5.2 Present Status of Energy Consumption, Measures for Energy Conservation, and Estimate of the Technical Potentials

5.2.1 Industry Sector

5.2.1.1 Introduction

(i) Selection of Target Industries

Four industries - cement, sheet glass, sugar, and iron and steel,- are selected as targets to be analyzed in the industry for the following reasons:

a) They are consuming a large amount of energy and are very energy intensive. Therefore, measures for energy conservation can result in energy saving in these industries.
b) The study team was able to visit some factories in the industries and get data and information necessary for analyzing the present status of energy consumption in them.
c) Data and information necessary for estimating the potential and the investment costs of energy conservation are available in Japan.

Energy consumption in manufacturing industries, which are categorized into nine groups, was estimated for the period of 13 years from 1974 to 1986 in a report entitled "Creating a Model for Energy Management in the Cement Industry." Indicated below are the nine groups into which the industries are categorized.

a) Food-related industry
Meat, dairy products, vegetable oil, sugar, drinks, tobacco, etc.
b) Textile-related industry
Weaving, dyeing and finishing, knitting, leather, shoes, etc.
c) Wood products industry
Bamboo and wood vessel, wood furniture, etc.
d) Paper and printing industry
Paper and pulp, printing, etc.

e) Chemical products industry
Chemical feedstock, chemical fiber, paint, pharmaceuticals, petroleum products, coal products, rubber, plastics, etc.

f) Non-metalic minerals industry
Cement, brick, glass, ceramics, etc.

g) Basic metals industry
Iron and steel, non-ferrous metals.

h) Machinery-related industry
Metal furniture, agricultural machinery, machine tools, home appliances, transport equipment, etc.

i) Others
Jewely, musical instruments, etc.

According to the report, the largest consumer of energy among the nine groups was the non-metalic minerals industry, which consumed nearly half of the total in 1986 in the Iranian calender (from March 21, 1986 to March 20, 1987), followed by the food-related, basic metals, chemical products, and textile industries (Table 5.1). Non-metalic minerals is also ranked at the highest in energy intensity, followed by food-related, basic metals, and chemical products in the same order as in energy consumption, but ranking fifth is the wood products industry in terms of energy intensity (Table 5.2).

As can be seen in the groups of industries shown above, cement and sheet glass are included in the non-metalic minerals industry, sugar in the food-related industry, and iron and steel in the basic metals industry.

(ii) Basic ways for energy conservation in the industry sector

Considering measures for energy conservation and estimating its potential in industries, our attention is turned to following basic ways for energy conservation:

a) Improvement of fuel combustion
b) Improvement of heating and cooling
c) Prevention of heat loss

Table 5.1 Share of Energy Consumption by Industry in I.R. Iran

(Unit:%)

Industries	1976	1981	1986
Food related	19.1	15.3	15.9
Textile related	8.4	8.2	6.2
Wood related	0.7	0.8	1.2
Paper related	1.2	2.3	1.2
Chemical	11.3	10.3	10.3
Non-metalic minerals	44.6	56.1	48.1
Basic metals	8.4	2.5	11.5
Machinery related	6.3	4.4	5.5
Others	0.0	0.1	0.1
Total	100.0	100.0	100.0

(Source) Mohammadi, A., "Creating a Model for Energy Management in the Cement Industry in I.R. Iran" 1992

Table 5.2 Energy Intensity in Various Industries in I.R. Iran

(Unit: Giga J./Million Rial)

Industries	1974	1977	1981	1986
Food related	775.7	703.1	545.4	1,265.5
Textile related	386.4	390.0	239.9	302.5
Wood related	415.5	258.1	352.7	642.0
Paper related	183.3	292.7	469.6	304.1
Chemical	272.8	496.9	546.7	571.6
Non-metalic minerals	2,982.4	2,877.8	2,178.0	2,633.3
Basic metals	1,071.0	666.1	2,656.0	889.1
Machinery related	277.9	172.1	105.6	205.2
Others	69.6	137.6	132.6	71.0
Total	721.1	718.7	604.5	867.0

(Source) The same as Table 5.1.

d) Recovery of waste heat
e) Improvement of conversion from heat to power
f) Prevention of electric resistance loss
g) Improvement of conversion from electricity to power

In other words, measures considered below are supposed to belong to at least one of these basic ways.

(iii) Three categories of measures for energy conservation

Measures for energy conservation are divided into three categories, defined as follows:

Category 1 : Measures which can be implemented by proper management of operation and maintenance and do not require significant investment.

