4-6 Estimation of Potential Gas Demand in the Commercial, Transportation, and Industrial Sectors by Bottom-up Procedure

In this study, gas supply systems are examined based on potential gas demand estimated for target sectors, which are presented for the power generation sector in 4-4 and for other sectors in 4-5 above.

The reason we have adopted a kind of macro method for other sectors than power generation in 4-5 is the un-availability of sufficient data and information necessary for adopting the micro or bottom-up method. Even for the industry sector, such detailed and specific data could not be collected by the MEMSI's survey.

For the commercial, transportation, and industrial sectors, however, we can confirm the availability of some data and information necessary for adopting the micro or bottom-up method. Accordingly, we use this method to substitute the macro method, for estimating the potential demand for these sectors.

Potential gas demand estimated by the bottom-up method is to some extent larger than that estimated by the macro method for the commercial sector (4-6-1), while no demand is estimated for the transportation sector until 2025 even in the Gas Promotion Scenario as it is in the macro method (4-6-2). Therefore, considering the importance of the transportation sector from the view point of preventing air pollution, we estimate potential demand in the case that promotional policy measures, which are added to those incorporated in the Gas Promotion Scenario, are introduced for the sector (4-6-2).

In contrast, potential gas demand estimated by the bottom-up method is fairly larger than that by the macro method for the industrial sector (4-6-3). The following two points should be taken into account on such results of the estimation.

First, data, which is essential for estimating gas demand, including number and scale of boilers, furnaces, and other combustion equipment and facilities in factories by target area, has never been available, while, for the commercial sector, statistics on the number and floor space of buildings and facilities, including hotels, restaurants, stores, hospitals, and offices, by target area, and, for the transportation sector, those on the number of vehicles (taxies, jeepneys and buses) by target area and by fuel (gasoline and diesel fuel oil) are available for the year 2000. Such availability of data has caused the results of estimation for the industry sector to be much rougher than other two sectors.

Second, current energy and fuel (LPG in particular) consumption in the industry sector, which has been estimated by using official statistics and data in 4-5, is fairly smaller than that estimated by the bottom-up method. It means that we can confirm no existence of at least a part of energy supply estimated by the bottom-up method, if we depend on official statistics and data used in 4-5. Accordingly, we have assumed that energy supply, which is not recorded in the official statistics and data, is actually made. This is one of the most important reasons why specific and detailed surveys should be implemented on potential gas demand in factories before determining the construction of pipelines.

4-6-1 Estimation of Potential Demand in the Commercial Sector

(1) Procedure for estimation

The procedure for estimating conversion into natural gas in the sector is shown in the following figure.

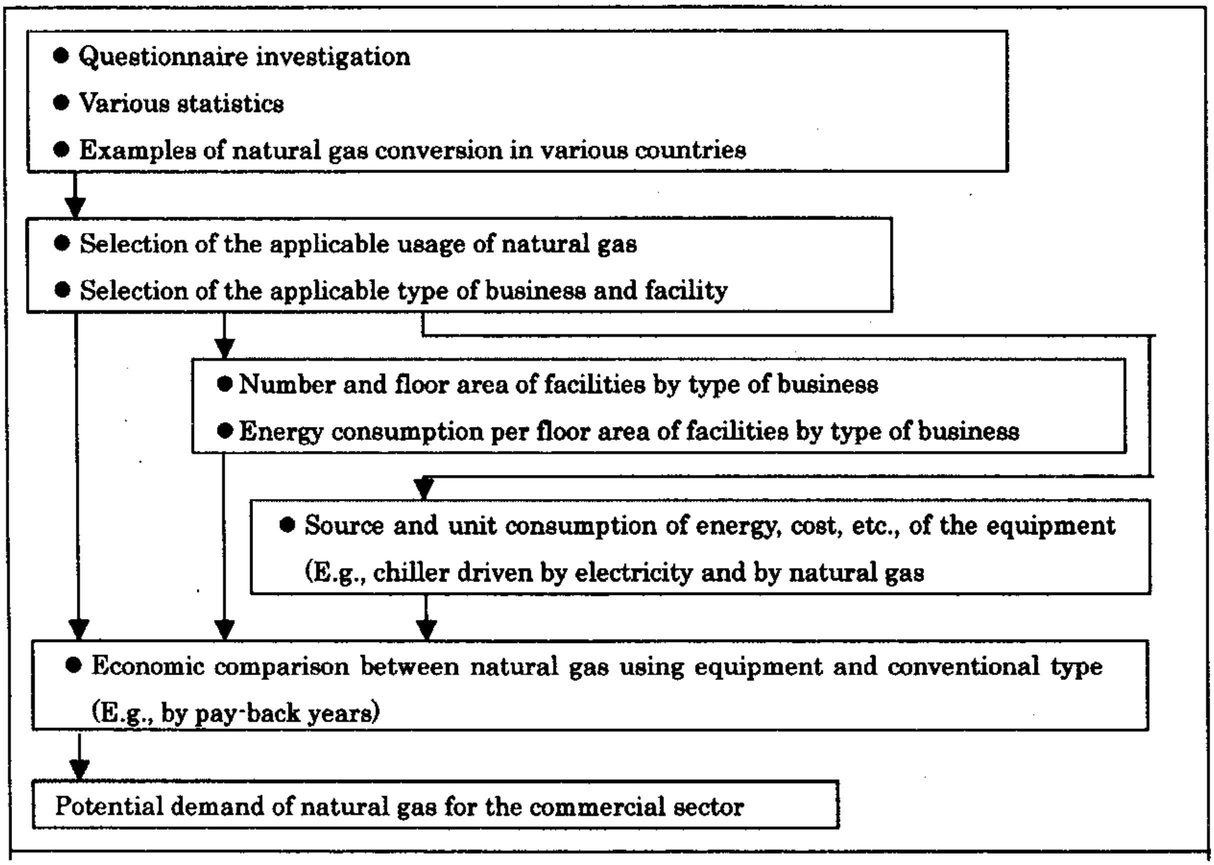


Figure 4-6-1 Procedure for Estimating Potential Demand

(2) Technologies utilizing natural gas

Natural gas is used for air conditioning, generating electricity (including co-generation), and for cooking and boilers in the commercial sector. The possibility of using natural gas for the following applications is examined.

1) Air conditioning

- Air conditioning using an absorption chiller: So far, a compression-type chiller of the electric drive using fluorocarbon refrigerant has been adopted. The requirement not to use fluorocarbons became strong because of its adverse effect on global warming and breaking ozone layers in the stratosphere. Natural gas can be used as a clean energy source for the chiller, and the operating cost is less than the electric type. These factors promote the penetration of absorption chillers. Natural gas, steam, and hot water can be used as heat sources. Large office buildings, supermarkets, department stores, some cold storage, and other facilities use this type of chiller.

- Gas heat pump(GHP): The compressor motor of a conventional chiller is driven by the electric motor. Compression and expansion of refrigerant achieve low temperatures. The combustion heat of the fuel is converted into mechanical power, and the rotation of the rotor of the generator generates electricity. A GHP uses mechanical power directly without changing it into electricity. Although the cost of GHP is higher than the electric type, the operating cost of the chiller is generally low. This type of chiller was developed to replace electric packaged air conditioners. GHPs are used for small and medium-sized buildings, although absorption chillers are used for large buildings. GHPs are used for small office buildings, and medium-size and large restaurants, etc.

2) Generation (including co-generation)

- Generation: There are many emergency generators installed in the Philippines, because the grid power is not reliable. Diesel oil is used as the fuel. Diesel oil contains environmentally polluting materials in the combustion gas. Because of the environmental effects, natural gas is expected to be the fuel used for generation in the future, when a generator is used for the base load, not for an emergency. But, there is an economic problem, and it is expected that the form of co-generation in the next section will be adopted for that purpose.
- Co-generation: A gas turbine or a gas engine is used for the drive. High-efficiency energy conversion can be attained, recovering heat while generating electricity at the same time. The heat is collected as steam and hot water. Generally, the recovered steam is used as the driving power for an absorption chiller in the commercial sector. Recovered hot water is used for bathrooms and other areas in hotels, hospitals, etc., although hot water can be used as the heat source of the absorption chiller. In the future, fuel cells will become available, in addition to gas turbine and gas engines. Because the investment cost for a co-generation system is large, it is economical to install the system in facilities that require continuous operation throughout the year.

Installing co-generation systems for hotels, hospitals, etc., that require electricity, air conditioning, and hot water day and night is economical.

3) A source of heat for cooking

A source of heat for cooking is the most fundamental application of natural gas.

4) A source of heat for a boiler

A source of heat for a boiler is also a fundamental application of natural gas, in the same way as a source of heat for cooking. But, because heating for air conditioning is unnecessary in the Philippines, boiler applications are rather limited to hot water, laundry, etc., in the commercial sector.

(3) Facilities using natural gas

The following facilities are thought to be potential users for natural gas.

- Hotel
- Hospital
- Office building
- Department store, supermarket
- Restaurant
- School
- Cold warehouse
- Theater, city hall, meeting place
- Amusement center
- Social welfare facilities

The energy demand (electricity, heat) in the commercial sector is almost in proportion to floor area of the facilities, depending upon the type of business (E.g., hotel and hospital) and (E.g., driving power and lighting, air conditioning, and cooking).

(4) Evaluation of natural gas use by type of equipment

The economics of applying natural gas to commercial facilities is examined by type of equipment. Investment pay-back period is calculated by incremental investment cost and incremental operating cost for two cases. One of the two cases is the case of installing a new facility or replacing an installed facility that is at the end of its life.

Another case is replacing an installed facility that can still be used.

1) Absorption chiller for air conditioning

An example for an office building is shown in Table 4-6-1. The capacity of the chiller for a 9,000m² office building is 327RT(RT: Refrigeration ton). The operating cost of the absorption chiller is low compared to a turbo-chiller, although the investment cost is high. The pay-back period of the additional capital for the absorption chiller is 2.1~21 years, when the natural gas price is 21.8Peso/Nm³. For the case of a new installation, the pay-back period is 2.1 years. The pay-back period is 21 years when the chiller is substituted by an absorption-type although a turbo-chiller is already installed and it can still be used.

Table 4-6-1 Pay-back period of absorption chiller (office building)

Economic Evaluation (Air Conditioning) — Evaluation Year: 2010

Absorption Chiller vs. Turbo-Chiller

(1) Conditions/Assumptions

<Case>	High		
<Scenario>	Gas Use & Gas Promotion		
<Facility> Type	Office Building		
Floor area	9,000	m²	
Operation	11	hr/day	
	261	day/year	
Avr. Load	56.6	kcal/m²/hr	
	169	RT	
Avr./Max.	0.515	-	
< Chiller> Design load	110.0	kcal/m²/hr	
Capacity/unit	327	RT	
No. of operation	1	unit	
No. of stand-by	0	unit	

	Absorptior chiller	Turbo-chiller	
<Power price>			
Source	Meralco Model		
Type	Non-industrial Service		
Facility peak load	333	607	kW
Power charge	6.65	6.65	Peso/kWh
<Fuel gas price>	21.8		Peso/Nm³
<Motor capacity>	17	291	kW/unit
<Gas consumption>	132,884	-	Nm³/year
<Equipment cost>	7.9	7.1	Mill. Peso

(2) Economic Analysis

<Annual running cost> 1,000Peso	Absorptior chiller	Turbo-chiller
Variable cost		
Fuel cost	2,897.2	
Power cost	2,158.3	5,519.3
Sub-total	5,055.5	5,519.3
Fixed cost		
Depreciation	473.4	425.6
Maintenance cost	236.7	212.8
Interest	631.2	567.5
Sub-total	1,341.3	1,205.9
Total	6,396.8	6,725.3

<Economic Evaluation>		
Pay-back period (New facility)	2.1	years
Pay-back period (Replacement)	21.0	years

The pay-back period for installing an absorption chiller for hotel, hospital, etc., is shown in Table 4-6-2.

Table 4-6-2 Pay-back period of absorption chiller

<Case> <Scenario> <Gas price>			High Gas Use & Gas Promotion 21.80 Peso/Nm3		Low Gas Use & Gas Promotion 18.32 Peso/Nm3	
Facility	Floor Area m2	Capacity RT	Pay-back Period		Pay-back Period	
			New	Replace	New	Replace
Hotel	10,000	225	0.9	9.5	1.3	13.4
	48,000	1,079	0.7	5.9	1.0	8.8
Hospital	10,000	240	0.6	5.8	0.8	8.7
	45,000	1,080	0.4	3.7	0.6	5.5
Office Building	9,000	327	2.1	21.0	3.8	37.2
	38,000	1,382	1.2	10.4	1.8	15.9
Store	7,500	370	0.9	9.1	1.4	13.9
	38,000	1,872	0.7	6.5	1.1	9.8

Pay-back period "New" means installing a chiller for a new building or replacing an the old one that cannot be used because it has reached the end of its life, and for other reasons. "Replace" means replacing a chiller that can still be used. Pay-back period is short, so an absorption chiller using natural gas is economical in the cases.

Generally, application for a cold warehouse is difficult. An absorption chiller cannot be used for storing fish, child food, ice cream, or meat at a temperature less than zero degrees centigrade. The chiller can only be used for unripe banana, tomato, and other fruits kept and ripened in the warehouse. Gas demand can be expected in the future, although the number of such warehouses is small in the Philippines at present.

2) Gas Heat Pump (GHP)

An example for a restaurant with a floor area of 1,100m^2 is shown in Table 4-6-3. Table 4-6-4 shows the pay-back period for the cases. Reduction in the operating cost by GHP cannot be expected in all cases, so that the possibility to install GHP is small in the Philippines.

Table 4-6-3 Pay-back period of GHP (Restaurant)

Economic Evaluation (Air Conditioning) — Evaluation Year: 2010

GHP vs. Package

(1) Conditions/Assumptions

<Case>	High		
<Scenario>	Gas Use & Gas Promotion		
<Facility> Type	Restaurant		
Floor area	1,100	m²	
Operation	12	hr/day	
	292	day/year	
Avr. Load	84.2	kcal/m²/hr	
	31	RT	
Avr./Max.	0.565	-	
<Chiller> Design load	149.0	kcal/m²/hr	
Capacity/unit	54	RT	
No. of operation	1	unit	
No. of stand-by	0	unit	

	GHP	Package	
<Power price>			
Source	Meralco Model		
Type	Non-industrial Service		
Facility peak load	243	306	kW
Power charge	6.65	6.65	Peso/kWh
<Fuel gas price>	21.8		Peso/Nm³
<Motor capacity>	-	64	kW/unit
<Gas consumption>	98,396	-	Nm³/year
<Equipment cost>	2.4	1.4	Mill. Peso

(2) Economic Analysis

<Annual running cost> 1,000Peso	GHP	Package
Variable cost		
Fuel cost	2,145.3	
Power cost	1,382.4	2,428.3
Sub-total	3,527.7	2,428.3
Fixed cost		
Depreciation	143.3	83.8
Maintenance cost	71.6	41.9
Interest	191.0	111.8
Sub-total	405.9	237.5
Total	3,933.6	2,665.8

<Economic Evaluation>

Pay-back period (New facility)	-0.8	years
Pay-back period (Replacement)	-2.0	years

Table 4-6-4 Pay-back period of GHP

<Case>			High		Low	
<Scenario>			Gas Use & Gas Promotion		Gas Use & Gas Promotion	
<Gas price>			21.80 Peso/Nm3		18.32 Peso/Nm3	
	Floor Area	Capacity	Pay-back Year		Pay-back Year	
Facility	m2	RT	New	Replace	New	Replace
Restaurant	1,100	54	-0.8	-2.0	-1.1	-2.7
Office Building	1,000	36	-1.1	-2.8	-1.5	-3.8
Store	1,000	49	-0.8	-1.9	-1.1	-2.6

3) Co-generation

Balance and timing of power and heat in demand and supply greatly influence the economy of co-generation . Usually, a co-generation system is operated at the capacity of power demand, and the steam produced is used to operate an absorption chiller. Steam produced cannot be stored and the steam is discarded if it exceeds the amount needed for the chiller. Therefore, the energy demand for every time zone must be evaluated.

Engine or turbine generators are adopted for co-generation systems, too. The possibility of using fuel cells for the system is small ,because the investment cost is high, although the technology is established. Besides, gas consumption is similar to that of an engine co-generation system in the case of a fuel cell.

The energy demand of a hotel can be roughly divided into electric power for lighting elevator, air conditioner, and hot water supply to a bathroom. A typical energy consumption pattern during a day is shown by the consumption ratio (the ratio of hourly demand for each time zone against daily demand) for every time zone.

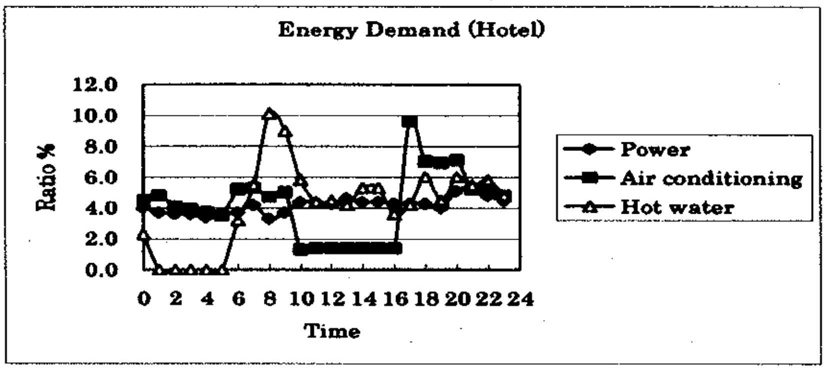


Figure 4-6-2 Energy Pattern of Hotel

The result of an economic evaluation for the system of a 48,000m² hotel is shown in Table 4-6-5. Recovered steam is used for an absorption chiller and the rest of the steam is utilized for hot water. A system without a spare engine could be practical, because an extra charge from a commercial power source is not necessary in the Philippines, even if electric demand is only in the case of emergency shutdown (Meralco) . The number of engines, system efficiency, utilization rate of the system, and other factors greatly affect the economy of the system. The capacity of a cogeneration system should be optimized, considering consumption pattern during a day.

Table 4-6-5 Economic evaluation of co-generation system

Economic Evaluation (Cogeneration) — Evaluation Year: 2010

(Gas Engine Cogeneration + Absorption Chiller: CGS) vs.
(Power Company Supply Electricity + Conventional Chiller: Conv.)

(1) Conditions/Assumptions

<Case>		High	
<Scenario>		Gas Use & Gas Promotion	
<Facility>	Type	Hotel	
	Floor Area	48,000	m2
<Capacity>		620	kW
<No. of Unit>		2	
	Stand-by	0	
<Equipment Cost>			
CGS	Unit Cost	0.043	Mill. Ps/kW
	Eq. Cost	53.5	Mill. Ps
	Others	2.7	Mill. Ps
	Total	56.2	Mill. Ps
Absorption Chiller		10.3	Mill. Ps
Conv. Chiller		9.2	Mill. Ps
H-water boiler (CGS		0.0	Mill. Ps
H-water boiler (Con		0.8	Mill. Ps
<Fuel>	Gas Price	21.8	Ps/Nm^3

<Cogeneration Max. Efficiency>			
Power	35.0		%
Steam	28.0		%
Hot Water	17.0		%
Total	80.0		%
<Boiler Efficiency>	85.0		%
<Power Price>	CGS	Conv.	
Source	Meralco		
Type	Non-industrial Service		
Facility peak load	632	2,569	kW
Power charge	6.94	6.65	Peso/kWh
<Accounting Conditions>			
Labor Cost	0.20		Mill. Ps/Operator
No. of Operator	0.5		
Depreciation Year	14		years
Salvage Value	10		%
Interest	8.0		%
Maintenance cost	0.4		Ps/kWh

(2) Result

<Amount (-/y)>	CGS	Conv.	CGS Benefit
Power Demand MWh	11,130	13,652	2,522
CGS Power MWh	9,660	-	-9,660
Purchased Power MW	1,470	13,652	12,182
Steam Demand Gcal	8,583	-	-8,583
H-water Demand Gcal	4,806	4,806	0
CGS Steam Util'd Gca	6,233	-	-6,233
CGS H-water Util'd Gcal	4,806	-	-4,806
CGS Purged Gcal	331	-	-331
CGS Fuel Nm3/1,000	2,736	-	-2,736
Boiler Fuel Nm3/1,000	253	517	264

<Economic Calculation (Mill. Ps/year)>	CGS	Conv.	CGS Benefit
Power Charge	10.2	90.8	80.6
CGS Fuel	59.7	-	-59.7
Boiler Fuel	5.5	11.3	5.8
Sub-total	75.4	102.0	26.7
Labor & Interest	4.6	-	-4.6
Maintenance	3.9	-	-3.9
Sub-total	8.5	-	-8.5
Total	83.8	102.0	18.2
Depreciation	1.8	-	-1.8

<CGS Operation>		<Power cost (Ps/kWh)>	
Power Self-generated %	86.8	Variable Cost	5.6
Heat Self-supplied %	82.5	Fixed Cost	1.1
Heat Utilized %	97.1	Sub-total	6.6
Operation time %	100.0	Purchased Power C	6.9
Average Load %	93.6	Average Cost	6.7
Operating Efficiency %	79.0	Conventional Cost	6.6

<Economic Evaluation>		
Pay-back period (New facility)	3.1	year
Pay-back period (Replacement	3.7	year

**Remarks: H-water/Hot Water, Utilz'd/Utilized, CGS/Cogeneration System, Conv./Conventional System

The pay-back period of a co-generation system for hotel, hospital, and office building is shown in Table 4-6-6. The pay-back period for a hotel is short. In the case of an office building, installing a system is not economical. This is because the efficiency of the system is low. The operation time is short because the system stops at night and there is no way to use the hot water. The system capacity in Table 4-6-6 is decided to cover around 85% of the whole power demand of the facility. The economy is improved by optimizing the capacity.

Table4-6-6 Pay-back period of co-generation

<Case>			High		Low	
<Scenario>			Gas Use & Gas Promotion		Gas Use & Gas Promotion	
<Gas price>			21.80 Ps/Nm3		18.32 Ps/Nm3	
	Floor Area	Capacity	Pay-back period		Pay-back period	
Facility	m2	kW	New	Replace	New	Replace
Hotel	10,000	390	2.5	3.6	3.7	5.2
	48,000	1,800	3.1	3.7	4.7	5.5
Hospital	10,000	240	6.4	10.2	14.2	22.8
	45,000	1,080	10.1	13.8	44.2	60.5
Office Building	60,000	2,100	-31.9	-39.6	-13.3	-16.5

(5) Estimation of number of facilities by type of business, by Case and by area

Number of facilities by type of business, by Case and by area in Table 4-6-7~11 is estimated from data of NSO (National Statistic Office), DOT (Department of Tourism), DOH (Department of Health), MEMSI report and others.

