An Assessment of the Cost Effectiveness of a DSM Program in the Southern Part of Thailand

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T. Arunthanakit and C. Sorapipatana
The Joint Graduate School of Energy and Environment,
King Mongkut's University of Technology Thonburi,
91 Pracha-Uthit Rd., Bangmod, Tungkru, Bangkok 10140
THAILAND

ABSTRACT

Due to the inadequacy of the electrical power supply to meet the demand in the Southern part of Thailand in recent years, electrical power from nearby areas from the Central part of Thailand and Malaysian needs to be transmitted through high power tie-lines. This often causes some technical problems in power transmission systems, particular during peak time period, due to electric power transmission instability, as affected by the long distances of the tie-lines. As a result, it often black out in this region. The failure of electrical supply would be worsen as the trend of the electrical demand generally increases in the future. Traditionally, the solution for this problem is to expand the transmission lines or install more power generation capacities in this region, but it spends more costs and time consumes. An alternative to solve this problem is to adopt the Demand-Side Management (DSM) program to stimulate and implement energy saving program to reduce both electrical energy and power peak load demand. In this study, we estimate the potential of the electrical energy saving and reduction in the averaged power peak in the Southern part of Thailand in the next 10 years, if energy saving program is introduced by encouraging consumers to switch to use more efficient appliances in various sectors.

A regression technique was adopted to predict the demand of the electrical energy in the Southern part of Thailand in the next decade. It was found that the energy demand highly depends on the two parameters: the Real Gross Regional Products (RGRP) and populations. The result of the predicted electrical energy demand was then used to estimate the peak demand. Then, the potential of energy saving amounts were estimated, if more efficient appliances were introduced to replace of non-efficient appliances. To simplify the problem, we assumed that only those major common appliances are replaced by the more efficient appliances as follows: (a) lighting, refrigerators, and air-conditioners for residential sector, (b) lighting and air-conditioners for commercial sector, and (c) motors for industrial sector.

Finally, the benefit of the total saving energy cost and the total investment costs of the high-efficient appliances were analyzed to determine whether it is economical feasible or not. The result indicates that the alternative solution of the DSM program would be more cost-effective, as compared to the expansion of new high power tie-lines of the conventional supply side planning.

1. INTRODUCTION

Presently, the total capacity of electrical power supplies in the Southern part of Thailand are 2,031.3 MW (in year 2001), of which some of the power supplies are transmitted through the tie-lines from power generation plants in the Central part. The tie-lines have a total limited capacity of 350 MW [1].

Due to the growing up of electricity demands in this region, the electrical utility has to supply more electric power to meet the demand in the near future, any supply of the electric power over this limit is unlikely possible because of the over capacity of the tie-lines.

In this study, a tie-line expansion project of the supply-side management and an energy saving program of the demand-side management are compared to find out an appropriate solution with a minimum investment cost, in order to cope with the unbalance of the supply and demand in the near future.

2. METHODOLOGY

2.1 The Prediction Equations for Electric Power Consumption in a Long-term

In this study, we, initially, forecast the electric energy and peak demand in the Southern Part of Thailand in the next decade.

2.1.1 The Prediction Equation for the Electric Energy Demand

The electric energy demand is determined by the real gross regional products (RGRP) and populations. The energy demand was found to be well correlated with both parameters. The energy demand equation is given by:

$$\text{Log}\, ENER_t = \alpha_1 + \alpha_2 \,\text{Log}\, RGRP_t + \alpha_3 \,\text{Log}\, POP_t \qquad (1)$$

where, $ENER_t$ = the energy demand in year t,
$RGRP_t$ = the real gross regional products in year t,
POP_t = the populations in year t, and
$\alpha_1, \alpha_2, \alpha_3$ = constant parameters.

The $RGRP_t$ in year t of the Eq. (1) is determined by:

$$RGRP_t = RGRP_o(1 + GR)^t \qquad (2)$$

where $RGRP_t$ = the real gross regional products in year t,
$RGRP_o$ = the real gross regional products in the base year, and
GR = the averaged annual growth rate of the real gross regional products in the prediction.

In this study, the GR in Eq. (2) was determined by using the most update predicted RGDP (Real Gross Domestic Products) growth rates in the long-term, which were forecasted by various well-known financial institutions and were published in June 2003 (See Table 1).