Category 2 : Measures which can be implemented by converting or adding to existing facilities and which require a certain amount of investment.

Category 3 : Measures which can be implemented by the replacement or modernization of existing facilities and which require significant investment.

More specifically, the category 1 contains the following items:

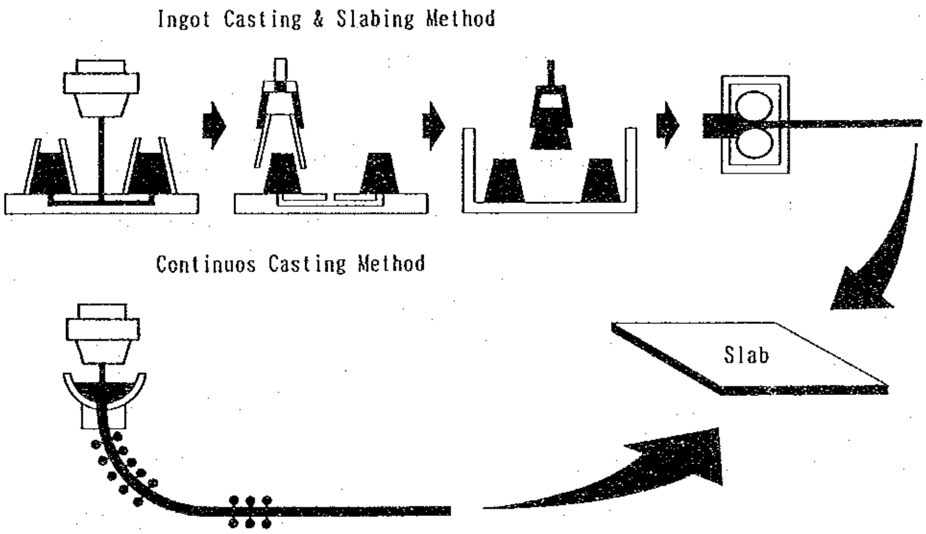
a) Shutdown of some operations when not needed.
b) Repairing leakages of oil, water, steam, etc.
c) Repairing insulations for heat contamination.
d) Opening furnace door and inspection window for shorter time.
e) Cleaning heat transfer part.
f) Checking and adjusting fuel/air ratio.
g) Proper maintenance of combustion equipment.
h) Optimizing temperature fixed for heating and cooling.
i) Optimizing location of heated items.

In addition to these countermeasures, (1) increased awareness, motivation, and training of employees, and (2) management endorsement and interest are indispensable for factories or plants to succeed in promoting energy conservation.

Examples of category 2 are heat contamination with additional insulation, including insulation on equipment and piping and installing equipment for recovering waste heat from condensate or process steam.

One of the examples of category 3 is introducing continuous casters in the iron and steel industry. Conventionally, molten steel from the basic oxygen furnace is cast into ingots, which are then removed from the case, and rolled into slabs, blooms or billets on primary mills -- a process that precedes hot rolling. Continuous casting, which eliminates the ingot-making process, casts molten steel directly into slabs or blooms. These are passed to the reheating furnance while hot (Fig. 5.1).

Fig. 5.1 An Example of Category 3



Another example is the replacement of an existing wet type of kiln with an NSP kiln in the cement industry. As can be seen in Fig. 5.2, a large amount of energy saving is achieved by this measures. (If a dry type of kiln is converted, not replaced, to an NSP kiln, such a measure is classified as category 2.)

