Chapter 4

Optimizing Power Infrastructure Development

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CHAPTER 4

Optimizing Power Infrastructure Development

This chapter will present in quantitative terms the optimal potential and advantages for the entire power infrastructure (power plants and power grids) in 13 countries in East Asia (Bangladesh, Brunei Darussalam, Cambodia, China [Yunnan & Guangxi], India [North-East], Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam).

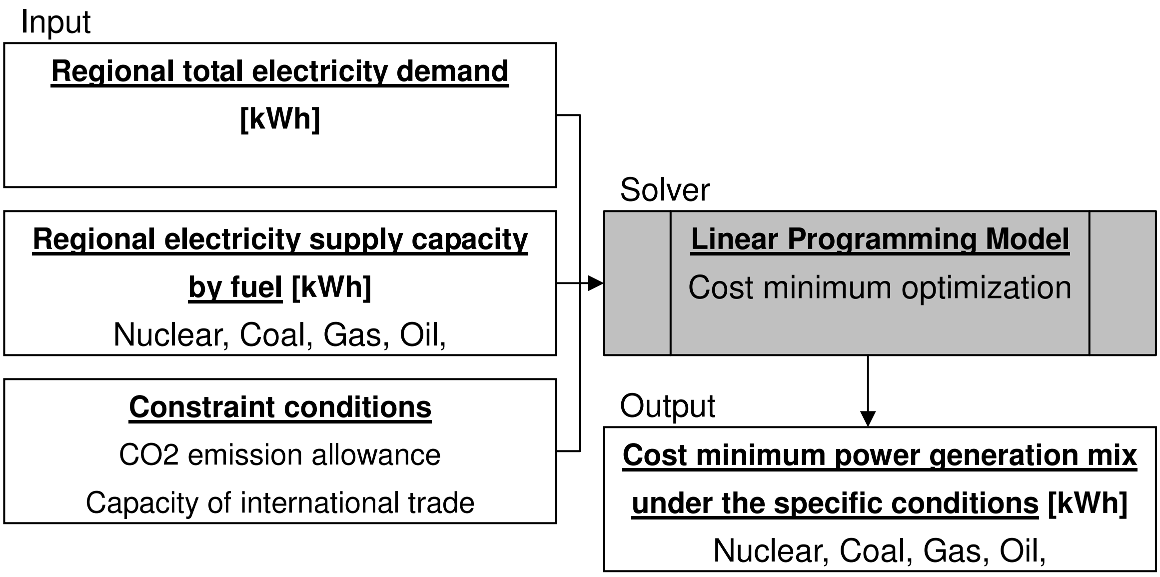
Through this, the ingredients will be provided for East Asian nations in the future to create trade in international power in order to mutually increase economic and technical rewards and to achieve an energy mix for the realization of power transport that spans nations throughout the region.

1. Optimal Inter-state Power Supply Model

A linear programming (LP) model was formulated in order to examine the optimal inter-state power supply system in East Asia.

Power generation capacity and power generation costs by energy source for the East Asian nations were estimated, and overall optimization of the power supply to meet total demand in each country was attempted. The objective function in this case was cost minimization.

Figure 4-1: Overview of LP Model



The following constraints were set in this model.

- Total regional power demand = Total regional power supply volume
- Total regional power supply volume <= Total regional power supply capacity
- Each country's import/export power volume <= Transmission line capacity (each country's interchange capacity)
- Total regional CO_2 emission volume <= Target value for total regional CO_2 emission volume
- Each country's amount of power from renewable energy = Target value for each country's adoption of renewable energy

Ordinarily, when considering optimal power supply, one must consider numerous factors for each country, such as peak demand, wheeling charges, and the construction costs of individual power plants and interconnection lines. In this model, however, because of data limitations, such factors are not reflected.

Moreover, in actual equipment planning, power source mixes and amounts of power import/export are considered based on load curve data. In this model, however, as a simplified method, the advantages of international grid interconnection are analyzed by simulating each country's annual supply capacity and demand balance.

2. The Model's Preconditions

The preconditions in the linear programming (LP) model are each country's power demand, the interchange capacities of international interconnection lines, power supply capacity by source type, generating costs by power source, and CO_2 emission factor by power source.

2-1 Power Demand

First, for each country's power demand in GWh as of 2020 and 2030, for countries in which figures were made clear in power source development plans and so on, those figures were used. For countries in which power source development plans are not clear, estimates were calculated using power generation output figures for BAU (Business as Usual) Cases in "ERIA Research Project Report 2011, No. 18 ANALYSIS ON ENERGY SAVING POTENTIAL IN EAST ASIA REGION." (See Table 4-1.)

2-2 Transmission Capacity and Scenarios

In this model, projections for the interchange capacity (GWh) of international interconnection lines were set in a Base Case and an Accelerated Case and compared with the Status Quo Case (in which interchange capacity remains the same as now, with no new increases or investment in current interchange capacity estimated).

The projected Base Case for each country's interchange capacity was set based on the "AIMS II Report (ASEAN Interconnection Master Plan Study No. 2)," published by the Heads of ASEAN Power Utilities/Authorities (HAPUA). However, for Bangladesh, China (Yunnan Province and Guangxi Zhuang Autonomous Region), and India (North-East), which are not covered by the "AIMS II Report," figures were set based on each country or region's own power import/export plan.

Figures for the Accelerated Cases were set in order to analyze the result if each country's interchange capacity in the Base Case were to be doubled. (See Table 4-2.)

Figure 4-2: Scenario for Interconnection

	2020	2030
Status Quo Case	Same international interchange capacity as today	
Base Case	International interchange capacity as planned in AIMS II	
Accelerated Case	-	International interchange capacity double that of AIMS II

2-3 supply Capacity

In this model, each country's power supply capacity (GWH) by power source as of 2020 and 2030 refers to the maximum supply capacity of the generating equipment in each country. In short, it is calculated based on an operation rate that keeps downtime for periodic inspections and so on to a minimum. It does not necessarily match the operation rates assumed in national power source development plans, etc. This is because, in this model, the objective is to maximize utilization of international interconnection and optimize the energy balance for the entire region, so supply capacity distribution in accordance with peak power demand in each country was minimized to the extent possible.

In concrete terms, each country's generating equipment capacity by power source as discussed in Chapter 2 was multiplied by the following operation rates(= plant factor) to set maximum supply capacity. (See Table 4-3.)

- Base power source: 80 percent
- Middle to peak power source: 60 percent (in light of interchange reduction to ensure reserve power for fluctuations in power demand)
- Nuclear power: 60 percent in 2020 (in light of test operation periods after recent introduction), 80 percent in 2030

- Hydropower: 45 percent (in light of seasonal fluctuations due to rainy and dry seasons)
- Geothermal: 80 percent
- Other renewable energy: biomass 60 percent, wind power 20 percent, small hydropower 40 percent, solar 12 percent

2-4 Generation Cost

For generation cost (US$/kWh) by power source, since data for each country could not be obtained, in this model, the generation price by power source mainly in Thailand and Indonesia was used as a base to set the value for each country.

As for the generation cost for coal-fired thermal power plant, it was set lower for countries such as Indonesia and Vietnam that produce a great deal of coal domestically and use it as fuel than it was for countries that use mainly imported coal.

In the same way, a price difference for the generation cost of gas-fired thermal power plant was set between the gas producing nations of Bangladesh, Brunei, Indonesia, and Myanmar and countries that rely on pipeline gas or LNG imports.

For the generation cost of nuclear, oil-fired, renewables of each country that could not be obtained, in this model, they were set mainly based on the value of Thailand. (See table 4-4.)

2-5 CO_2 Emission Factor

Finally, CO_2 emission factor (kt-CO_2/GWh) by power source is affected by the generating efficiency of each country's power plants. In this model, therefore, figures for the thermal efficiency of thermal power plants found in "ERIA Research Project Report 2011, No. 18 ANALYSIS ON ENERGY SAVING POTENTIAL IN EAST ASIA REGION" were used. Additionally, the following values were used as the CO_2 emission factors[42] by energy source that formed the basis for calculations. (See Table 4-5.)

- Coal (fuel coal): 3.7927 Gg-CO_2/10^{10} kcal (= 0.326 kt-CO_2/GWh)
- Natural gas (LNG): 2.0675 Gg-CO_2/10^{10} kcal (= 0.178 kt-CO_2/GWh)

[42] EDMC, "HANDBOOK OF ENERGY & ECONOMIC STATISTICS in JAPAN 2013"

- Bunker C fuel oil: 2.9992 Gg-CO_2/10^{10} kcal (= 0.258 kt-CO_2/GWh)

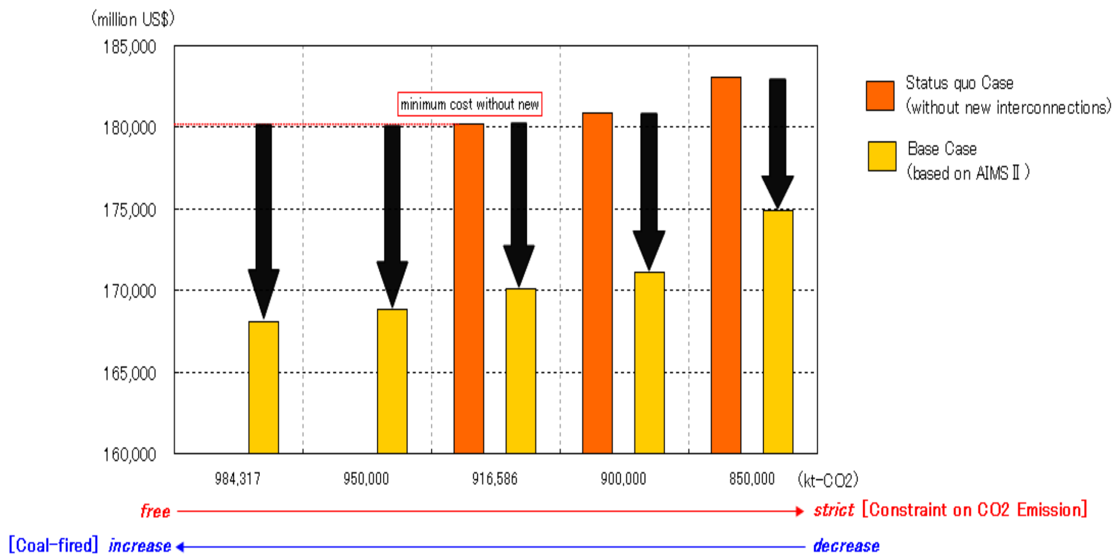
3. Calculation Results

Table 4-6 shows a model in which optimal energy mixes were calculated using each country's power demand and supply capacity by power source as of 2020, with interchange capacity of international interconnection lines as in the Base Case and CO_2 emission volume unrestricted.

Of course, when there are no restrictions on CO_2 emissions, countries will select power sources with the lowest prices first to meet domestic power demand. Furthermore, countries with a power surplus from power sources cheaper than those in other nations will export electricity to the extent enabled by the interchange capacity of international interconnection lines. In other words, the calculation results shown in Table 4-6 are the optimal distribution for cost minimization as of 2020 in the Base Case.

Figure 4-3 shows a comparison of total generation cost for the East Asian nations as a group in the Base Case and the Status Quo Case (in which no new increases and investment in current interchange capacity are estimated) as of 2020, and a cost comparison when restrictions on CO_2 emission volume are made stricter.

Figure 4-3: Comparison of Total Generation Cost in 2020



(million US$)

Target of total CO2 emission	984,317*	950,000	916,586**	900,000	850,000
Status quo Case[①] (without new interconnections)			180,199	180,841	183,077
Base Case[②] (with new interconnections based on AIMS Ⅱ)	168,057	168,830	170,129	171,139	174,921
Savings[=②-①]	▲ 12,142	▲ 11,369	▲ 10,070	▲ 9,702	▲ 8,156

* 984,317kt-CO2 = Maximum CO2 emission in Base Case
** 916,586kt-CO2 = Maximum CO2 emission in Status quo Case

In the Base Case, the calculation results with no restrictions on CO_2 emission volume applied and optimal distribution for cost minimization attempted found a total generation cost of 168,057 million US$ and a total CO_2 emission volume of 984,317 kt. In the Status Quo Case, if restrictions on CO_2 emission volume are not applied, the calculations obtained a total generation cost of 180,199 million US$ and a total CO_2 emission volume of 916,586 kt. Comparing the two cases, if the international power grid is augmented to the degree seen in the Base Case, and if its use is maximized, the East Asian nations as a group could reduce generation cost by 12,142 million US$.

Next, comparisons were carried out of total generation cost when restrictions on CO_2 emission volume were gradually made stricter, going from no limits to 850,000 kt. The calculation results use hydropower and nuclear power, which are clean and have low generation costs, as base power sources. Since no further excess supply exists, power supply from coal-fired thermal power with its high CO_2 emission volume is reduced, while the role of gas-fired thermal in the power supply is increased.

Compared with the case when there are no restrictions on CO_2 emission volume, electricity trade volume decreases by 44,218 GWh, from 181,330 GWh to 137,112 GWh.

