energy model. Details on the end-use sectors will give the city a picture of, for example, how the energy is consumed, how to plan for more efficient energy consumption, and how to plan for energy supply to meet city energy demand. A detailed model of energy production becomes less important at the city level since in most cities, energy is supplied from outside of their boundaries, and the cities do not have any control on domestic energy production or import. Therefore, a city energy model is basically a model utilized to calculate city energy demand with detailed end-use sectors assuming that energy supply will always be available to meet the demand.

- Issues such as energy security of supply become less important in a city energy model as compared to the issue of energy efficiency and conservation improvements. Due to the fact that most energy savings could come from the energy end-use sector in big cities, energy efficiency and energy conservation issues should be a central focus of a city energy model. This also supports the need for having more details on the energy-consuming sectors and paying less attention on the energy-producing sectors.

- When a national energy model is adapted for a city energy model, modifications of the model components are often required due to the different objectives of the study. For example, when the national energy model is designed for a specific purpose such as to estimate greenhouse gas (GHG) emissions, end-use sector such as the commercial sector might not be given a great deal of attention because it contributes much less GHGs than the transportation or industrial sectors. In contrast, the commercial sector might be more of interest in a city energy model due to its relative importance at the city level and its potential contribution to large energy savings if energy efficiency and energy conservation measures are implemented.

- Modifications are also needed in a national energy model for a city energy model in the transportation sector. At a national level, both short- and long-distance trips are made, and the long-distance travel demand can be met by planes, trains, automobiles, or boats. However, at a city level, there is no need to disaggregate travel distance since all travels in a city are considered short distance and traveling by planes is not an option.

III. A City Energy Model: Case Study of the Metropolitan Area of Thailand

This study uses the metropolitan area of Thailand (MAT) as a case study to illustrate a modeling framework to estimate city energy use. In this study, the MAT includes four provinces—Bangkok, Nonthaburi, Samut Prakarn, and Pathum Thani.[2] The MAT, instead of Bangkok which is the capital of Thailand, is selected for the study of city energy use for two principal reasons. First, in the case of Thailand, defining the use of energy within the boundary of Bangkok would underestimate city energy use. The MAT is closely connected, with Bangkok as the center, Nonthaburi and Pathum Thani located in the north (with the distance of 20 kilometers and 46 kilometers, respectively, from Bangkok), and Samut Prakarn, 29 kilometers southeast of Bangkok. These three provinces are also closely tied with Bangkok in economic and social activities. About half of the people who work or conduct businesses in Bangkok are residing in Nonthaburi, Samut Prakarn, and Pathum Thani, and commute every day. Second, because of their close connection, most of detailed statistics required for the study, if available, are collected as data for MAT, and not separated into Bangkok itself.

The purpose of this study is not to identify exactly how much energy is consumed in each end-use sector for MAT. Instead, it is to show how a city energy model might be constructed to represent the energy situation in a city. Some of the assumptions and data used in this study could be adopted to estimate energy use in other Asian cities directly or with some modifications.

Background on the Metropolitan Area of Thailand

The MAT is composed of four provinces, Bangkok, Samut Prakarn, Nonthaburi, and Pathum Thani, with the total area of 4,717.5 km^2. The population in MAT in 1995 was about 9 million people, or about 13 percent of the total population in Thailand. Of the total MAT population, 77 percent (6.9 million people) lived in Bangkok, 10 percent (0.9 million people) in Samut Prakarn, 8 percent (0.7 million people) in Nonthaburi, and 5 percent (0.5 million people) in Phathum Thani. Total Gross Provincial Products (GPP) of MAT in 1995 was 2,020,003 million baht, or about 48 percent of the Gross Domestic Products. Manufacturing is the major sector in the MAT and contributed about 30 percent of total GPP in 1995. Table 1 compares GPP, population, and GPP per capita, of the four provinces of MAT.

[2] Since there is no official definition of MAT, sometimes it is defined to include only three provinces—Bangkok, Nonthaburi, and Samut Prakan.

Table 1: Gross Provincial Products, Population, and Gross Provincial Products Per Capita of the Metropolitan Area of Thailand in 1995

	Bangkok	Samut Prakarn	Nonthaburi	Pathum Thani	Total MAT	Whole Kingdom
GPP[1/]	1,652,599	174,615	73,569	119,219	2,020,003	4,202,835
Population[2/]	6.9	0.9	0.7	0.5	9.0	59.0
GPP Per Capita[3/]	238,849	189,182	105,099	236,078	224,444	70,754

Notes: [1/] Gross Provincial Products, at 1995 market prices, in million baht
[2/] in million people
[3/] in baht

Source: National Statistics Office

The energy consumption in MAT in 1995 was 126,658.2 kboe, or about 45 percent of total economy's energy consumption (see Table 2).

Table 2: Energy Consumption in the Metropolitan Area of Thailand By Fuel Type in 1995

Unit: kboe

	Bangkok	Samut Prakarn	Nonthaburi	Pathum Thani	Total MAT	Whole Kingdom
Gasoline	12,213.5	1,008.8	828.4	751.4	14,802.1	33,896.4
Kerosene	158.6	59.0	0	31.3	248.8	598.8
Diesel	23,139.4	2,878.8	1,079.5	3,659.6	30,757.3	34,307.2
JP	17,875.3	0	0	297.2	18,172.5	18,713.1
Fuel Oil	29,735.1	4,406.1	308.5	2,113.6	36,563.4	70,278.3
LPG	3,363.4	1,201.7	433.5	294.1	5,292.7	12,476.6
Biomass	na	na	Na	na	115.7	64,789.8
Electricity	12,888.3	4,645.8	929.8	2,241.9	20,705.7	44,158.6
Total	**99,373.7**	**14,200.2**	**3,579.6**	**9,389.0**	**126,658.2**	**279,218.6**

Sources: National Energy Policy Office, Metropolitan Electricity Authority, Provincial Electricity Authority, and Department of Energy Development and Promotion

While detailed data on energy consumption for the whole kingdom are available, information on energy consumption at the city level is very incomplete. The data was published only by type of fuel and not by end-use sector. This study illustrates a methodology to estimate energy consumption at end-use sector, sub-sector, and devices for the MAT. The year 1995 is used as a base year for data estimation since most of the data are available for this year.

Methodology for City Energy Demand Estimation

The MAT city energy model is composed of 5 end-use sectors: residential, transportation, industrial, agricultural, and commercial sectors. The methodology used to estimate energy demand in each end-use sector is explained below.

Residential Sector. The residential sector is classified into four end uses: cooking, lighting, cooling, and other demands (for example, refrigeration, water heating, television, radio, washing machines, and ironing).[3] Fuels used in the residential sector include LPG for cooking, biomass for cooking, and electricity for cooking, lighting, cooling, and other demands. The devices used in the residential sector are LPG stoves, biomass stoves, and rice cookers for cooking demand; fluorescent lights for lighting demand; air conditioners and table fans for cooling demand; and miscellaneous appliances for other demands.

To estimate energy demand, the residential sector is disaggregated into 6 income classes, (<5000, 5001-7000, 7001-15000, 15001-25000, 25001-50,000, and >50000, baht per month), and 5 dwelling types (detached houses, rowhouses, townhouse, apartments /condominiums, and flats).[4] The disaggregation in income classes is to capture differences in standard of living that will affect the demand for energy. The disaggregation by dwelling types is also to capture differences in patterns of energy demand.

Total energy demand in the residential sector includes residential electricity demand and residential non-electricity demand. Residential electricity demand is estimated by multiplying the average number of appliances owned in each type of end-use with their average capacities and the average number of hours these appliances are used per year.[5] Residential non-electricity demand is estimated by multiplying the number of devices with the specific fuel consumption of each device.[6] The specific fuel consumption determines the amount of energy consumed by each type of device per year.