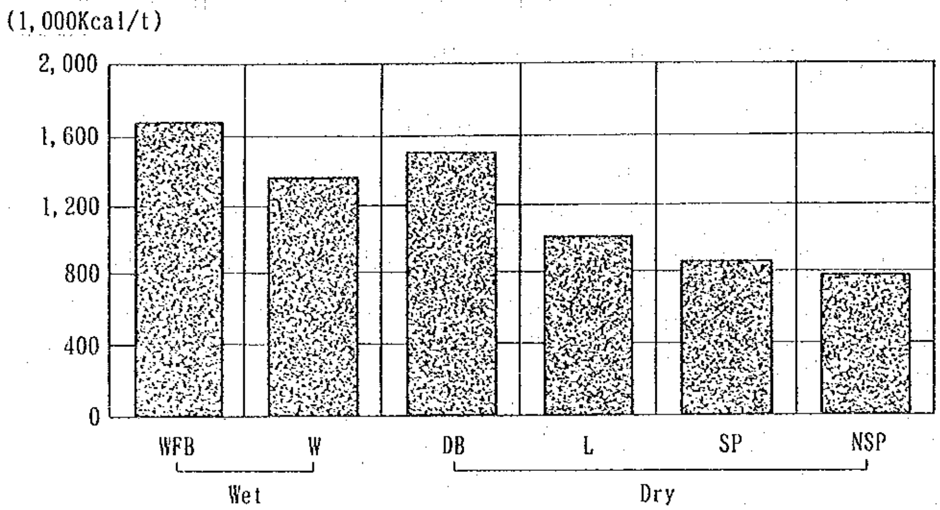


Fig. 5.2 Fuel Consumption of Kilns

(iv) Characteristics to be taken into account in I. R. Iran

(ii) and (iii) mentioned above are common in every country, but the following items should also be taken into account when studying measures for energy conservation and estimating its potential in the Islamic Republic of Iran:

a) Many years have passed since plants or equipment were installed.
b) Plants or equipment have not necessarily been well maintained or rehabilitated because of the war or the lack of foreign currency.
c) Many plants operate at lower rates.
d) The scale of plants or equipment are generally small because of a) and b) above and the national scale of demand itself.

Among these items, a), b), and c) imply that future measures for energy conservation will result in a large volume of energy saving while item d) will not.

(v) How to estimate the technical and economic potential of energy conservation

a) Technical Potential

The technical potential of energy conservation achieved in exciting plants in an industry by a certain year in future can be defined as follows:

$$PTE = \frac{a \cdot a' + b \cdot b' + c \cdot c' + d \cdot d' \ldots}{t}$$

where PTE: Technical potential in existing plants,

a,b,c: Effect of energy conservation achieved by measures A, B, C......,

a', b', c': Production in plants in which measures A, B, C...... have been implemented,

t : Total production in all existing plants.

And the technical potential of energy conservation achieved in existing and new plants in an industry by a certain year in future is shown in the following equation:

$$PT = PTE \cdot \frac{E}{T} + PTN \cdot \frac{N}{T}$$

where PT: The technical potential in an industry as a whole,

PTN: The technical potential in new plants,

E: Production in existing plants,

N: Production in new plants,

T: Total production in the industry.

b) Economic potential

The economic potential of energy conservation achieved in existing plants in an industry by a certain year in future is equivalent to the part of the technical potential which is economically justifiable in the meaning mentioned above. For instance, if measures A and D are justified and B and C not , the economic potential in existing plants (PEE) is shown in the following equation:

$$PEE = \frac{a \cdot a' + d \cdot d' \ldots\ldots}{t}$$

As discussed later, if we consider the potential for a short period of around five years to come, measures which are economically justifiable in I.R.Iran are mainly those belonging to category 1.

The economic potential is defined in the same way as the technical one as follows:

$$PE = PEE \bullet \frac{E}{T} + PEN \bullet \frac{N}{T}$$

where PE: The economic potential in an industry as a whole,

PEN: The economic potential in new plants.

5.2.1.2 Cement

(i) Present Status of Energy Consumption

a) Demand and supply of cement

Demand for cement has been rapidly increasing since the cease-fire in 1988. It is supposed that the potential demand exceeds significantly the actual supply. There are several reasons for the rapid increase in demand for cement.

(1) Reconstruction of areas damaged during the war.

(2) Rapid population growth - the growth requires new residential centers, educational facilities, hospitals, roads, and others.

(3) Reconstruction of areas ruined by the eathquake and floods in recent years.

(4) A large number of agricultural and industrial development projects.

Production of cement increased from 12,118,000 tons in 1988 to 15,190,000 tons in 1991 (Table 5.3), but rapid growth of demand caused the shortage of cement in 1992.

Table 5.3 Production and Imports of Cement in I.R. Iran

(1,000 tons)

Year	Production	Imports	Exports
1976	7,375	1,300	50
1977	7,706	2,600	—
1978	7,150	2,100	—
1979	7,620	400	—
1980	7,895	300	—
1981	9,231	100	—
1982	10,001	—	—
1983	10,912	—	—
1984	11,803	—	—
1985	12,095	—	—
1986	11,273	2	—
1987	12,618	1.5	127
1988	12,118	2.3	45
1989	12,830	1.3	169
1990	15,150	2	60
1991	15,190	n.a.	30

(Source) Ministry of Industry (I.R. Iran)

b) Production of cement

Cement is produced in 17 factories owned by 13 companies (Table 5.4). The largest cement manufacturer in the Islamic Republic of Iran is Fars and Khouzestan Cement Company, which has a total production capacity of 18,050 tons per day. The second largest is Tehran Cement Company, which has a daily production capacity of 9,600 tons, followed by Sepahan Cement (6,600 tons per day) and Soufian Cement (4,600 tons per day).

