IMPACT OF DAYLIGHTING APPLICATION ON EMISSIONS: the Case Study of Thai Commercial Sectors

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ABSTRACT

Daylighting and efficient lighting integration can improve lighting quality. Task lighting design can reduce lighting power and cooling load of the commercial buildings as well as emissions from the power generation plants. This paper presents a method of analyzing an impact of daylighting application in the commercial buildings on the emissions. The impacts are analyzed through an investigation of electricity in Thai office buildings. The major emissions include sulfur dioxide and carbon dioxide. Such emissions are contributions of fossil-fuel use from power plants.

Keywords: Energy conservation; Daylighting; Energy conservation promotion Act; SO_2 and CO_2 Emissions.

INTRODUCTION

The large-scale consumption of fossil fuels in a country contributes significantly to the impact on the environment. Consequences on environmental effects are extremely divers, difficult, and costly to remedy.

Power for lighting in an air-conditioned building is highly energy intensive, typically accounted for 20% of the total electricity use of the building. Cooling load due to lighting also contributes to the size of chiller, and thus the power demand of the buildings. daylighting conserves energy and helps reduce daytime coincident power demand for commercial buildings.

A consequence of daylighting application is the relative reduction of fossil fuel consumption. In this paper, the requirement for energy consumption in commercial buildings are described. The expected results in energy and demand reduction are calculated up to the year 2006. The 1993 Power Development Plan (PDP) of the Electricity Generating Authority of Thailand (EGAT) is used as the reference. Based on the planned generation mix, consequential reduction in CO_2 and SO_2 emissions are estimated.

DAYLIGHTING APPLICATION

A study reported in [1] considers benefits of daylighting, summarized in this section. Daylighting is the planned use of natural daylight. Such use is usually supplemented by artificial electric lighting to achieve good lighting comfort. Daylighting has an aesthetic value, similar to that from the we of window. The trend to use large glazed area in air-conditioning building causes large cooling load due to the adverse transmission of solar radiation. Such adverse conflict of nature caused by inadvertent designs leads the architects and engineers to adopt an inappropriate solution of using glazing of very low visible transmission. In such situation, interior lighting relies totally on electric lighting. The view of the outside world is almost lost from the building occupants and the glazing give uncomfortably high radiant temperature. Traditional architecture recognizes the importance of daylight. Most school buildings still rely almost on natural daylight.

Daylight comprises a part of light from the sun, called sunlight and a part from the sky, called skylight.

Sunlighting

Sunlight can provide illuminance deep into the interior of a highlight buildings through elaborate design. In such a case, the sunlight is used indirectly for illuminance.

Skylighting

Since the sunlight is too intense and generally causes uncontrollable glare, only skylight is recommended in daylighting application. The skylight illuminance at a point in a building is contributed by:

- Sky Component (SC), the light flux from the sky,
- Externally Reflected Component (ERC), which comprises a Ground Reflected Component (GRC), and an Internal-Surface Reflected (ISR) component, as illustrated by Fig 1.

Figure 2 illustrates the general pattern of daylight illuminance in a building interior from window side.

THE ENERGY CONSERVATION PROMOTION ACT

The provision on energy conservation for buildings in the Energy Conservation Promotion Act (ECP) seeks to reduce heat transfer through building envelope, enhance energy efficient lighting and air-conditioning, promote use of energy efficient equipment, and entrance energy efficient operation of building.

The ECP Act applies to controlled buildings, both new and the medium and the large buildings under the utilities' classification (whose connected loads exceed 1,000 kW). The Act requires the owners of the controlled buildings to set up energy conservation plans, to report energy consumption on a regular basis, and to responsible for satisfying the specific requirements for energy conservation. the Act assigns the Department of Energy Development and Promotion (DEDP) of the ministry of Science Technology and Environment (MOSTE) to enforce the requirements. In December 1995, the Ministerial Regulation were announced by the Thai Government Cabinet. The regulations describe:

(1) the requirements on the energy performance of Controlled buildings.
(2) The criteria, means, and methods for estimation of the energy performance of building.