Transportation Sector. The demand for transportation is divided into passenger and freight demand. Both passenger and freight demands are disaggregated into demand for road, rail, and water. Passenger road demand includes cars (using gasoline and diesel), taxies (using gasoline), buses (using gasoline and diesel), motorcycles (using gasoline), and motortricycles (using gasoline and LPG). Freight road demand is the demand for trucks (using gasoline and diesel). Passenger ships use gasoline and diesel, while freight ships use diesel.

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[3] The residential demand is classified by based on the detailed end-use model developed by Thailand's Load Forecast Subcommittee (TLFS 1993).

[4] Data is taken from Thailand Load Forecast Subcommitte (TLFS 1993) and the 1989/90 MEA Surveys.

[5] Data comes from the 1989/90 MEA Surveys.

[6] Data comes from the 1989/90 MEA Surveys.

Passenger demand is estimated as the products of numbers of vehicles[7], load factors per vehicle, and travel distances. The unit is passenger-kilometers (pkm)

Freight demand of each transport mode is estimated as the product of number of vehicles[8], average maximum load for each type of transport mode and average travel distance per year. The unit of freight demand is tonne-kilometer (tkm).

The assumptions for passenger and freight demand for the MAT model are shown in Table 3.

Table 3: Assumptions on Load Factors and Travel Distances by Transport Mode

Type of Vehicle	Load Factors (persons per vehicle) & (ton per vehicle)	Travel Distances (km per year)
Passenger Demand		
Car	1.5	12,000
Taxi	2	20,000
Motorcycle	1.5	9,000
Motortricycle	2	20,000
Bus		
Small bus	30	60,000
Medium bus	45	80,000
Large bus	60	40,000
Train		
Ship		
Long tail boat	40	47,000
Chao Praya Express	50	118,000
Freight Demand		
Trucks		
Light truck	2	31,000
Medium truck	6	30,700
Heavy truck	12	30,000
Train		
Ship	0.5	24,000

Source: Intarapravich (1996)

[7] The data on number of vehicles comes from Alpha Research Co.Ltd.(1997), and National Statistics Office (1996).

[8] Ibid 7.

Industrial Sector. Energy demand in the industrial sector is estimated by detailing energy use in 11 industrial sub-sectors: construction, food & beverage & tobacco, textiles & leather, wood & furniture, paper pulp & print, chemicals, non-metal, basic metal, fabricated metal, mining & quarrying, and other manufactures. The energy demand in these industrial sub-sectors is further disaggregated into fuel demand at end-use level (including thermal, mechanical, and other electricity uses) and end-use devices (for example, boilers, motors, kilns, engines, dryers, etc.).

One way to estimate energy consumption of each type of end-use device in each end-use activity of each industrial sub-sector is to use the energy intensity (such as, in Gigajoules per million baht) of each type of end-use device in each end-use activity multiplied by the value added (such as, in million baht) of the industrial sub-sector that utilizes that device. In the case of MAT, none of this information is available. However, surrogate data at the national level is available. The surrogate data is thus adjusted to be used for an estimate of the industrial energy consumption in MAT.

The energy intensity of each device of the industrial sub-sector in MAT is assumed to be the same as that of the whole kingdom.[9] The value added (or GPP) of the MAT industrial sector is not disaggregated into the sub-sector level. The study thus uses the proportion of GDP by industrial sub-sector of the total industrial sector GDP multiplied by the MAT industrial sector GPP[10] to estimate the MAT industrial sub-sector GPP. This is based on the assumption that each industrial sub-sector contributes to total industrial sector's value added at the same proportion in MAT as in the whole kingdom.

Commercial Sector. The commercial sector is separated into energy use in office buildings, retail buildings, education buildings, hotels, hospitals, and other buildings. "Other buildings" refer to small commercial buildings of all types. The end-use activities in office, retail, and education buildings are classified into lighting, cooling, and other. The end-use activities in hotels, hospitals, and other buildings are classified into lighting, cooling, cooking, water heating, and other. Fuels used in the commercial sector are electricity, fuel oil, diesel, and LPG.

The study needs the information on energy consumption in the MAT commercial sector by end-use. Such information is not available from any published statistics. Only total electricity consumption[11] by building type is available. The approach in this study is to first estimate the floor space of each building type in the MAT, by dividing total electricity consumption in that building type with electricity intensity of that building type.[12] The

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[9] The estimated energy intensities are taken from Union of Concerned Scientists (1991) and International Institute for Energy Conservation (1992).

[10] GDP and GPP data come from the National Economic and Social Development Board, http://www.nesdb.go.th/download.html

[11] Data comes from the Metropolitan Electricity Authority.

existing floor space times energy intensities (electricity and other fuel intensities[13]) at the end-use level will then give us the energy consumption by end-use of each building type. Since the energy intensities of the MAT are not available, the energy intensities of the whole kingdom are adopted.

Agricultural Sector. The energy consumption in the agricultural sector can be estimated at the detailed level by disaggregating total consumption into end-use sub-sector of, for example, crops, livestock, forestry, and fisheries sub-sectors, or into end-use activities of, for example, irrigation, land preparation, harvesting, and fishing, or into end-use devices of, for example, electric pumps, diesel pumps, diesel and gasoline tractors, and other equipment with various fuel types. However, for the case of MAT, since the agricultural sector is a small sector, and consumes less than 1 percent of total energy consumption in the MAT, the energy consumption in the agricultural sector is not estimated at the detailed sub-sector level.

Instead, the energy consumption in the agricultural sector is estimated by using the MAT agricultural sector GPP times energy intensities. The energy intensities are estimated by taking the energy consumption in the agricultural sector of the whole kingdom divided by GDP from the agricultural sector. It is assumed that energy intensity of the agricultural sector of the MAT is the same as that of the whole kingdom

Results of the Model

This study shows that the transportation sector was the largest MAT energy consumer. It consumed energy of about 96,686 kboe, or about 71 percent of total energy use in the MAT, in 1995. The second largest energy consumer in the MAT was the industrial sector, consuming about 24,407 kboe of energy or 18 percent of total energy use in 1995. The commercial, residential, and agricultural sectors consumed energy at 7,903 kboe, 6,235 kboe, and 892 kboe, respectively. The total MAT energy consumption in 1995 estimated in this study was 136,123 kboe, which is about 7.5 percent more than the quantities reported by the government, or 126,658 kboe.

Passenger transport consumed about 63,501 kboe, or 65.7 percent of total energy consumption in the transport sector, in 1995. Road was by far the major end-use demand in both passenger transport (63,367 kboe) and freight transport (33,148 kboe). The

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[12] For the metropolitan area of Thailand, the electric intensities of each type of building are taken mainly from reports prepared for Thailand by IIEC (1992). Data from these studies were based on actual tests conducted on prototype buildings in Thailand. These are supplemented by a 1991 study commissioned by the Department of Energy Development and Promotion (DEDP 1991), and data from Thailand Load Forecasting Subcommittee (TLFS 1993). For non-electric energy use, energy intensities are derived by dividing the actual energy consumed by the total floor area of each type of building. The actual data is for 1992. The 1995 data for this study is based on 1992 data and assumed 1 percent annual reduction in energy intensities to reflect naturally occurring energy efficiency improvements.

[13] Electricity intensity is in unit of kWh/m^2. Energy intensity is in the unit of $litre/m^2$).

transport mode that consumed the most energy in the passenger transport category was buses (46,447 kboe), and then cars (9,899 kboe). Heavy trucks were the main transport mode for freight demand, followed by light trucks, consuming energy at 18,156 kboe and 14,992 kboe, respectively.