Table 5.4 List of Cement Kilns in I.R. Iran (as of 1991)

Company Name	Plant Name	Nos & Type of Kiln: Wet	Dry: Dry	Dry: SP	Dry: NSP	Capacity (ton/day)	Establish-ed Year	Manufacturer of Kiln	Clinker Production (1000t/y)	Cement Production (ton/day)	Cement Production (1000t/y)	Fuel Type
Fars and Khuzestan Cement Co. (State)	Abyek Factory		1 1			3.500 4.000	1974 1980	Polysious Polysious	2,250	7,800	2.300	NG
	Behbehan Factory			1		2,750	1979	I.H.I	825	2,860	880	FO
	Doroud Factory	1 1 1		 1	 1	300 300 400 1,000 2,500	1959 1965 1968 1969 1980	Edger-Alen Edger-Alen Alice-chalmerz Polysious I.H.I	1,197	4,680	1,440	NG NG NG NG NG
	Fars Factory		1 1 1 1			300 500 1,250 1,250	1966 1967 1974 1978	Krupp Krupp K.H.D K.H.D	1,051.5	2,718	1,056	na na na na
Gharb Cement Co. (Private)			1			2,000	1977	K.H.D	600	2,080	640	FO
Mazandaran (Neka) Cement Co.				1		2,000	1981	K.H.D	600	2,080	640	na
Esfahan Cement Co. (Private)				1 1 1		500 700 900	1968 1975 1976	Polysious Polysious Polysious	679.5	2,184	672	na na na
Kerman Cement Co. (Private)				1 1 1		300 1,000 2,300	1970 1974 1979	Polysious K.H.D Polysious	1,104	3,744	1,152	na na na
Khazer Cement Co.			1			1,500	1987	West-Alpin	600	2,080	640	na
Shargh Cement Co. (Private)				1 1		300 1,250	1970 1975	Krupp Polysious	492.756	1,612	496	FO
Ourmia Cement Co.					1	2,300	1989	F.L.S	600	2,392	736	na
Sepahan Cement Co. (State)				1 1		3,300 3,300	1978 1981	K.H.D K.H.D	1,980	6,864	2,112	na
Shemal Cement (State)	(White) Ghani Abad	1 1		 1		60 200 2,000	1958 1967 1979	G.H.H F.L.S K.H.D	85.8 99 660.0	2,558	883	na na na
Loushan Cement Co.			1			300	1958	Polysious	99	312	96	na
Soufian Cement Co. (Nationalized)			1 1 1	 1		600 1,000 1,000 2,000	1971 1976 1978 1984	F.L.S F.L.S F.L.S F.L.S	1,428	4,784	1,472	FO FO FO FO
Tehran Cement Co. (State)	No.1 Factory No.2 Factory	1 1 1 1	 1 1	 1		300 300 600 300 2,100 4,000 2,000	1956 1958 1966 1969 1972 1979 1984	F.L.S F.L.S F.L.S G.H.H F.L.S Polysious Pergo-inoset	2,226 600	9,672	2,976	NG/FO NG/FO NG/FO NG/FO NG/FO NG/FO NG/FO
		9	14	16	2	56,460			17,267.56	58,420	18,191	

(Source) CEMBUREAU, 1991, and Ministry of Industry (I.R. Iran) (Note) NG;Natural Gas, FO;Fuel Oil, na;not avaibable

The study team visited No. 1 and No. 2 factories of Tehran Cement, Ourmeh Cement, and Soufian Cement. As can be seen in the Table 5.4, the six kilns in Tehran Cement's No. 1 factory were built in 1956, 1958, 1966, 1969, 1972, and 1979, and one kiln in the company's No. 2 factory in 1984. The four kilns in Soufian Cement were constructed in 1971, 1976, 1978, and 1984, and one kiln in Ourmeh Cement in 1989. These commissioning years show that the factories the study team visited include the oldest, middle aged, and youngest ones.

c) Energy consumption in cement manufacturing process

There are three main parts in the process of manufacturing cement -- preparing materials, burning, and finishing.

First, limestone, clay, and other materials are crushed, dried and mixed. Secondly, the materials are fed into a rotary kiln in which they are heated at the temperature of around 1,450℃ and clinker as a mediate product is produced through a chemical reaction. Thirdly, clinker is cooled, gypsum is added, and crushed to be moved to a cement silo.