As a result, total generation cost in the Base Case increased by 6,864 million US$ to 174,921 million US$. Total generation cost in the Status Quo Case increased by 2,878 million US$ to 183,077 million US$. The cost reduction effect of utilizing the international power grid shrunk to 8,156 million US$. This was because, in order to lower CO_2 emissions, use of coal-fired thermal power was reduced, while use of gas-fired thermal power was increased, raising the average generation cost.

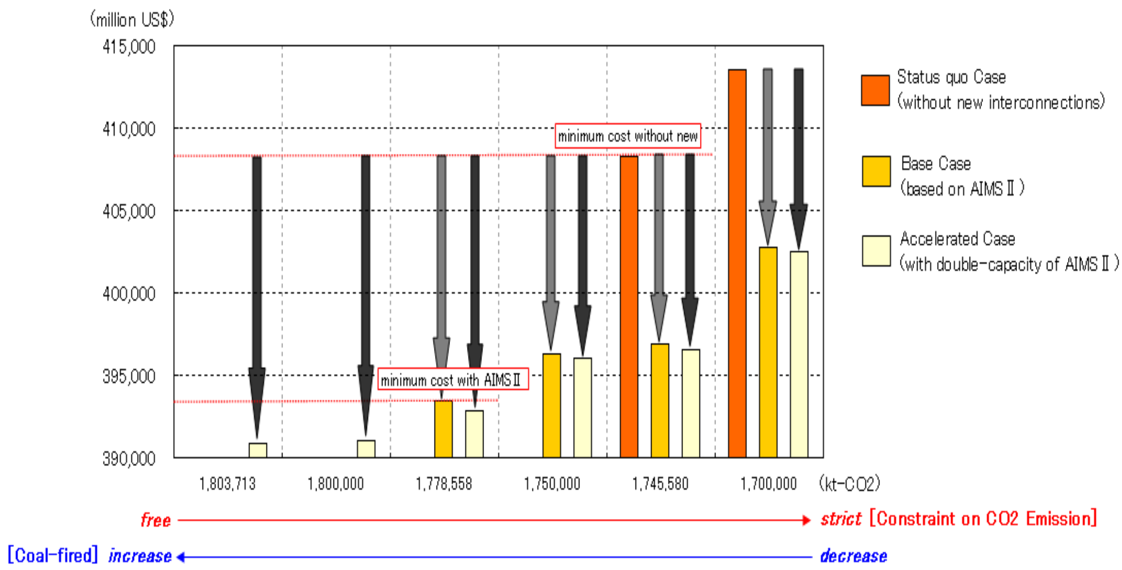
Next, the calculation results for 2030 will be analyzed.

Table 4-7 shows a model in which optimal energy mixes were calculated using each country's power demand and supply capacity by power source as of 2030, with interchange capacity of international interconnection lines as in the Accelerated Case and CO_2 emission volume unrestricted. Table 4-8 shows the result when interchange capacity is kept in the Base Case scenario and all other conditions remain unchanged.

As discussed above, if CO_2 emissions are not restricted, countries will select power sources with the lowest prices first to meet domestic power demand. Furthermore, countries with a power surplus from power sources cheaper than those in other nations will export electricity to the extent enabled by the interchange capacity of international interconnection lines. In other words, the calculation results shown in Table 4-7 and Table 4-8 are the optimal distributions for cost minimization as of 2030 in the different international interconnection scenarios.

Figure 4-4 shows a comparison of total generation cost for the East Asian nations as a group as of 2030 if the interchange capacity of international interconnection lines changes as in the Accelerated, Base, and Status Quo Cases, and a cost comparison when restrictions on CO_2 emission volume are made stricter.

Figure 4-4: Comparison of Total Generation Cost in 2030



(million US$)

Target of total CO2 emission	1,803,713*	1,800,000	1,778,558**	1,750,000	1,745,580***	1,700,000
Status quo Case[①] (without new interconnections)					408,281	413,542
Base Case[②] (with new interconnections based on AIMS Ⅱ)			393,446	396,336	396,894	402,785
Accelerated Case[③] (with double-capacity of AIMS Ⅱ)	390,871	391,025	392,880	395,999	396,575	402,516
Savings[=③-②]	▲ 2,575	▲ 2,421	▲ 566	▲ 337	▲ 319	▲ 269
Savings[=③-①]	▲ 17,410	▲ 17,256	▲ 15,401	▲ 12,282	▲ 11,706	▲ 11,026

* 1,803,713kt-CO2 = Maximum CO2 emission in Accelerated Case
** 1,778,558kt-CO2 = Maximum CO2 emission in Base Case
*** 1,745,580kt-CO2 = Maximum CO2 emission in Status quo Case

In the Accelerated Case, with no restrictions on CO_2 emission volume applied and optimal distribution for cost minimization attempted, the calculation results found a total generation cost of 390,871 million US$ and a total CO_2 emission volume of 1,803,713 kt. In the Base Case, with the same condition and optimal distribution for cost minimization attempted, the calculation results were a total generation cost of 393,446 million US$ and a total CO_2 emission volume of 1,778,558 kt. In other words, if the transmission capacity between states is doubled from the Base Case scenario and its use is maximized, the East Asian nations as a group are projected to reduce generation cost by 2,575 million US$.

In the Status Quo Case, with no restrictions on CO_2 emission volume applied, total generation cost was calculated at 408,281 million US$ and total CO_2 emission volume at 1,745,580 kt. If CO_2 emission volume is ignored, and only total generation cost is compared, if international interconnection can be expanded to the Accelerated Case, cost will be reduced by 17,410 million US$. Even if the comparison is the Base Case scenario, a cost reduction of 14,835 million US$ can be expected.

Next, comparisons were carried out of total generation cost when restrictions on CO_2 emission volume were gradually made more strict, going from no limits to 1,700,000 kt. because hydropower and nuclear power, which are clean and have low generation costs, are used as base power sources, no further excess power supply can be projected. Therefore, in an environment in which restrictions on CO_2 emissions are applied, power supply from coal-fired thermal power with its high CO_2 emission volume will be reduced, while the role of gas-fired thermal in the power supply will increase.

At that time, electricity trade volume in the Accelerated Case will shrink by 85,150 GWh, from 247,345 GWh to 162,195 GWh, compared to the case without restrictions on CO_2 emission volume.

An increase in the use of higher-priced gas-fired thermal power had the following results. In the Accelerated Case, total generation cost rose by 11,645 million US$ to 402,516 million US$. In the Base Case, total generation cost rose by 9,339 million US$ to 402,785 million US$. In the Status Quo Case, total generation cost rose by 5,261 million US$ to 413,542 million US$. Thus, in regard to the cost reduction effect of the international interconnection grid, in the comparison with the Accelerated Case and the Base Case it shrank by 269 million US$, and in comparison with the Status Quo Case it shrank by 11,026 million US$.

4. Optimal Energy Mix

As became clear in the previous section, changing the constraints changes the optimal distribution of each country's energy mix. Table 4-9 shows the changes in countries' optimal energy mixes as of 2020 and 2030, with no restrictions on CO_2 emission volume applied, when the interchange capacity of international interconnection lines is increased from the Status Quo Case to the Base Case scenario to the Accelerated Case scenario.

In almost every one of the East Asian nations that were the subject of this research, a steady rise in power demand due to population increase and economic growth is projected. On the other hand, these countries each have their own specific energy resources and environmental constraints. Against this background, in order to achieve the optimal energy mix in terms of factors such as supply stability, economy, and lessening environmental impact, the calculation results in the previous section suggest that considering the balance of the East Asian nations as a group would bring greater benefits than attempting to build up the power grids of individual countries.

As discussed in Chapter 2, Laos and Cambodia have very high hydropower development potential. Clean, high cost performance power exports are projected, but improvement of their domestic transmission grids has been slow. In the coal producing countries Indonesia and Vietnam and the gas producing countries Bangladesh, Brunei, Indonesia, and Myanmar, effective use of domestic resources is expected to produce low-cost, stable power supplies for them and for their neighbors. On the other hand, in Thailand in particular, although it produces coal, oil, and gas, supply capacity cannot keep up with booming domestic demand, so it relies on large fuel imports. At the same time, it has powerful environmental restrictions that make development of coal-fired thermal power and hydropower difficult. Thus, resource availability and demand are mismatched in the East Asian nations. The findings of this research show that it is possible to alleviate this mismatch by improving international interconnection of transmission lines.

Table 4-1: Electricity Demand (GWh)

[2020]

Bangladesh	Brunei	Cambodia	China*	India**	Indonesia	Lao PDR
90,950	5,500	8,200	393,723	21,560	355,862	15,234
Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam	
130,000	48,900	94,995	60,700	246,164	330,000	

[2030]

Bangladesh	Brunei	Cambodia	China*	India**	Indonesia	Lao PDR
191,933	7,524	13,489	541,980	41,491	956,929	35,863
Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam	
160,000	95,068	149,067	71,500	346,767	675,000	

* For China, Yunnan Province and Guangxi Zhuang Autonomous Region are covered.

** For India, the North-East area is covered.

Table 4-2: International Interconnection Transmission Capacity (GWh)

[Base Case scenario]

Bangladesh	Brunei	Cambodia	China*	India**	Indonesia	Lao PDR
8,760	1,752	35,890	76,825	8,760	33,288	99,198
Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam	
41,172	46,682	8,760	31,536	141,036	26,254	

[Accelerated Case scenario]

Bangladesh	Brunei	Cambodia	China*	India**	Indonesia	Lao PDR
17,520	3,504	71,780	153,650	17,520	66,576	198,396
Malaysia	Myanmar	Philippines	Singapore	Thailand	Vietnam	
82,344	93,364	17,520	63,072	282,072	52,508	

* For China, Yunnan Province and Guangxi Zhuang Autonomous Region are covered.

** For India, the North-East area is covered.

Table 4-3: Capability of Electricity Supply (GWh)

Bangladesh (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
10,512	28,524	84,446	1,301	3,863	3,774	-	-

Bangladesh (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
28,032	46,516	137,707	1,301	6,302	6,155	-	-

Brunei (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	8,872	-	-	-	-	-	-

Brunei (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	12,138	-	-	-	-	-	-

Cambodia (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	7,979	19,410	-	-	-	11

Cambodia (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	13,124	31,934	-	-	-	11

China (Yunnan & Guangxi) (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	194,856	264,362	-	-	-	648

China (Yunnan & Guangxi) (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	268,492	364,261	-	-	-	648

India (North-East) (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	12,525	2,218	21,523	-	752	-	799

India (North-East) (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	24,998	4,426	42,960	-	752	-	799

Indonesia (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	98,119	348,221	35,411	11,826	28,761	52,574	2,656

Indonesia (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	176,770	627,363	63,793	11,826	28,761	94,720	2,656

Lao PDR (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	13,161	26,199	-	11	-	28

Lao PDR (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	13,161	50,020	-	11	-	28

Malaysia (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	52,034	77,088	14,585	-	-	-	10,512

Malaysia (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
14,016	52,560	88,301	16,651	-	10,512	-	18,396

Myanmar (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	21,245	3,627	39,767	-	-	1,402	3,620

Myanmar (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	21,245	5,203	83,756	-	-	1,402	3,620

Philippines (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	26,075	39,434	16,210	3,416	18,096	16,083	378

Philippines (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	37,113	62,876	26,037	3,416	31,236	24,941	378

Singapore (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	70,634	-	-	19,053	-	-	1,556

Singapore (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	87,593	-	-	19,053	-	-	1,929

Thailand (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	192,314	41,249	16,107	1,656	21	-	7,251

Thailand (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
14,016	265,687	51,768	16,280	1,656	3,963	-	10,047

Vietnam (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
5,256	65,043	252,288	75,292	-	-	-	4,415

Vietnam (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
56,064	87,323	509,152	87,142	-	-	-	13,913

Table 4-4: Generation Cost by Power Source (US$ / kWh)

Bangladesh (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
0.134	0.100	0.144	0.053	0.334	0.483	-	-

Bangladesh (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
0.146	0.150	0.161	0.064	0.399	0.583	-	-

Brunei (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.100	-	-	-	-	-	-

Brunei (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.150	-	-	-	-	-	-

Cambodia (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	0.144	0.053	-	0.483	-	0.169

Cambodia (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	0.161	0.064	-	0.583	-	0.200

China (Yunnan & Guangxi) (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	0.144	0.053	-	-	-	0.169

China (Yunnan & Guangxi) (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	0.161	0.064	-	-	-	0.200

India (North-East) (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.180	0.144	0.053	-	0.483	-	0.169

India (North-East) (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.216	0.161	0.064	-	0.583	-	0.200

Indonesia (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.100	0.080	0.016	0.334	0.267	0.083	0.169

Indonesia (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.150	0.120	0.016	0.399	0.267	0.083	0.200

Lao PDR (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	0.144	0.059	-	0.483	-	0.169

Lao PDR (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	-	0.161	0.058	-	0.583	-	0.200

Malaysia (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.127	0.100	0.150	-	-	-	0.110

Malaysia (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
0.146	0.127	0.100	0.150	-	0.583	-	0.100

Myanmar (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.100	0.144	0.053	-	-	0.083	0.169

Myanmar (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.150	0.161	0.064	-	-	0.083	0.200