Food, Beverage and Tobacco was the principal energy consumer of the industrial sector. In 1995, it consumed about 28.1 percent of total industrial energy consumption which was more than double that of the second and third largest energy end-users—the chemical industry, and the non-metallic industry, respectively. The main end-use demand in these three industrial sub-sectors was the demand for thermal energy. The major thermal energy demand device in the Food, Beverage and Tobacco industrial sub-sector was boilers; in the chemical industrial sub-sector it was dryers, and in the non-metallic industrial sub-sector it was kilns.

The major end-use of energy demand in the residential sector was cooking. However, cooling was the main end-user of electricity, consuming 38.2 percent of total electricity used in the residential sector. The principal energy used in the residential sector was electricity, at 6302.1 GWh (or 3907.3 kboe). Other fuels were LPG (2,212.0 kboe) and biomass (115.7 kboe).

The major use of energy in the commercial sector was in offices, and then hotels, retail, hospitals, and education buildings. The major end-use demand of the sector was cooling (3,287.6 kboe), then lighting (1,995.3), cooking (1,425.8), water heating (364.8), and others (829.3). Electricity was consumed at 10,515.5 GWh (or 6469.3 kboe), LPG at 1253.8 Kboe, fuel oil at 135.5 kboe, and diesel at 44.3 kboe.

The results of the study are shown in detail in Table 4.

Table 4: Estimated Energy Consumption in the Metropolitan Area of Thailand By End-Use Sector in 1995

Sector	Sub-Sector	End-Use Demand	End-Use Device	Fuel	Quantity (Kboe)
Residential	**Total**				**6,235.0**
		Cooking			2,719.4
			LPG stoves	LPG	2,212.0
			Biomass stoves	Biomass1/	115.7
			Rice cookers	Electricity	391.7
		Lighting	Fluorescent Lights	Electricity	263.3
		Cooling			1,492.9
			Air-conditioners	Electricity	1,260.4
			Fans	Electricity	232.5
		Others		Electricity	1,759.4

Continued

Sector	Sub-Sector	End-Use Demand	End-Use Device	Fuel	Quantity (Kboe)
Commercial	**Total**				**7,902.9**
	Office				1,585.5
		Lighting	Lighting appliances	Electricity	741.4
		Cooling	Cooling appliances	Electricity	638.6
		Others	Other appliances	Electricity	205.5
	Retail				897.6
		Lighting	Lighting appliances	Electricity	249.7
		Cooling	Cooling appliances	Electricity	570.2
		Others	Other appliances	Electricity	77.7
	Hotel				956.5
		Lighting	Lighting appliances	Electricity	185.5
		Cooling	Cooling appliances	Electricity	431.0
		Cooking	LPG stoves	LPG	96.9
		Water heating			139.3
			Heating equipment	Electricity	9.5
			Heating equipment	Fuel oil	97.8
			Heating equipment	Diesel	32.0
		Others	Other appliances	Electricity	103.8
	Hospital				368.8
		Lighting	Lighting appliances	Electricity	71.8
		Cooling	Cooling appliances	Electricity	166.5
		Cooking	LPG stoves	LPG	37.4
		Water heating			53.6
			Heating equipment	Electricity	3.6
			Heating equipment	Fuel oil	37.7
			Heating equipment	Diesel	12.3
		Others	Other appliances	Electricity	39.5
	Education				265.5
		Lighting	Lighting appliances	Electricity	58.8
		Cooling	Cooling appliances	Electricity	148.0
		Others	Other appliances	Electricity	58.7
	Others				3,829.0
		Lighting	Lighting appliances	Electricity	688.2
		Cooling	Cooling appliances	Electricity	1333.3
		Cooking			1,291.5
			LPG stoves	LPG	1,119.5
			Electric stoves	Electricity	172.0
		Water heating	Heating equipment	Electricity	172.0
		Others	Other appliances	Electricity	344.0

Continued

Sector	Sub-Sector	End-Use Demand	End-Use Device	Fuel	Quantity (Kboe)
Transport	**Total**				**96,686.1**
	Passenger				63,501.4
		Road			63,366.8
			Cars		9,899.0
				Gasoline	9,798.0
				Diesel	101.0
			Taxies	Gasoline	1,340.0
			Motortricycles		94.8
				Gasoline	21.5
				LPG	73.3
			Buses		46,446.8
				Gasoline	12,425.7
				Diesel	34,021.1
			Motorcycles	Gasoline	5,586.2
		Rail	Trains	Diesel	19.1
		Water	Ships		115.5
				Gasoline	51.8
				Diesel	63.7
	Freight				33,184.7
		Road			33,148.4
			Light trucks		14,992.1
				Gasoline	643.7
				Diesel	14,348.4
			Heavy trucks	Diesel	18,156.3
		Rail	Trains	Diesel	36.3
		Water	Ships	Diesel	0.01
Industrial	**Total**				**24,406.7**
	Construction				351.1
		Thermal use	Boilers	Fuel oil	63.1
		Mechanical use	Engines	Diesel	288.0
	Mining& Quarry				0.4
		Thermal use	Boilers	Fuel oil	0.1
		Mechanical use	Engines		0.3
				Gasoline	0.004
				Diesel	0.3
				Kerosene	0.002

Continued

Sector	Sub-Sector	End-Use Demand	End-Use Device	Fuel	Quantity (Kboe)
Industrial	Food& Beverage& Tobacco				6,865.1
		Thermal use			5,971.7
			Boilers		5,854.9
				Fuel oil	1,391.2
				Coal	118.2
				Biomass	4,345.5
			Curing equipment	Lignite	116.8
		Mechanical use			794.9
			Engines	Diesel	218.8
			Motors	Electricity	576.1
		Other electric use	Lights, A/C, etc.	Electricity	98.5
	Textile &				1,411.8
		Thermal use	Boilers		749.0
				LPG	21.6
				Fuel oil	727.4
		Mechanical use			565.0
			Engines	Diesel	11.4
			Motors	Electricity	553.6
		Other electric use	Lights, A/C, etc.	Electricity	97.8
	Wood & Furniture				125.8
		Thermal use	Wood dryers		74.2
				Fuel oil	44.2
				Biomass	30.0
		Mechanical use			44.9
			Engines	Diesel	6.4
			Motors	Electricity	38.5
		Other electric use	Lights, A/C, etc.	Electricity	6.7

Continued

Sector	Sub-Sector	End-Use Demand	End-Use Device	Fuel	Quantity (Kboe)
Industrial	Paper Pulp & Print				862.9
		Thermal use	Boilers		623.8
				Fuel oil	190.9
				Lignite	432.9
		Mechanical use			206.0
			Engines	Diesel	17.4
			Motors	Electricity	188.6
		Other electric use	Lights, A/C, etc.	Electricity	33.1
	Chemical				3,314.9
		Thermal use			2,953.0
			Boilers		155.1
				LPG	80.2
				Kerosene	74.9
			Dryers		2,797.9
				Fuel oil	1,010.4
				Lignite	311.3
				Electricity	1,476.2
		Mechanical use			188.8
			Engines		72.4
				Gasoline	8.7
				Diesel	63.7
			Motors	Electricity	116.4
		Other electric use	Lights, A/C, etc.	Electricity	173.1

Continued

Sector	Sub-Sector	End-Use Demand	End-Use Device	Fuel	Quantity (Kboe)
Industrial	Non-metallic				3,307.4
		Thermal use			3,141.4
			Boilers	LPG	128.4
			Kilns		2,542.9
				Fuel oil	969.9
				Lignite	1,573.0
			Coke ovens	Coke	47.8
			Process equipment	Electricity	422.3
		Mechanical use			105.0
			Engines	Diesel	64.2
			Motors	Electricity	40.8
		Other electric use	Lights, A/C, etc.	Electricity	61.0
	Basic metal				851.7
		Thermal use			696.7
			Boilers		53.8
				LPG	47.4
				Kerosene	6.4
			Copper dryers	Fuel oil	303.5
			Coke ovens	Coke	33.4
			Process equipment	Electricity	306.0
		Mechanical use			100.7
			Engines	Diesel	63.6
			Motors	Electricity	37.1
		Other electric use	Lights, A/C, etc.	Electricity	54.3
	Fabricated metal				29.7
		Thermal use			7.6
			Copper dryers		4.3
				LPG	2.2
				Fuel oil	2.1
			Kilns	Electricity	3.3
		Mechanical use			18.7
			Engines	Diesel	1.7
			Motors	Electricity	17.0
		Other electric use	Lights, A/C, etc.	Electricity	3.4