Table 4-6-7 Estimated number of facilities (Hotel)

Hotel		Case: High					Case: Low				
	Floor Area m2	2006	2010	2015	2020	2025	2006	2010	2015	2020	2025
L-1	-5,000	1	2	2	3	4	1	2	2	3	3
North	5-20,000	10	13	17	22	29	9	11	14	19	24
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	11	15	19	25	33	11	12	16	22	28
L-1	-5,000	9	11	14	19	25	8	9	12	16	21
Central	5-20,000	30	38	51	67	87	28	32	43	57	73
	20-50,000-	29	36	48	64	83	26	31	41	54	70
	Total	67	86	113	150	194	62	73	96	127	164
L-1	-5,000	0	0	0	0	0	0	0	0	0	0
South	5-20,000	1	2	2	3	4	1	2	2	3	3
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	1	2	2	3	4	1	2	2	3	3
L-3	-5,000	7	9	12	12	20	6	8	10	10	17
	5-20,000	1	2	2	2	4	1	2	2	2	3
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	8	11	14	15	24	8	9	12	12	20
L-2	-5,000	1	2	2	3	4	1	1	2	2	3
	5-20,000	12	15	20	26	33	11	13	17	22	28
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	14	17	22	29	37	13	15	19	25	31
C-M	-5,000	3	4	5	6	8	3	3	4	5	7
	5-20,000	1	2	2	3	4	1	2	2	3	3
	20-50,000-	7	9	12	16	20	7	8	10	13	17
	Total	11	14	19	25	32	10	12	16	21	27
D	-5,000	3	4	5	6	8	3	3	4	5	7
	5-20,000	1	2	2	3	4	1	2	2	3	4
	20-50,000-	7	9	12	16	21	7	8	10	14	18
	Total	11	15	19	26	34	10	12	16	22	28
Grand	-5,000	24	31	40	50	69	22	26	34	42	58
Total	5-20,000	58	74	97	127	165	54	62	82	108	140
	20-50,000-	43	55	72	95	124	39	46	61	81	105
	Total	125	159	210	273	358	115	135	178	231	303

Table 4-6-8 Estimated number of facilities (Hospital)

Hospital		Case: High					Case: Low				
	Floor Area m2	2006	2010	2015	2020	2025	2006	2010	2015	2020	2025
L-1 North	-5,000	80	102	135	178	231	74	86	114	151	196
	5-20,000	30	38	51	67	87	28	32	43	57	73
	20-50,000-	6	7	10	13	17	5	6	8	11	14
	Total	116	148	195	258	334	107	125	165	218	283
L-1 Central	-5,000	53	67	89	118	153	49	57	76	100	129
	5-20,000	29	36	48	64	83	26	31	41	54	70
	20-50,000-	10	13	17	22	29	9	11	14	19	24
	Total	92	117	154	204	264	84	99	131	173	224
L-1 South	-5,000	40	51	67	89	116	37	43	57	76	98
	5-20,000	1	2	2	3	4	1	2	2	3	3
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	42	53	70	92	120	38	45	59	78	101
L-3	-5,000	156	197	258	338	436	143	167	218	287	369
	5-20,000	6	7	9	12	16	5	6	8	10	13
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	161	204	267	351	451	149	173	226	297	382
L-2	-5,000	148	185	241	313	400	136	157	204	265	339
	5-20,000	4	5	7	9	11	4	4	6	7	9
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	152	191	247	322	411	140	161	209	272	348
C-M	-5,000	30	38	50	66	85	28	32	42	56	72
	5-20,000	10	13	17	22	28	9	11	14	19	24
	20-50,000-	1	2	2	3	4	1	2	2	3	3
	Total	41	52	69	91	118	38	44	59	77	100
D	-5,000	165	211	281	373	486	152	179	238	316	412
	5-20,000	6	7	10	13	17	5	6	8	11	14
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	170	218	291	386	503	157	185	246	327	426
Grand Total	-5,000	671	852	1,121	1,476	1,907	618	722	949	1,250	1,615
	5-20,000	85	109	144	189	245	79	92	122	160	208
	20-50,000-	17	22	29	38	49	16	19	24	32	42
	Total	774	983	1,294	1,703	2,202	713	832	1,096	1,443	1,865

Table 4-6-9 Estimated number of facilities (Office building)

Office Building		Case: High					Case: Low				
	Floor Area m2	2006	2010	2015	2020	2025	2006	2010	2015	2020	2025
L-1 North	-5,000	13	17	23	30	39	12	14	19	25	33
	5-20,000	8	11	14	19	24	8	9	12	16	20
	20-50,000-	2	2	3	4	5	2	2	3	3	4
	Total	24	30	40	52	68	22	25	34	44	58
L-1 Central	-5,000	1,342	1,710	2,261	2,987	3,871	1,236	1,449	1,915	2,529	3,278
	5-20,000	833	1,061	1,403	1,853	2,402	767	899	1,188	1,570	2,034
	20-50,000-	182	232	306	404	524	167	196	259	342	444
	Total	2,357	3,003	3,969	5,244	6,796	2,170	2,544	3,362	4,441	5,756
L-1 South	-5,000	13	17	23	30	39	12	14	19	25	33
	5-20,000	8	11	14	19	24	8	9	12	16	20
	20-50,000-	2	2	3	4	5	2	2	3	3	4
	Total	24	30	40	52	68	22	25	34	44	58
L-3	-5,000	65	82	107	140	181	59	69	91	119	153
	5-20,000	40	51	66	87	112	37	43	56	74	95
	20-50,000-	9	11	14	19	24	8	9	12	16	21
	Total	113	143	188	246	317	104	121	159	208	269
L-2	-5,000	162	203	263	342	438	149	172	223	290	371
	5-20,000	101	126	163	212	272	93	107	138	180	230
	20-50,000-	22	27	36	46	59	20	23	30	39	50
	Total	285	356	462	601	769	262	302	391	509	651
C-M	-5,000	121	154	203	268	346	112	131	172	227	293
	5-20,000	75	96	126	166	215	69	81	107	141	182
	20-50,000-	16	21	28	36	47	15	18	23	31	40
	Total	213	271	357	470	608	196	229	302	398	515
D	-5,000	90	115	153	204	266	83	98	130	173	225
	5-20,000	56	72	95	127	165	51	61	81	107	140
	20-50,000-	12	16	21	28	36	11	13	18	23	30
	Total	158	202	269	358	466	145	171	228	303	395
Grand Total	-5,000	1,807	2,299	3,032	4,000	5,178	1,664	1,947	2,568	3,388	4,386
	5-20,000	1,121	1,426	1,882	2,482	3,213	1,033	1,208	1,594	2,102	2,721
	20-50,000-	245	311	411	542	701	225	264	348	459	594
	Total	3,173	4,036	5,325	7,024	9,092	2,922	3,418	4,510	5,949	7,701

Table 4-6-10 Estimated number of facilities (Restaurant)

Restaurant	No. of Seats	Case: High 2006	2010	2015	2020	2025	Case: Low 2006	2010	2015	2020	2025
L-1 North	<=100	404	515	681	899	1,165	372	436	576	762	987
	101-200	428	545	721	952	1,234	394	462	610	806	1,045
	200-	190	242	320	423	548	175	205	271	358	464
	Total	1,022	1,302	1,721	2,274	2,947	941	1,103	1,458	1,926	2,496
L-1 Central	<=100	279	356	470	621	805	257	301	398	526	682
	101-200	296	377	498	658	852	272	319	422	557	722
	200-	131	167	221	292	379	121	142	187	247	321
	Total	706	900	1,189	1,571	2,036	650	762	1,007	1,330	1,724
L-1 South	<=100	150	191	253	334	432	138	162	214	283	366
	101-200	159	202	267	353	458	146	171	227	299	388
	200-	71	90	119	157	203	65	76	101	133	172
	Total	379	483	639	844	1,094	349	409	541	715	926
L-3	<=100	177	224	294	386	497	163	190	249	327	421
	101-200	0	0	0	0	0	0	0	0	0	0
	200-	0	0	0	0	0	0	0	0	0	0
	Total	177	224	294	386	497	163	190	249	327	421
L-2	<=100	57	71	93	121	154	53	61	79	102	131
	101-200	227	284	369	480	613	209	241	312	406	519
	200-	57	71	93	121	154	53	61	79	102	131
	Total	341	427	554	721	922	314	362	469	611	781
C-M	<=100	40	50	66	87	113	36	43	56	74	96
	101-200	67	85	112	148	191	62	72	95	125	162
	200-	61	78	103	135	175	57	66	87	115	148
	Total	168	213	281	370	479	155	181	238	314	406
D	<=100	39	50	67	89	116	36	43	57	76	98
	101-200	20	26	34	46	60	19	22	29	39	51
	200-	13	16	22	29	38	12	14	18	25	32
	Total	72	93	123	164	214	67	79	104	139	181
Grand Total	<=100	1,147	1,458	1,923	2,537	3,283	1,056	1,235	1,629	2,148	2,780
	101-200	1,196	1,519	2,001	2,636	3,408	1,102	1,287	1,695	2,233	2,886
	200-	523	665	878	1,157	1,497	482	564	743	980	1,268
	Total	2,866	3,643	4,802	6,330	8,188	2,640	3,085	4,067	5,361	6,935

Table 4-6-11 Estimated number of facilities (Store)

Store	Floor Area m2	Case: High 2006	2010	2015	2020	2025	Case: Low 2006	2010	2015	2020	2025
L-1 North	-5,000	82	105	139	183	238	76	89	118	155	201
	5-20,000	0	0	0	0	0	0	0	0	0	0
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	82	105	139	183	238	76	89	118	155	201
L-1 Central	-5,000	57	73	96	127	164	52	61	81	107	139
	5-20,000	6	8	11	14	19	6	7	9	12	16
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	63	81	107	141	183	58	68	90	119	155
L-1 South	-5,000	31	39	52	68	88	28	33	44	58	75
	5-20,000	0	0	0	0	0	0	0	0	0	0
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	31	39	52	68	88	28	33	44	58	75
L-3	-5,000	14	18	24	31	40	13	15	20	26	34
	5-20,000	1	1	1	1	2	1	1	1	1	1
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	15	19	25	32	42	14	16	21	27	35
L-2	-5,000	28	34	45	58	74	25	29	38	49	63
	5-20,000	1	1	2	2	3	1	1	1	2	2
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	29	36	46	60	77	26	30	39	51	65
C-M	-5,000	14	17	23	30	39	12	15	19	25	33
	5-20,000	1	1	1	1	1	0	1	1	1	1
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	14	18	24	31	40	13	15	20	26	34
D	-5,000	6	7	10	13	17	5	6	8	11	15
	5-20,000	0	0	0	1	1	0	0	0	0	1
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	6	8	10	14	18	6	7	9	12	15
Grand Total	-5,000	231	294	387	510	660	213	249	328	432	559
	5-20,000	9	11	15	19	25	8	9	12	16	21
	20-50,000-	0	0	0	0	0	0	0	0	0	0
	Total	240	305	402	530	685	221	258	340	449	580

(6) Unit energy consumption by type of facility

Average energy unit consumption is shown in Table 4-6-12. Energy demand (electric power, heat) is in proportion to the floor area of facilities by type of business (hotel, hospital, etc.) and by usage (power and lighting, air conditioning, cooking, etc.).

Table 4-6-12 Average energy unit consumption

	Hotel	Hospital	Office Building	Store	Restaurant
Electricity (kW/m2)	0.026	0.013	0.011	0.010	0.054
Cooling (kcal/m2/h)	20.5	33.6	56.6	84.2	84.2
Hot Water (kcal/m2/h)	11.4	6.3	0	0	0.5
Cooking (kcal/m2/y)	2,371	4,741	0	0	474,102

(7) Selection of natural gas utilization technologies

Table 4-6-13 shows the selected gas utilization technologies considering size of facilities, energy consumption pattern, economics etc. From economical view point, cogeneration and absorption chiller are assumed to be installed for large facilities only. Fuel for cooking and boiler is assumed to be converted into natural gas. Investment to convert LPG and diesel oil into natural gas is not so high and natural gas substitutes LPG and diesel oil because of convenience for users, if the price is not higher.

Table 4-6-13 Assumed technologies

Facility	Floor Area m2	Technology	Remarks
Hotel	-5000	--	Electrical window-type air conditioner is more economical.
	5,000-	Engine cogeneration & Absorption chiller	
Hospital	-5000	--	Electrical window-type air conditioner is more economical.
	5,000-	Absorption chiller	
Office Building	-5000	--	Electrical window-type air conditioner is more economical.
	5-20,000	Absorption chiller	
	20,000-	Absorption chiller	
Store	-5000	--	Electrical window-type air conditioner is more economical.
	5,000-	Absorption chiller	
Restaurant		--	Electrical window-type air conditioner is more economical.

(8) Economic evaluation of natural gas utilization

The most important factor for natural gas conversion is economy. Natural gas conversion is evaluated by the following criteria to estimate natural gas demand. The percentage of natural gas conversion is set rather low considering installation for existing buildings.

① 70% of facilities convert to natural gas, if pay-back period is less than one year.
② 50% of facilities convert to natural gas, if pay-back period is less than two years.
③ 20% of facilities convert to natural gas, if pay-back period is less than three years.
④ 10% of facilities convert to natural gas, if pay-back period is less than four years.
⑤ No facilities convert to natural gas, if pay-back period is more than four years.

(9) Estimation of potential demand

Table 4-6-14 shows potential natural gas demand of typical facilities. Potential natural gas demand for commercial sector is shown in Table 4-6-15.

Table 4-6-14 Estimation of potential demand of typical facilities

Scenario:	Gas Use	Case: High				mmscfd	Case: Low				mmscfd
		2006	2010	2015	2020	2025	2006	2010	2015	2020	2025
Hotel	L-1 North	0.2	0.4	0.6	0.8	1.1	0.1	0.1	0.2	0.3	0.4
	L-1 Central	2.6	3.8	5.6	8.0	10.9	1.6	1.9	2.6	3.5	4.5
	L-1 South	0.0	0.1	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.1
	L-3	0.1	0.1	0.1	0.2	0.2	0.0	0.0	0.1	0.1	0.1
	L-2	0.3	0.5	0.7	1.0	1.3	0.1	0.2	0.2	0.3	0.4
	C-M	0.5	0.7	1.0	1.5	2.0	0.3	0.4	0.5	0.7	0.9
	D	0.5	0.7	1.0	1.5	2.0	0.3	0.4	0.5	0.7	0.9
	Total	3.7	6.2	9.2	13.0	17.8	2.5	3.1	4.2	5.6	7.3
Hospital	L-1 North	0.8	1.2	1.8	2.6	3.5	0.6	0.8	1.2	1.8	2.5
	L-1 Central	1.1	1.6	2.5	3.6	4.9	0.7	1.0	1.6	2.4	3.4
	L-1 South	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.2
	L-3	0.3	0.4	0.5	0.6	0.8	0.3	0.3	0.4	0.5	0.7
	L-2	0.3	0.3	0.4	0.6	0.7	0.2	0.3	0.4	0.5	0.6
	C-M	0.2	0.3	0.5	0.7	1.0	0.2	0.2	0.4	0.5	0.7
	D	0.3	0.4	0.5	0.7	0.9	0.3	0.3	0.4	0.6	0.8
	Total	3.0	4.4	6.4	8.9	12.1	2.3	3.1	4.6	6.5	8.9
Office Building	L-1 North	0.0	0.1	0.1	0.2	0.2	0.0	0.0	0.1	0.1	0.2
	L-1 Central	2.8	5.7	10.1	15.9	23.4	2.3	4.3	7.8	12.5	18.5
	L-1 South	0.0	0.1	0.1	0.2	0.2	0.0	0.0	0.1	0.1	0.2
	L-3	0.1	0.3	0.5	0.8	1.1	0.1	0.2	0.4	0.6	0.9
	L-2	0.4	0.7	1.2	1.9	2.7	0.3	0.5	0.9	1.5	2.1
	C-M	0.3	0.5	0.9	1.4	2.1	0.2	0.4	0.7	1.1	1.7
	D	0.1	0.3	0.6	1.0	1.5	0.1	0.2	0.5	0.8	1.2
	Total	3.8	7.6	13.5	21.4	31.3	3.0	5.7	10.5	16.8	24.8
Restaurant	L-1 North	2.2	2.8	3.7	4.9	6.4	2.0	2.4	3.2	4.2	5.4
	L-1 Central	1.5	2.0	2.6	3.4	4.4	1.4	1.7	2.2	2.9	3.7
	L-1 South	0.8	1.1	1.4	1.8	2.4	0.8	0.9	1.2	1.6	2.0
	L-3	0.2	0.2	0.3	0.3	0.4	0.1	0.2	0.2	0.3	0.4
	L-2	0.8	1.0	1.3	1.7	2.2	0.7	0.8	1.1	1.4	1.8
	C-M	0.5	0.6	0.8	1.1	1.4	0.5	0.5	0.7	0.9	1.2
	D	0.1	0.2	0.2	0.3	0.4	0.1	0.2	0.2	0.3	0.4
	Total	6.2	7.9	10.4	13.7	17.7	5.7	6.7	8.8	11.6	15.0
Store	L-1 North	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	L-1 Central	0.0	0.1	0.1	0.2	0.3	0.0	0.0	0.1	0.1	0.2
	L-1 South	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	L-3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	L-2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	C-M	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	0.0	0.1	0.2	0.2	0.4	0.0	0.0	0.1	0.1	0.2

Table 4-6-15 Estimation of potential natural gas demand of commercial sector

Scenario: Gas Use & Gas Promotion	Case: High				mmscfd	Case: Low				mmscfd
	2006	2010	2015	2020	2025	2006	2010	2015	2020	2025
L-1 North	3.6	4.9	6.8	9.3	12.4	3.0	3.7	5.2	7.0	9.3
L-1 Central	8.8	14.4	23.0	34.2	48.2	6.7	9.8	15.7	23.5	33.4
L-1 South	1.1	1.4	1.9	2.5	3.3	0.9	1.1	1.5	2.0	2.7
L-3	0.7	1.0	1.5	2.1	2.9	0.6	0.8	1.2	1.7	2.3
L-2	1.9	2.8	4.0	5.6	7.6	1.6	2.0	2.9	4.1	5.5
C-M	1.7	2.5	3.7	5.3	7.2	1.3	1.7	2.6	3.6	5.0
D	1.1	1.7	2.7	3.9	5.5	0.9	1.2	1.8	2.6	3.6
Total	18.9	28.7	43.5	62.9	87.1	15.1	20.5	30.9	44.7	61.8

(10) Gas Utilization in the Future

1) District Development

District development has been proceeding at Taguig in Metro Manila (Fort Bonifacio). In the business area, IT Center, IT Plaza, Incubator Office, Hotel, Government Center for Investment, school etc, are planned, and in the residential area, residences, schools, etc, are planned. Huge recreation areas are also planned. A LPG supply network is planned and LPG will substitute for natural gas in the future. Two absorption chillers driven by LPG are in operation at present. The total area is 25 hectares[11)]

The same kind of district development will be planned at other places and consume natural gas in the future. Natural gas demand is estimated for the assumed district development referring to the Fort Bonifacio Plan (Land Use Plan, Fort Bonifacio).

a) Assumed site area and floor area of buildings

Table 4-6-16 shows the assumed site areas and floor areas of buildings in the assumed district development. A total of 13.1 hectares for the business area and 6.9 hectares for the residential area are assumed.

---

11) Fort Bonifacio publication and personal communication.

Table 4-6-16 Assumed land and floor area

			Site Area m2	Floor Area m2
Business Area	Mixed-use		48,000	
		Office Building	42,240	168,960
		Hotel	1,440	5,760
		Shop	2,400	6,000
		Restaurant	1,920	3,840
	Convention Center		6,000	12,000
	Institutional		10,000	
		School	7,000	7,000
		Hospital	3,000	7,500
	Residential (High-rise)		4,000	16,000
	Parking		4,000	4,000
	Utility Use		4,000	4,000
	Open Space		15,000	15,000
	Road		40,000	40,000
	Sub-total		131,000	290,060
Residential Area	Village Mixed-use		10,000	
		Shop	4,000	10,000
		Restaurant	3,000	6,000
		Hall	3,000	6,000
	Residential (Family)		26,000	26,000
	Institutional School		2,000	2,000
	Open Space		11,000	11,000
	Road		20,000	20,000
	Sub-total		69,000	81,000
Total			200,000	371,060

b) Energy demand

District cooling is assumed for the business area, and residences are assumed to be equipped with stand-alone coolers powered by electricity. Figures 4-6-3～4-6-5 show energy demand patterns.

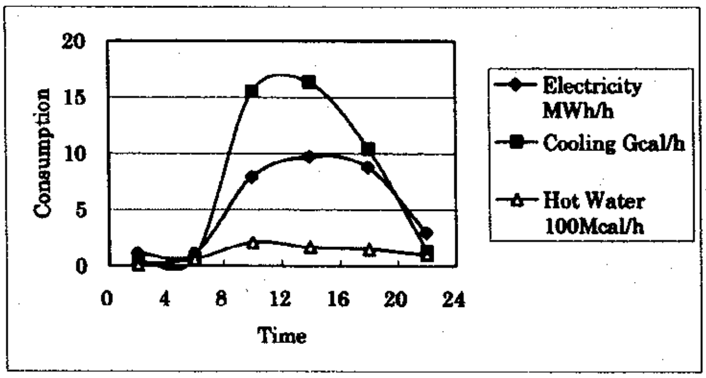


Figure 4-6-3 Energy Demand for Whole Area

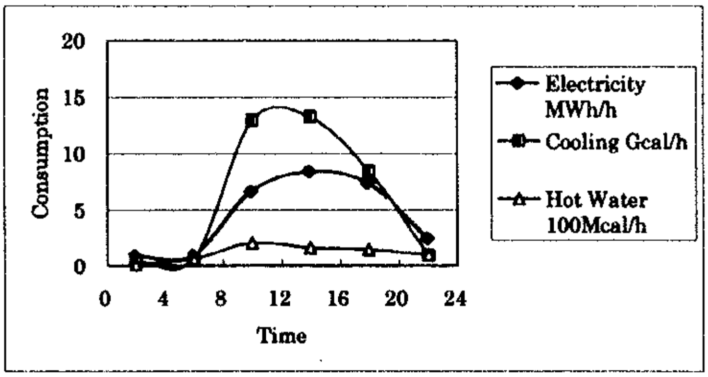


Figure 4-6-4 Energy Demand for Business Area

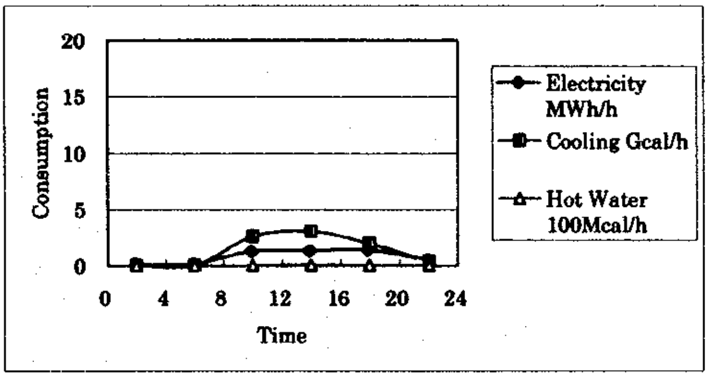


Figure 4-6-5 Energy Demand for Residential Area

Maximum demand for electricity, cooling, and hot water of the whole area is about 18MW, 10Gcal/h and 0.2Gcal/h respectively. Demand at night is small. This is because the demand of office buildings is large, and the demand of hotels and hospitals have little demand at nighttime is small. The operation rate of generators for this demand is low judging from the energy pattern. Electricity supplied by generators could be economical, if surplus nighttime electricity can be sold to power companies. Cogeneration could be economical, if there is any usage of surplus heat at night, in addition to electricity. Storing cold heat at night for daytime demand could be feasible. If there are no ways to utilize surplus energy, receiving electricity from commercial grid and an emergency generator is economical. District cooling using an absorption chiller could be economical. There are almost no differences in natural gas demand between district cooling and standalone cooling.

c) Natural gas demand

Estimated energy demand for the whole area is shown in Table 4-6-17.