Philippines (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.180	0.144	0.053	0.334	0.483	0.083	0.169

Philippines (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.216	0.161	0.064	0.399	0.583	0.083	0.200

Singapore (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.180	-	-	0.334	-	-	0.169

Singapore (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.216	-	-	0.399	-	-	0.200

Thailand (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
-	0.180	0.144	0.053	0.334	0.483	-	0.169

Thailand (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
0.146	0.216	0.161	0.064	0.399	0.583	-	0.200

Vietnam (2020)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
0.134	0.180	0.080	0.053	-	-	-	0.169

Vietnam (2030)

Nuclear	Gas	Coal	Hydro	Oil	Diesel	Geothermal	Renewable
0.146	0.216	0.120	0.064	-	-	-	0.200

Table 4-5: CO_2 Emission Factor by Power Source (kt-CO_2 / GWh)

Bangladesh

	Gas	Coal	Oil	Diesel
2020	0.415	1.059	0.789	0.789
2030	0.407	0.870	0.733	0.733

Brunei

	Gas	Coal	Oil	Diesel
2020	0.744	-	0.752	0.752
2030	0.744	-	0.752	0.752

Cambodia

	Gas	Coal	Oil	Diesel
2020	-	1.087	1.146	1.146
2030	-	1.087	1.146	1.146

China (Yunnan & Guangxi)

	Gas	Coal	Oil	Diesel
2020	0.423	0.858	0.665	0.665
2030	0.395	0.796	0.629	0.629

India (North-East)

	Gas	Coal	Oil	Diesel
2020	0.415	1.059	0.789	0.789
2030	0.407	0.870	0.733	0.733

Indonesia

	Gas	Coal	Oil	Diesel
2020	0.512	1.029	0.794	0.794
2030	0.512	1.029	0.794	0.794

Lao PDR

	Gas	Coal	Oil	Diesel
2020	-	0.932	-	-
2030	-	0.932	-	-

Malaysia

	Gas	Coal	Oil	Diesel
2020	0.361	0.852	0.772	0.772
2030	0.349	0.834	0.750	0.750

Myanmar

	Gas	Coal	Oil	Diesel
2020	0.642	1.087	-	-
2030	0.642	1.087	-	-

Philippines

	Gas	Coal	Oil	Diesel
2020	0.329	0.932	0.705	0.705
2030	0.329	0.896	0.705	0.705

Singapore

	Gas	Coal	Oil	Diesel
2020	0.379	-	0.727	0.727
2030	0.359	-	0.679	0.679

Thailand

	Gas	Coal	Oil	Diesel
2020	0.386	0.854	0.727	0.727
2030	0.374	0.777	0.727	0.727

Vietnam

	Gas	Coal	Oil	Diesel
2020	0.376	0.849	0.799	0.799
2030	0.362	0.834	0.789	0.789

Table 4-6: Calculation Results (Base Case in 2020)

[CO_2 emission volume not restricted]

	Unit	Bangladesh	Brunei Darussalam	Cambodia	China (Yunnan & Guangxi)	India (North-East)	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
Supply-Demand Balance															
Electricity Demand	GWh	90,950	5,500	8,200	393,723	21,560	355,862	15,234	130,000	48,900	94,995	60,700	246,164	330,000	1,801,788
Grid Capacity (Import:+)	GWh	8,760	1,752	35,890	76,825	8,760	33,288	99,198	41,172	46,682	8,760	31,536	141,036	26,254	
Grid Capacity (Export:-)	GWh	-8,760	-1,752	-35,890	-76,825	-8,760	-33,288	-99,198	-41,172	-46,682	-8,760	-31,536	-141,036	-26,254	
Supply Capacity (Nuclear)	GWh	10,512	0	0	0	0	0	0	0	0	0	0	0	5,256	
Supply Capacity (Gas)	GWh	28,524	8,872	0	0	12,525	98,119	0	52,034	21,245	26,075	70,634	192,314	65,043	
Supply Capacity (Coal)	GWh	84,446	0	7,979	194,856	2,218	348,221	13,161	77,088	3,627	39,434	0	41,249	252,288	
Supply Capacity (Hydro)	GWh	1,301	0	19,410	264,362	21,523	35,411	26,199	14,585	39,767	16,210	0	16,107	75,292	
Supply Capacity (Oil)	GWh	3,863	0	0	0	0	11,826	0	0	0	3,416	19,053	1,656	0	
Supply Capacity (Diesel)	GWh	3,774	0	0	0	752	28,761	11	0	0	18,096	0	21	0	
Supply Capacity (Geothermal)	GWh	0	0	0	0	0	52,574	0	0	1,402	16,083	0	0	0	
Supply Capacity (Renewables)	GWh	0	0	11	648	799	2,656	28	10,512	3,620	378	1,556	7,251	4,415	
Total Supply Capacity	GWh	132,421	8,872	27,400	459,866	37,817	577,567	39,398	154,220	69,660	119,693	91,242	258,597	402,294	2,379,047
Power Supply (Nuclear)	GWh	10,512	0	0	0	0	0	0	0	0	0	0	0	5,256	
Power Supply (Gas)	GWh	28,524	7,252	0	0	0	0	0	52,034	21,245	14,130	27,608	40,521	0	
Power Supply (Coal)	GWh	59,373	0	6,391	191,927	0	298,509	10,233	77,088	698	39,434	0	41,249	252,288	
Power Supply (Hydro)	GWh	1,301	0	19,410	264,362	21,523	35,411	26,199	0	39,767	16,210	0	16,107	75,292	
Power Supply (Oil)	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0	
Power Supply (Diesel)	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0	
Power Supply (Geothermal)	GWh	0	0	0	0	0	52,574	0	0	1,402	16,083	0	0	0	
Power Supply (Renewables)	GWh	0	0	11	648	799	2,656	28	10,512	3,620	378	1,556	7,251	4,415	
Total Power Supply	GWh	99,710	7,252	25,812	456,938	22,322	389,150	36,459	139,634	66,731	86,235	29,164	105,128	337,251	1,801,788
Power Trade (Import:+/Export:-)	GWh	-8,760	-1,752	-17,612	-63,215	-762	-33,288	-21,225	-9,634	-17,831	8,760	31,536	141,036	-7,251	0
Generation Cost															
Power supply unit Cost (Nuclear)	US$/kWh	0.134												0.134	
Power supply unit Cost (Gas)	US$/kWh	0.100	0.100			0.180	0.100		0.127	0.100	0.180	0.180	0.180	0.180	
Power supply unit Cost (Coal)	US$/kWh	0.144		0.144	0.144	0.144	0.080	0.144	0.100	0.144	0.144		0.144	0.080	
Power supply unit Cost (Hydro)	US$/kWh	0.053		0.053	0.053	0.053	0.016	0.059	0.150	0.053	0.053		0.053	0.053	
Power supply unit Cost (Oil)	US$/kWh	0.334					0.334				0.334	0.334	0.334		
Power supply unit Cost (Diesel)	US$/kWh	0.483				0.483	0.267	0.483			0.483		0.483		
Power supply unit Cost (Geothermal)	US$/kWh						0.083			0.083	0.083				
Power supply unit Cost (Renewables)	US$/kWh			0.169	0.169	0.169	0.169	0.169	0.110	0.169	0.169	0.169	0.169	0.169	
Generation Cost (Nuclear)	million US$	1,409	0	0	0	0	0	0	0	0	0	0	0	704	
Generation Cost (Gas)	million US$	2,852	725	0	0	0	0	0	6,608	2,124	2,543	4,969	7,294	0	
Generation Cost (Coal)	million US$	8,550	0	920	27,638	0	23,881	1,474	7,709	101	5,678	0	5,940	20,183	
Generation Cost (Hydro)	million US$	69	0	1,029	14,011	1,141	567	1,546	0	2,108	859	0	854	3,990	
Generation Cost (Oil)	million US$	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generation Cost (Diesel)	million US$	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generation Cost (Geothermal)	million US$	0	0	0	0	0	4,364	0	0	116	1,335	0	0	0	
Generation Cost (Renewables)	million US$	0	0	2	110	135	449	5	1,156	612	64	263	1,225	746	
Total Generation Cost	million US$	12,880	725	1,951	41,758	1,276	29,260	3,024	15,473	5,061	10,480	5,232	15,313	25,624	168,057
CO2 Emission															
CO2 Emission Coefficient (Nuclear)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Gas)	kt-CO2/GWh	0.415	0.744		0.423	0.415	0.512		0.361	0.642	0.329	0.379	0.386	0.376	
CO2 Emission Coefficient (Coal)	kt-CO2/GWh	1.059		1.087	0.858	1.059	1.029	0.932	0.852	1.087	0.932		0.854	0.849	
CO2 Emission Coefficient (Hydro)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Oil)	kt-CO2/GWh	0.789	0.752	1.146	0.665	0.789	0.794		0.772		0.705	0.727	0.727	0.799	
CO2 Emission Coefficient (Diesel)	kt-CO2/GWh	0.789	0.752	1.146	0.665	0.789	0.794		0.772		0.705	0.727	0.727	0.799	
CO2 Emission Coefficient (Geothermal)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Renewables)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission (Nuclear)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Gas)	kt-CO2	11,850	5,395	0	0	0	0	0	18,767	13,637	4,652	10,467	15,629	0	
CO2 Emission (Coal)	kt-CO2	62,876	0	6,949	164,740	0	307,146	9,536	65,650	759	36,749	0	35,221	214,295	
CO2 Emission (Hydro)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Oil)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Diesel)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Geothermal)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Renewables)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total CO2 Emission	kt-CO2	74,726	5,395	6,949	164,740	0	307,146	9,536	84,417	14,396	41,402	10,467	50,849	214,295	984,317
Target of Total CO2 Emission															9,999,999

Table 4-7: Calculation results (Accelerated Case in 2030)

[CO_2 emission volume not restricted]