Continued

Sector	Sub-Sector	End-Use Demand	End-Use Device	Fuel	Quantity (Kboe)
Industrial	Other manufactures				7,285.9
		Thermal use	Boilers		6,416.6
				LPG	395.4
				Fuel oil	5,790.3
				Lignite	230.9
		Mechanical use			778.8
			Engines	Diesel	245.7
			Motors	Electricity	533.1
		Other electric use	Lights, A/C, etc.	Electricity	90.5
Agriculture	**Total**				**892.2**
Total MAT					**136,123**

Note: [1/] Biomass includes fuel wood and charcoal.

Lesson Learned From the MAT City Energy Model

The pattern of energy consumption in MAT is probably representative of other megacities where the major use of energy is in the transportation sector. Passenger road demand, in particular, requires large amounts of energy. Traffic congestion in the MAT, especially in Bangkok, and lack of good public transport and mass transit all contribute to the high energy consumption in the MAT transportation sector.

This study aims to lay out a basic structure of a city energy model. The study does not intend to estimate exactly how much energy was used in MAT. Instead, it aims to illustrate how detailed city energy consumption could be estimated with limited data, and how a city energy model could be beneficial in providing information to facilitate IEUP-based projects.

As expected, the estimated total energy consumption does not exactly match those reported by the government. In this study, the estimated total MAT energy consumption was 7.5 percent above the officially reported energy consumption. One difficulty in building a city energy model and estimating city energy consumption is due to the fact that there are no definite boundaries for energy use. Communication and transportation are not limited only to a city. Many people live in one city and commute to work in another. It is thus difficult to know what are the actual quantities of energy consumed in the city. The use of energy modeling to estimate city energy consumption, however, gives a rough idea of the energy consumption pattern of the city and helps to establish priorities for implementing IEUP projects.

IV. The Study on Health Impacts of Air Pollution in Bangkok

There are not many studies on the health impacts of air pollution in Bangkok. Some of the recent health impact studies are reviewed below.

Impacts of Particulate Matter on Respiratory Systems

The Department of Health (1977)[14] conducted a study on impacts of particulate matter on the human respiratory system during the years 1994-1995. The study examined respiratory systems of 1,203 students in the age of 9-12 years old from 6 schools located in Bangkok, in areas with high particulate matter concentration (119.57 $\mu g/m^3$), medium particulate matter concentration (65.31-72.7$\mu g/m^3$), and low particulate matter concentration (54.75$\mu g/m^3$). The result of the study showed that the students from the schools that were located in the high and medium levels of particulate matter concentration areas had more problems with their respiratory system than those in the lower level. In addition, the probabilities that children from the high concentration of suspended particulate matter environment would have chronic morbidity of respiratory system were 1.8-3.2 times higher than those from the low suspended particulate matter concentration environment.

Impacts of Air Pollution on the Policemen in Bangkok

Sanghirunwatana (1994)[15] studied the effects of air pollution on policemen in Bangkok. The study sampled 174 policemen in Bangkok and found that 44 policemen or 25.29 percent had abnormal pulmonary function. Of the total policemen with abnormal pulmonary function, 33 policemen had restrictive lungs, 11 policemen had small airway obstruction, and 3 policemen had large airway obstruction.

Impacts of Carbon Monoxide on Human Health

The Department of Health (1997)[16] concluded that there was no report on health damage caused by carbon monoxide in Thailand. Except in some areas that had congested traffic, the concentration of carbon monoxide in Bangkok and vicinity provinces was lower than the standard. In the areas with traffic congestion, the concentration of carbon monoxide was found higher than the standard, but only for a short period. The concentration of carbon monoxide, however, has tended to increase and therefore stricter regulations should be implemented.

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[14] Department of Health, Ministry of Public Health, Health and Environment Situation, Vol.2, No.7, April 1997 (in Thai).

[15] Sawang Sanghirunwatana, "Impacts of Air Pollution in Bangkok on Policemen", Police Hospital, 1994, (in Thai).

[16] Department of Health, Ministry of Public Health, Air Pollution Problem: Health Impacts and Solutions", December 1997, (in Thai).

Study of Blood Lead Level

Poonakunt (1990)[17] studied the lead level in the umbilical cords of newborn babies in Bangkok during 1989-1990 and lead level in the blood of children in Bangkok, as compared to other provinces. The study collected 82 umbilical cords of newborn babies in Bangkok, and sampled 214 students in Bangkok and 132 students in Kanchanaburi province, age 6-13. The results of the study showed that the average lead content in newborn babies was 18 µg per 100 ml. In addition, the lead content in the blood of children who resided in Bangkok was 22±7.5 µg per 100 ml., as compared to 16.2±6.8 µg per 100 ml. of children who resided in Kanchanaburi province.

The Department of Health[18] did the similar study by comparing the lead level in blood of 637 children who lived in Bangkok and Sinkburi province in 1993-1994. The study found that the average lead content in blood of children in Bangkok was 9.27 µg per 100 ml. whereas that of the children in Sinkburi was 5.73 µg per 100 ml.

The Results of SPM on Morbidity and Mortality Rates of Bangkok Residents

The Ministry of Public Health[19] analyzed the hospitalization rates of people in Bangkok during the years 1988-1991 and found that the highest cause for admission (147.9 - 210.2 people out of 100,000 people) was due to respiratory morbidity. In addition, the rates of mortality of Bangkok residents related to the respiratory system in 1994 was 35.4 people per 100,000 people, and in 1995 was 38.2 people per 100,000 people. The rates of morbidity that needed not be hospitalized in 1994 and 1995 were 140.2 and 314.4 people per 100,000 people, respectively.

Air Pollution Situation in the Metropolitan Area

As reported by the Pollution Control Department [20], the air pollution situation in Bangkok improved in 1998. The air quality in Bangkok was found to be better and the concentration of total particulate matter declined. This was due to the government's measures to control air pollution emissions from automobiles and manufactures. It was also due to the economic crisis that resulted in the closing down of several manufactures and the decreased usage of automobiles in the metropolitan area. However, the concentration of PM10 in all main traffic congested streets in Bangkok increased. It was found that the concentration of PM10 in 1998 was 2-3 times higher than the standard (120

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[17] Lhuaphorn Poonakunt, "Impacts of Lead on Human Resource of Thailand", Faculty of Medical, Siriraj Mahidol University, 1990, (in Thai).

[18] No detailed reference for this study.

[19] Ibid 16.

[20] Pollution Control Department, "Bangkok Air Pollution Report", Thai Rath, January 4, 1999, (in Thai).

μg/m^3). In addition, in 1997 the ozone concentration, especially in the north of Bangkok, ranged between 80-174 part per billion (ppb) while the standard was 100 ppb.