Table 1 Predicted Percentage of Thailand Real Gross Domestic Products Growth Rate in Long-term after the Economic Crisis in 1998

Organization	Growth Rate (%)	Organization	Growth Rate (%)
Citybank	3.10	Thai Farmers Research Center	4.00
Asian Development Bank	3.25	Deutsche Bank	4.20
Bangkok Bank	3.40	HSBC	4.20
IMF	3.40	Nomura Research Institute	4.30
World Bank	3.50	Goldman Sachs	4.50
Bank of Thailand (BOT)	3.70	J.P. Morgan & CHASE	5.00
Merrill Lynch Phatra	3.80	TDRI	5.00
Morgan Stanley Asia	4.00	NESDB	5.00
IFCT	4.00	*Average*	*4.02*

Source: Thailand Investor Service Center (TISC), June 2003 [2]

Since the actual RGDP growth rate in the future is quite uncertain. From Table 1, the maximum, minimum, and averaged RGDP growth rates are 5.00%, 3.10%, and 4.02%, respectively, they were then used as the annual economic growth rate under high, low, and medium scenario for the long-term forecasting in this study, respectively. The POP_t in Eq. (1) was the population. The figures of it were predicted by Office of the National Education Commission (ONEC) [3] and were published in December 1999. They were adopted to be applied for the estimation in Eq. (1).

2.1.2 The Prediction Equation for the Peak Demand

A log-linear model was used to estimate the peak demand as follow:

$$\text{Log}\, PEAK_t = \beta_1 + \beta_2 \text{Log}\, AVG_t \qquad (3)$$

where, $PEAK_t$ = the peak demand in year t,
AVG_t = the annual average demand in year t, and
β_1, β_2 = constant parameters [4].

The annual average demand is defined as the average rate of energy demand per hour in a year (8,760 hours).

The past historical recorded data of RGRP and populations as published by National Statistical Office (NSO), and energy demand from 1992 to 1997 [1] were regressed to estimate the parameters of the energy demand Eq. (1). The stepwise regression method [5] was used to determine the best fitted equation, which was indicated by the highest coefficient of determination, R^2.

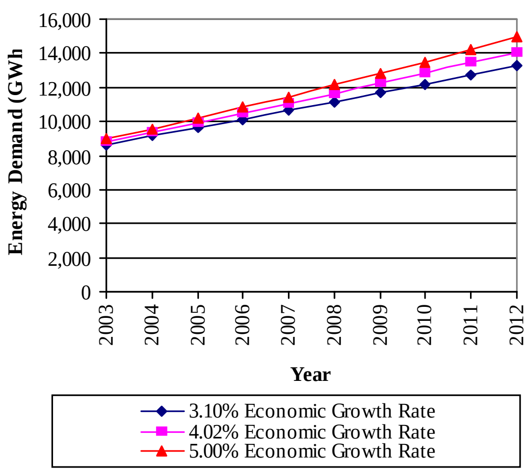
The results of the regression of Eq. (1) in this study gave the R^2 between 0.96 and 0.99. Then, the best fitted equation for estimating energy demand was then used to project the annual electric energy demand in the Southern part of Thailand for the next decade, under three scenario of the economic growth rates as mentioned before, starting from the base year in 2000. The results are shown in Table 2.

The coefficients of the peak demand in Eq. (3) could be found by regressing the past annual peak demand and the past average demand. These both past figures were published by Electricity Generating Authority of Thailand (EGAT), during year 1992 to 1997 [1]. The regression Eq. (3) of the peak demand was found to be well fitted with $R^2 = 0.99$. The regression Eq. (3) was then applied to project the peak demand in next 10 years during 2003 to 2012. The results were shown on Table 2