	Unit	Bangladesh	Brunei Darussalam	Cambodia	China (Yunnan & Guangxi)	India (North-East)	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
Supply-Demand Balance															
Electricity Demand	GWh	191,933	7,524	13,489	541,980	41,491	956,929	35,863	160,000	95,068	149,067	71,500	346,767	675,000	3,286,611
Grid Capacity (Import:+)	GWh	17,520	3,504	71,780	153,650	17,520	66,576	198,396	82,344	93,364	17,520	63,072	282,072	52,508	
Grid Capacity (Export:-)	GWh	-17,520	-3,504	-71,780	-153,650	-17,520	-66,576	-198,396	-82,344	-93,364	-17,520	-63,072	-282,072	-52,508	
Supply Capacity (Nuclear)	GWh	28,032	0	0	0	0	0	0	14,016	0	0	0	14,016	56,064	
Supply Capacity (Gas)	GWh	46,516	12,138	0	0	24,998	176,770	0	52,560	21,245	37,113	87,593	265,687	87,323	
Supply Capacity (Coal)	GWh	137,707	0	13,124	268,492	4,426	627,363	13,161	88,301	5,203	62,876	0	51,768	509,152	
Supply Capacity (Hydro)	GWh	1,301	0	31,934	364,261	42,960	63,793	50,020	16,651	83,756	26,037	0	16,280	87,142	
Supply Capacity (Oil)	GWh	6,302	0	0	0	0	11,826	0	0	0	3,416	19,053	1,656	0	
Supply Capacity (Diesel)	GWh	6,155	0	0	0	752	28,761	11	10,512	0	31,236	0	3,963	0	
Supply Capacity (Geothermal)	GWh	0	0	0	0	0	94,720	0	0	1,402	24,941	0	0	0	
Supply Capacity (Renewables)	GWh	0	0	11	648	799	2,656	28	18,396	3,620	378	1,929	10,047	13,913	
Total Supply Capacity	GWh	226,012	12,138	45,069	633,401	73,934	1,005,889	63,220	200,436	115,225	185,998	108,575	363,418	753,594	3,786,908
Power Supply (Nuclear)	GWh	28,032	0	0	0	0	0	0	14,016	0	0	0	14,016	56,064	
Power Supply (Gas)	GWh	46,516	11,028	0	0	10,827	176,770	0	52,560	21,245	24,975	38,035	57,434	0	
Power Supply (Coal)	GWh	133,605	0	13,124	268,492	4,426	627,363	13,161	88,301	5,203	62,876	0	51,768	509,152	
Power Supply (Hydro)	GWh	1,301	0	31,934	364,261	42,960	63,793	50,020	16,651	83,756	26,037	0	16,280	87,142	
Power Supply (Oil)	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0	
Power Supply (Diesel)	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0	
Power Supply (Geothermal)	GWh	0	0	0	0	0	94,720	0	0	1,402	24,941	0	0	0	
Power Supply (Renewables)	GWh	0	0	11	648	799	2,656	28	18,396	3,620	378	1,929	10,047	13,913	
Total Power Supply	GWh	209,453	11,028	45,069	633,401	59,011	965,303	63,209	189,924	115,225	139,208	39,964	149,546	666,271	3,286,611
Power Trade (Import:+/Export:-)	GWh	-17,520	-3,504	-31,580	-91,421	-17,520	-8,374	-27,346	-29,924	-20,157	9,859	31,536	197,221	8,729	0
Generation Cost															
Power supply unit Cost (Nuclear)	US$/kWh	0.146							0.146				0.146	0.146	
Power supply unit Cost (Gas)	US$/kWh	0.150	0.150			0.216	0.150		0.127	0.150	0.216	0.216	0.216	0.216	
Power supply unit Cost (Coal)	US$/kWh	0.161		0.161	0.161	0.161	0.120	0.161	0.100	0.161	0.161		0.161	0.120	
Power supply unit Cost (Hydro)	US$/kWh	0.064		0.064	0.064	0.064	0.016	0.058	0.150	0.064	0.064		0.064	0.064	
Power supply unit Cost (Oil)	US$/kWh	0.399					0.399				0.399	0.399	0.399		
Power supply unit Cost (Diesel)	US$/kWh	0.583		0.583		0.583	0.267	0.583	0.583		0.583		0.583		
Power supply unit Cost (Geothermal)	US$/kWh						0.083			0.083	0.083				
Power supply unit Cost (Renewables)	US$/kWh			0.200	0.200	0.200	0.200	0.200	0.100	0.200	0.200	0.200	0.200	0.200	
Generation Cost (Nuclear)	million US$	4,093	0	0	0	0	0	0	2,046	0	0	0	2,046	8,185	
Generation Cost (Gas)	million US$	6,977	1,654	0	0	2,339	26,515	0	6,675	3,187	5,395	8,216	12,406	0	
Generation Cost (Coal)	million US$	21,510	0	2,113	43,227	713	75,284	2,119	8,830	838	10,123	0	8,335	61,098	
Generation Cost (Hydro)	million US$	83	0	2,044	23,313	2,749	1,021	2,901	2,498	5,360	1,666	0	1,042	5,577	
Generation Cost (Oil)	million US$	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generation Cost (Diesel)	million US$	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generation Cost (Geothermal)	million US$	0	0	0	0	0	7,862	0	0	116	2,070	0	0	0	
Generation Cost (Renewables)	million US$	0	0	2	130	160	531	6	1,840	724	76	386	2,009	2,783	
Total Generation Cost	million US$	32,664	1,654	4,159	66,670	5,960	111,213	5,026	21,889	10,225	19,330	8,601	25,838	77,643	390,871
CO2 Emission															
CO2 Emission Coefficient (Nuclear)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Gas)	kt-CO2/GWh	0.407	0.744		0.395	0.407	0.512		0.349	0.642	0.329	0.359	0.374	0.362	
CO2 Emission Coefficient (Coal)	kt-CO2/GWh	0.870		1.087	0.796	0.870	1.029	0.932	0.834	1.087	0.896		0.777	0.834	
CO2 Emission Coefficient (Hydro)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Oil)	kt-CO2/GWh	0.733	0.752	1.146	0.629	0.733	0.794		0.750		0.705	0.679	0.727	0.789	
CO2 Emission Coefficient (Diesel)	kt-CO2/GWh	0.733	0.752	1.146	0.629	0.733	0.794		0.750		0.705	0.679	0.727	0.789	
CO2 Emission Coefficient (Geothermal)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Renewables)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission (Nuclear)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Gas)	kt-CO2	18,926	8,204	0	0	4,405	90,577	0	18,324	13,637	8,224	13,662	21,454	0	
CO2 Emission (Coal)	kt-CO2	116,208	0	14,269	213,597	3,849	645,515	12,265	73,660	5,657	56,342	0	40,203	424,734	
CO2 Emission (Hydro)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Oil)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Diesel)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Geothermal)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Renewables)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total CO2 Emission	kt-CO2	135,134	8,204	14,269	213,597	8,254	736,092	12,265	91,985	19,294	64,565	13,662	61,657	424,734	1,803,713
Target of Total CO2 Emission															9,999,999

Table 4-8: Calculation Results (Base Case in 2030)

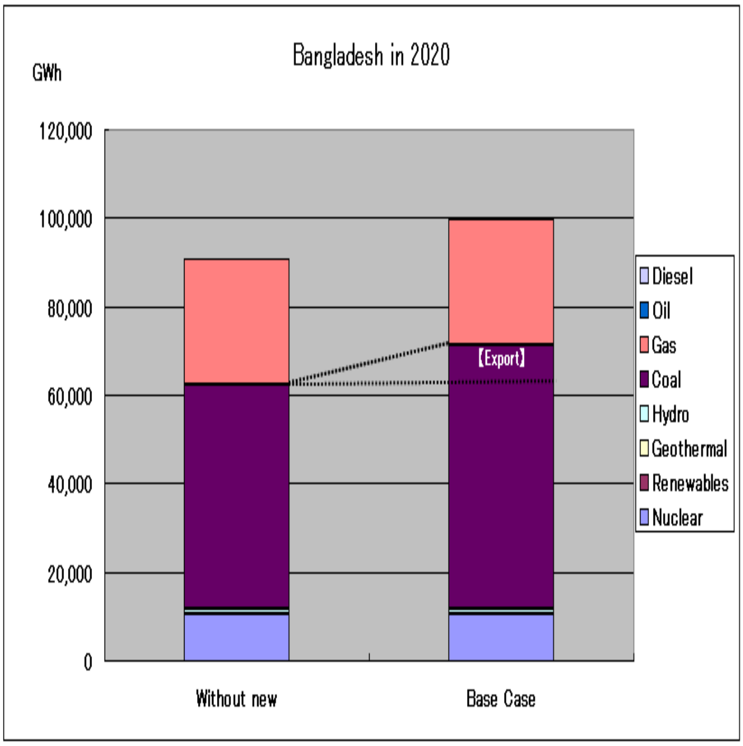
[CO_2 emission volume not restricted]

	Unit	Bangladesh	Brunei Darussalam	Cambodia	China (Yunnan & Guangxi)	India (North-East)	Indonesia	Lao PDR	Malaysia	Myanmar	Philippines	Singapore	Thailand	Viet Nam	Total
Supply-Demand Balance															
Electricity Demand	GWh	191,933	7,524	13,489	541,980	41,491	956,929	35,863	160,000	95,068	149,067	71,500	346,767	675,000	3,286,611
Grid Capacity (Import:+)	GWh	8,760	1,752	35,890	76,825	8,760	33,288	99,198	41,172	46,682	8,760	31,536	141,036	26,254	
Grid Capacity (Export:-)	GWh	-8,760	-1,752	-35,890	-76,825	-8,760	-33,288	-99,198	-41,172	-46,682	-8,760	-31,536	-141,036	-26,254	
Supply Capacity (Nuclear)	GWh	28,032	0	0	0	0	0	0	14,016	0	0	0	14,016	56,064	
Supply Capacity (Gas)	GWh	46,516	12,138	0	0	24,998	176,770	0	52,560	21,245	37,113	87,593	265,687	87,323	
Supply Capacity (Coal)	GWh	137,707	0	13,124	268,492	4,426	627,363	13,161	88,301	5,203	62,876	0	51,768	509,152	
Supply Capacity (Hydro)	GWh	1,301	0	31,934	364,261	42,960	63,793	50,020	16,651	83,756	26,037	0	16,280	87,142	
Supply Capacity (Oil)	GWh	6,302	0	0	0	0	11,826	0	0	0	3,416	19,053	1,656	0	
Supply Capacity (Diesel)	GWh	6,155	0	0	0	752	28,761	11	10,512	0	31,236	0	3,963	0	
Supply Capacity (Geothermal)	GWh	0	0	0	0	0	94,720	0	0	1,402	24,941	0	0	0	
Supply Capacity (Renewables)	GWh	0	0	11	648	799	2,656	28	18,396	3,620	378	1,929	10,047	13,913	
Total Supply Capacity	GWh	226,012	12,138	45,069	633,401	73,934	1,005,889	63,220	200,436	115,225	185,998	108,575	363,418	753,594	3,786,908
Power Supply (Nuclear)	GWh	28,032	0	0	0	0	0	0	14,016	0	0	0	14,016	56,064	
Power Supply (Gas)	GWh	46,516	9,276	0	0	0	176,770	0	52,560	21,245	26,074	38,035	113,619	0	
Power Supply (Coal)	GWh	124,844	0	1,924	253,896	3,280	627,363	4,159	88,301	5,203	62,876	0	51,768	509,152	
Power Supply (Hydro)	GWh	1,301	0	31,934	364,261	42,960	63,793	50,020	16,651	83,756	26,037	0	16,280	87,142	
Power Supply (Oil)	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0	
Power Supply (Diesel)	GWh	0	0	0	0	0	0	0	0	0	0	0	0	0	
Power Supply (Geothermal)	GWh	0	0	0	0	0	94,720	0	0	1,402	24,941	0	0	0	
Power Supply (Renewables)	GWh	0	0	11	648	799	2,656	28	18,396	3,620	378	1,929	10,047	13,913	
Total Power Supply	GWh	200,693	9,276	33,869	618,805	47,038	965,303	54,207	189,924	115,225	140,307	39,964	205,731	666,271	3,286,611
Power Trade (Import:+/Export:-)	GWh	-8,760	-1,752	-20,380	-76,825	-5,547	-8,374	-18,344	-29,924	-20,157	8,760	31,536	141,036	8,729	0
Generation Cost															
Power supply unit Cost (Nuclear)	US$/kWh	0.146							0.146				0.146	0.146	
Power supply unit Cost (Gas)	US$/kWh	0.150	0.150			0.216	0.150		0.127	0.150	0.216	0.216	0.216	0.216	
Power supply unit Cost (Coal)	US$/kWh	0.161		0.161	0.161	0.161	0.120	0.161	0.100	0.161	0.161		0.161	0.120	
Power supply unit Cost (Hydro)	US$/kWh	0.064		0.064	0.064	0.064	0.016	0.058	0.150	0.064	0.064		0.064	0.064	
Power supply unit Cost (Oil)	US$/kWh	0.399					0.399				0.399	0.399	0.399		
Power supply unit Cost (Diesel)	US$/kWh	0.583		0.583		0.583	0.267	0.583	0.583		0.583		0.583		
Power supply unit Cost (Geothermal)	US$/kWh						0.083			0.083	0.083				
Power supply unit Cost (Renewables)	US$/kWh			0.200	0.200	0.200	0.200	0.200	0.100	0.200	0.200	0.200	0.200	0.200	
Generation Cost (Nuclear)	million US$	4,093	0	0	0	0	0	0	2,046	0	0	0	2,046	8,185	
Generation Cost (Gas)	million US$	6,977	1,391	0	0	0	26,515	0	6,675	3,187	5,632	8,216	24,542	0	
Generation Cost (Coal)	million US$	20,100	0	310	40,877	528	75,284	670	8,830	838	10,123	0	8,335	61,098	
Generation Cost (Hydro)	million US$	83	0	2,044	23,313	2,749	1,021	2,901	2,498	5,360	1,666	0	1,042	5,577	
Generation Cost (Oil)	million US$	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generation Cost (Diesel)	million US$	0	0	0	0	0	0	0	0	0	0	0	0	0	
Generation Cost (Geothermal)	million US$	0	0	0	0	0	7,862	0	0	116	2,070	0	0	0	
Generation Cost (Renewables)	million US$	0	0	2	130	160	531	6	1,840	724	76	386	2,009	2,783	
Total Generation Cost	million US$	31,253	1,391	2,356	64,320	3,437	111,213	3,576	21,889	10,225	19,567	8,601	37,974	77,643	393,446
CO2 Emission															
CO2 Emission Coefficient (Nuclear)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Gas)	kt-CO2/GWh	0.407	0.744		0.395	0.407	0.512		0.349	0.642	0.329	0.359	0.374	0.362	
CO2 Emission Coefficient (Coal)	kt-CO2/GWh	0.870		1.087	0.796	0.870	1.029	0.932	0.834	1.087	0.896		0.777	0.834	
CO2 Emission Coefficient (Hydro)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Oil)	kt-CO2/GWh	0.733	0.752	1.146	0.629	0.733	0.794		0.750		0.705	0.679	0.727	0.789	
CO2 Emission Coefficient (Diesel)	kt-CO2/GWh	0.733	0.752	1.146	0.629	0.733	0.794		0.750		0.705	0.679	0.727	0.789	
CO2 Emission Coefficient (Geothermal)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission Coefficient (Renewables)	kt-CO2/GWh	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
CO2 Emission (Nuclear)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Gas)	kt-CO2	18,926	6,901	0	0	0	90,577	0	18,324	13,637	8,585	13,662	42,441	0	
CO2 Emission (Coal)	kt-CO2	108,588	0	2,092	201,985	2,853	645,515	3,875	73,660	5,657	56,342	0	40,203	424,734	
CO2 Emission (Hydro)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Oil)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Diesel)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Geothermal)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
CO2 Emission (Renewables)	kt-CO2	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total CO2 Emission	kt-CO2	127,514	6,901	2,092	201,985	2,853	736,092	3,875	91,985	19,294	64,927	13,662	82,644	424,734	1,778,558
Target of Total CO2 Emission															9,999,999

Table 4-9: Optimal Energy Mixes by Country if International Interconnection Grid is Augmented (Cases in which CO_2 emission volume is not restricted)