Table 4-6-17 Estimated energy demand for the whole area

Business Area	Electricity MWh/d	106.9
	Cooling Gcal/d	146.5
	Hot Water Gcal/d	2.8
	Cooking Gcal/d	5.4
Residential Area	Electricity MWh/d	19.3
	Cooling Gcal/d	32.3
	Hot Water Gcal/d	0.1
	Cooking Gcal/d	8.3
Total	Electricity MWh/d	126.2
	Cooling Gcal/d	178.8
	Hot Water Gcal/d	2.8
	Cooking Gcal/d	13.7

Table 4-6-18 shows a comparison between conventional and gas cooling systems. In conventional system electricity powered chillers and LPG are used. When natural gas is supplied, absorption chillers are assumed to use natural gas, and natural gas is assumed to substitute for LPG. In residential areas electricity powered coolers are assumed. In the gas cooling system about 70 MWh/d of electricity is saved and natural gas consumption is 0.7mmscfd.

Table 4-6-18 Energy demand comparison

		Conventional	Gas Cooling
Business Area	Electricity MWh/d	164	107
	LPG kg/d	6,793	
	NG mmcfd		0.76
Residential Area	Electricity MWh/d	32	19
	LPG kg/d	7,001	
	NG mmcfd		0.39
Total	Electricity MWh/d	195	126
	LPG kg/d	13,794	
	NG mmcfd		1.15

2) Fuel Cell

A fuel cell produces electricity directly by the electro-chemical reaction of hydrogen and oxygen. Fuel cells are classified by the kind of electrode material that passes ions. Output power and field to apply are different by type of fuel cell. Phosphoric acid fuel cell (PAFC) and polymer electrode fuel cell (PEFC) are operated at a rather low temperature, and are being targeted at the markets of distributed generators and power supplies of vehicles. Molten carbonate fuel cell (MCFC) and solid oxide fuel cell (SOFC at high temperatures of more than 600℃, and their target market is medium- size power plants.

PAFC is the most highly developed fuel cell and problems concerning performance and reliability have almost been solved. The cost is about ¥400,000/kW (Ps160,000/kW) and development efforts have been concentrated on reducing cost. Electricity efficiency is around 40% and total efficiency including heat recovery is 70～80%. As far as total efficiency is concern, it is almost as high as engine and turbine cogeneration. Its characteristic is high electricity efficiency.

Recently, many companies have been making big efforts on PEFC for automobiles. The target price of PEFC is said to be US$50/kW to compete with current internal combustion engines. After the target price is attained, PEFC would be used for residential cogeneration systems, portable power generators, etc.. The total efficiency of PEFC is as high as that of PAFC, but heat is recovered as hot water because of the low operating temperature. In the automobile industries, it is said that fuel cell vehicle will be available in the market in the year of 2003～2004. Commercialization of PEFC for cogeneration system will be realized in 5～6 years after the commercialization for automobile.

3) Micro-gas Turbine

The micro-gas turbine is attracting attention as a small-distributed generator. An output power of 25～250kW is the target for development. Total efficiency is around 60～80% and electricity efficiency is around 30%. The characteristics are reportedly ① turbine, compressor, and generator are combined in one body, ②number of revolutions is as high as 50,000～100,000RPM, and it is compact, ③an air bearing is used so maintenance is easy. This turbine is expected to be used for cogeneration systems The price is around 200,000¥/kW at present and the target price is said to be around 100,000¥/kW (Ps80,000/kW) . Electricity efficiency of 40% and target price will be reportedly realized in 5 years, and then PEFC will penetrate into the market. Convenience stores operated day and night, fast- food stores, small stores, small office buildings, small hospitals, small hotels, etc. are thought to be markets

4) Cold Storage

Cold storage is used mainly to stored food fresh and some are used to ripen vegetables and fruits. A temperature less than 0℃ is necessary to keep the food such as fish and shell fresh. For this purpose an absorption chiller is not useful. The temperature of a storage to ripen banana, tomato, and other fruits that do not ripen is above 10℃, so an absorption chiller using natural gas can be used. One of these cold storages is in Davao. There are not many this kind of cold storage at present, but in the future the number is expected to increase.

The floor area of the storage in Davao is 3,300m² and its power consumption is reportedly[12] 320,000kWh/y. In the case of using an absorption chiller the natural gas consumption is around 2,510cfd (=320,000×860/10,600/365*35.3).

5) Dimethyl Ether[13]

Dimethyl ether (DME) production process has been developing using natural gas from small to medium-size gas fields. DME can be easily distributed, stored, etc. using LPG-handling technology and is a possible clean energy. DME does not generate particulate matter in the combustion process, because there is no double carbon bond in its chemical structure. DME raises no concerns about greenhouse effect and ozone layer depletion. Nowadays, DME is used mainly as a propellant (cosmetics, paint, agricultural chemicals, etc.). A study confirms that its toxicity is extremely low, similar to that of LPG.

DME is now manufactured by a dehydration reaction of methanol. To use DME as a fuel, it must be produced at low cost in large quantities. DME synthesis technologies directly from synthesis gas have been under development for some years.

Because the physical properties of DME are similar to propane and butane, the main materials of LPG, DME is expected to be used as a LPG alternative fuel. Their combustion characteristics are similar to those of methane and a natural gas cooker can be used without any modification. There is reportedly an example using DME as LPG alternative fuel in China.

---

[12] MEMSI Report.

[13] NKK Corporation, *Development of Dimethyl Ether Synthesis Technology and its Diesel Engine Test*, 2001.

Table 4-6-19 Physical properties

Properties	DME	Propane	Methane
Chemical Formula	CH_3OCH_3	C_3H_8	CH_4
Boiling Point (℃)	-25.1	-42.0	-161.5
Liquid Density (g/cc@25℃)	0.67	0.49	0.42
Vapor Pressure (MPa@25℃)	0.61	0.93	-
Net Caloric Value (kcal/kg)	6.900	11,100	12,000

The Cetane number of DME is high at 55~60, so it can be used as a fuel for a diesel engine. Its exhaust gas is much cleaner than that of diesel oil and DME is expected to be a fuel for automobiles. The results of the economic evaluation are reported. Table 4-6-20 shows the conditions for the evaluation.

Table 4-6-20 Conditions for economic evaluation

Parameter	Value
Plant Capacity	2,500~10,000 t/day
Plant Capital Cost	US$365~924 million
Plant On-stream Factor	90 %
Natural Gas Consumption	1.114 Nm^3/t-DME
Other Variable Cost	US$5.56 /t-DME
Depreciation	10 years, constant
Other Capital Cost	US$18.65 /t-DME
IRR before Tax	12 %

DME price (FOB) of production rate 10,000t/day is reported (Figure 4-6-6). Gas price from Camago/Malampaya is expected to be around US$5 /MMBtu. DME (FOB) price is around US$9.8 /MMBtu and the price is almost equivalent to the price of LPG in the Philippines. Commercialization of DME is expected after 2010 and at same time some experts expect earlier commercialization.

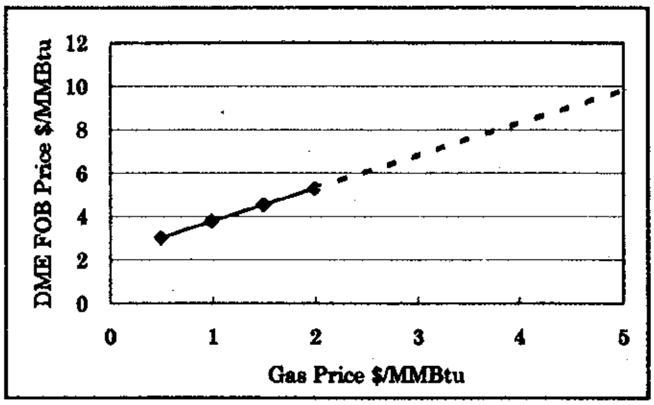


Figure 4-6-6 DME Price

6) Palay dryer

Palay dryers developed by National Postharvest Institute for Research and Extension (NAPHIRE) are used in the Philippines. The dryer is driven by a gasoline engine. Some farmers do not use the dryers because the gasoline price is high, so fuel conversion to marsh gas was examined.

Using a gas engine for a palay dryer is thought to be difficult economically for the following reasons.

① Developing gas engine for the dryer was pointed out to require several million pesos. The investment cost of the dryer is estimated to be very high even in the case of mass-production.

② Calories of marsh gas in the Philippines are reportedly low. It contains some air judging from analyzed gas data. The efficiency of high-calorie gas is around 30% and the efficiency is low in the case of low- calorie gas.

③ The flow rate of marsh gas in Davao seems to be several hundred liters per hour at most. Several thousand liter per hour of gas are needed to drive a 5 HP engine. Gas from many wells is necessary in this case, so an investment of gas piping is necessary to collect the gas.

④ Gas pressure has to have 200～300mmAq to feed gas to an engine. A gas blower is necessary.

4-6-2 Estimation of Potential Demand in the Transportation Sector

(1) Procedure of estimation

The energy density (the amount of stored energy per volume) of natural gas is small. Therefore, it is compressed and packed in a high-pressure container (compressed natural gas, CNG), and carried on vehicle. The power for compressing natural gas is large, moreover the compressor is expensive, too. Therefore, the construction cost of a CNG filling station for vehicles is expensive and the number of CNG filling stations will not increase rapidly. The driving range of a full CNG container for a vehicle is limited. Therefore, the most promising candidates for NGV would be taxi, Jeepney, bus, etc, that are driven in limited areas .
The estimation of demand based on economy, which is the most fundamental factor of penetration, is examined considering the influence of NGV penetration policy separately.

The process for estimating conversion into natural gas in the sector is shown in the following figure.

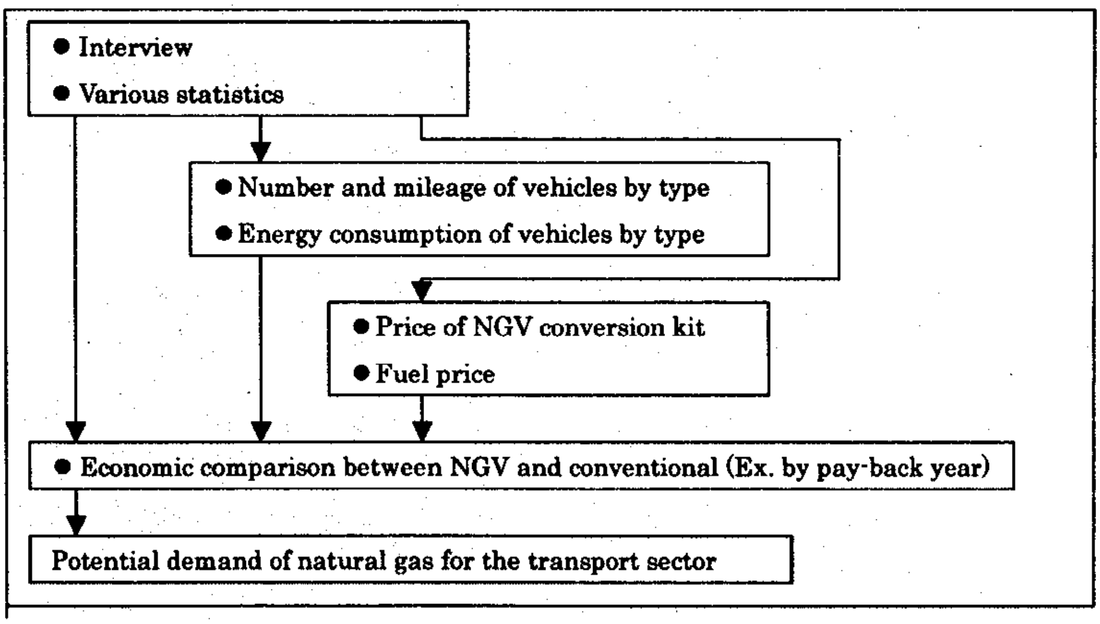


Figure 4-6-7 Procedure for estimating conversion in the Transport Sector

(2) Conversion technology for NGV

Natural gas can improve not only energy efficiency but also the power output of a vehicle by setting the compression ratio to a high level, because the octane value of CNG is high. But, it makes it expensive to design and manufacture an appropriate engine for NGV. The price of NGV with an optimized engine is 1.5～two times that of a regular gasoline vehicle.

At present, most NGV are remodeled gasoline vehicles. A gasoline engine can be remodeled by installing a NGV kit. A NGV conversion kit consists of a CNG cylinder, a regulator, a mixer, a fuel-air ratio control device, and other devices.

Almost all NGV are remodeled gasoline vehicles in Argentine, Italy, and other countries. Remodeled vehicles using NGV conversion kits are adopted in a project undertaken by DOE, PNOC-EDC-ERDC, and PNOC-EC. The ASEAN-New Zealand Economic Cooperation and PCIERD give financial and technical assistance to the project.

(3) Evaluation of conversion technology to NGV

1) Taxi

An economic evaluation of taxis using conversion kit is shown in the following table. This example shows pay-back period without subsidy. Gas price Ps25.7 /Nm^3 of Gas Use Scenario and Gas Promotion Scenario including Ps5.2 /Nm^3 as filling station's margin cannot reduce fuel expense and conversion to NGV is not economical.

Table 4-6-21 Pay-back period of taxi conversion kit

Economic Evaluation (NGV)

NGV vs. Gasoline and Diesel Vehicle — Evaluation Year 2010

(1) Conditions/Assumptions

<Case>	High	
<Scenario>	Gas Use & Gas Promotion	
<Vehicle> Type	Taxi	
<Operation> Driving distance	400	km/day
Working	292	day/year

		Gasoline Vehicle	Diesel Vehicle	
<Fuel consumption> Mileage	Conv.	10.0	10.5	km/Li
	CNG	9.5	10.5	km/Nm^3
Fuel consumption	Conv.	11,680	11,124	Li/Year
	CNG	12,295	11,124	Nm^3/Year
<Fuel price>	Conv.	23.7	19.2	Ps/Li
	CNG	25.7	25.7	Ps/Nm^3
<Kit price (→NGV)>		67.0	73.7	1,000Peso
Government support		0	0	%
Government support		0.0	0.0	1,000Peso

(2) Economic Analysis

		Gasoline Vehicle	Diesel Vehicle	
<Annual running cost> Fuel cost	Conv.	276,793	213,259	Ps/Year
	CNG	315,652	285,590	Ps/Year
<Economic Evaluation> Pay-back period (Conv.→NGV)		-1.7	-1.0	Years

Conv.: Gasoline, Diesel oil

The octane value of CNG is higher than that of gasoline, so that the higher compression ratio is applicable. But comparing with that of diesel engine, the compression ratio is low. In the case of conversion of diesel engine, the compression ratio is reduced by machining. In the case of gasoline engine, increasing the compression ratio is impossible, so that the mileage is a little short. Figure 4-6-8 and Figure 4-6-9 show the relationship between gas price (including margin for a gas filling station) and pay-back period. Conversion of diesel oil needs cheaper gas price compared with gasoline. Low Case needs lower gas price than High Case.

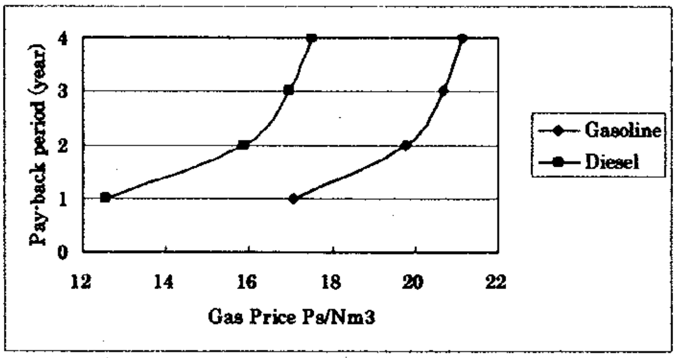


Figure 4-6-8 Gas price and pay-back period (taxi, High Case)

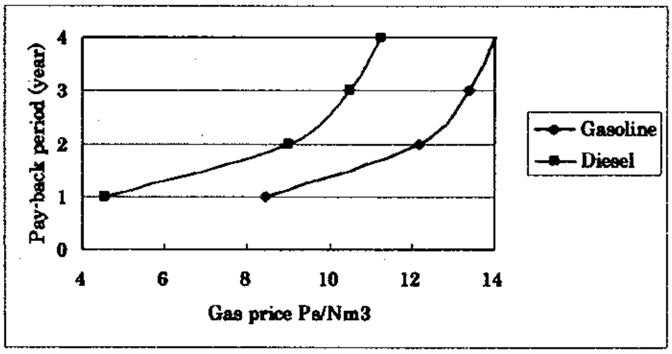


Figure 4-6-9 Gas price and pay-back period (taxi, Low Case)

2) Jeepney

The result of an economic evaluation for a Jeepney is shown in the following table. All Jeepneys are equipped with a diesel engine. Conversion to NGV for Jeepney is not economical like to the case of taxi.

Table 4-6-22 Pay-back period of Jeepney conversion kit

Economic Evaluation (NGV)

NGV vs. Gasoline and Diesel Vehicle

Evaluation Year: 2010

(1) Conditions/Assumptions

<Case>	High		
<Scenario>	Gas Use & Gas Promotion		
<Vehicle>	Type	Jeepney	
<Operation>	Driving distance	240	km/day
	Working	292	day/year

		Gasoline Vehicle	Diesel Vehicle	
<Fuel consumption>				
Mileage	Conv.	7.0	7.3	km/Li
	CNG	6.7	7.3	km/Nm^3
Fuel consumption	Conv.	10,011	9,600	Li/Year
	CNG	10,460	9,600	Nm^3/Year
<Fuel price>	Conv.	23.7	19.2	Ps/Li
	CNG	25.7	25.7	Ps/Nm^3
<Kit price (→NGV)>		80.4	88.4	1,000Peso
Government support		0	0	%
Government support		0.0	0.0	1,000Peso

(2) Economic Analysis

		Gasoline Vehicle	Diesel Vehicle	
<Annual running cost>				
Fuel cost	Conv.	237,252	184,046	Ps/Year
	CNG	268,540	246,468	Ps/Year
<Economic Evaluation>				
Pay-back period (Conv.→NGV)		-2.6	-1.4	Years

Conv.: Gasoline, Diesel oil

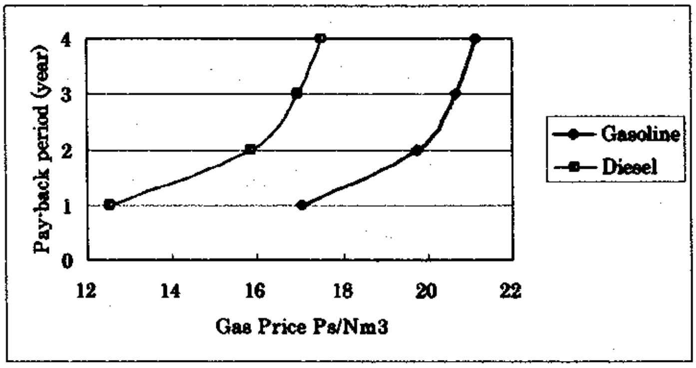


Figure 4-6-10 Gas Price and Pay-back Period (Jeepney, High Case)

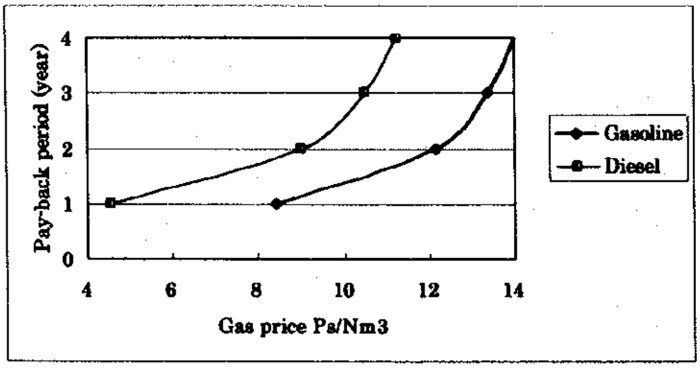


Figure 4-6-11 Gas Price and Pay-back Period (Jeepney, Low Case)

3) Bus

The result of an economic evaluation for a bus is shown in the following table. Almost all buses use diesel oil. Conversion to NGV for bus is not economical like to the cases of taxi and Jeepney.

Table 4-6-23 Pay-back period of bus conversion kit

Economic Evaluation (NGV)

NGV vs. Gasoline and Diesel Vehicle — Evaluation Year: 2010

(1) Conditions/Assumptions

<Case>	High		
<Scenario>	Gas Use & Gas Promotion		
<Vehicle>	Type	Bus	
<Operation>	Driving distance	250	km/day
	Working	276	day/year

		Gasoline Vehicle	Diesel Vehicle	
<Fuel consumption> Mileage	Conv.	2.0	2.1	km/Li
	CNG	1.9	2.1	km/Nm^3
Fuel consumption	Conv.	34,500	32,857	Li /Year
	CNG	36,316	32,857	Nm^3 /Year
<Fuel price>	Conv.	23.7	19.2	Ps/Li
	CNG	25.7	25.7	Ps/Nm^3
<Kit price (→NGV)>		565	622	1,000Peso
Government support		0	0	%
Government support		0	0	1,000Peso

(2) Economic Analysis

		Gasoline Vehicle	Diesel Vehicle	
<Annual running cost> Fuel cost	Conv.	817,583	629,918	Ps/Year
	CNG	932,363	843,567	Ps/Year
<Economic Evaluation> Pay-back period (Conv.→NGV)		-4.9	-2.9	Years

Conv.: Gasoline, Diesel oil

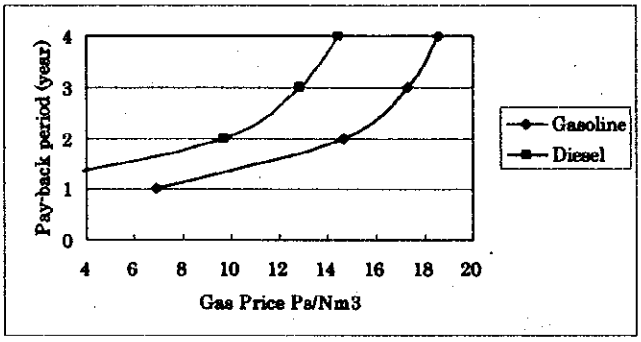


Figure 4-6-12 Gas Price and Pay-back Period (Bus; High Case)

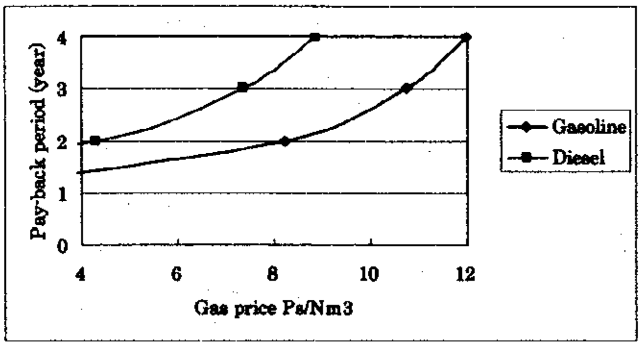


Figure 4-6-13 Gas Price and Pay-back Period (Bus; Low Case)

4) Gas filling station

For NGV penetration, a sufficient number of gas filling stations should be prepared. The construction cost of a filling station with compressor capacity of 500Nm³/h is about 30 million Pesos, excluding land. A huge investment is required to satisfy the users needs for convenience. The pay-back period of an investment on a filling station should be four to five years at longest. Generally, Philippine companies require a shorter pay-back period on investments. Margin for a gas filling station requires Ps5~6/Nm³ to satisfy a pay-back period of five years for the investment. Sufficient subsidies must be prepared to maintain enough number of filling stations to maintaining competitiveness against gasoline and diesel oil. Table 4-6-24 shows the economics of a typical filling station.