Economic Valuation and Health Damage from Air Pollution

A growing number of epidemiological studies have identified substantial economic costs from urban air pollution. Mortality from chronic obstructive pulmonary disease and acute respiratory infections appeared to be substantially higher in developing countries than in developed countries. Pearce (1996)[21] summarized results from several city studies of air pollution health damage.[22] The study suggested that some forms of air pollution, notably inhalable particulate matter and ambient lead, are serious matters for concern in the developing world. Health damage costs per capita in developing countries appeared fairly consistent in the range of US$20-160, while the estimates for Bangkok suggested that overall damages per capita could be very much higher, that is, US$97-402.[23] The damage per capita of particulate matter in Bangkok was estimated at US$57-209[24], while those of Mexico City[25] and Santiago[26] were US$50 and US$15[27], respectively. Lead health damage showed up in the form of reduced IQ scores in children and hypertension, coronary heart disease, and mortality in adults. The estimated lead health damage in Bangkok was US$39-193 per capita[28], while the Mexico[29] and Jarkata[30] studies showed

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[21] David Pearce, "Economic Valuation and Health Damage from Air Pollution in the Developing World", Energy Policy, Vol. 24, No. 7, 1996, pp. 627-630.

[22] The health damage studies proceeded first by establishing average levels of ambient concentration of each pollutant. The next stage was to relate those concentration to health effects such as premature mortality and morbidity. The final stage was to apply unit economic values.

[23] World Bank, Thailand: Mitigating Pollution and Congestion Impacts in a High Growth Economy. Country Operations Division, Country Department I, East Asia and Pacific Region, World Bank, Washington, DC, February 1994.

[24] Estimated costs in 1989.

[25] S. Margulis, Back of the Envelope Estimates of Environmental Damage Costs in Mexico. Working Paper WPS 824, Country Department II, Latin America and the Caribbean Regional Office, World Bank, Washington, DC, January 1992.

[26] World Bank. Chile: Managing Environmental Problems-Economic Analysis of Selected Issues, Environment and Urban Development Division, Country Department II, Latin America and the Caribbean Region, World Bank, Washington, DC, 1994.

[27] Estimated costs in 1990.

[28] Estimated costs in 1990.

[29] Estimated costs in 1989.

[30] Estimated costs in 1990.

much lower per capita damages at around US$ 8 per person. Table 5 illustrates the summary of economic cost of air pollution in Bangkok by type of pollution.

Table 5: Economic Costs of Air Pollution Damage to Human Health in Bangkok

Type of Pollution	Mortality Cost (US$ million)	Morbidity Cost (US$ million)	Total Health Cost (US$ million)	Cost Per Capita (US$)
Particulate matter[1/]	138-1315	302-309	440-1624	57-209
Sulphur oxides[1/]	0	0.2	0.2	<1
Low level ozone[2/]	0	9-36	9-36	1-5
Ambient lead[2/]	291-1470	6-8	297-1478	39-193
Total economic costs	429-2785	317-353	746-3138	97-402

Notes: [1/] Costs in 1989
[2/] Costs in 1990
Source: Pearce (1996)

The study showed that particulate matter and lead should be a prime concern for the Thai government. Energy conservation and vehicle traffic control measures should be focused to address the problems. Overall, the transport sector should receive the most attention for air pollution remedies in Bangkok.

Health Effects of Particulate Matter Air Pollution in Bangkok

The most recent study on health effects in Bangkok was the research project funded by a grant from Japan to the Royal Thai Government, under the administration of the World Bank.[31] Hagler Bailly, a U.S.-based international consulting firm, managed the project. The project was a cooperative effort of both researchers from the United States and Thailand. The Pollution Control Department played an integral role in providing pollution monitoring and planning the study. The College of Public Health, Chulalongkorn University, conducted the symptom diary fieldwork and other local data collection efforts.

The study had five components:

- An analysis of daily mortality counts in Bangkok from 1992 through 1995,
- An analysis of daily hospital admissions for respiratory and cardiovascular illnesses at five major hospitals in Bangkok for 1992 through 1993,
- An analysis of acute daily respiratory symptoms diaries collected for this study for a sample of 251 Bangkok residents from late December 1995 through early April 1996,
- An assessment of the economic values (also referred to as willingness to pay) from a sample of 155 Bangkok residents for avoiding a day with respiratory symptoms,

[31] Lauraine G. Chestnut, et al., Health Effects of Particulate Matter Air Pollution in Bangkok, Prepared for Air Quality and Noise Management, Pollution Control Department, Bangkok, Thailand, March 1998.

- A sampling of indoor particulate matter concentrations in homes and shops taken during the symptom diary study and analyzed in relation to indoor sources and outdoor particulate matter concentrations.

In summary, the results revealed that health effects were associated with airborne particulate matter in Bangkok to a similar degree as that found in other cities around the world. The results indicated that at current PM10 concentrations in Bangkok, there might be as many as 4,000 to 5,500 premature deaths each year in the metropolitan area attributable to short term exposures to outdoor airborne particulate matter (assuming a total population of 10 million). In addition, hospital admissions for respiratory and cardiovascular illnesses were higher when PM10 concentrations were higher.

The results also indicated that for highly exposed adults who did not spend much time in air-conditioned environments, the difference between the highest and lowest daily PM10 concentrations during the winter months (about 180 $\mu g/m^3$) approximately doubled the probability of having acute respiratory symptoms on a given day. For adults who spent substantial time in air conditioned environments, the difference between the highest and lowest daily PM10 concentrations during the winter months was associated with about a 50 percent higher probability of having symptoms.

Regarding indoor particulate matter concentrations, the results indicated that indoor concentrations where there was no air conditioners and some indoor sources were present, such as cigarette smoke or charcoal, were as high or higher than those measured outdoors. In indoor locations with no notable indoor sources (including some with air conditioning), indoor particulate matter concentrations were between 50 percent and 100 percent of outdoor concentrations.

The results of these studies provide convincing evidence that the Bangkok population is being adversely affected by the particulate matter air pollution to which they are regularly exposed. All of the health effects that were considered in this study were the effects of short-term fluctuations of particulate matter, and the findings showed health effects that were comparable to those seen in studies throughout the world. It is therefore reasonable to assume that other types of health effects, namely effects of long-term exposures on chronic respiratory health, that have been documented in other locations are also happening in Bangkok.

The results suggested that there are likely to be substantial benefits, in terms of improved public health, productivity, and quality of life, from reducing particulate matter in Bangkok. The study estimated that a 20 $\mu g/m^3$ reduction in average PM10 concentrations across the metropolitan area would result in a reduction in premature mortality of between 1,400 and 4,000 deaths each year. The estimated annual value to the Bangkok residents of the reduced health effects and quality of life improvements ranged from 65 and 175 billion baht (based on 1995 prices and U.S. to baht exchange rate of $1 to 25 baht).

V. Energy Decisions in Thailand

Energy Decisions at the National Level

The decisions on energy policies in Thailand are made at the national level. The National Energy Policy Council (NEPC) was established under the National Energy Policy Council Act, B.E. 2535 (1992) to manage the Thai energy sector. The National Energy Policy Office (NEPO) is acting as the Secretariat of the NEPC. The Energy Policy Committee (EPC) was also established to assist with the work of the NEPC.

The NEPC is responsible for promoting energy conservation and managing the Energy Conservation Fund according to the Energy Conservation Promotion Act, B.E. 2535 (ECPA 1992). Accordingly, the Energy Conservation Promotion Fund Committee was established to assist with the management of the Fund and ensure that fund allocations are made in compliance with the regulations stipulated in the Act.[32]

The authorized duties of NEPC include:

- To recommend national energy policies and national energy management plans to the cabinet,
- To set rules and conditions for prescribing energy prices in accordance with national energy policies and national energy management plans,
- To monitor, supervise, coordinate, support and expedite the operations of all committees with authorities and duties related to energy, including government agencies, state enterprises, and the private sector, to ensure that their operations are in accordance with national energy policies and national energy management and development plans,
- To evaluate the implementation of national energy policies and national energy management and development plans,
- To perform other functions as assigned by the Prime Minister or the cabinet.