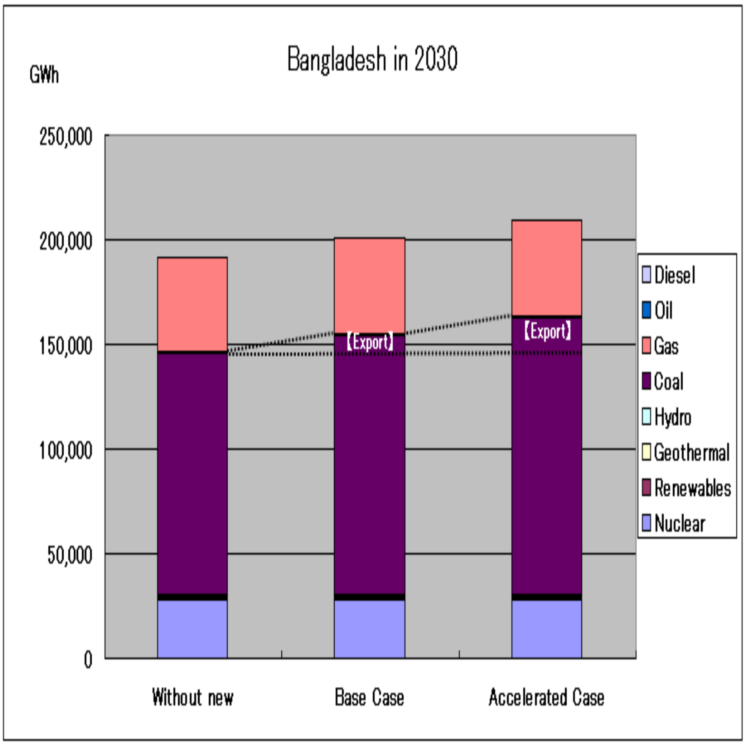
Bangladesh in 2020

	Without new	Base Case	Accelerated Case
Nuclear	10,512	10,512	
Renewables	0	0	
Geothermal	0	0	
Hydro	1,301	1,301	
Coal	50,613	59,373	
Gas	28,524	28,524	
Oil	0	0	
Diesel	0	0	
Total Supply	90,950	99,710	
Power Trade	0	-8,760	



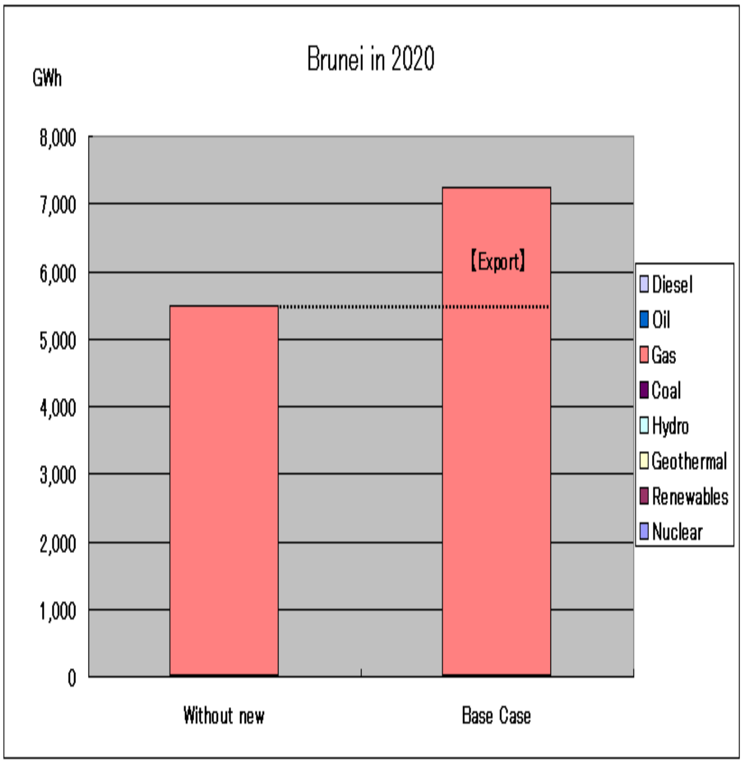
Bangladesh in 2030

	Without new	Base Case	Accelerated Case
Nuclear	28,032	28,032	28,032
Renewables	0	0	0
Geothermal	0	0	0
Hydro	1,301	1,301	1,301
Coal	116,085	124,844	133,605
Gas	46,516	46,516	46,516
Oil	0	0	0
Diesel	0	0	0
Total Supply	191,933	200,693	209,453
Power Trade	0	-8,760	-17,520



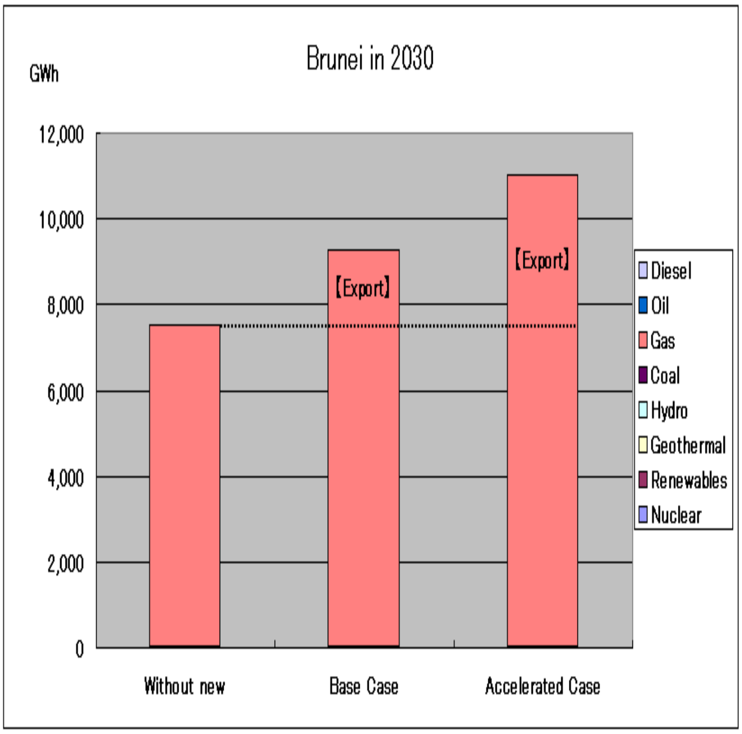
Brunei in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	0	0	
Geothermal	0	0	
Hydro	0	0	
Coal	0	0	
Gas	5,500	7,252	
Oil	0	0	
Diesel	0	0	
Total Supply	5,500	7,252	
Power Trade	0	-1,752	



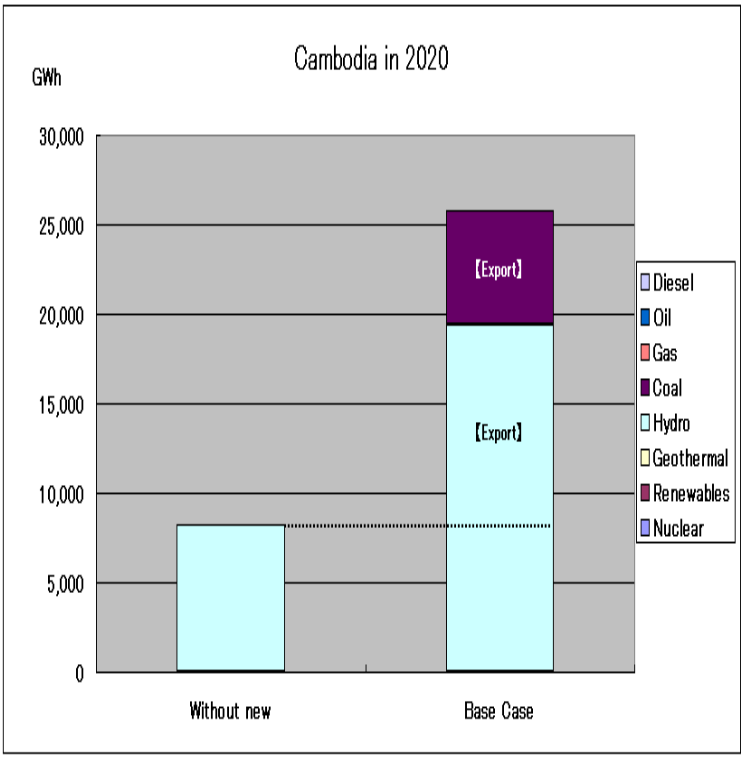
Brunei in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	0	0	0
Geothermal	0	0	0
Hydro	0	0	0
Coal	0	0	0
Gas	7,524	9,276	11,028
Oil	0	0	0
Diesel	0	0	0
Total Supply	7,524	9,276	11,028
Power Trade	0	-1,752	-3,504



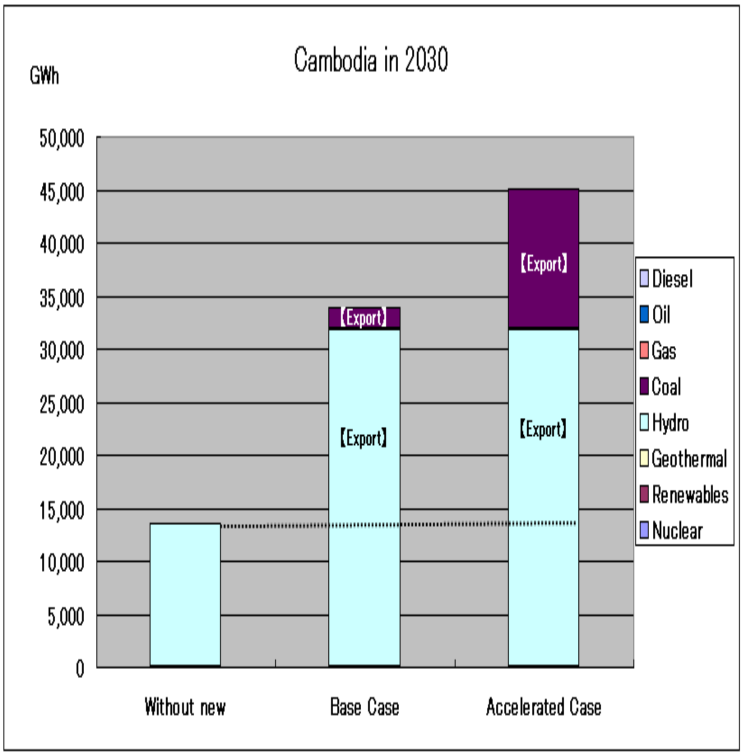
Cambodia in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	11	11	
Geothermal	0	0	
Hydro	8,189	19,410	
Coal	0	6,391	
Gas	0	0	
Oil	0	0	
Diesel	0	0	
Total Supply	8,200	25,812	
Power Trade	0	-17,612	



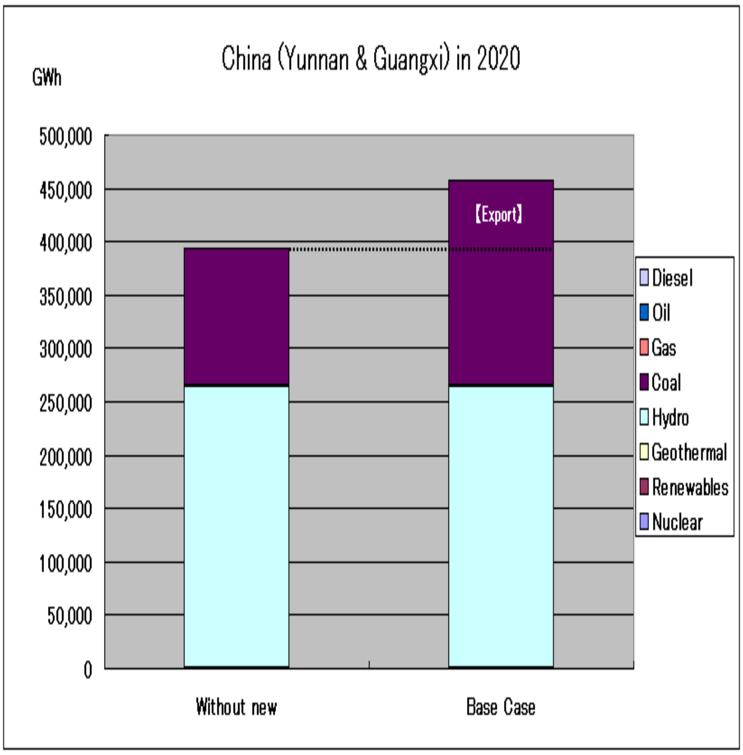
Cambodia in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	11	11	11
Geothermal	0	0	0
Hydro	13,478	31,934	31,934
Coal	0	1,924	13,124
Gas	0	0	0
Oil	0	0	0
Diesel	0	0	0
Total Supply	13,489	33,869	45,069
Power Trade	0	-20,380	-31,580