THAILAND'S POWER GENERATION SYSTEM

The power sector in Thailand is organized into two distinct units: Generating and Distribution Authorities. The Electricity Generating Authority of Thailand (EGAT) is responsible for electricity generation and transmission while the Provincial Electricity Authority (PEA) and Metropolitan Electricity Authority (MEA) are responsible for electricity distribution in the rural and metropolitan areas respectively. Historically Bangkok and the nearby provinces consumed more electricity than the rest of the country, but with the emphasis on rural electrification that now reaches 97% of upcountry villages, the differences have dramatically narrowed such that by 1989 MEA and PEA each sold equal amount of electricity. Virtually all electricity is handled through this institutional structure although EGAT does supply directly to some large industrial customers. The generation and distribution utilities are regulated by the government through the National Energy Policy Council (NEPC).

Production of Electric Energy

The historical and projected primary energy mixes for electric power production from 1980 to 2006 are shown in Table 1. As can be seen from the projected values in the table, oil will sharply decrease its share in the future, while the share of natural gas and lignite will slightly decrease. The average selling price of electricity is 1.49 B/kWh (EGAT, 1993). The cost of producing electricity from lignite and natural gas is less than the average selling price by 5% and 12% respectively (EGAT, 1993). For this reason, Thailand Power Development Plan (PDP) moves towards use of lignite, natural gas, and coal.

The Present Status of Power Generation System

As of September 1993, EGAT operated 127 units of various generating stations with total capacity of 12,178.3 MW; of which 2,429.2 MW is from hydro; 6,101.5 MW from conventional oil/gas and lignite-fired thermal; 3,423.6 MW from combined cycle; and 224.0 MW from gas turbine power plants.

FOSSIL FUELS FOR ELECTRIC GENERATION AND ENVIRONMENTAL IMPACT

Natural Gas

An estimation of the natural gas resource in Thailand is about 19.25 TCF. Recoverable reserves are about 16.1 TCF of which 8.6 TCF is proven reserve. Most of the gas reserves are located in the Gulf of Thailand. Now, natural gas is supplied to power plants at Rayong, Bang Pakong and South Bangkok.

Crude Oil and Condensate

The crude oil reserves in Thailand are of small quantity. The known reserves of crude oil and condensate are about 1,150 million barrels. It is expected that recoverable reserves are 498 million barrels, of which 236 million barrel is proven reserve.

Thailand is an oil importing country. With the current low prices of fuel oil, new oil-fired power plant is considered as a competitive option.

Lignite

The total geological reserve is estimated about 2,069.2 million tons. The significant reserves are located in the North about 1,598.3 million tons or equivalent to 77.2% of the total reserves of the country, and the other 470.9 million tons (22.8%) is located in the South.

The estimated mineable reserve of lignite for the whole country is expected to be about 1,017 million tons with 812 million tons at Mae Moh, Lampang Province, 20 million tons at Krabi, Krabi Province, 137 million tons at Saba Yoi, Songkhla Province, 23 million tons at Sin Pun, Krabi Province, and 25 million tons at Wang Haeng, Chieng Mai Province.

Imported Coal

Imported coal is an important option that has been considered in Thailand long-term generation plan. A total of 4,200 MW generating capacity is planned to be developed at Ao Phai location. However, due to the current low oil price, the Ao Phai power plant will be initially fired with oil for three years (1997-2000) before converting to coal.

Environmental Impact Assessment (EIA)

In 1992, full operation of the lignite-fired facilities with an unexpected weather condition at Mae Moh causes a damaging impact of SO_2 emission near the generation site. The Thai Government then resolved to impose an environmental impact assessment study on new power plants whose capacities are greater than 10 MW. The main concerns for air quality are SO_2, No_x and particulate. The methods of pollution control to reduce the SO_2 concentration have been limited to used of high stacks and to reduce NO_x concentration by using low NO_x burner and firing control. New power plants will use flue gas defulphurization (FGD) technology that can reduce SO_2 by 85%. For the particulate control, the electrostatic precipitators are installed to reduce the particulate by 99.7%, however fabric filter of high efficiency will also be employed.