Based on the national energy policies, the work on energy efficiency and energy conservation is conducted in both mandatory and voluntary manners. Only three agencies have direct responsibilities for energy activities in Thailand. Those include the National Energy Policy Office (NEPO), the Department of Energy Development and Promotion (DEDP), and the Electricity Generating Authority of Thailand (EGAT).

The National Energy Policy Office (NEPO). NEPO is a cabinet-level committee under the Office of the Prime Minister. Being the Secretariat of the NEPC, NEPO plays very crucial roles in setting the direction of energy policies and energy sector management for Thailand. Its responsibility is to set the energy policies for Thailand, to transform the energy policies into practice, and to oversee that the direction of the Thai energy sector is going as planned. In addition, NEPO is in charge of promoting voluntary and

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[32] National Energy Policy Office (NEPO) Inter-Agency Manual for the Operation and Management of the Energy Conservation Program of Thailand, Bangkok, December 1994.

complementary activities in the areas of energy efficiency, energy conservation, and renewable energy, associated with the ECPA 1992.

The Department of Energy Development and Promotion (DEDP). DEDP is under the Ministry of Science, Technology and Environment. It has responsibility for compulsory energy efficiency and conservation activities as specified under the ECPA 1992.

The Electricity Generating Authority of Thailand (EGAT). EGAT is a state-owned enterprise. It is responsible for producing electricity throughout Thailand. EGAT distributes electricity to the Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA) which are state enterprises under the direction of the Ministry of Interior. The MEA is responsible for electricity distribution to consumers in the metropolitan area and PEA is responsible for electricity distribution to consumers in the provincial areas. EGAT's role in energy efficiency and energy conservation is to promote energy saving under its Demand-Side Management (DSM) Program.

Voluntary and Complementary Programs of the Energy Conservation Program. The ECPA 1992 is seen as innovative as it blends incentives with mandatory regulations to facilitate the implementation of mandated energy-efficiency measures. The Energy Conservation Program was set up under the ECPA 1992, consisting of Compulsory Program, Voluntary Program, and Complementary Program. The Energy Conservation Promotion Fund was established to provide financial support to government agencies, state enterprises, non-government organizations, individuals, and businesses that wish to implement measures to increase energy efficiency. In 1999, the Fund contains about 14 billion baht, with additional fund coming from a fuel tax of 0.04 baht per litre of gasoline, diesel and fuel oil, amounting to about 14 million baht per year.

While the Compulsory Program of the Energy Conservation Program is under the direction of DEDP, NEPO is responsible for the Voluntary and Complementary Programs. The Voluntary Program covers activities concerning new and renewable energy for rural and small industry, research, development and demonstration of technologies, and energy conservation business facilitation for private sector. The Complementary Program covers activities concerning public relations and human resources development.

The involvement and authorities of the government agencies in energy efficiency and energy conservation in Thailand are discussed by end-use sector as follows:

Commercial Sector. The agencies working on energy efficiency and energy conservation in the commercial sector are DEDP and EGAT.

DEDP has a mandate for the legal energy conservation work in buildings as specified by the ECPA 1992. The buildings that fall into the category of designated buildings and are required by law to participate in the Energy Conservation Program are all buildings with an installed electrical demand of at least 1 MW or an installed transformer capacity of 1,175 kilo volt-ampere (kva) and up, or buildings with a total commercial energy consumption greater than 20 million MJ/year. These buildings are required by law to establish energy conservation targets and plans and conserve energy in accordance with the targets and plans to achieve the standards prescribed in the Ministerial Regulations of ECPA 1992.

EGAT established the "Business/Government/State Enterprise Program" as part of the DSM Program, to encourage commercial buildings (including shopping centers, hotels, hospitals, and offices) to use electricity more efficiently in compliance with, or exceeding, the standards specified in the Ministerial Regulations of the ECPA 1992. EGAT launched the Green Building Program in September 1995 with 231 participants voluntarily joining the program.

Industrial Sector. The Department of Industrial Work (DIW), Ministry of Industry is responsible for overseeing, promoting, and supporting the operations of the Thai industries. The DIW stated that one of its main duties is to insure that the Thai industries are conducting their businesses with concerns for environmental protection, safety, health, and energy savings. However, the DIW does not develop special programs or policies related to energy efficiency and energy conservation. The work on energy efficiency and energy conservation in the industrial sector has been conducted by DEDP according to the ECPA 1992 and by EGAT through the DSM Program.

DEDP has implemented Energy Conservation in Factories since 1998. The designated factories are the ones with an installed electrical demand from 1,000 kW up, or installed transformer capacity from 1,175 kVA up, or a total consumption of commercial energy including electricity and steam from 20 million MJ/year and up. The program is designed to cover only a small target group in the first year (only large energy consumers) and expands the target group every year to cover smaller energy consumers, until it will cover all factories in Thailand in the fourth year. The owners of designated factories are required by law to submit energy conservation targets and plans to the government and conserve energy in accordance with the targets and plans to achieve the standards prescribed in the Ministerial Regulations of ECPA 1992.

Under the DSM Industrial Program, EGAT established a High Efficiency Motor Program to focus on replacing existing standard efficiency motors with high efficiency motors. The program promotes the use of high efficiency 3 phase motors with 7.5 to 500 HP motor ratings. The motors must be certified by acceptable institutions to meet the U.S. National Electrical Manufacturers Association (NEMA)'s efficiency standard. In addition, the Industrial Energy Efficiency Program is set up to promote the use of all types of energy efficient equipment and processes in the industrial sector.

Residential Sector. Energy efficiency and energy conservation programs in the Thai residential sector have been conducted through the EGAT's DSM Program and NEPO's Energy Conservation Public Relations Program. Public participation in both programs is voluntary. There is no legal requirement or government mandate to implement any legal measures for energy efficiency and energy conservation in the residential sector.

The residential programs of the DSM program aim to encourage the residential sector to utilize higher efficiency equipment, such as, more efficient lighting equipment, refrigerators, and air conditioners. Currently, EGAT is also working on a pilot project on roof top solar photovoltaic (PV) electricity and grid connected solar PV electricity. This project is supported by money from the Energy Conservation Fund. So far EGAT has already installed 8 PV units of 2.25 kW and 2 PV units of 2.88 kW. It is estimated that the total electricity generated by solar cells within 25 years will be 1.25 GWh, estimated to provide 3.125 million baht of energy conservation.[33]

The Energy Conservation Public Relations Program[34] is part of the complementary program of the Energy Conservation Program. It was initiated in 1996. The main objective of this program is to create and promote an energy conservation consciousness amongst the general public, and to provide understanding of the importance of conserving energy and other natural resources. The program is designed to create awareness on how the proper and economical use of various forms of energy and natural resources (such as fuel, water, and electricity) can positively affect the environment and national economy. This program employs various communication tools, ranging from public relations, general advertising, direct marketing, and event marketing. The activities of the program are all linked together through the program concept of "Divide Energy by 2".

Transportation Sector. There are thirty or more government institutions responsible for transportation and urban development in Thailand. However, none of these agencies approaches transportation problems with a mandate to improve energy efficiency.

The Office of the Commission for the Management of Land Traffic (OCMLT) is the designated coordinating and evaluating body under the Commission for the Management of Land Traffic (CMLT). OCMLT is the principal agency responsible for transportation planning for Thailand and to develop the Transportation Master Plan. OCMLT will then coordinate the plans and projects prepared by the line agencies according to the Master Plan. OCMLT also prepared a report on traffic and transportation for the current Eighth National Economic and Social Development Plan (1997-2001) for improving Thailand's transportation sector.

Some current policies on transportation include:

- Imposition of taxes on the initial purchase of private vehicles,
- Collection of fuel taxes on gasoline, diesel, and LPG,
- Control on emissions from vehicles, for example, set up emission control standards for new vehicles, require annual inspection of all vehicles, spot check emissions of vehicles on the road, and testing vehicles for standard compliance,

[33] National Energy Policy Office, Report of the project under the sponsor of ENCON fund, June 1997.