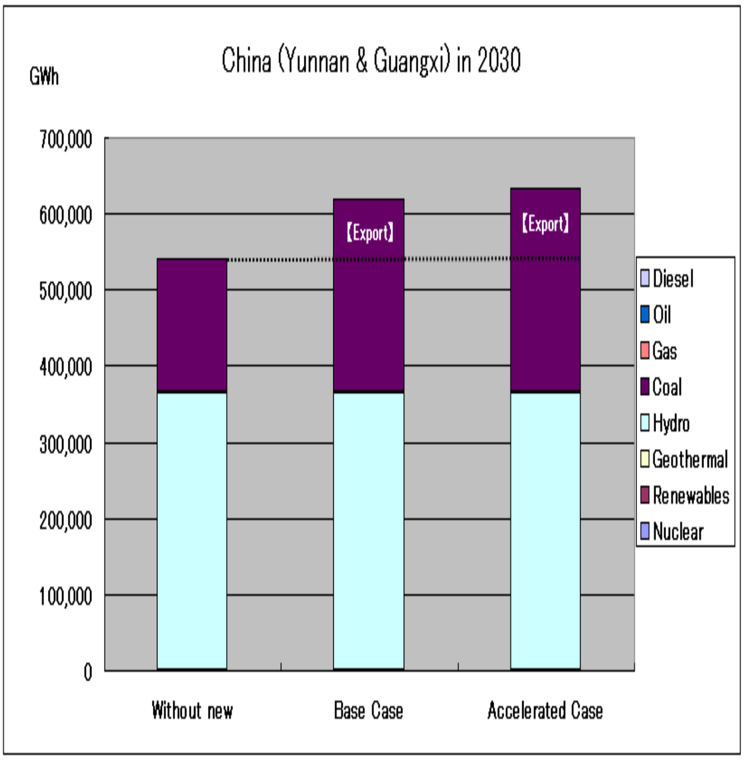
China (Yunnan & Guangxi) in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	648	648	
Geothermal	0	0	
Hydro	264,362	264,362	
Coal	128,712	191,927	
Gas	0	0	
Oil	0	0	
Diesel	0	0	
Total Supply	393,723	456,938	
Power Trade	0	-63,215	



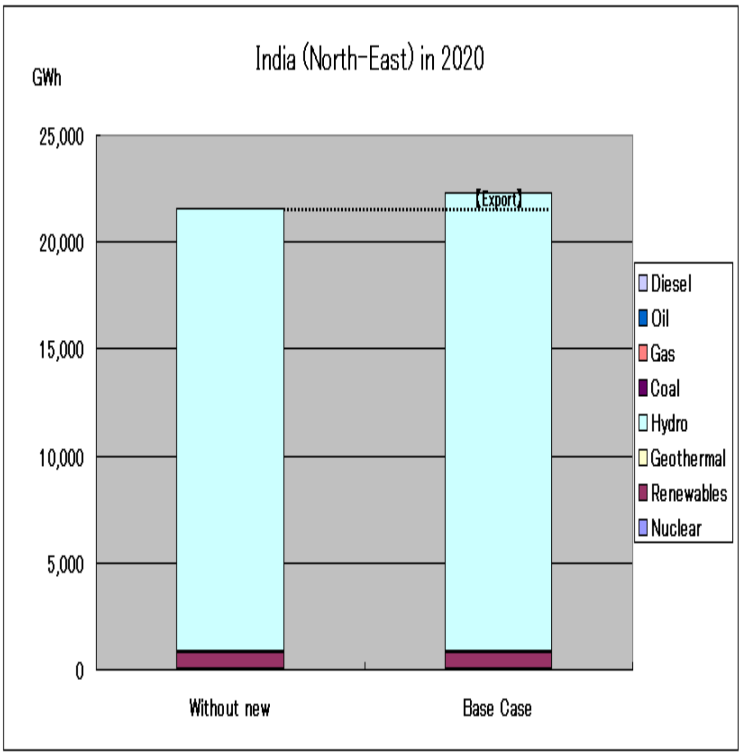
China (Yunnan & Guangxi) in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	648	648	648
Geothermal	0	0	0
Hydro	364,261	364,261	364,261
Coal	177,071	253,896	268,492
Gas	0	0	0
Oil	0	0	0
Diesel	0	0	0
Total Supply	541,980	618,805	633,401
Power Trade	0	-76,825	-91,421



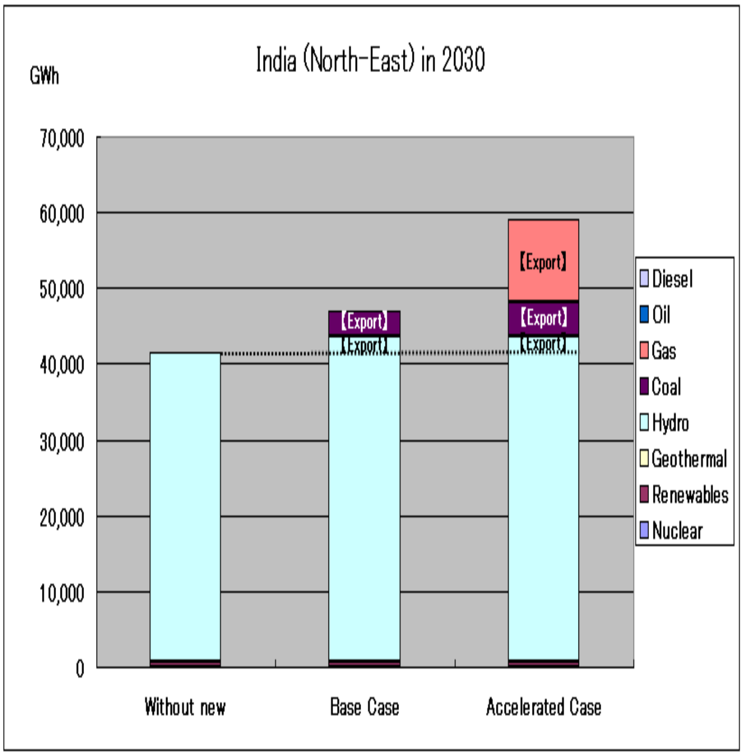
India (North-East) in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	799	799	
Geothermal	0	0	
Hydro	20,761	21,523	
Coal	0	0	
Gas	0	0	
Oil	0	0	
Diesel	0	0	
Total Supply	21,560	22,322	
Power Trade	0	-762	



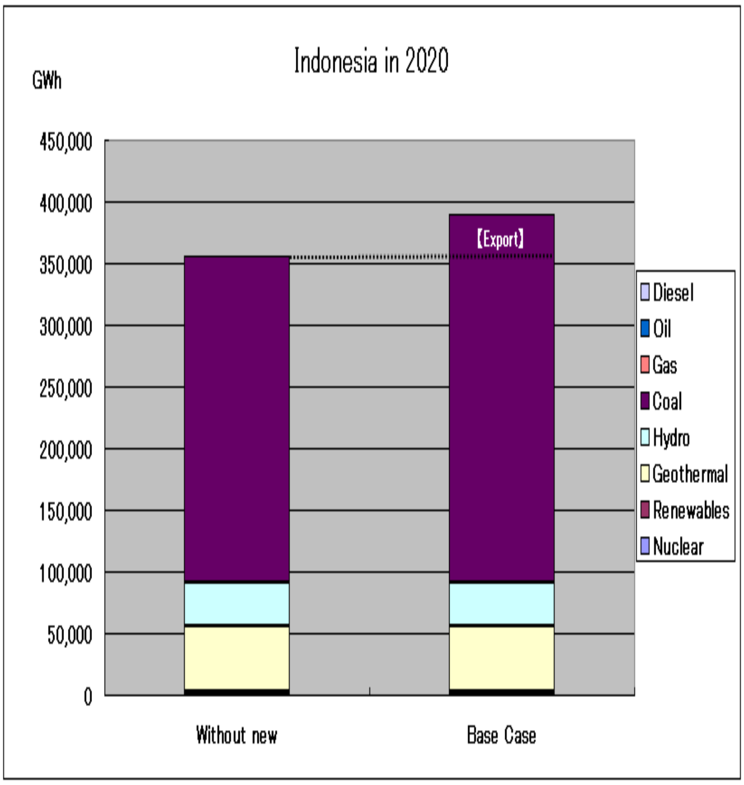
India (North-East) in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	799	799	799
Geothermal	0	0	0
Hydro	40,692	42,960	42,960
Coal	0	3,280	4,426
Gas	0	0	10,827
Oil	0	0	0
Diesel	0	0	0
Total Supply	41,491	47,038	59,011
Power Trade	0	-5,547	-17,520



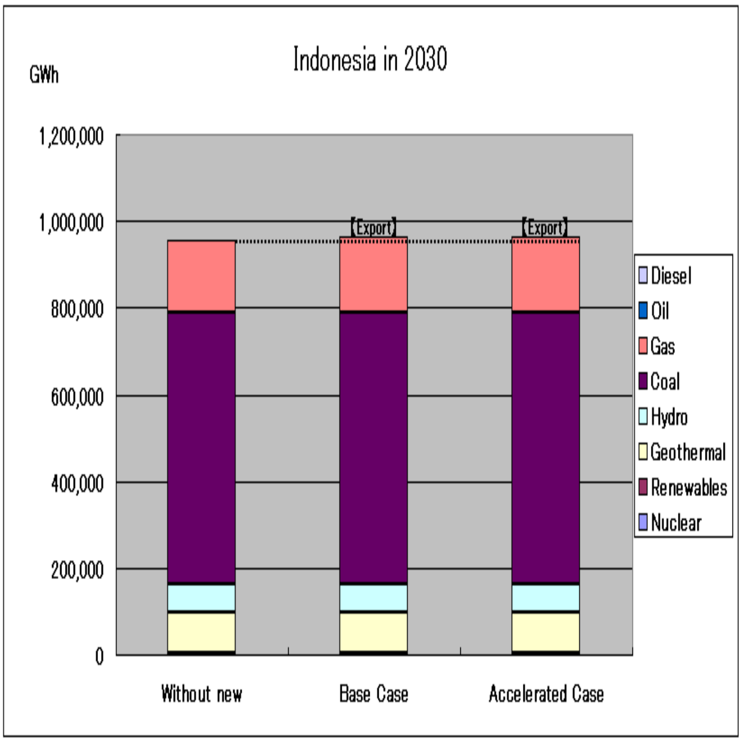
Indonesia in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	2,656	2,656	
Geothermal	52,574	52,574	
Hydro	35,411	35,411	
Coal	265,221	298,509	
Gas	0	0	
Oil	0	0	
Diesel	0	0	
Total Supply	355,862	389,150	
Power Trade	0	-33,288	



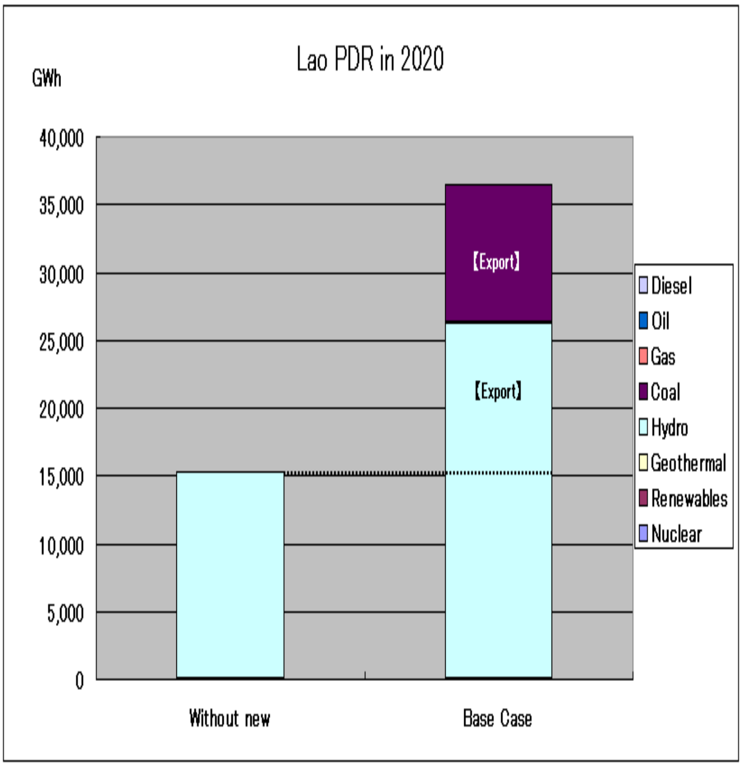
Indonesia in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	2,656	2,656	2,656
Geothermal	94,720	94,720	94,720
Hydro	63,793	63,793	63,793
Coal	627,363	627,363	627,363
Gas	168,396	176,770	176,770
Oil	0	0	0
Diesel	0	0	0
Total Supply	956,929	965,303	965,303
Power Trade	0	-8,374	-8,374