LOAD FORECAST FOR THE THAILAND ELECTRIC SYSTEM

The early electric load development was traditionally dominated by the increase in residential consumption, due to accelerated rural electrification programs which brings supply of electricity to a large number of rural households. The resultant load shape with a load factor of around 0.68 has not changed for two decades up to 1993, by which year over 95% of the country is electrified.

Since 1991 the Load Forecast Working Group (LFWG) has linked load forecast to the national economic forecast used in national development plans. During 1996-2001 and 2002-2006, the average GDP growth rates of 7.47% and 6.26% per year are projected respectively. The peak load was forecast to increase to 13,075 MW by the end of 1996. This represents an average annual growth rate of 10.2% during 1992-1996, which is lower when compared to 14.0% of that during 1987-1991. For longer period, the average annual demand growth will further decline to 7.76% and 6.07% in the periods 1997-2001 and 2002-2006 respectively [2].

DAYLIGHTING BENEFITS: DOE-2 Simulation

A study reported in [1] investigated a reference building model to each type of prevalent commercial buildings. Simulation were performed using DOE.2 [1] to improve alternative building models which comply with the ECP Act. Another series of DOE2.1D simulation runs have been performed by the author in a similar way on the office building model considered viable for daylighting application [3]. the pertinent features of the office building model appears in Table 2. Figure 3 illustrates the models.

Energy Consumption Pattern

Table 3 shows a summary of annual energy consumption and average monthly electricity demand for the two cases. The electricity-consumption patterns for the base cases also tally with what are generally observed. Air-conditioning accounts for over 60% of the total energy consumption. In most situations, improvements in the building envelope result in substantial energy reductions. Equally substantial reductions can be achieved by a reduction in lighting intensity, partly because of the resulting reduction in cooling load.

The daylighted building assume the same feature as the standard-complying buildings. But in addition, daylighting is used with step dimming of eletric lighting a 3 steps, 30%, 60% and 100% electric lighting. Fig.4 shows the load shapes of the office building model from DOE-2 simulation for the two cases.

The Emission Impact - Medium and Large Office Buildings

Given a fuel type, the emissions from power generation per unit of energy generated can be estimated with the aid of emission factors. The methodology for such calculation is outlined by the author [4]. In general, the methodology produces relatively accurate results for CO_2 and SO_2 estimates. Also, these emissions are dominant power generation.

Based on the methodology, and given the forecasted generation mix of Table A1, and the comparative energy consumption in Table 4. Table 5 shows the results of the calculation of the comparative emissions for the base case and the daylighting case. The Table also shows the resulting reduction in the emissions.

CONCLUSION

Daylighting contributes to a further reduction to the cooling load and reflecting in the reduced size of the chillers, and the corresponding reduction in electric energy requirements Results of DOE-2 simulation show that daylighting also contributes to reduction in the day-time peak power demand. One of the important impacts is the reduction of the adverse effects o electricity generation in the country. The results show a substantial benefits of emissio reduction to be expected.

REFERENCES

1. Chirarattananon, S. & Limmeechokchai, B., A New Building Energy-Efficiency Law in Thailand: Impact on New Buildings, *Energy, The International Journal*, 1993

2. *Load Forecast for The Thailand Electric System*, LFWG, 1993.

3. Chirarattananon, S. & Limmeechokchai, B., Lighting and Efficient Lighting Integrations, *Proceedings of the Workshop on Electric Power Quality, Safety and Efficiency of Its Uses*, AIT, 1995.

4. Chirarattananon, S. & Limmeechokchai, B., Impact of Energy Conservation Programs on CO2 Emissions in Thailand: the Case of Commercial Sector, *Proceedings of the Workshop on Global Warming Issues in Asia*, AIT, 1994.