Table 4-6-24 Economic evaluation of filling station (High Case)

Economic Evaluation (NGV Gas Filling Station) Evaluation Year: 2010

(1) Conditions/Assumptions

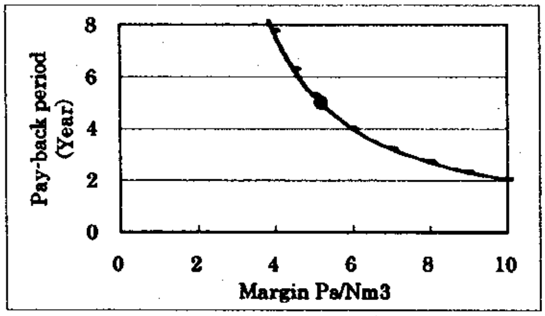
<Case> High

<Equipment Spec.>		
Compressor	500	Nm^3/h
Gas Cylinder	4.0	m^3
Dispenser	2	Unit
<Operation>		
Max. Sales Amoun	9,100	Nm^3/d
	700	Nm^3/h
Avr. Sales Amount	4,830	Nm^3/d
	372	Nm^3/h
	1,738,800	Nm^3/y
Working	360	d/y

<Construction Cost>	29.7	Mil. Ps
Government suppo	0	%
Government suppo	0.0	Mil. Ps
<Operating Cost>		
Power Consumed	970	kWh/d
Power Price	6.6	Ps/kWh
Power Expense	2,320	1,000Ps/y
Labor	536	1,000Ps/y
Maintenance	890	1,000Ps/y
Interest	8	%

(2) Economic Analysis

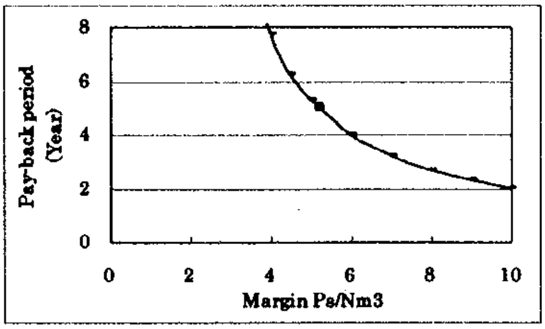
Margin Ps/Nm^3	Pay-back period (year)
3.0	20.2
4.0	9.2
5.0	6.0
6.0	4.4
10.0	2.2
5.6	Ps/Nm^3 is needed for
5	years pay-back period



Margin = Gas Selling Price - Gas Buying Price

Table 4-6-25 Economic evaluation of filling station (Low Case)

Margin Ps/Nm³	Pay-back period (year)
3.0	14.7
4.0	7.8
5.0	5.3
6.0	4.0
10.0	2.0
5.2	Ps/Nm³ is needed for
5	years pay-back period



The operating conditions of a typical filling station (compressor capacity 500Nm³/h) are shown in Table 4-6-26. The frequency of vehicles coming to fill up with gas is not constant. Usually two peaks are observed, in the morning and afternoon. The average filling frequency of taxi is 1.3 times a day and the average number of vehicles filling up with gas is 169 cars per day for a station. Operating hours of the station are assumed as 13 hours a day.

Table 4-6-26 Operating conditions of typical filling station

Type	Taxi	Jeepney	Bus	Unit
Driving Distance	300	250	200	km/1Filling
	400	240	250	km/day
Mileage	10.5	7.3	2.1	km/Nm3
Filling Amount	29	34	95	Nm3/1Filling
Frequency of Filling	1.3	1.0	1.3	Times/day
Number of Vehicle	169	141	51	Vehicle/day/Station
	127	147	41	Vehicle/Station

At least 1,300 stations are necessary for the target area, if all of diesel vehicles (taxi, Jeepney, bus) are converted to NGV (1999 base).

Table 4-6-27 Minimum numbers of filling stations

Area		L-1	L-3	L-2	C-M	D	Total
CARS	No. of NGV	21,278	0	3	60	76	21,417
(Taxi)	No. of Station	168	0	0	0	1	169
UV	No. of NGV	56,585	14,351	16,937	7,822	6,450	102,145
(Jeepney)	No. of Station	385	98	115	53	44	695
BUS	No. of NGV	10,339	1,752	3,111	624	1,011	16,837
	No. of Station	255	43	77	15	25	415
Total	No. of NGV	88,202	16,103	20,051	8,506	7,537	140,399
	No. of Station	808	141	192	69	69	1,279

(Remarks) No. of St'n: number of stations

(4) Estimation of number of vehicles by type, by Case and by area

The number of registered vehicles is estimated and shown in Table 4-6-28.

Table 4-6-28 Estimated registered number of vehicles

			Case: High					Case: Low				
			2006	2010	2015	2020	2025	2006	2010	2015	2020	2025
CARS (Taxi)	L-1 North	Gasoline	21,789	25,119	30,869	38,019	45,878	22,971	27,732	32,420	37,980	45,463
		Diesel	13,336	16,369	22,846	31,945	42,719	14,780	19,845	25,203	32,045	42,419
		Total	35,125	41,488	53,715	69,964	88,596	37,751	47,577	57,624	70,025	87,882
	L-1 Central	Gasoline	28,655	33,034	40,597	49,999	60,335	30,209	36,471	42,636	49,948	59,789
		Diesel	17,538	21,527	30,045	42,011	56,180	19,438	26,099	33,145	42,142	55,785
		Total	46,194	54,561	70,641	92,010	116,514	49,647	62,570	75,782	92,091	115,574
	L-1 South	Gasoline	4,243	4,892	6,012	7,404	8,934	4,473	5,401	6,314	7,396	8,854
		Diesel	2,597	3,188	4,449	6,221	8,319	2,878	3,865	4,908	6,240	8,261
		Total	6,840	8,079	10,461	13,625	17,254	7,352	9,265	11,222	13,637	17,114
	L-3	Gasoline	42	49	60	73	89	44	54	63	73	88
		Diesel	0	1	1	1	1	0	1	1	1	1
		Total	43	49	60	74	90	45	54	63	74	89
	L-2	Gasoline	404	466	572	705	850	426	514	601	704	843
		Diesel	5	6	9	13	17	6	8	10	13	17
		Total	409	472	581	717	867	432	522	611	717	859
	C-M	Gasoline	6,706	7,731	9,500	11,701	14,120	7,070	8,535	9,978	11,689	13,992
		Diesel	94	115	160	224	300	104	139	177	225	298
		Total	6,800	7,846	9,661	11,925	14,419	7,173	8,674	10,155	11,914	14,290
	D	Gasoline	3,175	3,660	4,498	5,540	6,685	3,347	4,041	4,724	5,534	6,624
		Diesel	119	146	204	286	382	132	177	225	287	379
		Total	3,294	3,806	4,702	5,825	7,067	3,479	4,218	4,949	5,821	7,004
Total		Gasoline	65,015	74,949	92,108	113,441	136,890	68,540	82,747	96,736	113,325	135,652
		Diesel	33,689	41,352	57,714	80,701	107,917	37,339	50,134	63,670	80,953	107,160
		Total	98,705	116,301	149,821	194,141	244,808	105,878	132,881	160,405	194,278	242,813
UV (Jeepney)	L-1 North	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	35,464	43,531	60,754	84,952	113,602	39,305	52,775	67,024	85,217	112,805
		Total	35,464	43,531	60,754	84,952	113,602	39,305	52,775	67,024	85,217	112,805
	L-1 Central	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	46,639	57,248	79,898	111,721	149,400	51,691	69,405	88,143	112,070	148,351
		Total	46,639	57,248	79,898	111,721	149,400	51,691	69,405	88,143	112,070	148,351
	L-1 South	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	6,906	8,477	11,831	16,544	22,123	7,654	10,278	13,052	16,595	21,968
		Total	6,906	8,477	11,831	16,544	22,123	7,654	10,278	13,052	16,595	21,968
	L-3	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	22,575	27,709	38,673	54,076	72,313	25,020	33,594	42,664	54,244	71,806
		Total	22,575	27,709	38,673	54,076	72,313	25,020	33,594	42,664	54,244	71,806
	L-2	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	26,642	32,702	45,641	63,820	85,344	29,528	39,647	50,351	64,019	84,745
		Total	26,642	32,702	45,641	63,820	85,344	29,528	39,647	50,351	64,019	84,745
	C-M	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	12,304	15,103	21,078	29,474	39,414	13,637	18,310	23,254	29,566	39,138
		Total	12,304	15,103	21,078	29,474	39,414	13,637	18,310	23,254	29,566	39,138
	D	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	10,146	12,454	17,381	24,304	32,501	11,245	15,099	19,175	24,380	32,273
		Total	10,146	12,454	17,381	24,304	32,501	11,245	15,099	19,175	24,380	32,273
Total		Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	160,677	197,225	275,256	384,891	514,696	178,081	239,107	303,663	386,092	511,086
		Total	160,677	197,225	275,256	384,891	514,696	178,081	239,107	303,663	386,092	511,086
BUS	L-1 North	Gasoline	266	306	376	463	559	280	338	395	463	554
		Diesel	6,480	7,954	11,101	15,522	20,757	7,182	9,643	12,246	15,571	20,611
		Total	6,745	8,260	11,477	15,985	21,316	7,462	9,981	12,641	16,033	21,165
	L-1 Central	Gasoline	349	403	495	609	735	368	445	520	609	729
		Diesel	8,522	10,460	14,599	20,413	27,298	9,445	12,681	16,105	20,477	27,106
		Total	8,871	10,863	15,093	21,023	28,033	9,813	13,126	16,625	21,086	27,835
	L-1 South	Gasoline	52	60	73	90	109	55	66	77	90	108
		Diesel	1,262	1,549	2,162	3,023	4,042	1,399	1,878	2,385	3,032	4,014
		Total	1,314	1,609	2,235	3,113	4,151	1,453	1,944	2,462	3,122	4,122
	L-3	Gasoline	31	36	44	54	66	33	40	46	54	65
		Diesel	2,755	3,382	4,720	6,601	8,827	3,054	4,100	5,208	6,621	8,765
		Total	2,787	3,418	4,765	6,655	8,892	3,087	4,140	5,254	6,676	8,830
	L-2	Gasoline	20	24	29	36	43	22	26	30	36	43
		Diesel	4,894	6,007	8,384	11,723	15,676	5,424	7,283	9,249	11,759	15,566
		Total	4,914	6,030	8,412	11,758	15,719	5,445	7,309	9,279	11,795	15,609
	C-M	Gasoline	9	10	12	15	18	9	11	13	15	18
		Diesel	982	1,205	1,682	2,352	3,145	1,088	1,461	1,855	2,359	3,123
		Total	990	1,215	1,694	2,367	3,163	1,097	1,472	1,868	2,374	3,141
	D	Gasoline	10	12	14	18	21	11	13	15	18	21
		Diesel	1,591	1,952	2,725	3,810	5,095	1,763	2,367	3,006	3,822	5,059
		Total	1,601	1,964	2,739	3,828	5,116	1,773	2,380	3,021	3,839	5,080
Total		Gasoline	737	850	1,044	1,286	1,552	777	938	1,097	1,285	1,538
		Diesel	26,485	32,509	45,372	63,443	84,839	29,354	39,413	50,054	63,641	84,244
		Total	27,222	33,359	46,416	64,729	86,391	30,131	40,351	51,150	64,926	85,782
Grand Total		Gasoline	65,752	75,798	93,152	114,727	138,442	69,316	83,685	97,832	114,610	137,190
		Diesel	220,851	271,086	378,342	529,035	707,453	244,773	328,654	417,387	530,685	702,490
		Total	286,604	346,885	471,493	643,761	845,895	314,089	412,339	515,219	645,295	839,680

(5) Economic evaluation of conversion to NGV

The most important factor for natural gas conversion is an economy. Conversion of NGV is evaluated according to the following criteria. Many used vehicles from Japan, Korea and other countries are being used as taxis and buses. Jeepneys use imported used diesel engines. The percentage of conversion is set rather low level considering these facts.

① 70% of vehicles convert to natural gas, if pay-back period is less than one year.
② 50% of vehicles convert to natural gas, if pay-back period is less than two years.
③ 10% of vehicles convert to natural gas, if pay-back period is less than three years.
④ No vehicles convert to natural gas, if pay-back period is more than three years.

Five years of pay-back period for a gas filling station are assumed.

(6) Estimation of potential natural gas demand

The results of NGV economic evaluation for High Case and Low Case are shown in Table 4-6-29 and 4-6-30. The pay-back period for both cases is more than tree years. Looking at the situation of taxi, Jeepney and bus business in the Philippines, it would be very difficult to convert the vehicles to NGV except special cases, if the pay-back period is more than tree years. So that natural gas demand for the industry cannot be expected. For NGV penetration, some political supports would be inevitable.

Table 4-6-29 Economic evaluation of NGV (High Case)

Case: High		Scenario: Gas Use & Gas Promotion				
Unit: Ps/Nm^3		Gas price for covering conversion cost (Note 1)	Gas price supplied through pipeline (Note 2)	Gas filling station cost (Note 3)	Gas price when filling CNG (Note 4)	Surplus (Note 5)
Taxi	Gasoline	20.7	20.1	5.6	25.7	-5.0
Taxi	Diesel	17.0	20.1	5.6	25.7	-8.7
Jeepney	Diesel	20.1	20.1	5.6	25.7	-5.6
Bus	Gasoline	17.3	20.1	5.6	25.7	-8.4
Bus	Diesel	12.9	20.1	5.6	25.7	-12.8

(Note 1) Gas price for covering conversion cost with three-year pay-back period
(Note 2) Gas price supplied through pipeline
(Note 3) Gas price for covering filling station cost with five-year pay-back period
(Note 4) Gas price when filling CNG = Gas price supplied through pipeline + Gas filling stat
(Note 5) Surplus = Gas price for covering conversion cost - Gas price when filling CNG

Table 4-6-30 Economic evaluation of NGV (Low Case)

Case: Low		Scenario: Gas Use & Gas Promotion				
Unit: Ps/Nm³		Gas price for covering conversion cost (Note 1)	Gas price supplied through pipeline (Note 2)	Gas filling station cost (Note 3)	Gas price when filling CNG (Note 4)	Surplus (Note 5)
Taxi	Gasoline	14.0	16.9	5.2	22.1	-8.1
Taxi	Diesel	11.3	16.9	5.2	22.1	-10.8
Jeepney	Diesel	13.4	16.9	5.2	22.1	-8.7
Bus	Gasoline	10.8	16.9	5.2	22.1	-11.3
Bus	Diesel	7.4	16.9	5.2	22.1	-14.7

(7) Political support for NGV penetration

The exhaust gas from a diesel engine is one of the biggest problems. NGV conversion of diesel vehicles cannot be expected judging by the estimated fuel prices. The following political supports are effective for NGV conversion of diesel vehicles.

① Investment support for conversion kits

② Investment support for gas filling stations

③ Gas price support for NGV

1) Investment support and gas price support

An estimation of total amount of the support is necessary before the support implementation. Table 4-6-31 is an example of investment support and gas price support. The support is applied only for diesel vehicles.

This example shows the result for 60% conversion kit support and 80% gas filling station support. An investor of the station needs Ps22.9/Nm³ gas price including margin to cover the investment cost in five years. Taxi needs Ps18.3 /Nm³ gas price to cover the conversion kit investment in three years. Jeepney and bus needs 17.9and Ps16.6 /Nm³ for the covering respectively. The gas price support must cover the difference between station's gas price and user's gas price. The amount of the support for one gas filling station is shown in Table 4-6-31. The percentage of taxis, Jeepney and buses is assumed to be 25, 65 and 10% respectively. The percentage is decided according to the ratio of diesel vehicles in NCR. The investment support for conversion kits and for a filling station are US$0.32 million and US$0.41 million respectively. The gas price support is US$0.25 million per year.

Table 4-6-31 Example of investment and gas price support

Government Support for NGV					
(1) Assumptions / Conditions					
Base Year		2010	Exchange Rate	58.6 Ps/$	
Case		High			
Scenario		Gas Use			
Fuel Price		Estimated	Base price	Up due to ACC etc.	
	Gasoline	23.7 Ps/Li	23.7 Ps/Li	0 %	Margin for Filling Station
	Diesel Oil	19.2 Ps/Li	19.2 Ps/Li	0 %	5 years for Pay-back
	CNG	22.9 Ps/Nm³	20.1 Ps/Nm³	0 %	2.8 Ps/Li
Investment Cost					
Conversion Kit for Diesel Engine Vehicles		Investment	Government Support	Government Support	
	Taxi	73,699 Ps	60 %	44,219 Ps	
	Jeepney	88,439 Ps	60 %	53,063 Ps	
	Bus	621,752 Ps	60 %	373,051 Ps	
Filling Station		Investment	Government Support	Government Support	
		29.7 Million Ps	80 %	23.7 Million Ps	
Number of Vehicles supplied CNG by One Filling Station					
	Taxi	56	25	% of Vehicles/Station	
	Jeepney	147	65	% of Vehicles/Station	
	Bus	23	10	% of Vehicles/Station	
	NGV Total	226	100	% of Vehicles/Station	
(2) Gas Price for Covering Conversion Kit Cost of Diesel Vehicles with Three-year Pay-back Period					
	Taxi	18.3 Ps/Nm³			
	Jeepney	17.9 Ps/Nm³			
	Bus	16.6 Ps/Nm³			
(3) Government Support for One Filling Station					
Investment Cost Support					
Conversion Kit for Diesel Engine Vehicles					
	Taxi	2.5 Million Ps	0.04 Million $		
	Jeepney	7.8 Million Ps	0.13 Million $		
	Bus	8.4 Million Ps	0.14 Million $		
	Total	18.7 Million Ps	0.32 Million $		
Filling Station		23.7 Million Ps	0.41 Million $		
Total		42.4 Million Ps	0.72 Million $		
Fuel Price Support					
	Taxi	2.9 Million Ps/y	0.05 Million $/y		
	Jeepney	7.0 Million Ps/y	0.12 Million $/y		
	Bus	4.7 Million Ps/y	0.08 Million $/y		
	Total	14.6 Million Ps/y	0.25 Million $/y		

If five filling stations are constructed every year, the investment support is US$3.62 Million per year and the gas price support is US43.75 Million per year after three years.

Table 4-6-32 Example of total amount of support

	First year	Second Year	Third year
No. of stations	5	10	15
No. of NGVs			
Taxi	282	564	846
Jeepney	734	1,467	2,201
Bus	113	226	339
Total	1,129	2,257	3,386
Investment Support (Million$)			
Conersion kit	1.60	1.60	1.60
Filling staion	2.03	2.03	2.03
Total	3.62	3.62	3.62
Fuel Support (Million$/y)	1.25	2.50	3.75

The rate and the amount of support for diesel vehicles are shown in Figure 4-6-14~ Figure 4-6-17 for High Case and Low Case. The amount of the support for one filling station can be calculated using these figures.

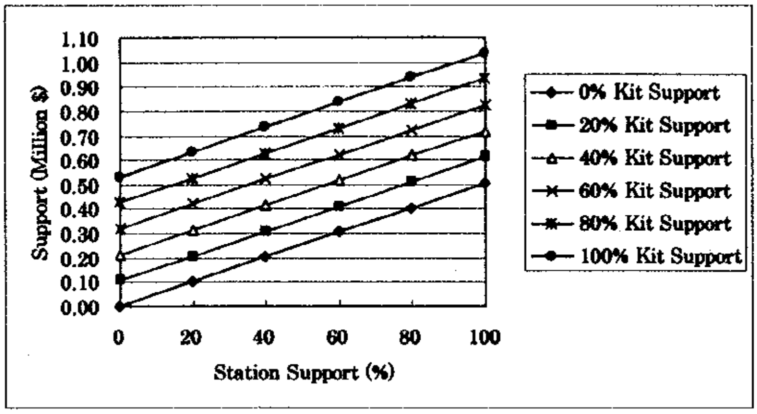


Figure 4-6-14 Investment support (High Case)

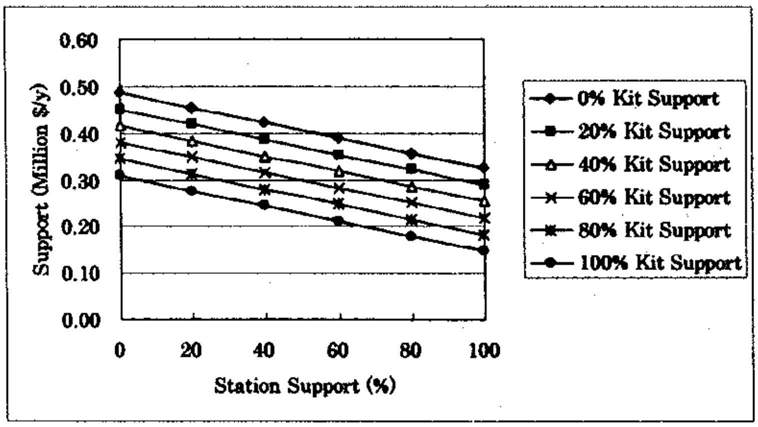


Figure 4-6-15 Gas price support (High Case)

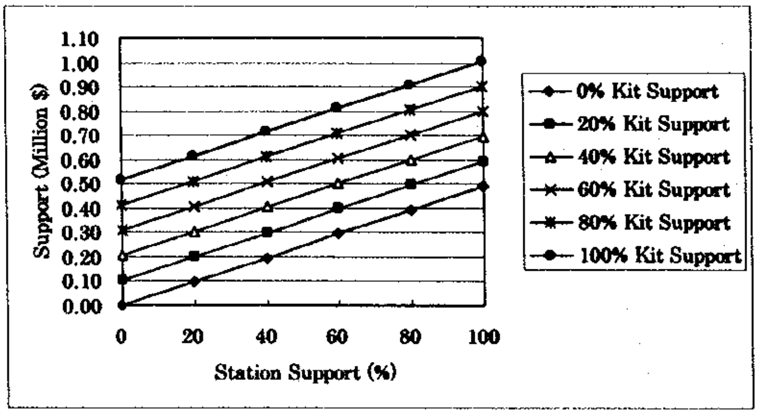


Figure 4-6-16 Investment support (Low Case)

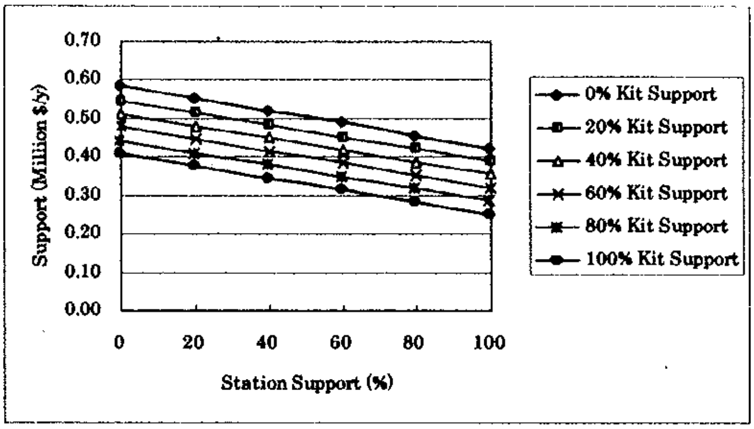


Figure 4-6-17 Gas price support (Low Case)

Table 4-6-33 shows the result of 100% support for conversion kit and filling station investment in High Case. Even if 100% support is given, NGV conversion is not economical. Gas price support is inevitable. Gas Promotion Scenario-A gives 100% support for conversion kit and filling station investment, and gas price support that make gas price competitive with diesel oil. The results are shown in Table 4-6-33 and Table 4-6-34. Gas prices to NGV become Ps19.2/Nm^3 and Ps13.5 /Nm^3 in High Case and Low Case respectively.