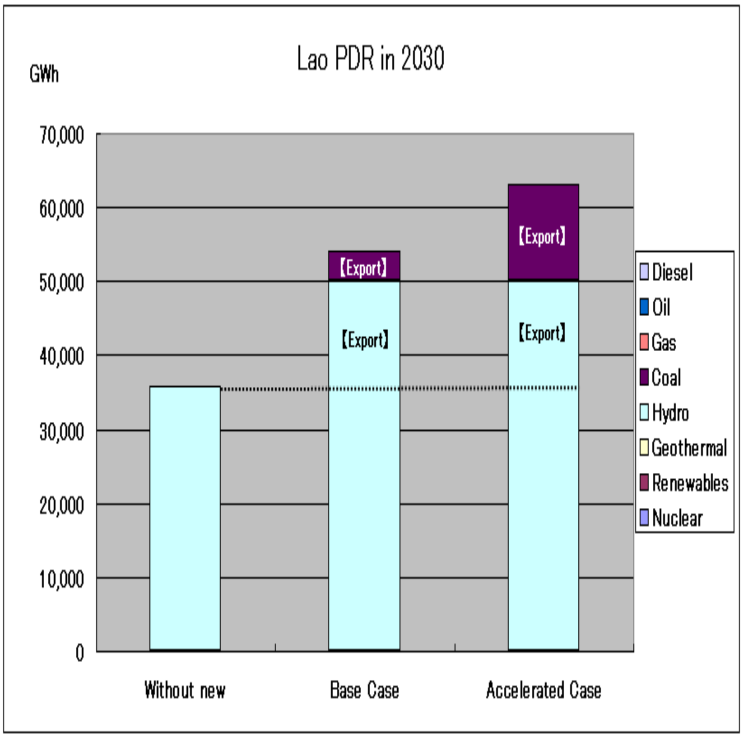
Lao PDR in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	28	28	
Geothermal	0	0	
Hydro	15,206	26,199	
Coal	0	10,233	
Gas	0	0	
Oil	0	0	
Diesel	0	0	
Total Supply	15,234	36,459	
Power Trade	0	-21,225	



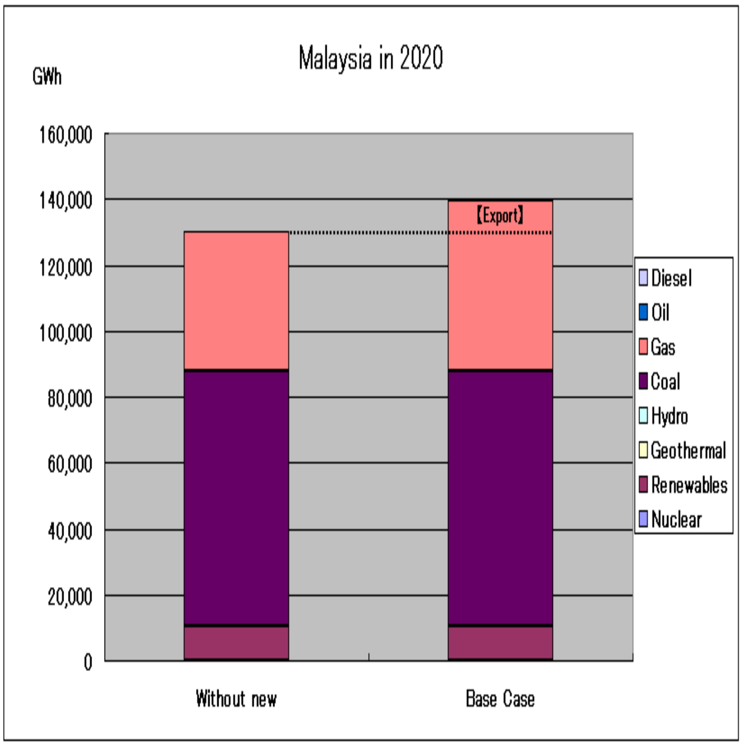
Lao PDR in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	28	28	28
Geothermal	0	0	0
Hydro	35,835	50,020	50,020
Coal	0	4,159	13,161
Gas	0	0	0
Oil	0	0	0
Diesel	0	0	0
Total Supply	35,863	54,207	63,209
Power Trade	0	-18,344	-27,346



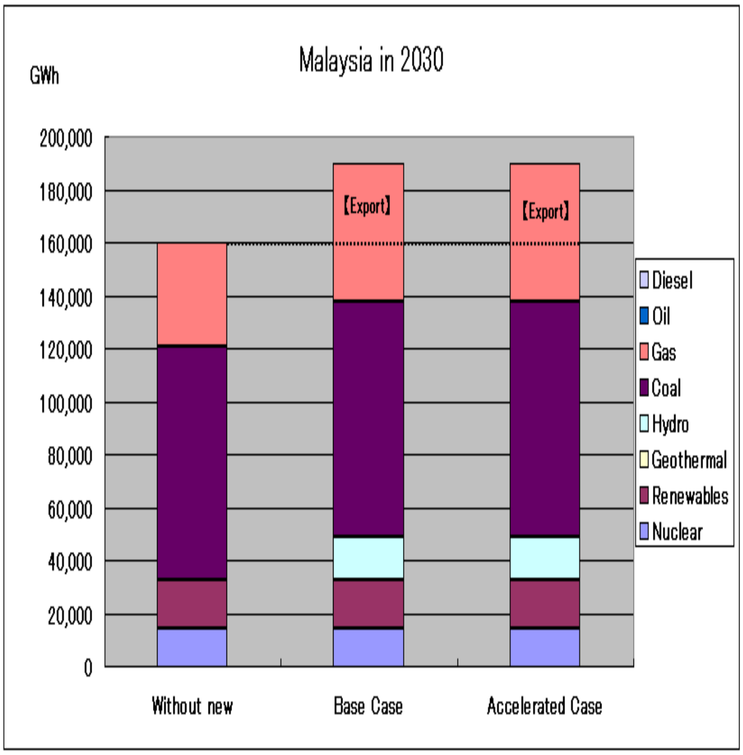
Malaysia in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	10,512	10,512	
Geothermal	0	0	
Hydro	0	0	
Coal	77,088	77,088	
Gas	42,400	52,034	
Oil	0	0	
Diesel	0	0	
Total Supply	130,000	139,634	
Power Trade	0	-9,634	



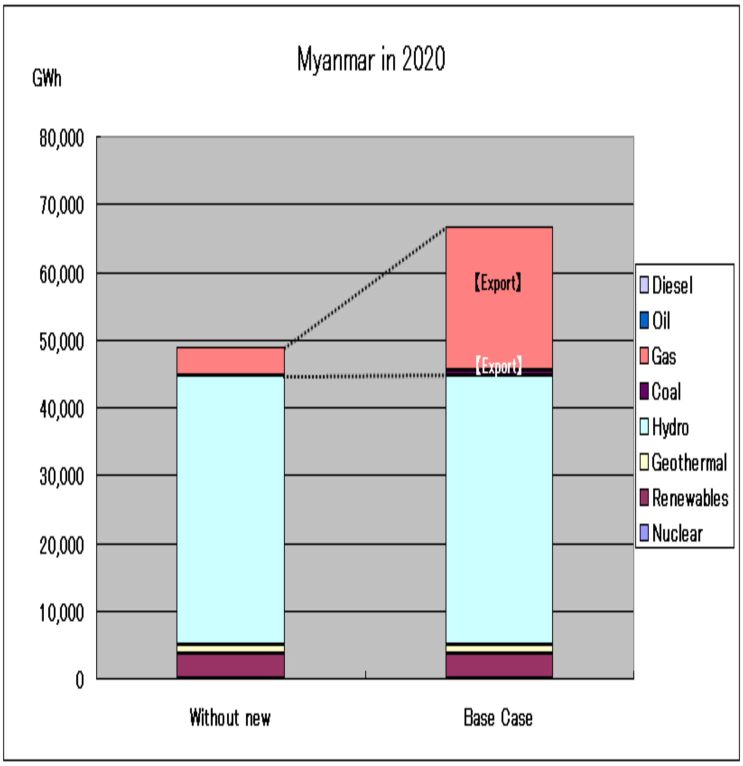
Malaysia in 2030

	Without new	Base Case	Accelerated Case
Nuclear	14,016	14,016	14,016
Renewables	18,396	18,396	18,396
Geothermal	0	0	0
Hydro	0	16,651	16,651
Coal	88,301	88,301	88,301
Gas	39,287	52,560	52,560
Oil	0	0	0
Diesel	0	0	0
Total Supply	160,000	189,924	189,924
Power Trade	0	-29,924	-29,924



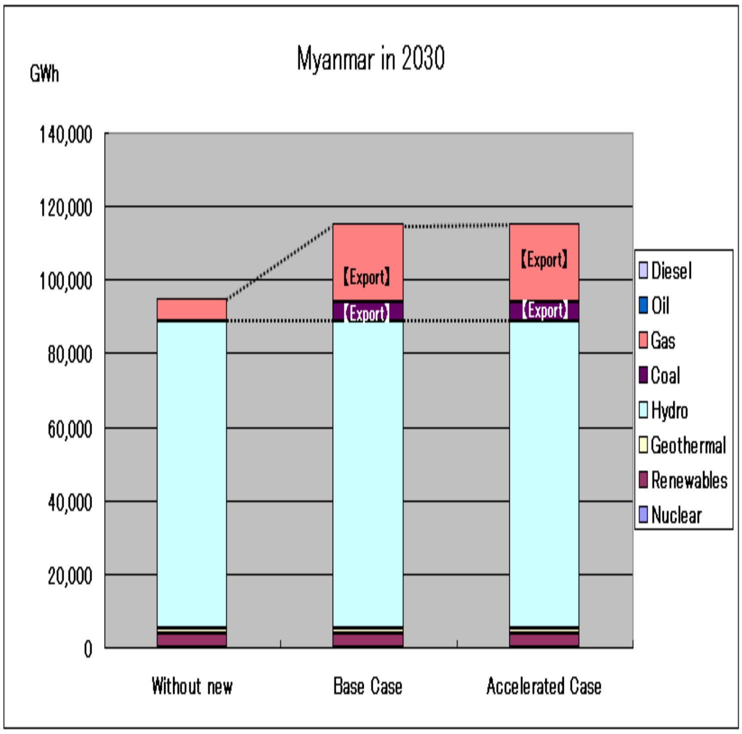
Myanmar in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	3,620	3,620	
Geothermal	1,402	1,402	
Hydro	39,767	39,767	
Coal	0	698	
Gas	4,112	21,245	
Oil	0	0	
Diesel	0	0	
Total Supply	48,900	66,731	
Power Trade	0	-17,831	



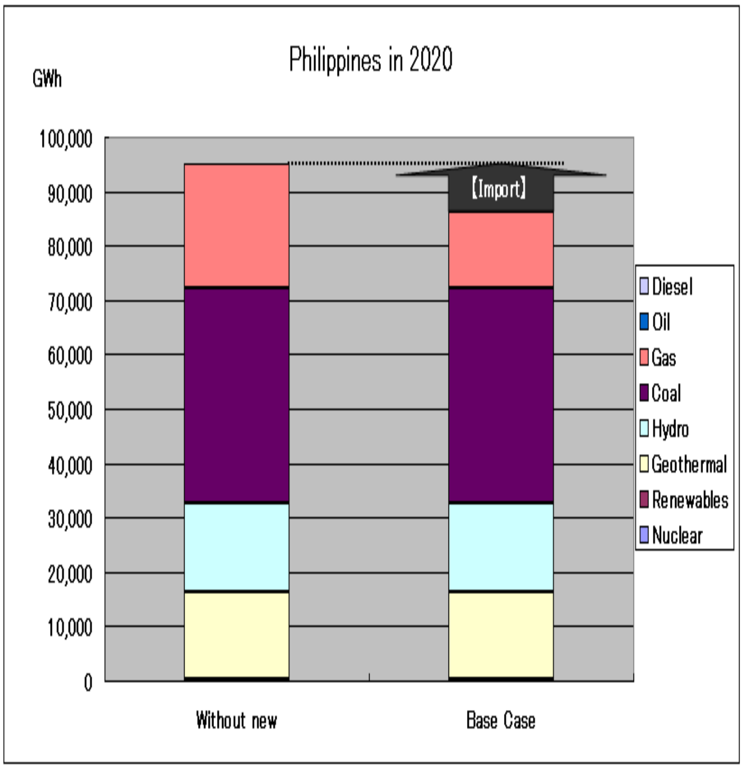
Myanmar in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	3,620	3,620	3,620
Geothermal	1,402	1,402	1,402
Hydro	83,756	83,756	83,756
Coal	0	5,203	5,203
Gas	6,291	21,245	21,245
Oil	0	0	0
Diesel	0	0	0
Total Supply	95,068	115,225	115,225
Power Trade	0	-20,157	-20,157