[34] National Energy Policy Office, Printed Matter, July 1998.

- Construction of expressways and overpasses at 18 of the city's most congested intersection,
- Restrictions on freight trucks from entering Bangkok at various hours during the day,
- Designation of bus lanes, and
- Construction of mass transit, elevated rails, and a subway system.

As can be seen, there are no specific policies designed for energy efficiency in the transportation sector.

Agricultural Sector. The agricultural sector is not a main energy-consuming sector in Thailand. In 1997, the energy consumption in the agriculture sector was 1,494 ktoe, accounting for only 2.8 percent[35] of the total final energy consumption of the economy. Due to this small fraction of consumption, the agricultural sector is not a principal target for energy conservation and there are no measures or any government programs designed for energy efficiency and energy conservation in the agricultural sector.

Energy Decisions at the City Level

There are no special energy policies or programs designed at the city level. In addition, there is no particular government agency that has a mandate to control city energy use. Yet, local government can make decisions to implement an energy project in its own jurisdiction.

When talking about MAT, it generally refers to four provinces, Bangkok, Sumutprakarn, Nonthaburi, and Pathum Thanee. These four provinces are connected via land boundaries, and in economic and commercial activities, which make the separation of the energy consumption statistics difficult. However, regarding provincial administration, they are four separate provinces with separate local governments. Being the capital, Bangkok is more independent from the central government, and its structure of administration is different from other provinces.

Bangkok Metropolitan Administration. Bangkok is administered under the Bangkok Metropolitan Administration Act, which came into effect on August 31, 1985. According to the Act, the Governor of Bangkok is elected by popular vote for a four-year term. The Governor then appoints four Deputy Governors. Bangkok comprises of 36 districts. Each district will elected its representatives to be members of the Bangkok Metropolitan Assembly. The number of assemblymen in each district depends on the population of that district—one assemblyman for each hundred thousand people. At present, there are 60 assemblymen. The Bangkok Metropolitan Assembly is responsible for administration and management of Bangkok as a whole.

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[35] Department of Energy Development and Promotion, "Thailand Energy Situation 1997", Ministry of Science Technology and Environment, 1997.

In addition to the administration at the provincial level by the Bangkok Metropolitan Assembly, there is also an administration at the district level by District Council. The District Council is composed of the elected members from 36 districts. The number of the members of the District Council in each district depends on the population in the district. The elected members of the District Council have direct responsibility to look after the people in their districts.

The functions of Bangkok Metropolitan Administration according to the Bangkok Metropolitan Administration Act 1985 are not concerned with any energy activities.[36] Its principal functions are listed below.

- Maintaining law and order and enforcing city ordinances,
- Registration according to the law,
- Preventing and relieving public disaster,
- Maintaining cleanliness and orderliness of city,
- City planning,
- Providing and maintaining roads, waterways, and the drainage system,
- Providing traffic engineering,
- Transportation management,
- Providing and controlling markets, ports, and ferries,
- Maintenance of public places,
- Building construction standards,
- Improving slums and providing public housing,
- Providing and maintaining recreational centers,
- Developing and conserving the environment,
- Providing public utilities and facilities,
- Providing public health, family hygiene, and medical services,
- Providing and controlling cemeteries and crematorium,
- Controlling animal husbandry,
- Providing and controlling animal slaughtering,
- Controlling orderliness and sanitation in theaters and other public places,
- Providing compulsory education,
- Community development,
- Providing social welfare,
- Occupational training and employment promotion,
- Managing Bangkok Metropolitan Enterprise,
- Other functions as assigned by the Prime Minister, the Cabinet, Minister of Interior, or as specified by laws.

Other Provinces of the Metropolitan Area. The administration of Sumut Prakarn, Puthum Thanee, and Nonthaburi (as well as the other provinces in Thailand besides

[36] More detail about the functions of BMA is available in the BMA web site (www.bma.go.th).

Bangkok) is based on the same structure.[37] Each province has a governor as the head of the province. The governor is appointed by the central government. Each province is composed of several districts. Each district is administered by government officers who are appointed from the central government.

Each province also has local administration in the form of one or more municipalities. Municipalities are classified into 3 levels, sub-district municipality, town municipality, and city municipality. The classification of municipalities is based on the density of the population residing in the area and the annual income. The sub-district municipality is the smallest one (having the least density of population and obtaining the least annual income), and city municipality is the largest one. Municipalities are administered by municipal councils. Members of the municipal council are elected by popular vote for four-year terms. Members of the municipal council then elect the municipal cabinet and mayor.[38] The municipal cabinet of a sub-district and a town municipality are both composed of one mayor and two members. In cases where the town municipality's income is greater than 20 million baht, there will be an additional member in the cabinet. The municipal cabinet of a city municipality has one mayor and four cabinet members.

The duties of the three municipalities are basically the same. Those duties include:

- Maintaining cleanliness and orderliness of city,
- Providing and maintaining roads and waterways,
- Maintenance of public places,
- Providing compulsory education,
- Providing public health, family hygiene, and medical services,
- Providing the drainage system,
- Providing the water supply,
- Providing the health center or hospital,
- Providing and controlling markets, ports, and ferries,
- Providing public lavatories,
- Providing and controlling animal slaughtering,
- Providing and controlling cemeteries and crematorium,
- Occupational training and employment promotion.
- Other functions as assigned by Minister of Interior or as specified by laws.

The municipality does not have any mandate related to city energy use.

[37] Thailand comprises of 76 provinces.

[38] The new law (effective in elections held after 1999) requires that the mayor be elected by popular vote.

Sources of income of local government. The sources of income of local government according to the law are:

- Income from taxes which can be divided into 2 types:
  - ♦ Taxes that are collect by the local government, including building and land tax, local administration tax, signboard tax, and slaughter tax,
  - ♦ Taxes that are collected by the central government, including value added tax, liquor tax, excise tax, and car and trailer tax
- Income from fees, tolls, and fines. This includes, for example, the building control fee under the 1989 Building Act.
- Income that is collected by the government or government organization.
- Income from the local property.
- Income from local government enterprises such as pawn shops.
- Income from the central government which can be divided into two types:
  - ♦ General subsidy such as the restoration of public properties.
  - ♦ Specific subsidy such as repair or construct road.

The local government has no specified mandate related to city energy use. However, the local government is responsible for designing their own plan for city development and allocates their budget according to the plans, though the plan has to be approved by the governor of the province before being implemented. The local government can, therefore, include any IEUP-based projects into its plan, if desired.

VI. Organizations Working on Energy Research

There are many research institutes, government agencies, universities, and non-government organizations that are doing research in energy efficiency related fields. The followings are some of the well-known organizations working on energy research projects in Thailand.

Department of Energy Development and Promotion

Department of Energy Development and Promotion (DEDP) conducts research by cooperating with consulting firms or research institutes. The research is normally funded by the money from the Energy Conservation Fund. DEDP is interested in energy research across all energy sectors. Numerous research projects have been funded through DEDP. Some examples of the projects are:

- Energy conservation in government enterprise buildings,
- The study of wind energy potential in Thailand, and
- Energy conservation building designs.

Electricity Authorities

All of the Thai Electricity Authorities, namely, Electricity Generating Authority of Thailand (EGAT), Provincial Electricity Authority (PEA), and Metropolitan Electricity Authority (MEA), are not only in charge of the generation and distribution of electricity but they also conduct research on energy conservation, energy management, and alternative energy sources. Some examples of the research conducted by these organizations are:

- Load management of cool storage air conditioning systems, and
- The study of load characteristics.