5. Chirarattananon, S.,Rakwansuk, P. and Kaewkiew, J., A Proposed Building Performance Standard for Thailand: An Introduction and a Preliminary Assessment, *Proceeding of the ASHRAE Far East Conference on Air-Conditioning in Humid Climate*, Kuala Lumpur (Nov. 1989).

6. Electricity Generating Authority of Thailand (1993), *EGAT Power Development Plan.*

7. Electricity Generating Authority of Thailand (1995), *EGAT Power Development Plan.*

8. National Energy Administration (1986), *Thailand Power Tariff Structure Study.*

9. National Energy Administration (1993), *Electric Power In Thailand 1992.*

Table 1. Production of electric energy by type of resources.

YEAR	1960	1970	1980	1985	1990	2000	2005
Total Production (10^3 GWh)	0.49	4.09	14.15	22.61	44.20	112.6	157.1
Oil (%)	100	55.4	76.4	18.8	23.5	12.8	5.9
Hydro Power (%)	0	30.5	16.5	17.1	11.3	6.5	5.3
Lignite (indigenous)	0	6.1	8.9	19.7	25.0	18.2	24.4
Coal (imported)	0	0	0	0	0	29.2	44.4
Natural Gas	0	0	0	44.5	40.2	32.7	19.6

SOURCE: EGAT (1985, 1987, 1992, and 1993)

Table 2. Summary information for office building model.

Item	Base case	Daylighting case
Location	Bangkok	Bangkok
No. of stories	12	12
A/C area, m²	11,096	11,096
Service spaces	8-office floors	8-office floors
Lighting, Wm^{-2}	25	16
Avg. space temperature	24.5 °C	25.0°C

Table 3. Energy-consumption patterns (DOE2 SIMULATION).

Item	Base case	Daylighting Case
Chiller size, RFT	645	420
Annual elec. use, MWh	2605	1603
Air-cond., MWh	1690	1091
Lighting, MWh	788	381
Lifts, MWh	76	76
Misc., MWh	38	38
Monthly elec., MWh	217	134
Max. annual peak, kWe	1121	749
Elec. index, $kWhm^{-2}yr^{-1}$	207	128

Table 4. Comparison of forecasted electricity consumption of commercial buildings, base case and daylighting case.

Year	Base case (GWh)	Daylighting case (GWh)
1990	4,514	4,514
1991	5,659	5,659
1992	6,523	6,523
1993	8,395	8,395
1994	9,632	9,632
1995	11,004	11,004
1996	12,415	11,269
1997	13,741	12,473
1998	15,079	13,687
1999	16,795	15,245
2000	17,947	16,290
2001	19,449	17,654
2002	20,798	18,879
2003	22,177	20,130
2004	23,639	21,457
2005	25,186	22,861
2006	26,792	24,318

Table 5. Comparative emissions: impact of the daylighting application.

Year	Base case		Daylighting case		Reduction	
	CO_2 (kton)	SO_2 (kton)	CO_2 (kton)	SO_2 (kton)	CO_2 (kton)	SO_2 (kton
1990	27,652	257	27,652	257	-	-
1991	28,557	265	28,557	265	-	-
1992	32,213	306	32,213	306	-	-
1993	36,217	375	36,217	375	-	-
1994	38,846	385	38,846	385	-	-
1995	42,696	468	42,696	468	-	-
1996	47,755	527	45,551	503	2204	24
1997	53,110	619	50,659	590	2451	29
1998	56,716	640	54,098	610	2618	30
1999	61,378	719	58,545	686	2833	33
2000	55,106	438	52,563	418	2543	20
2001	59,044	470	56,319	448	2725	22
2002	64,240	540	61,275	515	2965	25
2003	67,288	557	64,182	531	3106	26
2004	72,927	599	69,561	571	3366	28
2005	75,693	576	72,199	549	3496	27
2006	77,421	598	73,847	570	3574	28