Table 2 Predicted Annual Electric Power Consumption

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Energy Demand (GWh)										
3.10%	8,642.13	9,129.58	9,625.41	10,129.23	10,639.26	11,155.02	11,676.89	12,203.79	12,735.46	13,272.55
4.02%	8,799.68	9,338.09	9,889.81	10,454.58	11,030.70	11,617.80	12,216.36	12,825.40	13,444.74	14,075.17
5.00%	8,969.09	9,563.35	10,176.78	10,809.35	11,459.52	12,127.11	12,812.86	13,515.92	14,236.31	14,975.08
Peak Demand (MW)										
3.10%	1,398.48	1,470.30	1,543.01	1,616.57	1,690.70	1,765.36	1,840.59	1,916.25	1,992.30	2,068.85
4.02%	1,421.73	1,500.92	1,581.66	1,663.90	1,747.39	1,832.08	1,918.05	2,005.14	2,093.34	2,182.75
5.00%	1,446.69	1,533.93	1,623.49	1,715.36	1,809.29	1,905.25	2,003.35	2,103.45	2,205.55	2,309.78

Remarks: 3.10%, 4.02%, 5.00% - Low, medium, and high economic growth rate scenario, as used in this study



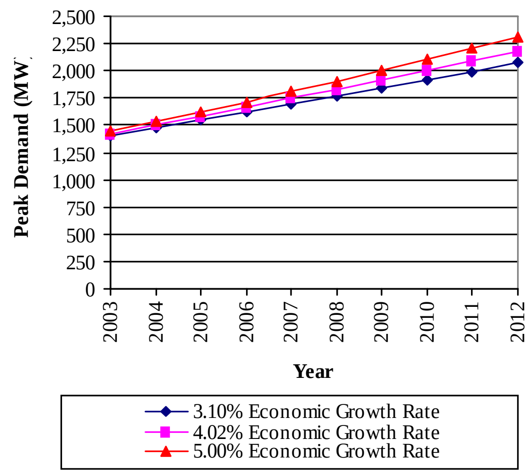


Fig. 1 The Predicted Annual Electric Power Consumption:
(a) Energy Demand (b) Peak Demand

The results of the predicted electric power consumption in the Southern part of Thailand from Table 2 were then used to determine a cost-effective solution between a supply-side and a demand-side alternative to solve the unbalancing problem of the energy demands and the supplies.

2.2 Demand-Side Management Program

In this study, only some types of the most common use conventional appliances were assumed to be replaced by those high-efficient appliances for energy saving, as this is a key strategy for the demand-side management in our study. From the past records, it showed that the most common used appliances, which shared large proportions in electrical energy consumption, for residential, commercial, and industrial sector in the Southern part of Thailand are (a) lighting, refrigerators, and air-conditioners, (b) lighting and air-conditioners, and (c) motors, respectively. These appliances are of interests in this study for energy saving.

From the statistical survey data [6, 7], the lighting, refrigerators, and air-conditioners shared about 10%, 20%, and 23% of total electrical energy consumption in residential sector, respectively. And the lighting and air-conditioners shared about 20% and 68% of total energy consumption in the commercial sector, respectively. And the motor load was about 75% of total electricity uses in industrial sector.

2.2.1 Technical Energy Saving Potential

The saving potential of the energy demand by the replacement of those high-efficient appliances can be expressed as:

$$ESAV_i = [\sum_{j=1}^{j=m}(PE_j * ME_j * \sum_{k=1}^{k=n}(MM_{j,k} * PS_{j,k} * PR_{j,k}))] * ENER_t * SC_i \quad (4)$$

where,
- $ESAV_i$ = the total amount of energy saving potential for end users in sector i,
- $ENER_t$ = the total energy demand in year t,
- SC_i = the proportion of total energy demand for end users in sector i,
- PE_j = the proportion of total energy consumption of all appliances in type j,
- ME_j = the percent share of the total conventional appliances in type j,
- $MM_{j,k}$ = the proportion of conventional appliance type j with a certain rated capacity in category k,
- $PS_{j,k}$ = the percentage of energy saving by using high-efficient appliances in type j of the rated capacity k,
- $PR_{j,k}$ = the percentage of replacing existing conventional appliances by high-efficient ones,
- m = the total type of the conventional appliances, and
- n = the total category of the conventional appliances with various rated capacities.

The recorded data of PE_j, ME_j, $MM_{j,k}$, and $PS_{j,k}$ were obtained by a survey, which was conducted and published by AGRA Monenco, Inc. [6] and ERM-Siam Co., Ltd. [7]. In this study, the percent shares of the high-efficient appliances $PR_{j,k}$, as adopted by the end users in all sectors, were then assumed to be 25%, 50%, 75%, and 100%, at the beginning of the implementation, for the substitution of those inefficient existing conventional appliances. And we assume that these percent shares are kept constant throughout a period of horizontal planning of a project life of new expansion tie-lines.