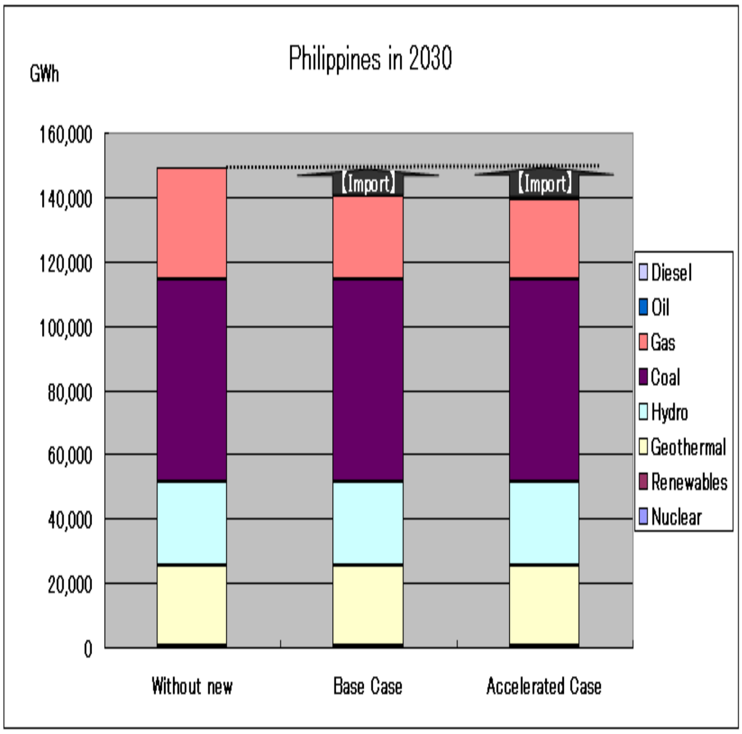
Philippines in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	378	378	
Geothermal	16,083	16,083	
Hydro	16,210	16,210	
Coal	39,434	39,434	
Gas	22,890	14,130	
Oil	0	0	
Diesel	0	0	
Total Supply	94,995	86,235	
Power Trade	0	8,760	



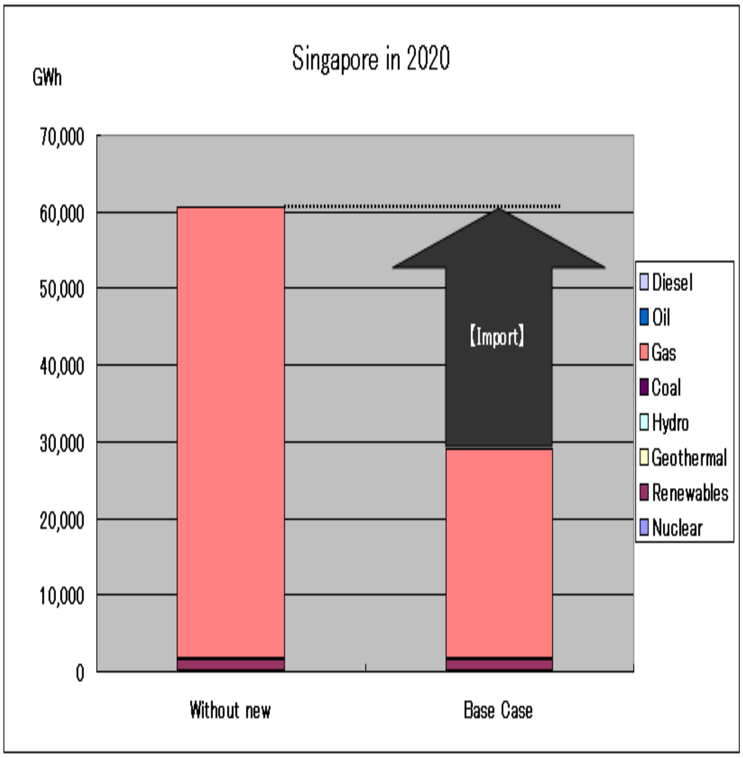
Philippines in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	378	378	378
Geothermal	24,941	24,941	24,941
Hydro	26,037	26,037	26,037
Coal	62,876	62,876	62,876
Gas	34,834	26,074	24,975
Oil	0	0	0
Diesel	0	0	0
Total Supply	149,067	140,307	139,208
Power Trade	0	8,760	9,859



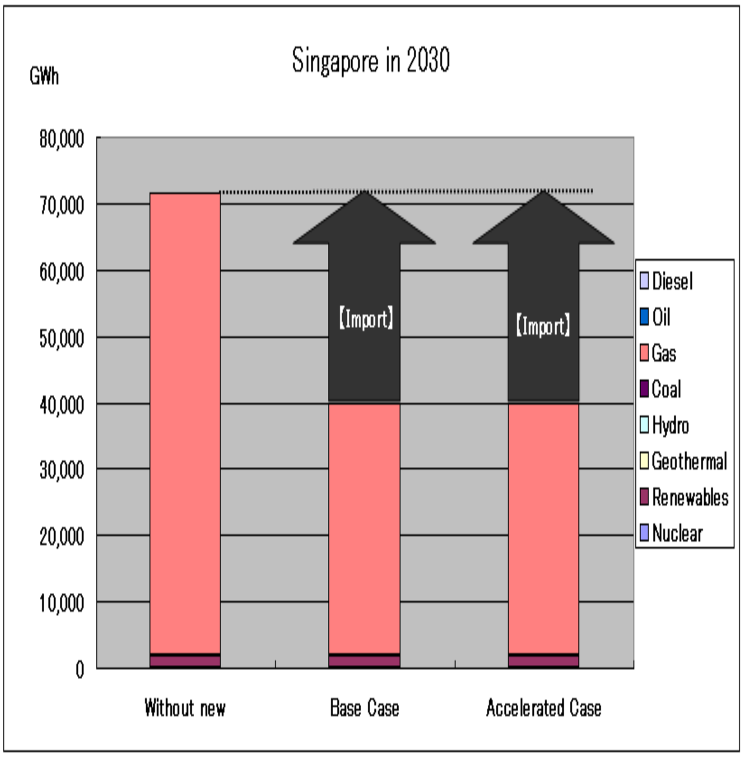
Singapore in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	1,556	1,556	
Geothermal	0	0	
Hydro	0	0	
Coal	0	0	
Gas	59,144	27,608	
Oil	0	0	
Diesel	0	0	
Total Supply	60,700	29,164	
Power Trade	0	31,536	



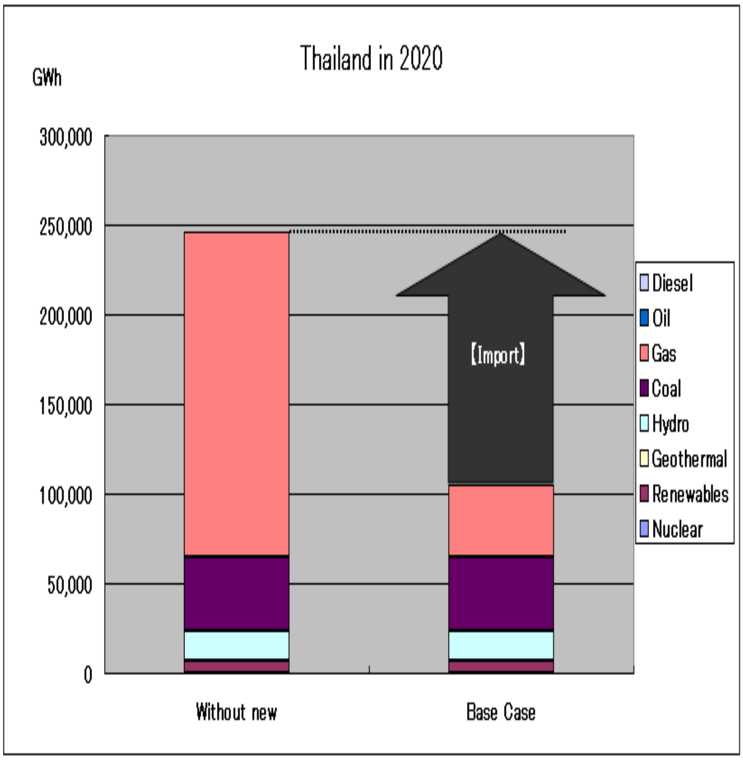
Singapore in 2030

	Without new	Base Case	Accelerated Case
Nuclear	0	0	0
Renewables	1,929	1,929	1,929
Geothermal	0	0	0
Hydro	0	0	0
Coal	0	0	0
Gas	69,571	38,035	38,035
Oil	0	0	0
Diesel	0	0	0
Total Supply	71,500	39,964	39,964
Power Trade	0	31,536	31,536



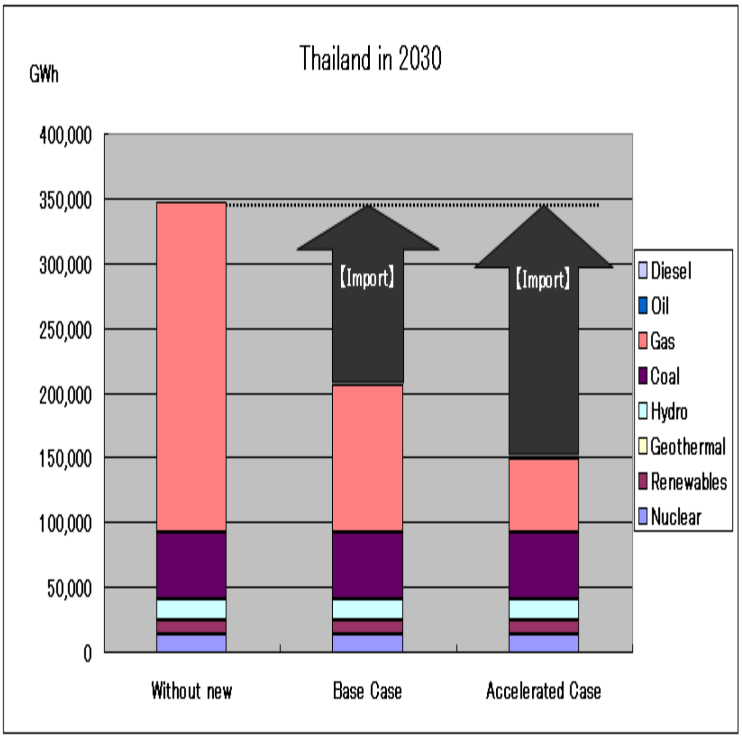
Thailand in 2020

	Without new	Base Case	Accelerated Case
Nuclear	0	0	
Renewables	7,251	7,251	
Geothermal	0	0	
Hydro	16,107	16,107	
Coal	41,249	41,249	
Gas	181,557	40,521	
Oil	0	0	
Diesel	0	0	
Total Supply	246,164	105,128	
Power Trade	0	141,036	



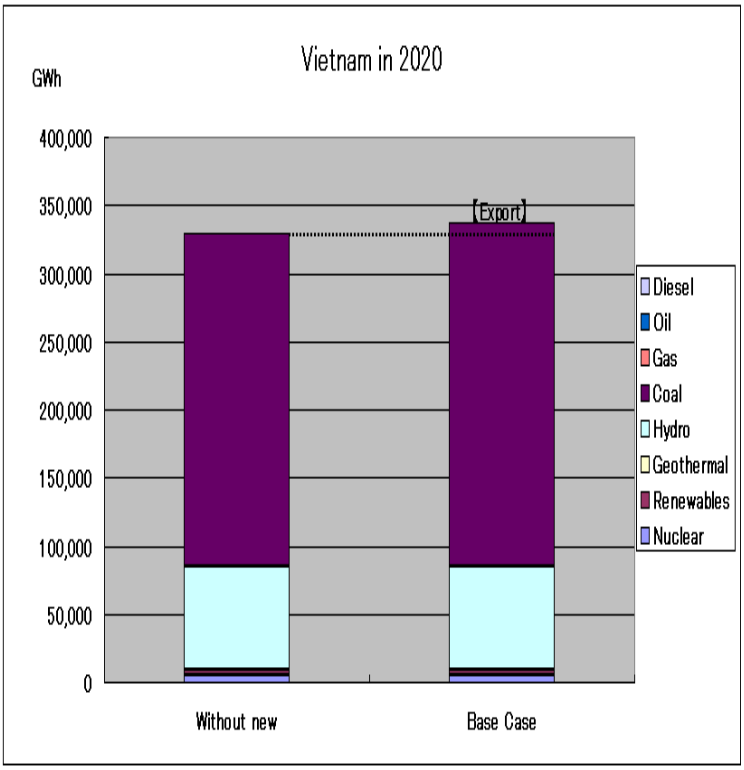
Thailand in 2030

	Without new	Base Case	Accelerated Case
Nuclear	14,016	14,016	14,016
Renewables	10,047	10,047	10,047
Geothermal	0	0	0
Hydro	16,280	16,280	16,280
Coal	51,768	51,768	51,768
Gas	254,655	113,619	57,434
Oil	0	0	0
Diesel	0	0	0
Total Supply	346,767	205,731	149,546
Power Trade	0	141,036	197,221



Vietnam in 2020

	Without new	Base Case	Accelerated Case
Nuclear	5,256	5,256	
Renewables	4,415	4,415	
Geothermal	0	0	
Hydro	75,292	75,292	
Coal	245,037	252,288	
Gas	0	0	
Oil	0	0	
Diesel	0	0	
Total Supply	330,000	337,251	
Power Trade	0	-7,251	



Vietnam in 2030

	Without new	Base Case	Accelerated Case
Nuclear	56,064	56,064	56,064
Renewables	13,913	13,913	13,913
Geothermal	0	0	0
Hydro	87,142	87,142	87,142
Coal	509,152	509,152	509,152
Gas	8,729	0	0
Oil	0	0	0
Diesel	0	0	0
Total Supply	675,000	666,271	666,271
Power Trade	0	8,729	8,729