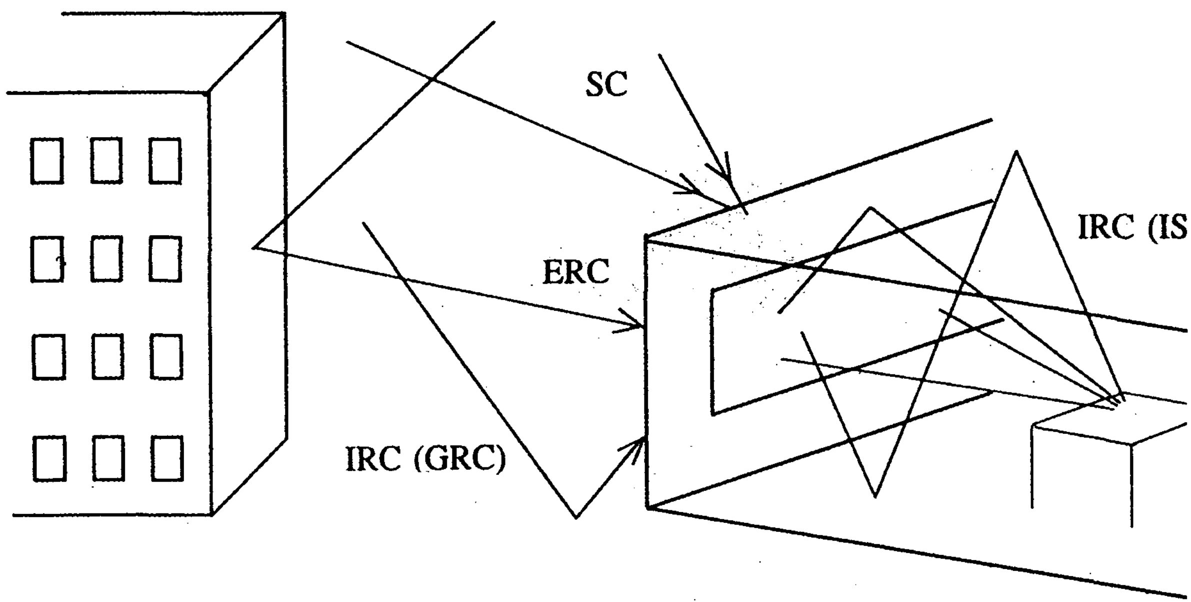
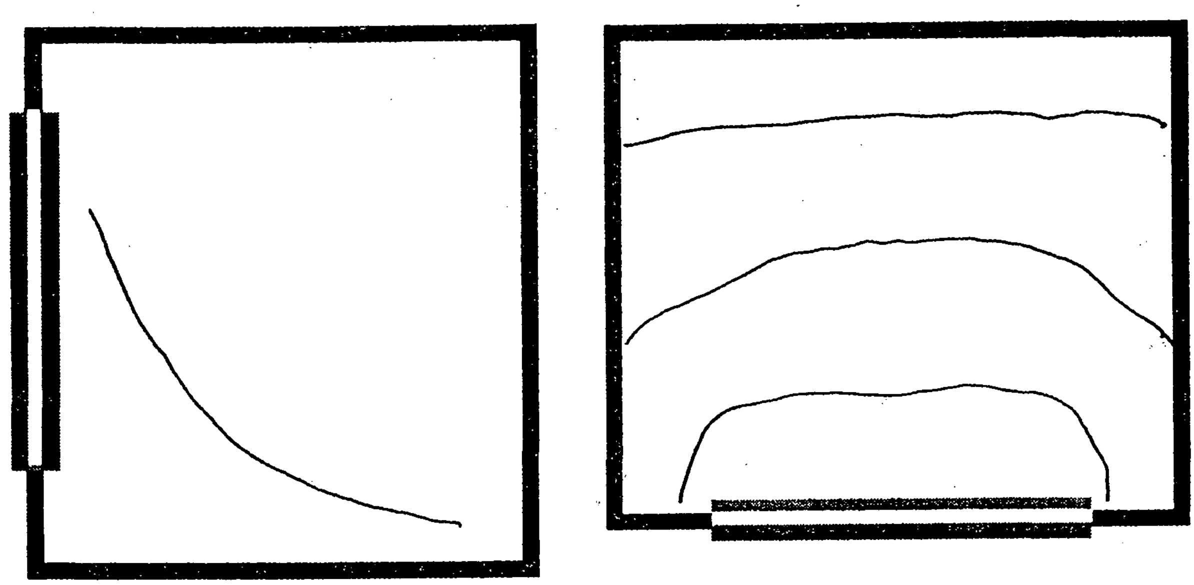