The financial investment costs and benefits of each percent share of the high-efficient appliance substitution were then evaluated and compared to that of tie-line investment, i.e. the supply-side alternative without any energy saving program. The results will be discussed later in section 3 and 4.

2.2.2 The Marginal Investment Cost of the Demand-Side Management Program

The net present worth of the marginal investment cost (MCSE) [8] for the energy saving program can be determined by:

$$MCSE = [AV + AC - (ESAV * P)/crf]/ESAV \quad (5)$$

where,
- AV = a cost of opportunity losses in early termination of conventional appliances before the end of their life, to be replaced by those more efficient appliances,
- AC = the first investment costs to substitute those conventional appliances by the higher efficient ones,
- $ESAV$ = the energy saving,
- P = the electricity unit price, and
- crf = the capital recovery factor ($crf = r/[1-(1+r)^{-n}]$; r is the discount rate, and n is the time period in years of the capital recovery factor).

2.3 The Energy Supply-Side Program

If there is no energy saving program implemented and new power tie-lines are expanded in order to increase their capacities to supply more power to meet the increasing demands, then the long-run marginal cost (LRMC) [8] for the expansion of the new tie-lines can be expressed as:

$$LRMC = [(I + C_{fix}/crf - S^{*}pwf)/8760] + [(C_{fuel} + C_{var})/crf] \quad (6)$$

where, I = the marginal initial capital cost,
C_{fix} = the annual marginal fixed O&M cost,
S = the salvage value, crf is the capital recovery factor,
pwf = the present worth factor ($pwf = 1/(1+r)^n$; r is the discount rate, and n is the time period in years of the present worth factor),
C_{fuel} = the annual marginal fuel cost, and
C_{var} = the annual marginal variable O&M cost.

The cost parameters in Eq. (5) were obtained from AGRA Monenco, Inc. [6] and ERM-Siam Co., Ltd. [7]'s survey reports, and from the specifications of energy efficient products book (June 2002) [9]. Some useful data for LRMC calculation were also supported by Electricity Generating Authority of Thailand (EGAT). 12% of the discount rate was used in this study. This figure is the practical value for project evaluations of several organizations in Thailand, which is recommended by National Economic and Social Development Board (NESDB) [10]. The marginal cost of the saving energy (MCSE) of the demand-side was then compared with the long-run marginal cost (LRMC) of the supply-side alternative. The lower values of MCSE than LRMC mean that the energy saving program is more cost-effective than the supply-side solution.

3. RESULTS

3.1 Technical Energy Saving Potential

The projected electrical supply needed in the Southern region was calculated based on the predicted electrical energy demands in Table 2, and included the allowances for the transmission and distribution (T&D) losses of 8%.

The total electrical power peak supply capacity required in the future is then estimated from the total projected electrical energy supply. The availability of the current electrical supply capacities (1,828.17 MW) to meet the estimated demands in the future was then compared with an allowance of 10% reserve of the current full capacities. The results showed that the current supply is not adequate to meet the demand in next 3 to 5 years, depending on the scenarios of the economic growth rate conditions. Additional required power supply capacities are 76.78, 57.40, and 22.83 MW for low, medium, and high economic growth rate in year 2008, 2007, and 2006, respectively. For all cases, two more new tie-lines are required, and they have a total capacity of 2x1,100 MW. In contrast, if the energy saving program is implemented instead of the expansion of the new tie-lines, then the amounts of energy can be saved and help to suppress the needs of more energy supply; the amounts of energy saving were shown on Tables 3, 4, and 5 for low, medium, and high economic growth rate scenario, respectively.