Table 4-6-33 Gas Promotion Scenario-A (High Case)

Government Support for NGV					
(1) Assumptions / Conditions					
Base Year		2010	Exchange Rate	58.6 Ps/$	
Case		High			
Scenario		Gas Use & Gas Promotion			
Fuel Price		Estimated	Base price	Up due to ACC etc.	
	Gasoline	23.7 Ps/Li	23.7 Ps/Li	0 %	Margin for Filling Station
	Diesel Oil	19.2 Ps/Li	19.2 Ps/Li	0 %	5 years for Pay-back
	CNG	22.3 Ps/Nm^3	20.1 Ps/Nm^3	0 %	2.2 Ps/Li
Investment Cost					
Conversion Kit for Diesel Engine Vehicles		Investment	Government Support	Government Support	
	Taxi	73,699 Ps	100 %	73,692 Ps	
	Jeepney	88,439 Ps	100 %	88,430 Ps	
	Bus	621,752 Ps	100 %	621,690 Ps	
Filling Station		Investment	Government Support	Government Support	
		29.7 Million Ps	100 %	29.7 Million Ps	
Number of Vehicles supplied CNG by One Filling Station					
	Taxi	56	25	% of Vehicles/Station	
	Jeepney	147	65	% of Vehicles/Station	
	Bus	23	10	% of Vehicles/Station	
	NGV Total	226	100	% of Vehicles/Station	
(2) Gas Price for Covering Conversion Kit Cost of Diesel Vehicles with Three-year Pay-back Period					
	Taxi	19.2 Ps/Nm^3			
	Jeepney	19.2 Ps/Nm^3			
	Bus	19.2 Ps/Nm^3			
(3) Government Support for One Filling Station					
Investment Cost Support					
Conversion Kit for Diesel Engine Vehicles					
	Taxi	4.2 Million Ps	0.07 Million $		
	Jeepney	13.0 Million Ps	0.22 Million $		
	Bus	14.0 Million Ps	0.24 Million $		
	Total	31.2 Million Ps	0.53 Million $		
Filling Station		29.7 Million Ps	0.51 Million $		
Total		60.8 Million Ps	1.04 Million $		
Fuel Price Support					
	Taxi	1.9 Million Ps/y	0.03 Million $/y		
	Jeepney	4.4 Million Ps/y	0.07 Million $/y		
	Bus	2.3 Million Ps/y	0.04 Million $/y		
	Total	8.6 Million Ps/y	0.15 Million $/y		

Table 4-6-34 Gas Promotion Scenario-A (Low Case)

Government Support for NGV					
(1) Assumptions / Conditions					
Base Year		2010	Exchange Rate	58.6 Ps/$	
Case		Low			
Scenario		Gas Use & Gas Promotion			
Fuel Price		Estimated	Base price	Up due to ACC etc.	
	Gasoline	16.6 Ps/Li	16.6 Ps/Li	0 %	Margin for Filling Station
	Diesel Oil	13.5 Ps/Li	13.5 Ps/Li	0 %	5 years for Pay-back
	CNG	18.8 Ps/Nm³	16.9 Ps/Nm³	0 %	1.9 Ps/Li
Investment Cost					
Conversion Kit for Diesel Engine Vehicles		Investment	Government Support	Government Support	
	Taxi	71,327 Ps	100 %	71,320 Ps	
	Jeepney	85,592 Ps	100 %	85,583 Ps	
	Bus	601,738 Ps	100 %	601,678 Ps	
Filling Station		Investment	Government Support	Government Support	
		28.7 Million Ps	100 %	28.7 Million Ps	
Number of Vehicles supplied CNG by One Filling Station					
	Taxi	56	25	% of Vehicles/Station	
	Jeepney	147	65	% of Vehicles/Station	
	Bus	23	10	% of Vehicles/Station	
	NGV Total	226	100	% of Vehicles/Station	
(2) Gas Price for Covering Conversion Kit Cost of Diesel Vehicles with Three-year Pay-back Period					
	Taxi	13.5 Ps/Nm³			
	Jeepney	13.5 Ps/Nm³			
	Bus	13.5 Ps/Nm³			
(3) Government Support for One Filling Station					
Investment Cost Support					
Conversion Kit for Diesel Engine Vehicles					
	Taxi	4.0 Million Ps	0.07 Million $		
	Jeepney	12.6 Million Ps	0.21 Million $		
	Bus	13.6 Million Ps	0.23 Million $		
	Total	30.2 Million Ps	0.51 Million $		
Filling Station		28.7 Million Ps	0.49 Million $		
Total		58.9 Million Ps	1.01 Million $		
Fuel Price Support					
	Taxi	3.3 Million Ps/y	0.06 Million $/y		
	Jeepney	7.5 Million Ps/y	0.13 Million $/y		
	Bus	3.9 Million Ps/y	0.07 Million $/y		
	Total	14.7 Million Ps/y	0.25 Million $/y		

2) Estimation of gas demand (Gas Promotion Scenario-A)

Gas Promotion Scenario-A gives investment support and gas price support targeting diesel vehicle conversion to NGV. Without investment support, gasoline taxi can take benefit by converting to NGV, if the gas price becomes cheap (Figure 4-6-8 and Figure 4-6-9). The estimated number of NGV including converted NGV from gasoline vehicle is shown in Table 4-6-35. The estimated gas demands are shown in Table 4-6-36 and Table 4-6-37 for both cases.

Large number of gasoline taxis converts to NGV. By comparing Table 4-6-35 and Table 4-6-28, the number of gasoline taxis can be calculated. If enough number of filling station is not constructed, the convenience of filling CNG is greatly spoilt, because number of NGV becomes large. If the number of gas filling stations becomes large, the amount of support becomes large and at the same time the amount of gas price support becomes large. The detailed feasibility study is necessary to implement support policies.

Table 4-6-35 Estimated numbers of NGV (Gas Promotion Scenario-A)

Scenario: Gas Promotion-A			Case: High					Case: Low				
			2006	2010	2015	2020	2025	2006	2010	2015	2020	2025
CARS (Taxi)	L-1 North	Gasoline	16,342	18,839	23,152	28,514	34,408	21,822	26,346	30,799	36,081	43,190
		Diesel	8,668	10,640	14,850	20,764	27,767	9,607	12,899	16,382	20,829	27,572
		CNG	10,115	12,009	15,713	20,685	26,421	6,322	8,332	10,442	13,115	17,120
	L-1 Central	Gasoline	21,492	24,775	30,447	37,499	45,251	28,698	34,647	40,505	47,451	56,800
		Diesel	11,400	13,993	19,529	27,307	36,517	12,634	16,964	21,544	27,392	36,261
		CNG	13,302	15,793	20,665	27,204	34,747	8,314	10,958	13,733	17,247	22,514
	L-1 South	Gasoline	3,183	3,669	4,509	5,553	6,701	4,250	5,131	5,998	7,027	8,411
		Diesel	1,688	2,072	2,892	4,044	5,407	1,871	2,512	3,190	4,056	5,370
		CNG	1,970	2,339	3,060	4,028	5,145	1,231	1,623	2,034	2,554	3,334
	L-3	Gasoline	32	36	45	55	66	42	51	59	70	83
		Diesel	0	0	0	1	1	0	0	1	1	1
		CNG	11	12	15	19	23	2	3	3	4	5
	L-2	Gasoline	303	349	429	528	638	404	488	571	669	801
		Diesel	3	4	6	8	11	4	5	6	8	11
		CNG	103	119	146	181	218	23	28	34	40	48
	C-M	Gasoline	5,029	5,798	7,125	8,776	10,590	6,716	8,108	9,479	11,104	13,292
		Diesel	61	75	104	146	195	67	91	115	146	194
		CNG	1,709	1,973	2,431	3,004	3,635	390	476	561	663	804
	D	Gasoline	2,381	2,745	3,373	4,155	5,014	3,180	3,839	4,488	5,257	6,293
		Diesel	78	95	133	186	248	86	115	146	186	247
		CNG	835	966	1,196	1,485	1,805	214	264	315	377	464
Total		Gasoline	48,761	56,212	69,081	85,081	102,668	65,113	78,610	91,899	107,659	128,870
		Diesel	21,898	26,879	37,514	52,456	70,146	24,270	32,587	41,385	52,619	69,654
		CNG	28,045	33,211	43,227	56,605	71,994	16,495	21,684	27,121	34,000	44,289
UV (Jeepney)	L-1 North	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	10,639	13,059	18,226	25,486	34,081	11,792	15,832	20,107	25,565	33,842
		CNG	24,825	30,472	42,528	59,466	79,522	27,514	36,942	46,916	59,652	78,964
	L-1 Central	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	13,992	17,174	23,969	33,516	44,820	15,507	20,821	26,443	33,621	44,505
		CNG	32,648	40,074	55,929	78,205	104,580	36,184	48,583	61,700	78,449	103,846
	L-1 South	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	2,072	2,543	3,549	4,963	6,637	2,296	3,083	3,916	4,979	6,590
		CNG	4,834	5,934	8,282	11,581	15,486	5,358	7,194	9,137	11,617	15,378
	L-3	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	6,772	8,313	11,602	16,223	21,694	7,506	10,078	12,799	16,273	21,542
		CNG	15,802	19,397	27,071	37,853	50,619	17,514	23,516	29,864	37,971	50,264
	L-2	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	7,993	9,811	13,692	19,146	25,603	8,858	11,894	15,105	19,206	25,423
		CNG	18,650	22,892	31,949	44,674	59,740	20,670	27,753	35,246	44,813	59,321
	C-M	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	3,691	4,531	6,324	8,842	11,824	4,091	5,493	6,976	8,870	11,741
		CNG	8,613	10,572	14,755	20,632	27,590	9,546	12,817	16,278	20,696	27,396
	D	Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	3,044	3,736	5,214	7,291	9,750	3,374	4,530	5,752	7,314	9,682
		CNG	7,102	8,718	12,167	17,013	22,751	7,872	10,569	13,422	17,066	22,591
Total		Gasoline	0	0	0	0	0	0	0	0	0	0
		Diesel	48,203	59,167	82,577	115,467	154,409	53,424	71,732	91,099	115,828	153,326
		CNG	112,474	138,057	192,680	269,424	360,288	124,656	167,375	212,564	270,264	357,760
BUS	L-1 North	Gasoline	266	306	376	463	559	280	338	395	463	554
		Diesel	1,944	2,386	3,330	4,657	6,227	2,155	2,893	3,674	4,671	6,183
		CNG	4,536	5,568	7,770	10,865	14,530	5,027	6,750	8,572	10,899	14,428
	L-1 Central	Gasoline	349	403	495	609	735	368	445	520	609	729
		Diesel	2,557	3,138	4,380	6,124	8,189	2,833	3,804	4,832	6,143	8,132
		CNG	5,965	7,322	10,219	14,289	19,108	6,611	8,877	11,274	14,334	18,974
	L-1 South	Gasoline	52	60	73	90	109	55	66	77	90	108
		Diesel	379	465	649	907	1,213	420	563	715	910	1,204
		CNG	883	1,084	1,513	2,116	2,830	979	1,315	1,669	2,123	2,810
	L-3	Gasoline	31	36	44	54	66	33	40	46	54	65
		Diesel	827	1,015	1,416	1,980	2,648	916	1,230	1,562	1,986	2,629
		CNG	1,929	2,368	3,304	4,620	6,179	2,138	2,870	3,645	4,635	6,135
	L-2	Gasoline	20	24	29	36	43	22	26	30	36	43
		Diesel	1,468	1,802	2,515	3,517	4,703	1,627	2,185	2,775	3,528	4,670
		CNG	3,426	4,205	5,868	8,206	10,973	3,797	5,098	6,474	8,232	10,896
	C-M	Gasoline	9	10	12	15	18	9	11	13	15	18
		Diesel	295	361	505	705	943	326	438	557	708	937
		CNG	687	843	1,177	1,646	2,201	762	1,023	1,299	1,651	2,186
	D	Gasoline	10	12	14	18	21	11	13	15	18	21
		Diesel	477	586	817	1,143	1,528	529	710	902	1,147	1,518
		CNG	1,113	1,367	1,907	2,667	3,566	1,234	1,657	2,104	2,675	3,541
Total		Gasoline	737	850	1,044	1,286	1,552	777	938	1,097	1,285	1,538
		Diesel	7,945	9,753	13,611	19,033	25,452	8,806	11,824	15,016	19,092	25,273
		CNG	18,539	22,756	31,760	44,410	59,388	20,548	27,589	35,038	44,549	58,971
Grand Total		Gasoline	49,498	57,061	70,125	86,366	104,219	65,889	79,548	92,996	108,943	130,407
		Diesel	78,047	95,799	133,702	186,956	250,007	86,500	116,143	147,500	187,539	248,253
		CNG	159,058	194,024	267,666	370,439	491,669	161,700	216,648	274,723	348,813	461,019

Table 4-6-36 Estimated gas demand (Gas Promotion Scenario-A; High Case)

Condition: Case: High
Scenerio: Gas Promotion-A
Gas Price 19.2 Ps/Nm3 for NGV
17.0 Ps/Nm3 for Station
2.2 Ps/Nm3 Margin for Station

CNG mmscfd	2006	2010	2015	2020	2025
L-1 North	52	63	87	120	158
L-1 Central	68	83	114	157	208
L-1 South	10	12	17	23	31
L-3	22	27	38	53	70
L-2	30	37	51	72	96
C-M	13	16	21	30	39
D	12	14	20	28	37
Total	207	252	348	481	639

Table 4-6-37 Estimated gas demand (Gas Promotion Scenario-A; Low Case)

Condition: Case: Low
Scenerio: Gas Promotion-A
Gas Price 13.5 Ps/Nm3 for NGV
11.6 Ps/Nm3 for Station
1.9 Ps/Nm3 Margin for Station

CNG mmscfd	2006	2010	2015	2020	2025
L-1 North	51	69	87	110	146
L-1 Central	67	90	114	145	192
L-1 South	10	13	17	21	28
L-3	24	33	42	53	70
L-2	33	44	56	72	95
C-M	12	17	21	27	35
D	12	16	21	26	35
Total	211	282	358	454	600

4-6-3 Estimation of Potential Demand in the Industrial Sector

(1) Methodologies of estimation

Potential gas demand in the industry sector is estimated in the following methodologies. Basically, they are the same as those in 4-5 above.

1) Estimation of current fuel consumption in target areas
    ····We use mainly the results of the MEMSI's survey for the estimation.

2) Estimation of potential gas demand by industry in target areas
   a) Selection of target industries
   b) Selection of target equipment and facilities
   c) Examination of the economics of gas conversion (in existing factories) and gas use (in newly built factories)
   d) Assumption of gas conversion ratio and gas use ratio by industry in target areas based on the examination in c) above
   e) Estimation of potential gas demand by industry and by fuel

(2) Estimation of current fuel consumption in target areas
We estimate current consumption on fuels, which we consider can be converted to gas because of economics. In both of the High and Low Cases, they are LPG and diesel fuel oil (DFO). Table 4-6-38 shows the results of the estimation.

LPG consumption in target areas is estimated to be 274,000 t in 2000, around two-thirds of which was accounted by Area L-1, followed by Area L-2 having around 15% share. DFO consumption in target areas is estimated to be 269,000 t in 2000, around two-thirds of which was accounted by Area L-1, followed by Area L-2 having around 12% share.

Large users of LPG are food & beverage, chemicals, and metal-processing in this order, and those of DFO are machinery, food & beverage, rubber products, and metal-processing in this order. The reason why machinery is the largest user of DFO is that it fires a large volume of DFO for power generation, which might be caused by a small number of samples for this industry in MEMSI's survey.

Table 4-6-38 Estimated current fuel consumption in target areas (2000)

Industry	No. of factory	Diesel fuel oil (Kl)				LPG (Ton)		
		Boiler	Furnace	Power gen.	Total	Furnace	Others	Total
<Area L-1>								
Food & beverages	1,083	16,966	1,803	21,366	40,136	71,876	5,573	77,449
Textiles	383	3,863	0	2,028	5,891	541	608	1,150
Paper & products	247	1,383	0	1,795	3,179	2	1,805	1,807
Chemicals	598	131	0	150	281	45	53,820	53,865
Rubber & products	500	23,903	144	64	24,111	268	330	598
Glass & products	46	0	0	0	0	14,748	0	14,748
Cement	18	0	0	3,055	3,055	0	1	1
Basic precious and non-ferrous,others	327	1,187	2,570	8,945	12,702	19,389	3,369	22,759
Machinery & equipment	500	0	726	90,854	91,580	2,731	43	2,774
Total	3,702	47,433	5,243	128,258	180,934	109,600	65,549	175,150
<Area L-2>								
Food & beverages	413	6,470	688	8,148	15,306	27,410	2,125	29,535
Textiles	105	1,059	0	556	1,615	148	167	315
Paper & products	56	314	0	407	721	0	409	410
Chemicals	45	10	0	11	21	3	4,050	4,053
Rubber & products	30	1,434	9	4	1,447	16	20	36
Glass & products	6	0	0	0	0	0	0	0
Cement	4	0	0	679	679	0	0	0
Basic precious and non-ferrous,others	53	192	417	1,450	2,059	3,143	546	3,689
Machinery & equipment	55	0	80	9,994	10,074	300	5	305
Total	497	9,479	1,193	21,249	31,921	31,021	7,322	38,343
<Area L-3>								
Food & beverages	110	1,723	183	2,170	4,077	7,300	566	7,866
Textiles	30	303	0	159	461	42	48	90
Paper & products	8	45	0	58	103	0	58	59
Chemicals	17	4	0	4	8	1	1,530	1,531
Rubber & products	4	191	1	1	193	2	3	5
Glass & products	1	0	0	0	0	4	0	4
Cement	1	0	0	170	170	0	0	0
Basic precious and non-ferrous,others	10	36	79	274	388	593	103	696
Machinery & equipment	33	0	48	5,996	6,044	180	3	183
Total	219	2,302	311	8,832	11,444	8,123	2,311	10,434
<Area C-M>								
Food & beverages	265	4,151	441	5,228	9,821	17,587	1,364	18,951
Textiles	20	202	0	106	308	28	32	60
Paper & products	18	101	0	131	232	0	132	132
Chemicals	45	10	0	11	21	3	4,050	4,053
Rubber & products	30	1,434	9	4	1,447	16	20	36
Glass & products	6	0	0	0	0	8	0	8
Cement	3	0	0	509	509	0	0	0
Basic precious and non-ferrous,others	53	192	417	1,450	2,059	3,143	546	3,689
Machinery & equipment	55	0	80	9,994	10,074	300	5	305
Total	496	6,090	946	17,433	24,470	21,086	6,148	27,234
<Area D>								
Food & beverages	263	4,120	438	5,189	9,747	17,455	1,353	18,808
Textiles	8	81	0	42	123	11	13	24
Paper & products	9	50	0	65	116	0	66	66
Chemicals	20	4	0	5	9	2	1,800	1,802
Rubber & products	17	813	5	2	820	9	11	20
Glass & products	1	0	0	0	0	0	0	0
Cement	1	0	0	170	170	0	0	0
Basic precious and non-ferrous,others	20	73	157	547	777	1,186	206	1,392
Machinery & equipment	46	0	67	8,359	8,425	251	4	255
Total	385	5,141	667	14,379	20,187	18,914	3,453	22,367
<All Areas>								
Food & beverages	2,134	33,431	3,553	42,101	79,086	141,628	10,981	152,610
Textiles	546	5,508	0	2,891	8,398	772	867	1,639
Paper & products	338	1,893	0	2,457	4,350	3	2,470	2,473
Chemicals	725	159	0	182	341	54	65,250	65,304
Rubber & products	581	27,775	167	75	28,017	311	384	695
Glass & products	60	0	0	0	0	14,759	0	14,759
Cement	27	0	0	4,582	4,582	0	1	1
Basic precious and non-ferrous,others	463	1,681	3,639	12,665	17,985	27,453	4,771	32,224
Machinery & equipment	689	0	1,000	125,197	126,197	3,763	59	3,822
Total	5,563	70,446	8,359	190,151	268,955	188,744	84,783	273,527

(3) Estimation of potential gas demand by industry in target areas

1) Selection of target industries and equipment and facilities

First, we select target industries, excluding cement, basic iron and steel, and others, which have no possibility of gas use, by examining equipment and facilities used in each industry.

Next, we select target equipment and facilities by fuel in target industries.

For LPG, we select industrial furnaces, "ovens", and "stoves" (a large number of the latter two are installed in bread bakeries) as target equipment, excluding (a) boilers, for which LPG is used only for start-up fuel, and (b) cooker, for which a small volume of LPG is consumed.

For DFO, we select only boilers as target equipment, excluding (a) electric power generators (diesel engines), which can hardly be converted to gas-fired, (b) furnaces, "ovens", and "stoves," for which a small volume of DFO is consumed, and (c) vehicles, fuels for which should be treated as those for transportation.

We, however, assume that a certain part of DFO consumption will be used for power generation in the future, because power generators other than diesel engines can be fired by gas.

2) Examination of the economics of gas conversion and gas use

a) Existing equipment and facilities

We examine the economics of gas conversion in existing equipment and facilities, targeting furnaces, "ovens", and "stoves" for LPG and boilers for DFO.

Figure 4-6-18 shows the conversion costs of fuel to DFO in boilers, which have been prepared referring to a cost estimation made by an expert on boilers. The costs are estimated to be US$35,600 for 2t/h boiler and US$39,100 for 6t/h boiler, for instances.

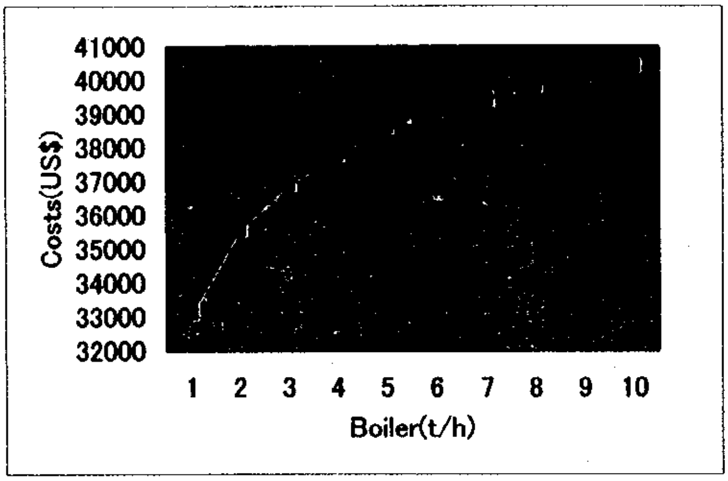


Figure 4-6-18 Conversion costs of fuel to DFO in Boilers

Figure 4-6-19 shows the conversion costs of fuel to LPG in heating furnaces in metal-processing factories, which have been prepared referring to a cost estimation made by an expert on furnaces. The costs are estimated to be US$17,900 for 1T/H furnace and US$18,900 for 5T/H, for instances. In addition, the conversion costs of fuel to LPG in "ovens" and "stoves" are estimated to be around US$8,000-8,500, because many of them are very small, as shown in the MEMSI's survey.