Fig. 1. The three components of daylight factors



a Daylight illuminance falls exponentially deep into a room interior

a Plan view of the iso-illuminance contour

Fig. 2. Pattern of daylight from side window

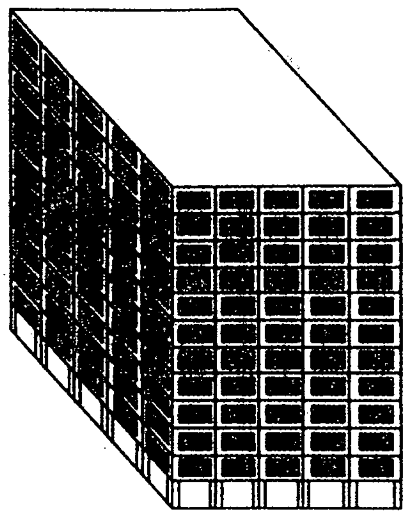


Fig.3. Office Building Model.

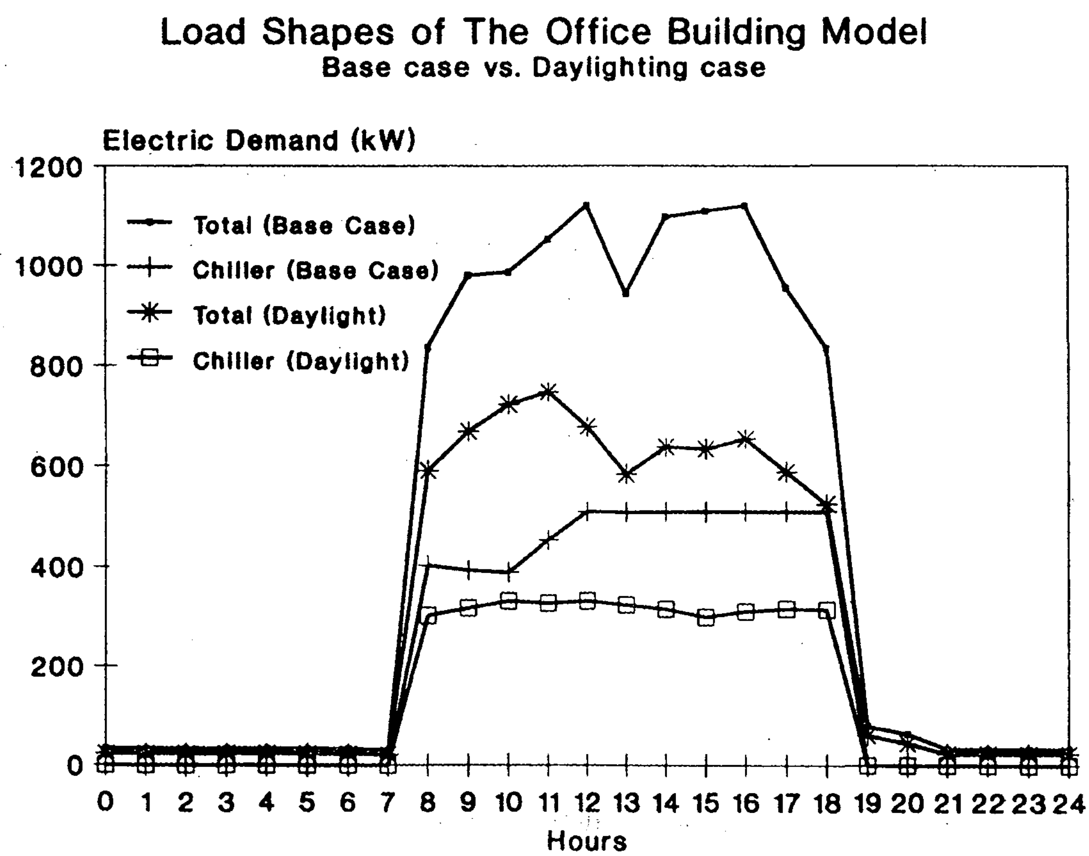


Fig.4. Load shapes of the office building model from DOE-2 simulation.