Table 3 Energy Saving by Energy Saving Program at 3.10% Economic Growth Rate (Low Economic Growth Rate Scenario)

Year	Energy Saving (GWh)															
	2005				2006				2007				2008			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Residential Sector																
Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.75	11.50	17.26	23.01
Refrigerators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.62	79.24	118.86	158.48
Air-Conditioners	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45.00	90.00	135.00	180.00
Commercial Sector																
Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.03	6.06	9.09	12.12
Air-Conditioners	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	80.12	160.24	240.35	320.48
Industrial Sector																
Motors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.27	82.54	123.81	165.08
Total Energy Saving	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*214.78*	*429.57*	*644.36*	*859.16*

Year	Energy Saving (GWh)															
	2009				2010				2011				2012			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Residential Sector																
Lighting	10.34	17.79	22.38	24.09	14.04	21.48	24.47	25.17	17.10	23.88	25.82	26.27	19.67	25.63	26.99	27.38
Refrigerators	71.19	122.56	154.13	165.89	96.73	147.97	168.57	173.38	117.78	164.45	177.84	180.93	135.48	176.50	185.88	188.56
Air-Conditioners	80.85	139.21	175.06	188.42	109.86	168.06	191.45	196.92	133.77	186.78	201.99	205.50	153.87	200.47	211.12	214.17
Commercial Sector																
Lighting	5.30	9.09	11.36	12.12	7.01	10.60	11.93	12.12	8.28	11.36	12.07	12.12	9.24	11.74	12.11	12.12
Air-Conditioners	140.20	240.35	300.44	320.48	185.27	280.41	315.47	320.48	219.07	300.44	319.22	320.48	244.42	310.46	320.16	320.48
Industrial Sector																
Motors	75.17	129.70	163.60	176.87	103.65	159.40	182.72	189.09	128.18	180.58	197.00	201.77	149.86	197.74	210.42	214.90
Total Energy Saving	*383.04*	*658.71*	*826.97*	*887.86*	*516.56*	*787.93*	*894.61*	*917.16*	*624.18*	*867.49*	*933.94*	*947.06*	*712.53*	*922.54*	*966.68*	*977.60*

Remarks: 25%, 50%, 75%, 100% - The percent shares of the replacement of the existing conventional appliance by those high-efficient ones, used in this study

Table 4 Energy Saving by Energy Saving Program at 4.02% Economic Growth Rate (Medium Economic Growth Rate Scenario)

Year	Energy Saving (GWh)															
	2005				2006				2007				2008			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Residential Sector																
Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.69	11.38	17.06	22.75	10.26	17.67	22.24	23.96
Refrigerators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.18	78.36	117.53	156.71	70.65	121.70	153.17	165.05
Air-Conditioners	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	44.49	88.99	133.49	177.99	80.24	138.23	173.97	187.47
Commercial Sector																
Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.13	6.25	9.38	12.50	5.47	9.38	11.72	12.50
Air-Conditioners	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.66	165.32	247.97	330.63	144.65	247.97	309.96	330.63
Industrial Sector																
Motors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.85	79.70	119.55	159.40	72.87	125.81	158.83	171.93
Total Energy Saving	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*214.99*	*429.99*	*644.98*	*859.99*	*384.12*	*660.76*	*829.89*	*891.54*

Year	Energy Saving (GWh)															
	2009				2010				2011				2012			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Residential Sector																
Lighting	13.99	21.43	24.46	25.20	17.11	23.94	25.96	26.45	19.76	25.84	27.29	27.73	22.08	27.43	28.60	29.03
Refrigerators	96.37	147.63	168.46	173.56	117.83	164.92	178.77	182.21	136.13	177.96	187.95	191.01	152.08	188.96	196.96	199.96
Air-Conditioners	109.46	167.68	191.33	197.12	133.83	187.31	203.04	206.95	154.60	202.12	213.47	216.95	172.73	214.62	223.70	227.12
Commercial Sector																
Lighting	7.23	10.94	12.31	12.50	8.55	11.72	12.45	12.50	9.54	12.11	12.49	12.50	10.28	12.31	12.50	12.50
Air-Conditioners	191.14	289.30	325.46	330.63	226.01	309.96	329.34	330.63	252.16	320.29	330.31	330.63	271.78	325.46	330.55	330.63
Industrial Sector																
Motors	100.91	155.42	178.48	185.04	125.36	177.07	193.67	198.73	147.27	195.04	208.17	213.00	167.43	211.47	222.96	227.89
Total Energy Saving	*519.10*	*792.40*	*900.50*	*924.05*	*628.69*	*874.93*	*943.23*	*957.47*	*719.46*	*933.37*	*979.67*	*991.82*	*796.37*	*980.25*	*1,015.26*	*1,027.14*