King Mongkut's University of Technology Thonburi

King Mongkut's University of Technology Thonburi (KMUTT) is one of the few universities in Thailand that has academic faculty in energy engineering. The School of Energy and Material contains the majority of faculty at the university who conduct research in both energy technology and energy management related fields. KMUTT conducts many research projects associated with renewable energy, energy conservation in all energy sectors, and cogeneration.

Energy Research Institute

Energy Research Institute (ERI) is a university research institute at Chulalongkorn University. The interdisciplinary focus of ERI links the energy related university departments and organizations in conducting energy research. ERI has under taken a number of research projects for the university and government agencies. The main sources of project funding are from DEDP, NEPO, EGAT, Asian Energy Institute (AEI), and Energy Conservation Fund. ERI conducted many research projects associated with the energy efficiency in the building, industry, residential, agricultural, and transportation sectors. Some of on-going projects of ERI are:

- Cogeneration for electricity utilities and industry,
- Technical suitability in connecting the national grid with a cogeneration system,
- Study on the requirements of manpower for the energy sector and implementation in accordance with the energy conservation, and
- Design and fabrication of hydraulically operated machines for commercial production of efficient cooking stoves.

Solar Energy Research and Training Center

Solar Energy Research and Training Center **(**SERT) is a university research institute, which is operated under Naresuan University. The objective of SERT is to serve the energy needs of southeast Asia, by promoting technology that is appropriate to the economic, cultural, and industrial condition of the region. The research of SERT is mainly related to solar energy. At present, SERT is working on several research projects related to solar energy, and NEPO is the main source of project funding.

Petroleum Authority of Thailand Research and Technology Institute

The role of the Petroleum Authority of Thailand Research and Technology Institute (PTT R&T Institute) is to be a national petroleum and petrochemical research institute. PTT R&T Institute conducts research on gas, petroleum, and petrochemical related fields as needed to maintain the leadership in product quality and environmental protection of Petroleum Authority of Thailand (PTT). Besides research efforts to meet PTT's own business needs, the institute renders technical support to the state agencies responsible for the formulation on policies and regulations related to petroleum products. It also provides technical data and information on policies and regulations related to petroleum products. Technical data and information obtained from research and development work are submitted to NEPO and the Fuel Division of the Ministry of Commerce to facilitate the revision of product specifications. In addition, the institute also conducts research in the area of energy conservation and environment. An example of energy conservation projects is the study of fuel economizer equipment, which is supported by the Energy Conservation Fund.

Thailand Environment Institute

Thailand Environment Institute (TEI) is a non-profit, non-governmental organization (NGO) found in 1993. TEI is governed by a Council of Trustees and a Board of Directors. The President, as Chief Executive of the Institute, is responsible to the Council and the Board for decisions on the Institute's finances, operations, and direction.

TEI aims to play a catalytic role regarding environmental issues in Thailand, and interacts with government, NGOs, academia, private sector, the media, and the general public. TEI helps to formulate environmental policies at the national level and collaborates with various international organizations to promote environmental awareness at the global level. The work conducted at TEI can be classified into 7 different areas: urban and environment, business and environment, energy and environment, grassroots action, natural resources management, industry and environment, and environmental information. Research projects associated with energy and environment include:

- Electricity project to examine alternative electricity demand and supply scenarios for Thailand,
- Thailand's Country Study on Climate Change, a project conducted as part of the US Country Study Program on Climate Change, and
- Asia Least Cost Greenhouse Gas Abatement Strategies project.
- Cities for Climate Protection Campaign Workshops in Thailand

VII. Conclusions

City Energy Modeling

In most economies, energy data is compiled and reported at the national level, and energy data at the city level does not exist. This study demonstrates how detailed city energy consumption could be estimated with limited data, and how a city energy model could be beneficial in producing information to facilitate IUEP based projects. The MAT is utilized as a case study. The MAT is a good example for the study since it well represents a picture of a typical megacity where energy consumption accounts for almost half of the total economy's energy consumption, it is facing problems of health impacts and air pollution from energy use, and it is lacking well-defined policies on city energy use.

This study estimates the MAT energy consumption by modifying an existing national level model to be appropriate for the analysis of city energy issues. Such modifications include, for example, an increase in the level of detail on the energy end-use sectors, especially for the end-use sectors that have high potential contributions to large energy savings if energy efficiency and energy conservation measures are implemented, and paying less attention to the energy-producing sectors. For a second example, modification is also made in the transportation sector of the national model by aggregating short and long distance trips of the national model, since all travel in a city is considered short distance and traveling by planes is not an option.

The results of the study shows that the transportation sector was the largest MAT energy consumer, consuming about 96,686 kboe or about 71 percent of total energy use in MAT in 1995. The industrial sector was the second largest energy consumer, but it consumed much less energy than the transportation sector—at about 24,407 kboe or 18 percent of total energy use in MAT in 1995. The commercial, residential, and agricultural sectors were the small energy consumers, consuming 5.8 percent, 4.6 percent, and 0.7 percent, respectively, of total energy use in MAT in 1995. This energy consumption pattern is different from that of the total economy, for which transportation, industrial, and residential sectors were considered principal energy consumers (see Table 6).

Table 6: Energy Consumption in the MAT and the Whole Kingdom in 1995

Unit: Percent

Sector	MAT	Whole Kingdom
Transportation	71.0	37.9
Industrial	17.9	31.8
Residential	4.6	22.7
Commercial	5.8	4.2
Agricultural	0.7	3.4
Total	**100**	**100**

This study estimates the total MAT energy consumption at 136,123 kboe in 1995, which was about 7.5 percent higher than those reported by the government. This is not surprising, and actually expected, since estimating city energy consumption faces the problem of porous boundaries for energy use. Due to the fact that communication and transportation are not limited only to a city, it is difficult to know what are the actual quantities of energy consumption in a city. However, the use of energy modeling to estimate city energy consumption gives a rough idea of the energy consumption pattern of the city and helps to establish priorities for implementing IEUP projects.

Health Impacts of Air Pollution in Bangkok

The impacts of air pollution on the health of Bangkok residents have been studied only recently. The studies found evidence of health damages related to air pollution in Bangkok, especially in the areas with traffic congestion. These include the impacts of particulate matter on the respiratory system, abnormal pulmonary function resulting from air pollution, an exceeding of the standards for carbon monoxide and PM10 in some congested traffic areas, and high blood lead concentrations.

One study estimated that a 20 $\mu g/m^3$ reduction in average PM10 concentrations across the metropolitan area would result in a reduction in premature mortality of between 1,400 and 4,000 deaths each year. The estimated annual value to the Bangkok residents of the reduced health effects and quality of life improvements ranged from 65 and 175 billion baht.

It was also found that the total economic costs of air pollution on health damage per capita were higher in Bangkok than in Mexico, Jakarta, and Santiago. The same study suggested that particulate matter and lead should be a prime concern for the Thai government and the transportation sector should receive the most attention for air pollution remedies in Bangkok.

The Thai government has set air emission standards, which are enforced all over Thailand. The government has also implemented several measures to control emissions from vehicles. However, there is no legal mandate in any government agency to improve energy efficiency in the transportation sector. Mandatory energy efficiency and energy conservation measures are implemented only for commercial buildings and factories.

Energy Decision Making in Thailand

Decisions on energy policies in Thailand are made at the national level. There are no special energy policies or programs designed at the city level. In addition, there is no particular government agency that has a mandate to control city energy use. However, local governments are responsible for designing their own plans for city development and allocate their budgets according to the plans. Local governments can, therefore, include any integrated urban energy planning-based projects into their plans, if desired.

Organizations Working on Energy Research

The organizations that are working on energy research projects in Thailand are mainly universities and their related research institutes. Government agencies normally do not conduct research by themselves but cooperate with consulting firms or research institutes.

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