APPENDIX A

Table A1. Comparisons of total generation mix and total fuel requirements in base case.

TOTAL GENERATION MIX

YEAR	Base case				Daylighting case			
	LIGNITE	COAL	OIL	GAS	LIGNITE	COAL	OIL	GAS
	GWh	GWh	GWh	GWh	GWh	GWh	GWh	GWh
1990	11,053	-	10,013	17,768	11,053	-	10,013	17,768
1991	12,000	-	11,600	20,000	12,000	-	11,600	20,000
1992	14,449	-	11,319	24,950	14,449	-	11,319	24,950
1993	14,733	-	16,346	25,688	14,733	-	16,346	25,688
1994	14,365	-	17,827	28,900	14,365	-	17,827	28,900
1995	15,240	-	23,190	29,207	15,240	-	23,190	29,207
1996	18,210	-	25,254	31,079	17,361	-	24,088	29,645
1997	19,610	-	31,256	30,827	18,705	-	29,813	29,404
1998	20,485	-	32,782	35,398	19,539	-	31,269	33,764
1999	20,485	-	39,398	36,261	19,539	-	37,579	34,587
2000	20,485	32,934	13,963	36,803	19,539	31,414	12,218	35,104
2001	22,585	39,492	14,400	35,576	21,542	37,669	13,735	33,934
2002	26,260	43,446	16,376	34,460	25,048	41,441	15,620	32,869
2003	33,785	48,702	13,343	33,193	32,225	46,454	12,727	31,661
2004	36,235	57,462	12,325	31,969	34,563	54,809	11,756	30,233
2005	38,335	69,726	8,827	30,731	36,566	66,508	8,419	29,313
2006	40,085	71,478	9,087	29,823	38,239	68,179	8,667	28,446

FUEL REQUIREMENTS

YEAR	Base case				Daylighting case			
	LIGNITE	COAL	OIL	GAS	LIGNITE	COAL	OIL	GAS
	kton	kton	10^6lit.	mmscf	kton	kton	10^6lit.	mmscf
1990	9,875	-	2,532	172,735	9,875	-	2,532	172,735
1991	10,000	-	2,650	180,000	10,000	-	2,650	180,,000
1992	12,294	-	2,899	189,900	12,294	-	2,899	189,,900
1993	12,538	-	4,061	192,900	12,538	-	4,061	192,,900
1994	12,234	-	4,304	231,300	12,234	-	4,304	231,,300
1995	12,953	-	5,609	215,400	12,953	-	5,609	215,,400
1996	15,355	-	6,172	231,000	14,646	-	5,887	220,338
1997	16,558	-	7,551	228,900	15,793	-	7,202	218,335
1998	17,315	-	7,768	267,000	16,515	-	7,409	254,676
1999	17,316	-	9,146	274,200	16,516	-	8,724	261,544
2000	17,315	11,086	3,397	278,400	16,516	10,574	3,420	265,550
2001	19,169	13,457	3,491	267,300	18,284	12,835	3,329	254,963
2002	22,189	14,642	3,977	257,400	21,165	13,966	3,793	245,520
2003	26,344	16,419	3,239	245,400	25,128	15,661	3,089	234,073
2004	30,326	19,382	2,997	234,000	28,926	18,487	2,858	223,199
2005	32,052	23,529	2,159	223,500	30,573	22,443	2,059	213,184
2006	33,428	24,122	2,211	216,000	31,885	23,008	2,108	206,030