Remarks: 25%, 50%, 75%, 100% - The percent shares of the replacement of the existing conventional appliances by those high-efficient ones, used in this study

Table 5 Energy Saving by Energy Saving Program at 5.00% Economic Growth Rate (High Economic Growth Rate Scenario)

Year	Energy Saving (GWh)															
	2005				2006				2007				2008			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Residential Sector																
Lighting	0.00	0.00	0.00	0.00	5.57	11.15	16.72	22.30	10.09	17.39	21.91	23.64	13.82	21.20	24.24	25.01
Refrigerators	0.00	0.00	0.00	0.00	38.39	76.78	115.17	153.57	69.49	119.79	150.90	162.80	95.19	146.04	166.94	172.29
Air-Conditioners	0.00	0.00	0.00	0.00	43.60	87.21	130.81	174.42	78.93	136.06	171.38	184.91	108.11	165.87	189.61	195.69
Commercial Sector																
Lighting	0.00	0.00	0.00	0.00	3.23	6.46	9.69	12.93	5.67	9.72	12.16	12.98	7.50	11.35	12.78	12.98
Air-Conditioners	0.00	0.00	0.00	0.00	85.46	170.93	256.39	341.86	149.92	257.10	321.56	343.29	198.26	300.19	337.85	343.29
Industrial Sector																
Motors	0.00	0.00	0.00	0.00	38.11	76.22	114.33	152.44	69.98	120.91	152.78	165.59	97.35	150.18	172.79	179.46
Total Energy Saving	*0.00*	*0.00*	*0.00*	*0.00*	*214.37*	*428.75*	*643.12*	*857.50*	*384.08*	*660.97*	*830.68*	*893.21*	*520.23*	*794.84*	*904.20*	*928.72*

Year	Energy Saving (GWh)															
	2009				2010				2011				2012			
	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
Residential Sector																
Lighting	16.97	23.82	25.88	26.43	19.70	25.85	27.38	27.88	22.12	27.61	28.87	29.36	24.31	29.25	30.38	30.89
Refrigerators	116.90	164.03	178.26	182.03	135.68	178.03	188.58	192.02	152.32	190.14	198.83	202.25	167.43	201.44	209.27	212.75
Air-Conditioners	132.77	186.31	202.46	206.75	154.10	202.20	214.19	218.09	173.00	215.96	225.83	229.72	190.16	228.80	237.68	241.64
Commercial Sector																
Lighting	8.87	12.17	12.93	12.98	9.90	12.57	12.97	12.98	10.67	12.78	12.98	12.98	11.25	12.88	12.98	12.98
Air-Conditioners	234.51	321.74	341.92	343.29	261.70	332.51	342.94	343.29	282.09	337.90	343.20	343.29	297.39	340.59	343.26	343.29
Industrial Sector																
Motors	121.53	172.13	188.75	194.07	143.50	190.78	204.26	209.43	164.01	208.16	220.22	225.54	183.62	225.31	236.90	242.46
Total Energy Saving	*631.55*	*880.19*	*950.21*	*965.55*	*724.58*	*941.93*	*990.31*	*1,003.68*	*804.21*	*992.53*	*1,029.93*	*1,043.14*	*874.16*	*1,038.27*	*1,070.48*	*1,084.01*

Remarks: 25%, 50%, 75%, 100% - The percent shares of the replacement of the existing conventional appliances by those high-efficient ones, used in this study

3.2 Comparison between Energy Saving Investment Cost and Long-run Marginal Cost

The Eqs. (5) and (6) were used to calculate the MCSE for energy saving program and the LRMC for the new tie-lines expansion, respectively. Fig. 2 showed that the energy saving program are found to be more cost-effective, when their MCSEs are lower than LRMC (LRMC = 1.2527 Baht/kWh or US$0.0275/kWh at exchange rate 45.56 Baht/US$).

4. DISCUSSIONS AND CONCLUSIONS

From the results of the projection, we found that installations of new tie-lines are needed to supply more energy to meet the increasing demands in the year 2008, 2007, and 2006 for low, medium, and high economic growth rate scenario, respectively.

Another alternative is to implement an energy saving program, in order to suppress the increasing of the electrical energy demands.