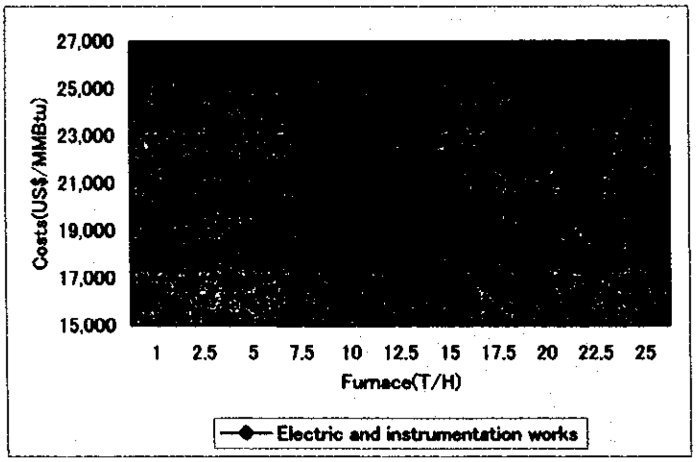


Figure 4-6-19 Conversion costs of fuel to LPG in furnaces

Figure 4-6-20 shows the costs of related construction works necessary for using gas inside factory sites, which have been prepared referring to a cost estimation made by an expert on gas supply. The costs are shown according to the scale of boiler, and, for other equipment and facilities, they can be measured by referring to a scale of boiler, the annual energy consumption of which is equal to energy consumed by the equipment or facilities. The costs are estimated to be US$6,900 for 1t/h boiler and US$28,400 for 10t/h, for instances.

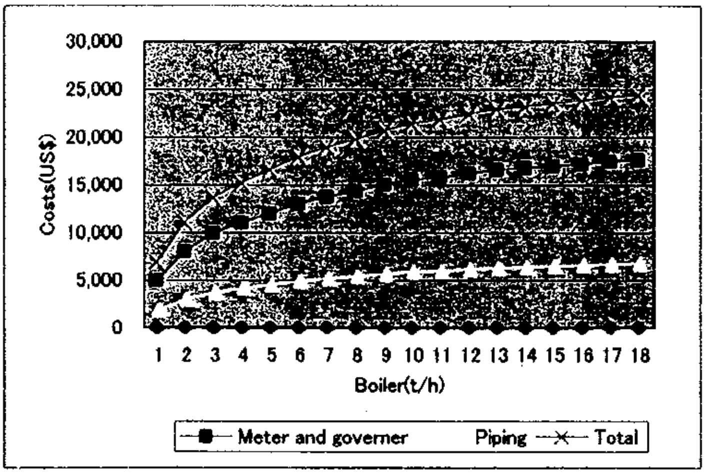


Figure 4-6-20 Costs of related construction works inside factory sites

Figure 4-6-21 and 4-6-22 show the payback period of investment for converting fuel for some boilers and heating furnaces, which have been selected from the MEMSI's survey (High Case). The payback periods will be less than three years for boilers with the capacity of larger than 1t/h after 2010 (Figure 4-6-21), and will be much shorter for all of three furnaces (Figure 4-6-22).

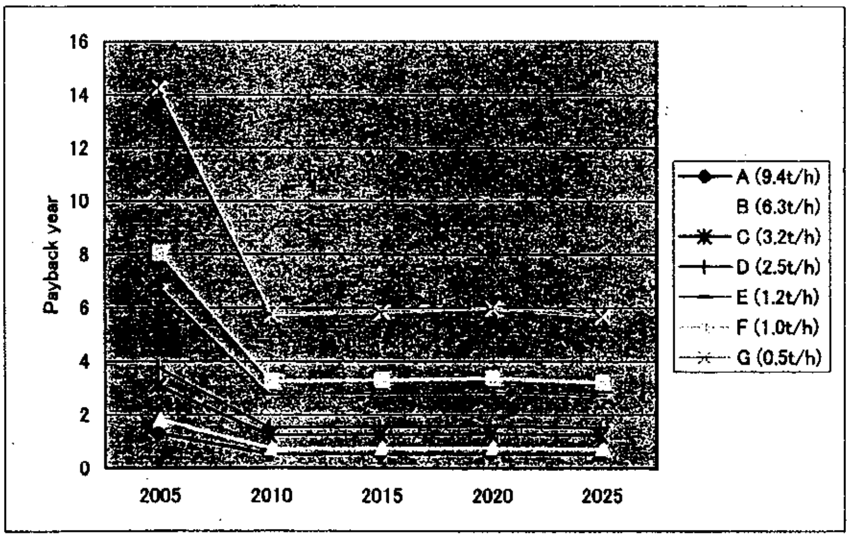


Figure 4-6-21 Payback period of converting DFO to gas for boilers (High Case)

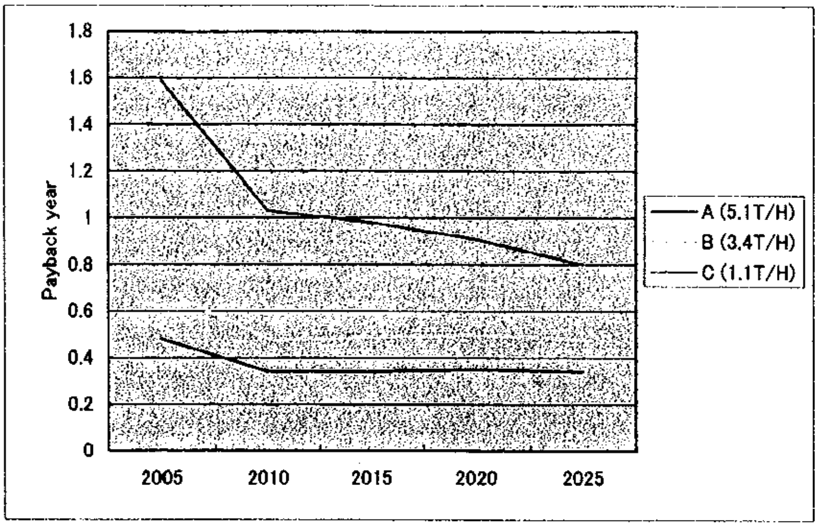


Figure 4-6-22 Payback period of converting LPG to gas for heating furnaces (High Case)

Figure 4-6-23 and 4-6-24 show the payback period of investment for converting fuel for some boilers and heating furnaces, which have been selected from the MEMSI's survey (Low Case). The payback periods will be less than three years for boilers with the capacity of 9.4 t/h after 2020 and for boilers with the capacity of 6.3 t/h in 2025 (Figure 4-6-23). Accordingly, we assume that no DFO will be converted at all for boilers. In contrast, the payback periods will be very short for all of three furnaces, although they will be not so short as in the High Case (Figure 4-6-24). Accordingly, we assume that LPG can be converted at higher ratios, as mentioned below.

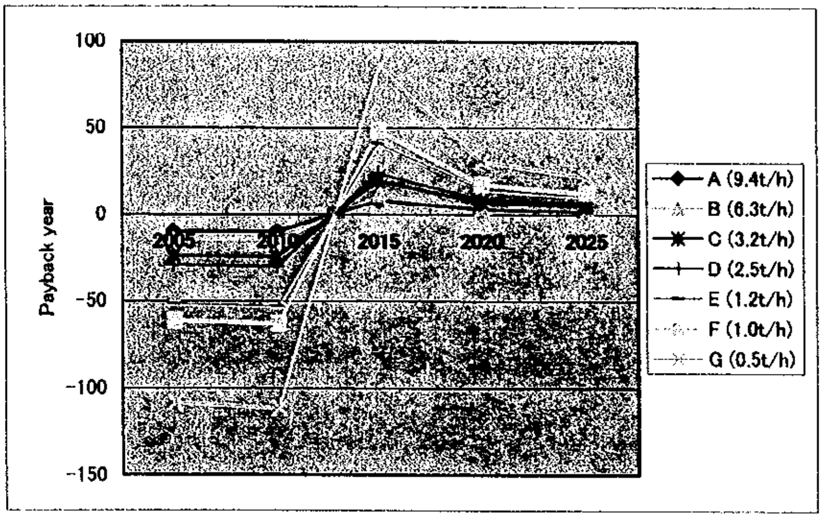


Figure 4-6-23 Payback period of converting DFO to gas for boilers (Low Case)

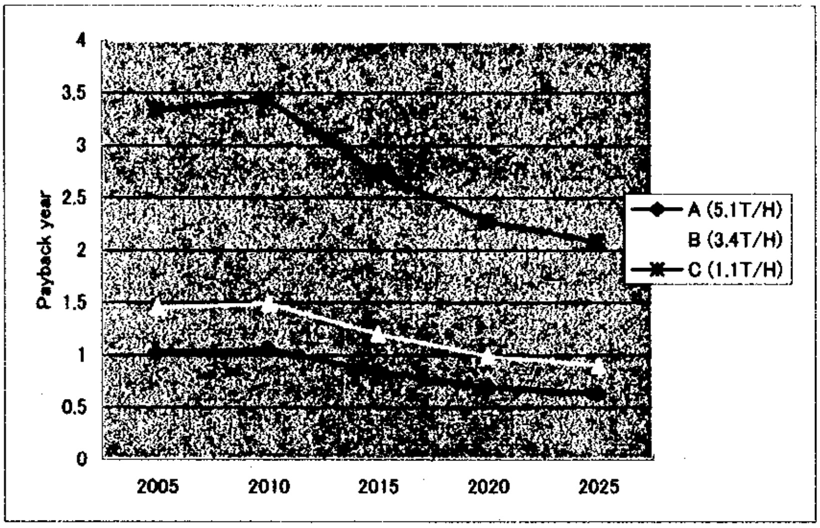


Figure 4-6-24 Payback period of converting LPG to gas for heating furnaces (Low Case)

b) Examination of the economics of gas use in newly built factories

We assume that there is no big difference between the construction costs of boilers and furnaces, including "ovens" and "stoves," whether they use DFO and LPG or gas, and that the latter will be selected as fuel if it is less expensive than the former. Assumed ratios, in which gas is selected by new factories (the gas use ratios), are shown in Table 4-6-39 below.

3) Assumption of gas conversion ratio and gas use ratio by industry in target areas

Based on estimated payback periods shown in 2) above and the estimated distribution of scale of equipment, we assume the gas conversion ratio and gas use ratio by industry in target areas in the following.

a) Existing factories (gas conversion ratio)

<High Case>

① Boiler (in every industry)

- 5t/h and larger than 5t/h, which account for 45% of the total in terms of energy consumption : Conversion ratio 60%
- 1t/h and smaller than 5t/h, which account for 40% of the total in terms of energy consumption : Conversion ratio 40%

·· Smaller than 1t/h, which account for 15% of the total in terms of energy consumption : Conversion ratio zero

② Heating furnace, "Oven," and "Stove"

·· 5t/h and larger than 5t/h, which account for 65% of the total in terms of energy consumption

Food & beverage : Conversion ratio 60%

Glass, metal-processing, machinery : Conversion ratio 70%

·· Smaller than 5t/h, which account for 35% of the total in terms of energy consumption

Food & beverage : Conversion ratio 50%

Glass, metal-processing, machinery : Conversion ratio 60%

<Low Case>

① Boiler (in every industry)

·· 5t/h and larger than 5t/h, which account for 45% of the total in terms of energy consumption : Conversion ratio zero

·· 1t/h and smaller than 5t/h, which account for 40% of the total in terms of energy consumption : Conversion ratio zero

·· Smaller than 1t/h, which account for 15% of the total in terms of energy consumption : Conversion ratio zero

② Heating furnace, "Oven," and "Stove"

·· 5t/h and larger than 5t/h, which account for 65% of the total in terms of energy consumption

Food & beverage : Conversion ratio 50%

Glass, metal-processing, machinery : Conversion ratio 60%

·· Smaller than 5t/h, which account for 35% of the total in terms of energy consumption

Food & beverage : Conversion ratio 50%

Glass, metal-processing, machinery : Conversion ratio 30%

b) Newly built factories (gas use ratio)

We assume the gas use ratios in newly built factories as shown below.

Table 4-6-39 Assumed gas use ratios for newly built factories

[New facilities] <High case>

Industry	Diesel fuel oil					LPG				
	2005	2010	2015	2020	2025	2005	2010	2015	2020	2025
	Boiler					Furnace, oven, and stove				
Food & beverages	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Textiles	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Paper & products	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Chemicals	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Rubber & products	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Glass & products	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Cement	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Basic precious and non-ferrous,others	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
Machinery & equipment	0.5	0.5	0.5	0.5	0.5	0.8	0.8	0.8	0.8	0.8
	Power gene.									
Food & beverages	0.2	0.3	0.4	0.5	0.5					
Textiles	0.2	0.3	0.4	0.5	0.5					
Paper & products	0.2	0.3	0.4	0.5	0.5					
Chemicals	0.2	0.3	0.4	0.5	0.5					
Rubber & products	0.2	0.3	0.4	0.5	0.5					
Glass & products	0.2	0.3	0.4	0.5	0.5					
Cement	0.2	0.3	0.4	0.5	0.5					
Basic precious and non-ferrous,others	0.2	0.3	0.4	0.5	0.5					
Machinery & equipment	0.2	0.3	0.4	0.5	0.5					

[New facilities] <Low case>

Industry	Diesel fuel oil					LPG				
	2005	2010	2015	2020	2025	2005	2010	2015	2020	2025
	Boiler					Furnace, oven, and stove				
Food & beverages	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
Textiles	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
Paper & products	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
Chemicals	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
Rubber & products	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
Glass & products	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
Cement	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
Basic precious and non-ferrous,others	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
Machinery & equipment	0.4	0.4	0.4	0.4	0.4	0.0	0.7	0.7	0.7	0.7
	Power gene.									
Food & beverages	0.1	0.2	0.3	0.4	0.4					
Textiles	0.1	0.2	0.3	0.4	0.4					
Paper & products	0.1	0.2	0.3	0.4	0.4					
Chemicals	0.1	0.2	0.3	0.4	0.4					
Rubber & products	0.1	0.2	0.3	0.4	0.4					
Glass & products	0.1	0.2	0.3	0.4	0.4					
Cement	0.1	0.2	0.3	0.4	0.4					
Basic precious and non-ferrous,others	0.1	0.2	0.3	0.4	0.4					
Machinery & equipment	0.1	0.2	0.3	0.4	0.4					

Table 4-6-40 Estimated potential gas demand by industry and by fuel (High Case)

LPG

	2000	2005	2010	2015	2020	2025
(ton)						
NCR	59,165	81,785	137,445	185,036	247,827	324,846
L-2	15,874	22,276	38,954	52,424	70,197	92,618
L-3	4,140	5,816	10,199	13,726	18,380	24,223
C-M	10,968	15,320	26,525	38,234	47,762	63,258
D	9,633	13,536	23,807	32,020	42,856	56,374
Total	99,779	138,733	236,930	321,440	427,022	561,320
(ktoe)	129.71	180.35	308.01	417.87	555.13	729.72
(mmscfd)	12.77	17.75	30.31	41.13	54.63	71.82

DFO

	2000	2005	2010	2015	2020	2025
(1,000 kl)						
NCR	20,396	29,338	63,895	113,585	192,427	268,992
L-2	4,076	6,860	11,849	20,521	34,164	47,555
L-3	990	1,855	3,648	6,808	11,891	16,743
C-M	2,619	4,602	8,407	15,064	25,652	35,903
D	2,211	3,867	7,025	12,548	21,324	29,830
Total	30,292	46,522	94,824	168,526	285,458	399,023
(ktoe)	26	39	80	143	242	338
(mmscfd)	2.53	3.88	7.91	14.05	23.80	33.27

Table 4-6-41 Estimated potential gas demand by industry and by fuel (Low Case)

LPG

	2000	2005	2010	2015	2020	2025
(ton)						
NCR	45,710	57,020	76,372	107,539	138,935	209,171
L-2	12,548	15,749	21,226	30,720	39,606	76,757
L-3	3,277	4,116	5,550	8,048	10,375	20,103
C-M	8,622	10,798	14,521	20,876	26,916	52,169
D	7,643	9,595	12,934	18,793	24,211	46,863
Total	77,800	97,277	130,604	185,975	240,042	405,062
(ktoe)	101.14	126.46	169.78	241.77	312.06	526.58
(mmscfd)	9.95	12.45	16.71	23.79	30.71	51.82

DFO

	2000	2005	2010	2015	2020	2025
(1,000 kl)						
NCR	0	4,194	16,103	28,601	45,954	66,021
L-2	0	865	3,850	6,617	10,441	14,884
L-3	0	243	1,062	1,857	2,948	4,224
C-M	0	592	2,843	4,828	7,557	16,841
D	0	492	2,226	3,828	6,035	8,607
Total	0	6,387	26,084	45,730	72,935	110,578
(ktoe)	0	5	22	39	62	94
(mmscfd)	0.00	0.53	2.17	3.81	6.08	9.22

Chapter 5　Natural Gas Supply Systems

5-1　Natural Gas Systems by Supply Source

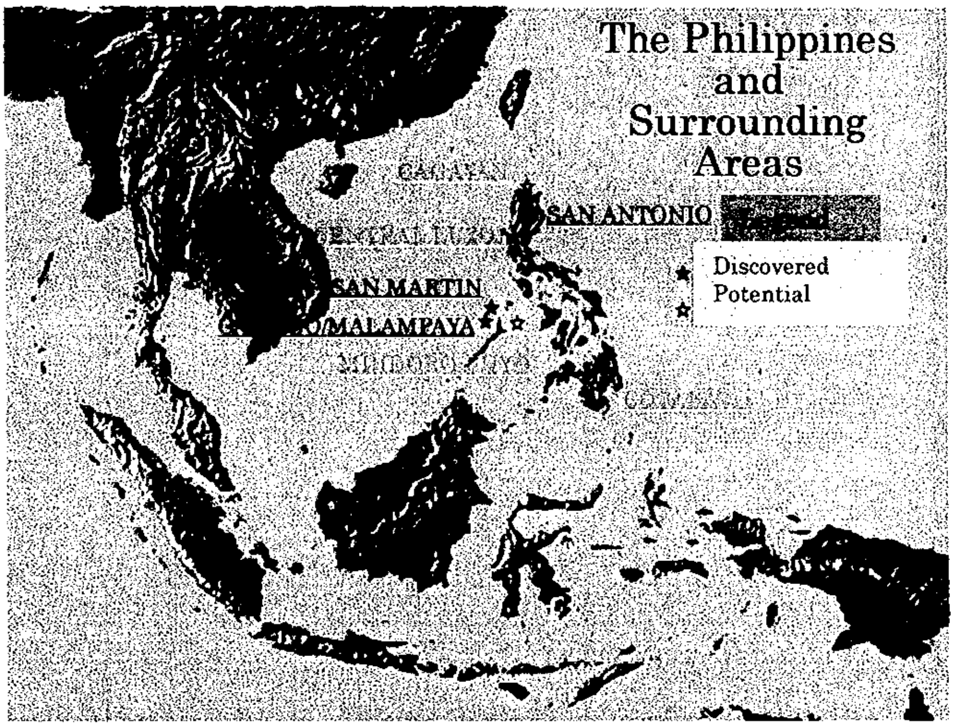
5-1-1　Indigenous Natural Gas

Table 5-1-1　Natural Gas Supply Sources

	Gas Fields	Minimum (BCF)	Prospective (BCF)	Maximum (BCF)
Proven	Camago/Malampaya	2,528	3,340	4,277
	San Martin	243	359	454
	San Antonio		4	
Potential	Mindoro-Cuyo	2,720	7,060	11,210
	Cotabato	60	1,158	1,760
	Cagayan	176	322	518
	Central Luzon	78	637	2,594

(Source) PNOC

Figure 5-1-1　Major Philippine Gas Fields



Potential reserves are not well confirmed and relevant gas fields need exploration and examination. This study will count only on proven fields. Further, as San Antonio has very few proven reserves, we will consider only Camago/Malampaya, and San Martin.

This Master Plan study assumes only proven reserves mentioned above. We will further study the effect on this plan of additional gas reserves of a range of one to five TCF which might get proven in a few years at the end of this chapter.

5-1-2 Supply and Demand Balance of Indigenous Natural Gas

Natural gas from Camago/Malampaya will be supplied to the three power plants (total power generation: 2,725 MW) shown in Table 5-1-2.

Table 5-1-2 Power Plants for Natural Gas from Camago/Malampaya

	Ilijan	Santa Rita	San Lorenzo
Capacity (MW)	1,200	1,000	525
Company	KEPCO Ilijan Corp.	First Gas Power Corp.	First Gas Power Corp.
Off taker	NPC	Meralco	Meralco
Commencement	2002	2000	2002

If we assume the capacity factor of the plants to be 75% and power generation efficiency to be 45% (based on a high heating value), it would amount to 365 mmcfd in terms of gas.

Figure 5-1-2 shows the relationship between these values and supply capacity and indigenous domestic natural gas reserves. At present, the Camago/Malampaya gas field has a platform capacity of 500 mmcfd and a sub-sea pipeline capacity of 650 mmcfd. From these figures, we calculate that there is a 135 mmcfd surplus supply of domestic gas (equivalent to 1,000 MW of power generation).

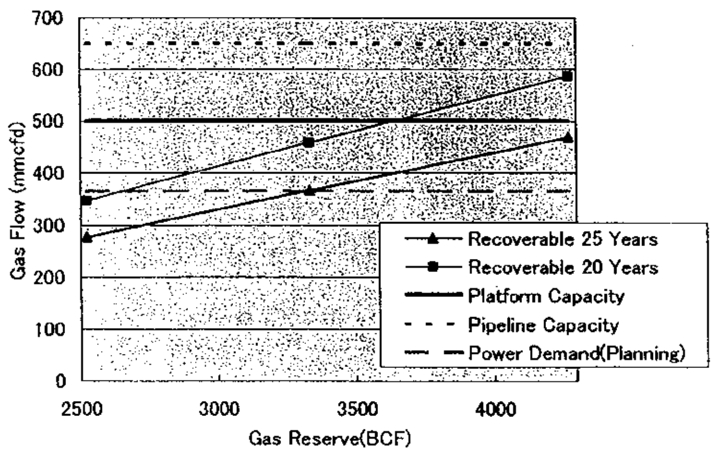


Figure 5-1-2 Supply Volume of Natural Gas from Camago/Malampaya

5-2 LNG Supply and Demand Balance and Prospective LNG Sources

5-2-1 Asian LNG – Current Status and Outlook

Natural gas consumption in Asia increased smoothly following the high economic growth in the early 1990s. LNG trade was also increasing in Japan, Korea, and Taiwan. Average growth rate of LNG imports in the region was 6.5%/year in the 1990-1999 period.

Since the Asian currency crisis in 1997, however, economic recession in the region has obscured the outlook for natural gas use and LNG imports. Under these circumstances, an example of the outlook for the LNG demand is shown in Table 5-2-1. The demand for LNG will still increase according to this table; its yearly growth, however, will be slower. The average growth rate for the period 1999-2010 is estimated at 4.2 %/year.