From the comparison of the costs of the new tie-lines expansion and that of energy saving program, the results showed that the energy saving program is more cost-effective. The cost saving of this program is proportional to the percent shares of the replacement of the inefficient conventional appliances by those high efficient ones. And it has a maximum potential of the saving at US$0.0275/kWh (which can be notified by the difference between long-run marginal cost-LRMC of supply side and the marginal investment cost-MCSE of the demand side). The MCSE is lowest at 100% shares of the replacement, as shown on Fig. 2. The reason for the energy saving program is more competitive at a higher percentage of the replacement of the inefficient appliances is because amounts of the electrical energy can be saved more when the larger percentages of the replacement are implemented.

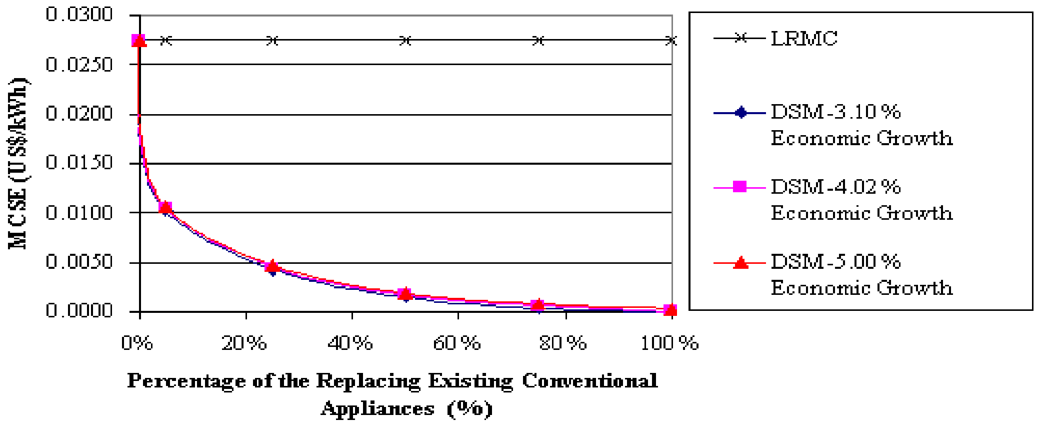


Fig. 2 Comparison between Marginal Investment Cost (MCSE) of Demand-Side Management Program and Long-Run Marginal Cost (LRMC) of the Supply Side Management

In addition, it can be seen from Fig. 2 that the curve of the marginal investment cost of energy saving program can be divided into three major parts. For the first part, the curve starts to decline rapidly from US$0.0275/kWh at 0% share of the replacement to US$0.0100/kWh at 5% shares of the replacement. This means that the decreasing rate of the investment cost of energy saving program is highly dependent on the percentage of the replacement. For the second part, the declining rate of the curve gradually declines after 5% to 80% of the replacement. And at the final part, the curve is saturated at the minimum cost of US$0.000/kWh. Thus, in this part, the investment cost is no more highly dependent on the percentage of the replacement of conventional appliances.

Although the investment costs of the energy saving program under three economic growth rate scenarios are different, as shown on Fig. 2. The difference of the investment cost is insignificant. This is because the economic growth rates, which were assumed for low, medium, and high economic growth rate scenario, are very close. Only about 2% of the growth rate is different between low and high scenario. However, it was found that if the difference between them is much larger, then the cost of MCSE under the high economic growth rate is significantly higher than that of the low economic growth rate one. This is because, under the high growth rate, we need to invest more in the first investment cost. Nevertheless, the increasing of the first investment cost in this condition is still low as compared to the LRMC cost of the supply side management. For instance, assumed that the growth rate is 12%, yet the MCSE is just US$0.0028/kWh at 100% replacement, which is equivalent to only 10% of LRMC. Moreover, the increment of this MCSE under the high growth rate, it costs only US$0.0028/kWh greater than that of the 3.10% low growth rate (i.e. the MCSE of the 3.10% growth rate is almost nil because the benefit of the energy saving nearly covers the first investment cost).

Hence, we can conclude that, in this case, the demand-side management program is a more cost-effective alternative than that by the supply-side management. And it is even more competitive at a higher percentage of the replacement. This can be noticed by its MCSE cost which is inversely proportional to the percentage of the replacement. Another advantage of the demand-side management in this case is that the MCSE is still considerably low even under the high prevailing economic growth rate.

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