On the other hand, if we look at specific regions, Taiwan, for example, is bullish about the use of LNG for newly planned IPPs expecting a high growth of an average of 8%/year. India and China, each having potentially huge appetites for energy, are planning to import LNG, increasing the demand for LNG. Aggregate LNG demand in Asia in the next 10 years will be heavily affected by the factors of LNG use in Taiwan, India, and China.

Table 5-2-1 Asian LNG Demand Outlook (Million tons p.a. [1])

		1999 (actual)	2010
Japan	Total	51.3	64.0
	Gas	14.3	22.5
	Power	37.0	41.4
	Other	0.0	0.1
Korea		12.9	22.0
Taiwan		4.2	11.0
Subtotal		68.4	97.0
India and China, etc.		0	11.0
Grand Total		68.4	108.0

Source: IEEJ (2000)

5-2-2 LNG Supply for Asia

To match the fast economic growth in Asia in the early 1990s, LNG liquefaction

[1] 1 mil. tons. p.a. (mta) LNG (10,500 kcal/Nm^3)= 140 mmscfd (9,530 kcal/Nm^3) methane

projects for The Asian market flourished with expansions of various existing plants and newly built ones, expanding the supply availability.

Table 5-2-2 lists LNG Liquefaction projects for Asian markets, which shows the current supply availability of 78.3 mta (Million tons per annum) at the end of 1999. Additional projects under construction or in preparation after contract closing amount to 23.4 mta, and further new negotiations are on going for 7.0 mta. Overall, it is expected that the supply availability will reach 109 mta in 2010.

Table 5-2-2 LNG Projects for Asian Markets

	Liquefaction capacity (Million t /y)	Remarks
Existing		
Asian Pacific	64.30	
Abu Dhabi	5.50	
Qatar (Qatargas and Ras Laffan)	8.50	
Subtotal	78.30	
Constructing or Contract or LOI Awarded		
Oman	6.60	Started in 2000
Qatar/ Ras Laffan	10.00	
Malaysia MLNG3	6.80	Targeted for 2003 inception 2003
Subtotal	23.40	
Progressing to Contract		
Australia NWS Expansion	7.00	MOU with Tuntex Gas signed
Subtotal	7.00	
Others in Planning		
Yemen	5.30	Targeted for 2003 operation
Gorgon (off NWS)	6.00	Targeted for 2005
Tangu (Indonesia)	6.00	
Bayou/Undan (Australia and Indonesia)	3.00	Targeted for 200, but BHP having retired in April 1999.
Sakhalin II (Russia)	8.00	Targeted for 2005 operation
Darwin (Australia)	7.50	Targeted for 2005or later
Iran	4.30	Considered for India
North Slope (Alaska)	14.00	Planned for 2007 inception
Scarborough (Australia)	5.00	
Natuna (Indonesia)	15.00	Targeted for 2007 or later
Papua-New Guinea	4.00	Targeted for 2005
Sub-total	78.60	
Grand Total	186.80	

(Source) IEEJ

5-2-3 LNG Supply and Demand Balance Estimated

Figure 5-2-1 shows the LNG supply – demand balance based on the outlook stated projects for The Asian market flourished with expansions of various existing plants and newly built ones, expanding the supply availability.

Table 5-2-2 lists LNG Liquefaction projects for Asian markets, which shows the current supply availability of 78.3 mta (Million tons per annum) at the end of 1999. Additional projects under construction or in preparation after contract closing amount to 23.4 mta, and further new negotiations are on going for 7.0 mta. Overall, it is expected that the supply availability will reach 109 mta in 2010.

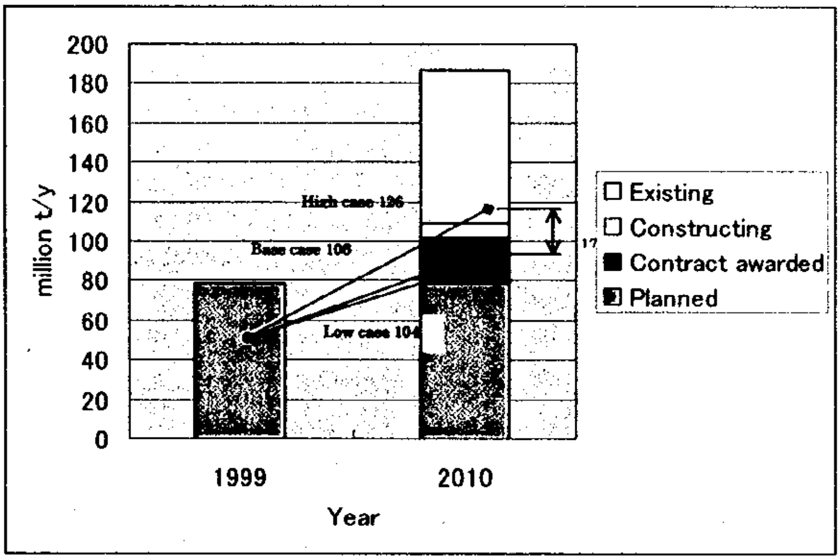
Table 5-2-2 LNG Projects for Asian Markets

	Liquefaction capacity (Million t /y)	Remarks
Existing		
Asian Pacific	64.30	
Abu Dhabi	5.50	
Qatar (Qatargas and Ras Laffan)	8.50	
Subtotal	78.30	
Constructing or Contract or LOI Awarded		
Oman	6.60	Started in 2000
Qatar/ Ras Laffan	10.00	
Malaysia MLNG3	6.80	Targeted for 2003 inception 2003
Subtotal	23.40	
Progressing to Contract		
Australia NWS Expansion	7.00	MOU with Tuntex Gas signed
Subtotal	7.00	
Others in Planning		
Yemen	5.30	Targeted for 2003 operation
Gorgon (off NWS)	6.00	Targeted for 2005
Tangu (Indonesia)	6.00	
Bayou/Undan (Australia and Indonesia)	3.00	Targeted for 200, but BHP having retired in April 1999.
Sakhalin II (Russia)	8.00	Targeted for 2005 operation
Darwin (Australia)	7.50	Targeted for 2005or later
Iran	4.30	Considered for India
North Slope (Alaska)	14.00	Planned for 2007 inception
Scarborough (Australia)	5.00	
Natuna (Indonesia)	15.00	Targeted for 2007 or later
Papua-New Guinea	4.00	Targeted for 2005
Sub-total	78.60	
Grand Total	186.80	

(Source) IEEJ

5-2-3 LNG Supply and Demand Balance Estimated

Figure 5-2-1 shows the LNG supply – demand balance based on the outlook stated above with three additional demand cases; i.e., high, base, and low. The balance in the base demand case in 2010 approximately coincides with the aggregate supply availability of existing and planned projects. In the low demand case, there will be a surplus of 5 mta in supply. In the high demand case, an additional 17 mta may be required from further planned projects, which in aggregate have a capacity of 78.6 mta, causing almost no shortage.



Cases: Base: IEEJ (May 2000); High and Low: other institutes
(Source) IEEJ 2000

Figure 5-2-1 LNG Supply Demand Balance in Asia

5-2-4 LNG Source Availability for the Philippines

Table 5-2-3 below shows projects having a physical surplus capacity with no commitment yet, which might be considered in our perspective for the Philippines.

Table 5-2-3 LNG Supply Projects with Possible Availability for The Philippines

Country of Supply	Project	Gas Fields	Proven Reserves (TCF)	Product-ion (mta)	Sponsors (Interest %)	Buyers (Quantity mta)	Surplus Availability mta (year)	Investment (Billion US$)	Remarks (Progress, etc. as of 2000; mta)
Qatar	Qatargas	North Field	250	6.00	QGPC (65), ExxonMobil (10), Total (Upstream20, Plant10), Mitsui (Up 2.5, Plant 7.5), Marubeni (Up2.5, Plant7.5))	Japan: Electric Powers (Tokyo, Chubu, Kansai, Kyushu) 4.0; Gas (Tokyo, Osaka, Toho) 2.0			Started January 1997. Price still under negotiation.
	Ras Laffan	North Field	250	10.00	QGPC (63), ExxonMobil (25), KLNG (5), Itochu (4), NIC (3)	Korea (4.8), India (7.5), India (2.5)	1.4 (2001); Qatargas+ Ras Laffan expansion 10.0 (2005)	Upstream: 1.6; Liquefaction 4.0; Transportation 3.0	Started for Korea in 1999 (0.66); India: Petronet (HOA 7.5), TIDCO (bid 2.5)
Oman	Oman	Saih Raoul Saih Niata Balik	10	6.60	Oman (51), Shell (30), Total (5.54), Mitsui (2.77), Mitsubishi (2.77), Itochu (0.92), Partex (2), Samsung, Daewoo, Hyundai (each 1), KGC(1.2), SK(0.8)	Korea (4.0), Osaka (.66), India (Bid 1.6)	Existing 0.85(2000) 3rd train 3.35(2004)	Upstream: 1.4; Liquefaction: 2.4 Transportation: 1.5	To start Enron Dabhol in 2000
Yemen	Yemen	Malibu	10	5.20	Total (36), ExxonMobil (14.5), Hunt (15.1), Yemen (21), SK (8.4), Hyundai (5)	India (MOU 2.65)	2.55 (2004)	Downstream: 2.5	BG Pipavau: MOU for 2002; May be delayed to 2003
Indonesia	Natuna	D-Alpha	45	14.00	ExxonMobil (76), Pertamina (24)	Not yet contracted	14.0 (yet)	Upstream: 3.8 Downstream: 2.600	High cost for CO2 removal; long-term perspective
	Tangu (Irian Jaya)	Wiriagar	14	6.00	BP (80), Kanematsu (20)	Yet	6.0 (yet)	Upstream: 1.5 Downstream: 3.0	Proven reserves reached 10 TCF; Indonesian first priority.
		Belau			BP (48), Kanematsu (12), Occidental (22.86), Nippon Oil (17.14)				
		Mutuli			BG (52.63), Cairns (47.37)				
Malaysia	MLNGⅢ	SK-8 SK-10	7.5	6.80	Patrons (60), Shell (10), Nippon Oil (10), Occidental (10), Sarawak Province (10)	Japan (LOI 0.5), India (MOU 2.6)	3.7 (2003)	Upstream: 1.3; Liquefaction: 2.0 Transportation: 5.0	To begin exports in 2001. Marketing.
Papua New Guinea	Onshore	Hides	6	4.00	ExxonMobil, Oil Search	Yet	4.0 (yet)		Targeting China for 2005.
Australia	North West Shelf (Expansion)	N. Rankin Goodwyn Belceus	18	7.00	BHP, BP, Shell, Chevron, Woodside Petroleum, MIMI (each 16.7)	Yet (Japan bidding)	7.0? (2004)	Upstream: 1.5 Liquefaction 2.0 Transportation: 1.25	Expansion of existing trains (7.5 mat) targeting 2003.
	Gorgon	Gorgon Criseo	7~14	6.00	WAPET (Shell (28.6), Chevron (28.6), Texaco (28.6), ExxonMobil (14.3))	Yet	6.0 (2007)		Targeting 2005 for starting; China?
	Darwin	Sunrise, Travador, Evans, Crosston	10~	7.50	Shell (50), Woodside Petroleum (50)	Yet	7.5 (yet)		Target 2005. Choice of domestic supply too?
	ZOCA	Bayous, Undan	2.5~6	2.00 ~ 3.00	BHP, Phillips	Yet	2.0~3.0 (yet)		Indefinite delay (March 1999)?
	Scarborough	Scarborough	8	5.00	BHP (50), ExxonMobil (50)	Yet	5.0 (yet)		
	Scot Reef	Scot Reef, Freenock	15~20		Woodside Petroleum(50), Chevron. (each 16.7), BHP · Shell(each 8.3)	Yet	Yet		
US (Alaska)	North Slope	North Slope	32	14.00	BP, ExxonMobil, Yukon Pacific	Yet	14.0 (2007)		Target 2007. 700km of pipelines needed.
Russia	Sakhalin 2	Lunskoye, Piltun Astokhskoye	14	8.00	Marathon (37.5), Mitsui, Shell (each 25), Mitsubishi (12.5)	Yet	18.00 (2007) incl. Sakhalin I		Oil production in 1999; LNG in 2005 or later.
	Sakhalin 3	Kirin, Aiyash	Yet	Yet	ExxonMobil, Texaco, Rossneft'	Yet	Yet		Rossneft' participating; candidate for PS contract.

(Notes) mta = Million tons per annum

5-3 Supply System

5-3-1 Overview

In order to build a supply system, it is essential to determine natural gas demand, supply areas, receiving terminals, and target year of supply system.

(1) Natural Gas Demand and Supply Areas

Usage of natural gas is considered for power generation use, industrial use, commercial use, and residential use. The amount of natural gas for power generation is greater than that for any other use, and it will have strong impact on the supply system.

Therefore, it is necessary to take into consideration the Philippines' overall construction plans for power supply facilities.

Capacities of 12,000 MW, 500 MW, and 500 MW in demand are respectively allocated to Luzon Island (Area L), the Cebu-Mactan area (Area C-M), and the Davao area (Area D). This is determined on the condition that the Philippines' total demand for power generation from natural gas at 2025 that will be approximately 13,000 MW (Refer to "Chapter 4 Estimation of "Potential" Gas Demand in Target Areas").

(2) Natural Gas Demand in Each Target Area

1) Area L

Batangas and the southern part of the Bataan Peninsula, where natural gas power plants are under construction or planning, are assumed to be big demand areas for natural gas.

Sucat Power Plant and the generation of electricity in the industrial areas of the Laguna and Batangas are also assumed to be demand areas of natural gas.

Assumed natural gas supply areas for industrial, commercial, and residential use are the Cavite, Laguna, and Batangas areas (Area L-2) and the Bulacan, Pampanga, Rizal, and Bataan area (Area L-3), besides the NCR area (Area L-1) as a major consumption area.

2) Area C-M

Assumed natural gas supply areas for industrial, commercial, and residential use are Cebu, Mandaue, and their vicinities (Consolacion, Cordora, Composta, Liloan, Minglanilla, and Naga).

3) Area D

Assumed natural gas supply areas for industrial, commercial, and residential use are Davao, Davao del Sur, Davao del Norte, Davao Oriental, Compostela Valley, and their vicinities.

(3) Depot Terminals of Natural Gas

The most efficient system will be constructed if the receiving terminals of natural gas are close to where natural gas is supplied. Therefore, the following receiving terminals are assumed for the respective natural gas sources.

1) Receiving Terminal of Domestic Natural Gas

The Tabangao Base in Batangas has been serving as a landing base for natural gas from Camago/Malampaya.

Natural gas will be transported from here to Area L through pipelines.

2) Receiving terminal of Imported LNG

In Area L, the proposed construction sites of receiving terminals of imported LNG are assumed to be in the Batangas area (Area L-2) and the southern part of the Bataan Peninsula (Area L-3).

In Area C-M, the proposed construction site of a receiving terminal is assumed to be in the coastal area in the suburbs of Cebu.

In Area D, the proposed construction of a receiving terminal is assumed to be in the suburbs of Davao.

3) Receiving Terminal of Trans-ASEAN Pipeline Natural Gas

The receiving terminal of the Trans-ASEAN pipeline gas is assumed to be located in the Batangas area, where the landing terminal of domestic natural gas is now located.

(4) Target Year

The target year of this project is set to 2025.

The transportation limit of the supply system will be considered to expire around the target year.

5-3-2 Candidates for a LNG-receiving terminal

(1) Area L-2: Batangas

LNG distributed via the pipeline from Camago/Malampaya is lifted at the gas processing and purification plant in Batangas. This location is within easy reach of major consumers: the Santa Rita and San Lorenzo power plants are 7 km to the west, and the Ilijan power plant lies 15 km to the south. A Shell refinery neighbors the lifting site, and other refineries and factories are located along the coastline of Batangas Bay, making the area into an industrial complex. Because the bay is deep enough to accommodate oil tankers and there is vacant flat land available, the area is a powerful candidate for a LNG-receiving terminal.

(2) Area L-3: Limay, Eastern Coast of the Bataan Peninsula

Because of its distance from Batangas, where the LNG from Camago/Malampaya is lifted, for security reasons it would make sense to build a second LNG supply terminal at Limay, taking into consideration a plan to develop a LNG trunk line network around the NCR (National Capital Region) of Luzon Island.

We had wanted to use a part of the premises of PNOC-OC (Philippine National Oil Company Petrochemicals), which is approx. 5 km to the south of the center of Limay, but manufacturing plants for ethylene and PVC (polyvinyl chloride) are being planned or implemented there. Because the only areas available for a LNG terminal are inland, it would be difficult to locate a LNG-receiving terminal there.

Alternate candidates for the terminal include the land for the NPC (National Power Corporation) power plant, which is within 1 km to the south of the center of Limay, and the land for NPC's CCGT power plant (operated by ABB ALSTOM), which is adjacent to the power plant.

They are also planning to build a LNG-receiving terminal and LNG power plant in Mariveles, which is at the southern tip of the Bataan Peninsula. If the plan goes through as scheduled, operations should start in 2005. Because of this, Mariveles is another potential candidate for a LNG-receiving terminal.

(4) Areas C-M

We had hoped to use part of a 300ha tract of the southern reclaimed land, which is being constructed in the southern part of Cebu. However, we would not be allowed to establish an energy-related relay station there, because the land is being created especially for export businesses for IT and other types of light industry. Furthermore, we cannot build large berths there because they have built an expressway along the coast. Thus, we have discounted this area as a candidate.

As an alternative, we may build a LNG-receiving terminal on the land along the coast in Talisay, which is a few kilometers south of the center of Cebu (to the south of the southern reclamation project). There are natural advantages to the area, such as flat topography and deep water, which gets still deeper to the south. The land is owned by the government and private businesses, and will be for sale. For our master plan, we are assuming the terminal will be built in this vicinity.

The coastal area stretching from Talisay down to Naga is another possible candidate. Although Naga is somewhat far from the center of Cebu, the city is host to a power plant and a cement factory, whose demand could be satisfied by the LNG terminal.

(5) Area D

Candidates for an LNG receiving terminal include: Sta. Cruz, which is approx. 45 km to the south of Davao; Malalag, approx. 100 km from the city; and Panabo, approx. 40 km to the north of the city.

In Sta. Cruz, there is a company called Prycegas, which accepts LPG. The locale also hosts a port for coconut exports.

The vicinity of Panabo is basically an industrial area. When an expansion of Sasa Port, the largest port in Davao, was planned, Panabo was cited as a potential candidate, and a 500 ha tract of reclaimed land is being projected. Panabo would be the top candidate for an LNG loading and filling terminal in the vicinity of Davao. By sea, Panabo could be reached by a route that runs to the east of Samar Island, because the Pakiputan Strait between Mindanao and Samar Islands is very narrow (1 km) and very busy.

5-3-3 Supply Options

(1) Supply Options in Area L

Based on natural gas supply areas and transmission pipeline routes, the following two

Options are studied.

1) Option 1

An option where the LNG terminal to be built in Area L-3 is connected to the landing terminal of domestic natural gas in Area L-2 through a transmission pipeline, which will be located along the coast of Manila Bay. Natural Gas is supplied to Areas L-1, L-2, and L-3.

2) Option 2

An option where the LNG terminal to be built in Area L-3 is connected to the landing terminal of domestic natural gas in Area L-2 through a transmission pipeline crossing Manila Bay. Natural gas is supplied to Areas L-1, L-2, and L-3.

(2) Supply Options in Areas C-M and D

An option where natural gas from the following resources is supplied to these two areas for generation, industrial, commercial, and residential use.

1) Use of Domestic Natural Gas

Natural gas will be supplied through a national pipeline, which will connect the landing terminal in the Batangas area.

2) Use of Imported Natural Gas

LNG terminals will be built in Area C-M and Area D, from which natural gas will be supplied.

3) Use of Natural Gas through Trans-ASEAN Pipeline

Natural gas is supplied to Area C-M and Area D through the Trans-ASEAN Pipeline.

5-3-4 Analysis of Transmission Pipeline Network

(1) Formula of Transmission Pipeline Flow Rate

A transmission pipeline network should be considered using a transportation formula to decide the proper diameter of the pipe. The following general flow equation is used in this project.

$$Q = 0.2394 \cdot (T_0/P_0) \cdot \sqrt{(1/(z \cdot T))} \cdot \sqrt{(1/f)} \cdot \sqrt{((P_1^2 - P_2^2) \cdot D^5/(S \cdot L))}$$

Where,

Q	:	Flow rate [$m^3 \cdot h$]
P_1	:	Start point pressure [kg/cm^2]
P_2	:	End point pressure [kg/cm^2]
D	:	Diameter of pipe (cm)
S	:	Gas specific gravity [air = 1.0]
L	:	Extension [m]
T	:	Gas temperature [°K]
T_0	:	Base temperature [°K]
P_0	:	Base pressure [kg/cm^2]
z	:	Compressibility factor
$\sqrt{(1/f)}$	:	Transmission Factor of Line

The following values are used for the consideration of the projected network.

Table 5-3-1 Values of Formula for General Flow Equation

Parameter	Value or formula
Gas specific gravity (S)	0.595 (air = 1.0)
Gas temperature (T)	25°C
Compression coefficient (z)	AGA formula
Transportation coefficient $\sqrt{}$ (1/f)	PanhandleA formula

(2) Calculation of Pile Load (Peak- hourly Sendout)

In order to analyze the transmission pipeline network, it is necessary to assume the peak-hourly sendout. Usually, gas flow rate per hour (m^3/h) is used to estimate the peak-hourly sendout. The value is obtained from the amount of daily demand multiplied by the peak rate.

The peak rate is determined by investigating the conditions of gas usage for each gas sector in the past. Because there is no actual data on gas usage in the Philippines, actual data in Japan are used as the peak rates in Table 5-3-2.

Table 5-3-2 Peak Rate

Sector	Peak Rate
Industrial use	0.0625
Commercial use	0.0625
Residential use	0.0625
Transportation use	0.0833

On the other hand, the hourly gas flow rate of power generation is calculated from the capacity of power generation (MW) as shown below.

(Hourly Gas Flow Rate) [Nm^3/h]
= (Capacity of power generation) [kW] × 860 [kcal/kWh]
÷ (Calorific value) [$kcal/Nm^3$] ÷ (Power generation efficiency)

A calorific value of 10,161 $kcal/Nm^3$ and a power generation efficiency of 45% are applied.

(3) Sendout Pressure and Supply Pressure

The send-out pressure of 7.0 MPa, which is often used to study transmission pipeline networks, is applied.

The lowest supply pressure at supply points is set at 1 MPa.

(4) Determination of Pipe Load

With the method specified in (2) used, the peak-hourly gas flow rate required at each supply point is calculated based on estimated demand. The sum total of each sector's peak-hourly gas flow rate at the each supply point is used to analyze the pipeline network.

Under the above conditions, the transmission pipeline network that can be supplied gas until the final year is determined.

5-3-5 Analysis of Distribution Pipeline Network

(1) Formula of Distribution Pipeline Network

1) Formula for Medium- or High- pressure Distribution Pipeline

The same formula for the transmission pipeline is used for or medium- or high-pressure distribution pipeline network analysis.

Usually, however, the PanhandleA formula is applied as a transmission factor to high-pressure lines and the IGU formula is applied to medium-pressure lines.

2) Formula for Low-pressure Distribution Pipeline

Generally, the following formula modified from the transportation pipeline formula is used.

$Q = (0.0587 \cdot \sqrt{(1/f)} \cdot \sqrt{((P_1 \cdot P_2) \cdot D^5/ (S \cdot L))}$

Where,

Q	:	Flow rate [m^3 per hour]
P_1	:	Starting point pressure [kg/cm^2.abs]
P_2	:	Terminal point pressure [kg/cm^2.abs]
P1 + P2	:	$2 \times (1.033 + 0.22) \times 10^{-4}$ [kg/cm^2.abs]
D	:	Pipe diameter (cm)
S	:	Specific gravity of gas [air = 1.0]
L	:	Extension [m]
T	:	Gas temperature [300.15k]
T_0	:	Base temperature [300.15k]
P_0	:	Base pressure [1.033 kg/cm^2.abs]
z	:	Compressibility factor
$\sqrt{(1/f)}$	:	Transmission factor of line (Muellar's formula)

(2) Distribution Pipeline System

1) Gas through the high-pressure distribution pipeline network is reduced by regulators near the supply area, and is supplied to the medium-pressure distribution pipeline network. Gas can be directly supplied through the high-pressure distribution pipeline network for power generation in the industrial areas.

2) In the supply area, gas is distributed through the medium-pressure pipeline network. The pressure of gas is reduced by regulators in the area and supplied to each house through the low-pressure distribution pipeline network. Gas can be directly supplied through medium-pressure distribution pipelines for commercial use, such as hotels, hospitals, and supermarkets.

3) An outline of pipes used for the distribution pipeline network is shown in Table 5-3-3.

Table 5-3-3 Outline of Pipes Used with Distribution Pipeline Network

Type	Pipe material	Pipe diameter	Pressure range
High-pressure distribution pipe	Steel pipe (weld pipe)	24"~8"	2 MPa~0.4 MPa
Medium-pressure distribution pipe	Polyethylene pipe	8"~4"	0.4 MPa ~ 30 kPa
Low-pressure distribution pipe	Polyethylene pipe	3"~ 1 "	3 kPa~1 kPa

(3) Method of Analyzing Distribution Pipeline Network

Usually, the locations of distribution points and the amount of demand at each distribution point are grasped. Then, the formula for the flow rate is used in the same way as the transmission pipeline network to determine the best distribution network. As the demand forecast of this study is macro estimation, we can get information on the distribution points. Therefore, the above-mentioned network analysis cannot be studied.

So, we use the actual distribution network system in Japan for reference, and get information on the amount of distribution pipeline network facilities (including pipes, pressure governors, and valves) per 1 km^2.

5-3-6 Study on Transmission Pipeline Network

Based on the supply scenarios in 5-3-3, the following transmission pipeline networks in the target areas are studied. Two Cases (High and Low) of gas demand are considered in Chapter 4. The pipeline networks in these cases are studied.

(1) Area L – Option 1

The LNG terminal constructed for power plants in Area L-3 will be connected to the landing terminal for domestic natural gas in Area L-2 through a transmission pipeline along the coast of Manila Bay.

Gas will be supplied to Areas L-1 and L-2 first, and finally to Area L-3.

Phase 1	Priority will be given to Areas L-1 and L-2. Domestic gas will be transported from the landing terminal for domestic gas in the Batangas area.
Phase 2	By the year when the capacity of the transmission pipeline in the above-mentioned section reaches its limit, a new pipeline will be constructed along the coast of Manila Bay to connect the LNG terminal in Area L-3 and the Phase 1 transmission pipeline.

Thereby, the double-source and two-terminal system for domestic and imported natural gas will be established and ensure a gas stable supply (See Figures 5-3-1 and 5-3-2).

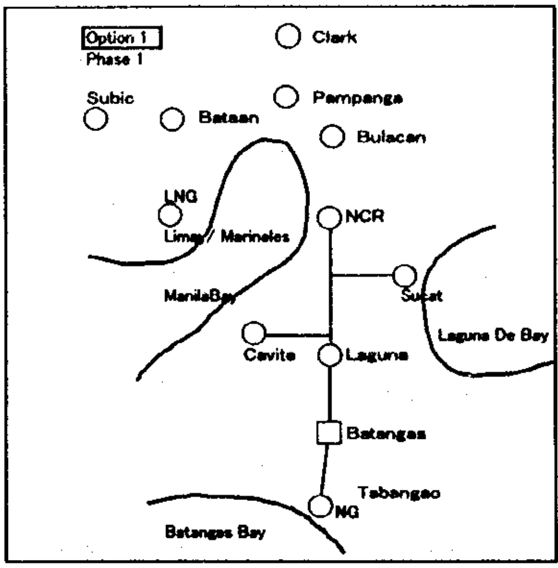


Figure 5-3-1 Area L -Option 1 (Phase 1)
(2006 to 2015)—High Case
(2006 to 2012)—Low Case

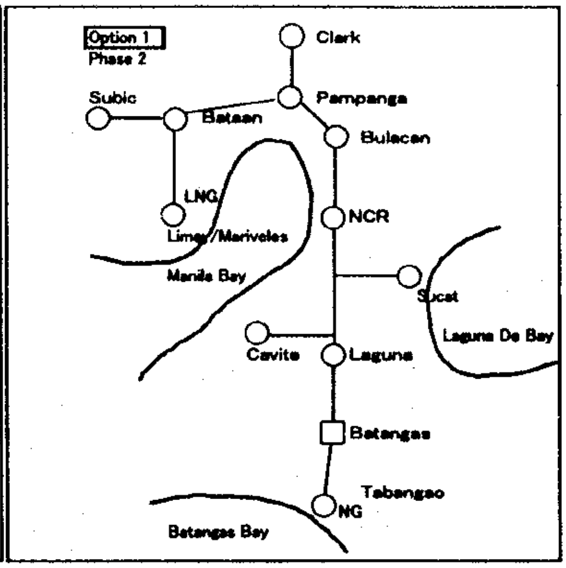


Figure 5-3-2 Area L–Option 1 (Phase 2)
(2016 to 2025)···High Case
(2013 to 2025)···Low Case

The peak-hourly gas flow rate at each supply point obtained from two demand forecast cases is shown in Table 5-3-4.

Table 5-3-4 Peak-hourly Gas Flow Rate in Area L – Option 1 (Nm^3/h)

No	Point	Demand Case	2006	2010	2015	2020	2025
3	Santo Tomas (Batangas)	High	396	7,619	14,213	17,095	20,172
		Low	277	6,477	11,276	11,994	13,265
4	Cabuyao (Laguna)	High	367	1,483	3,585	6,257	9,108
		Low	257	425	863	1,529	2,707
6	Alabang (NCR-S)	High	1,104	4,801	11,902	21,022	30,892
		Low	763	1,327	2,776	5,002	9,026
9	Manila (NCR-C)	High	3,317	14,423	35,757	63,157	92,811
		Low	2,293	3,987	8,339	15,029	27,117
10	NCR-N (NCR-N)	High	3,966	17,246	42,755	75,518	110,976
		Low	2,742	4,767	9,971	17,970	32,424
11	Cavite (Cavite)	High	401	1,619	3,913	6,830	9,942
		Low	280	463	943	1,669	2,954
12	Sucat (Rizal)	High	355	114,284	116,316	118,899	121,655
		Low	248	410	113,685	114,328	115,466
13	Santa Rita (Bulacan)	High	-----	-----	-----	5,014	7,334
		Low	-----	-----	694	1,233	2,191
14	San Fernando (Pampanga)	High	-----	-----	-----	3,336	4,880
		Low	-----	-----	462	820	1,458
15	Clark (Bataan)	High	-----	-----	-----	125	184
		Low	-----	-----	17	31	55
18	Limay/Mariveles (Bataan)	High	-----	-----	-----	1,066	1,560
		Low	-----	-----	148	262	466
19	Subic (Bataan)	High	-----	-----	-----	63	92
		Low	-----	-----	9	15	27

The transmission pipeline network using the two Options are shown in Figures 5-3-3 to 5-3-5 (High Case) and in Figures 5-3-6 to 5-3-8(Low Case).

1) High Case

① The Network in the Final Year (2015) in the Phase 1

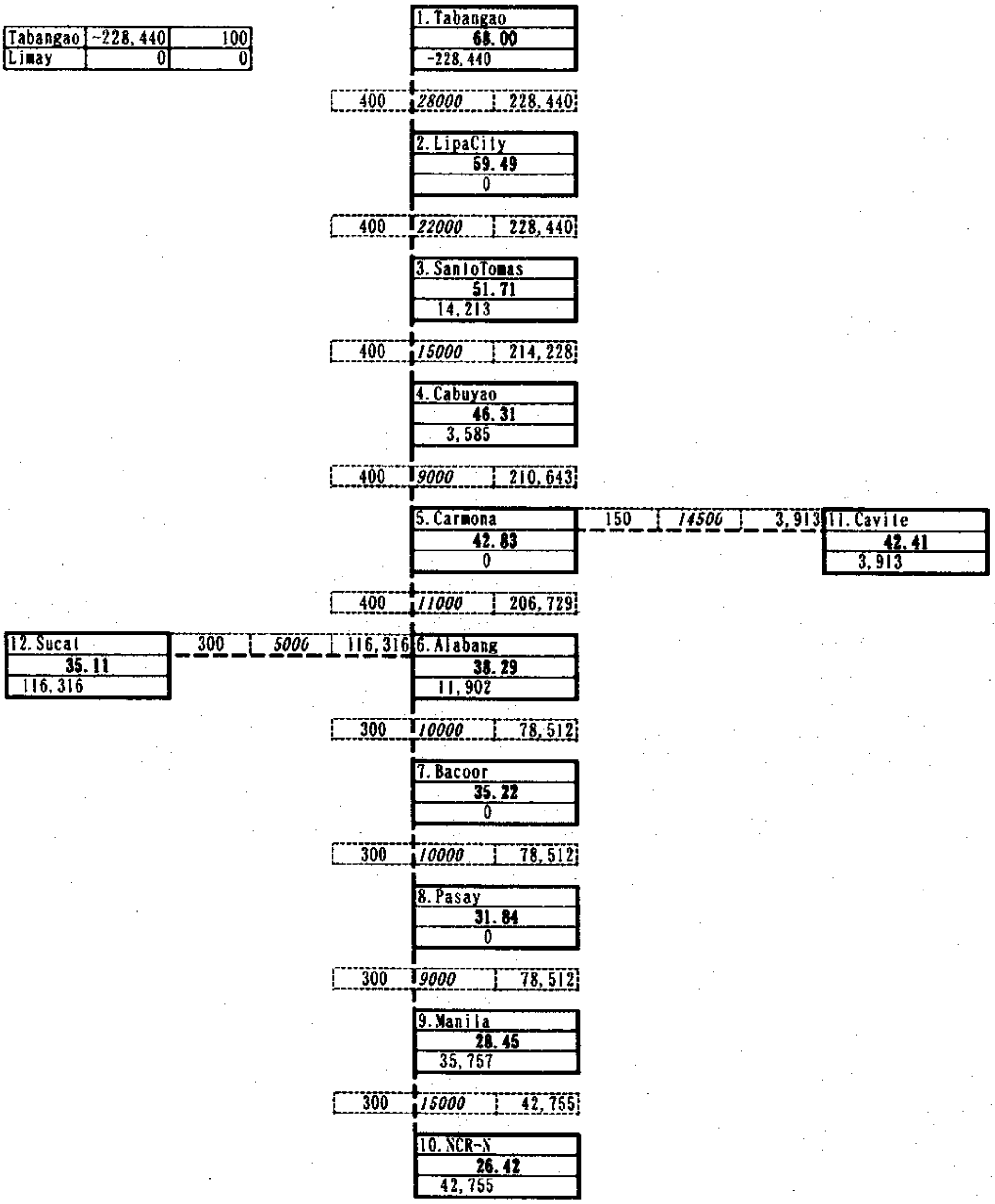


Figure 5-3-3 Pipeline Network (Option 1/ High Case in 2015)

② The Network in the Starting Year (2016) in the Phase 2

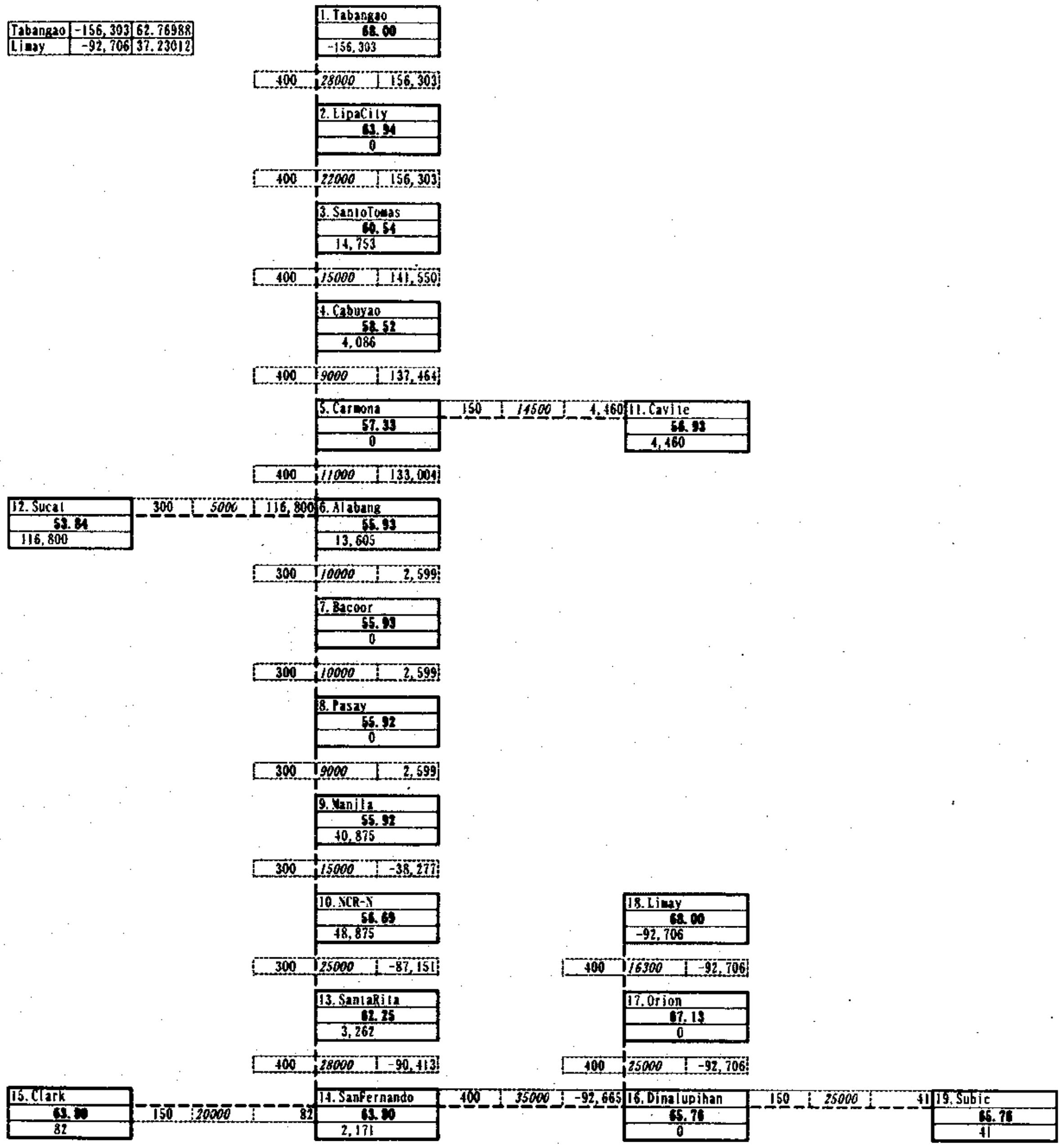


Figure 5-3-4 Pipeline Network (Option 1/ High Case in 2016)

③ The Network in the Final Year (2025)

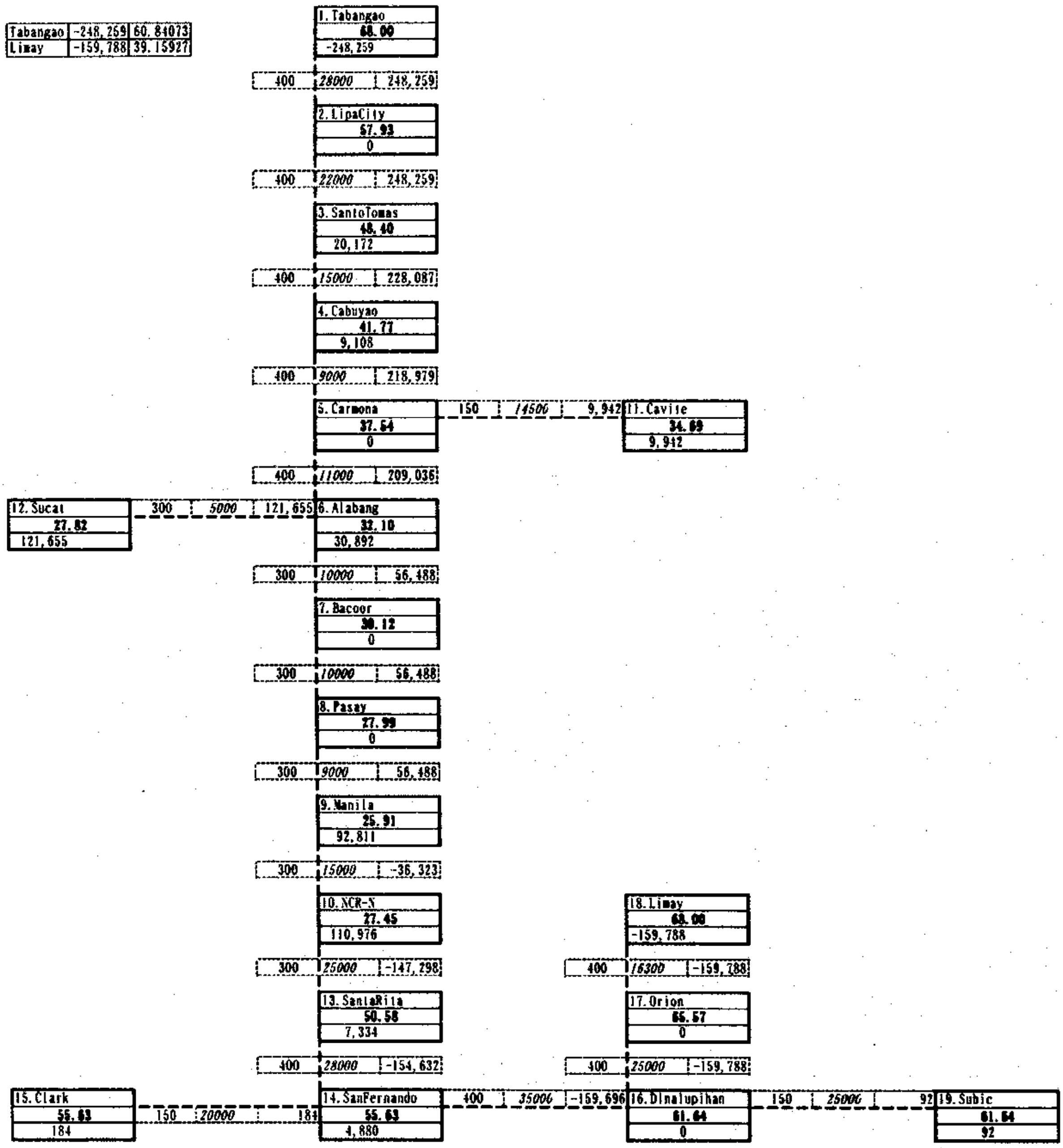


Figure 5-3-5 Pipeline Network (Option 1/ High Case in 2025)

2) Low Case

① The Network in the Final Year (2012) in the Phase 2

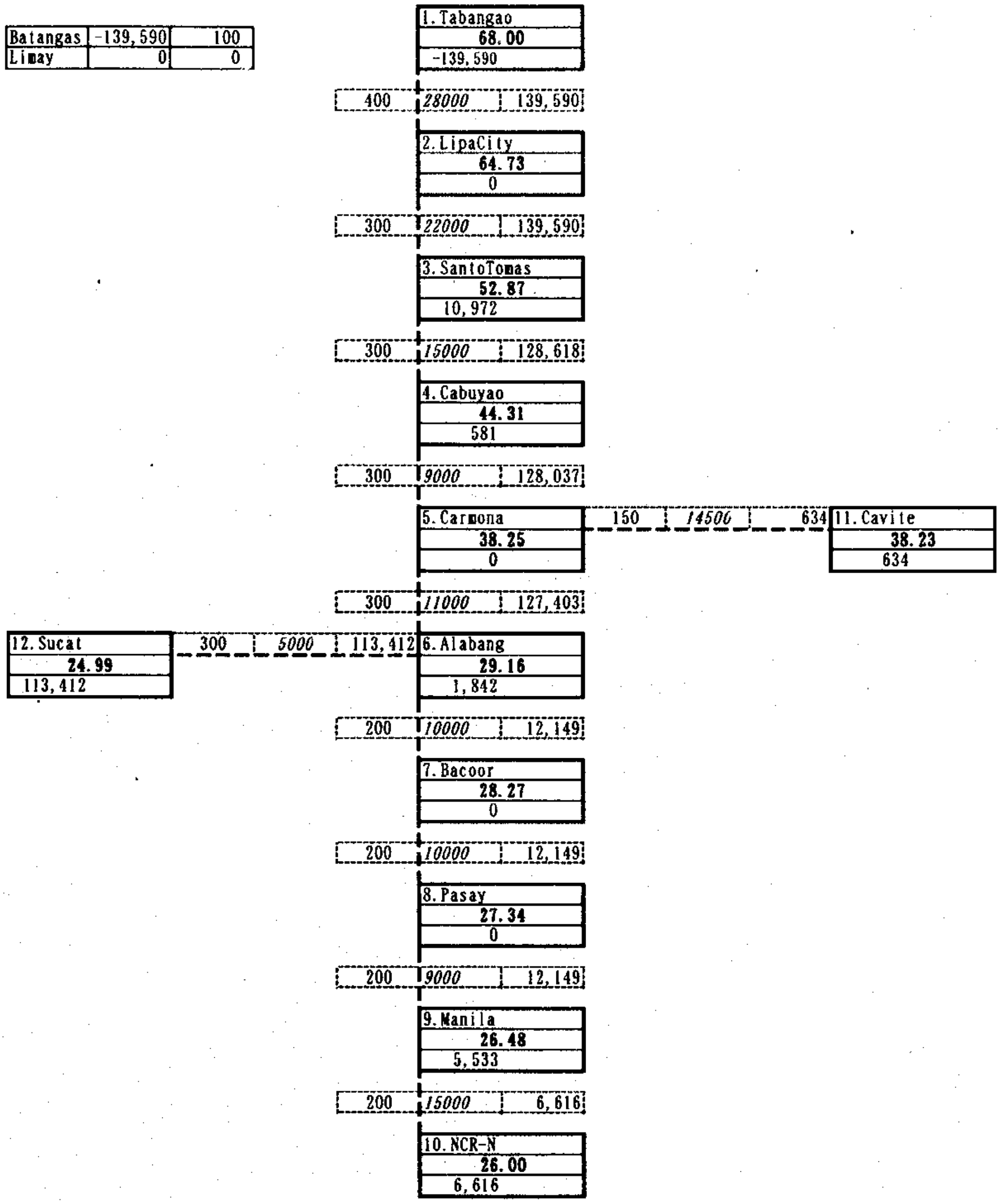


Figure 5-3-6 Pipeline Network (Option 1/ Low Case in 2012)