Fig. 5.3 shows a cement manufacturing flow. The figures include the raw mill and blending process in the material preparing process, kiln and clinker silo in the burning process, and cement mill in the finishing process.

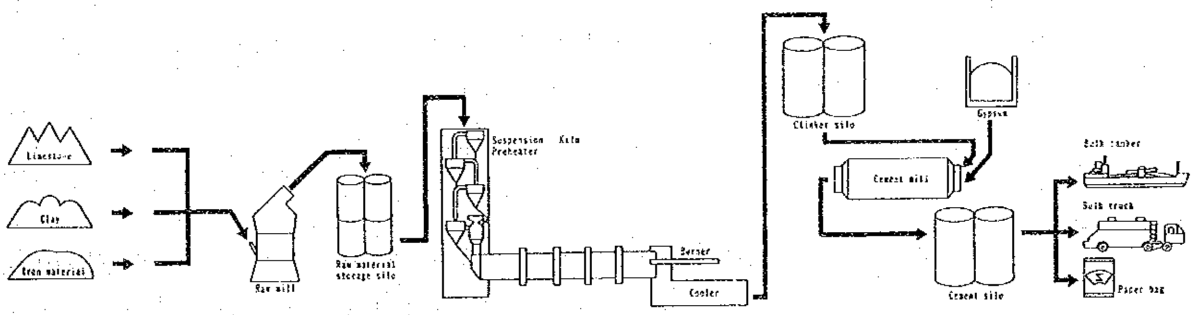


Fig. 5.3 Cement Production Flow Sheet

Almost all of energy consumed in the preparing process is electricity used for crushing while a small amount of fuel is used in the process for drying. Crushing has traditionally been done by a ball-type mill, but newly-built factories are often equipped with roller type mills as this type of crushing mill is more efficient and consumes less electricity.

Almost all of the fuel required for manufacturing cement is consumed in the burning process. In order to save fuel, technologies for pre-treating materials have been developed. In 1960s, the suspension-preheater kiln (SP kiln), which uses waste heat from the kiln for preheating materials, was commercialized, and in 1970s, the new suspension-preheater kiln (NSP kiln), which has a calciner installed with a preheater, was developed. Fuel consumption has been decreased drastically by adopting these SP and NSP kilns.

Comparing energy consumption in an NSP kiln to that in a Lepol kiln which is a dry type kiln, a big difference can be seen in fuel consumption while there is not a big difference in electricity (Fig. 5.2). Thus, energy consumption for manufacturing cement in a country is usually determined by the "kiln-mix" which shows the composition of various kinds of kilns.

Finally, electricity used for crushing is the main energy source in the finishing process as in the preparing process. A ball-type mill is usually used for crushing cooled clinker. Looking at the trend of electricity consumption by process in Japan (Table 5.5), consumption in the preparing and finishing stages were almost the same in 1960s, but finishing is the largest electricity consuming process at present after electricity consumption in the preparing process decreased largely although that in the finishing process decreased only slightly in 1970~80s.

d) Specific energy consumption in cement manufacturing

Specific fuel consumptions are 800~1,250 Mcal/ton-clinker and specific electricity consumptions are 113~132 kwh/ton-clinker in four (4) factories the study team visited, which show that the figure is largely different from each other (Table 5.6).

In estimating the average the specific energy consumption in cement manufacturing in the Islamic Republic of Iran, we consider that the 800 Mcal/ton-clinker of Soufian Cement's No. 3 and No. 4 kilns is rarely small compared to other kilns and factories, and that 950 Mcal/ton-clinker of

Table 5.5 Trend of Electricity Consumption in Manufacturing Cement by Process in Japan

(Kwh/t-cl.)

Year	Preparing Materials	Burning	Finishing	Others	Total
1950	57	28	47	10	142
1955	56	27	48	9	135
1960	49	25	46	7	127
1965	45	23	47	5	120
1970	43	25	47	4	119
1975	44	31	48	3	126
1980	39	32	46	3	121
1985	31	29	45	2	108
1989	29	28	43	3	103

(Source) Environment Protection Agency (Japan)

Ourmeh Cement is more appropriate to be used for the lower end of the scale to calculate the average. As the upper end of the scale, the 1,250 Mcal/ton-clinker of Soufian Cement's No. 1 and No. 2 factories is considered appropriate. And 113 Kwh/ton-clinker of Ourmeh Cement and 132 Kwh/ton-clinker of Tehran Cement's No. 1 factory are used for the lower end and upper end of the scale, respectively to estimate the average specific electricity consumption. Such a way of estimating the average can be said appropriate if the commissioning years and types of kilns shown in Table 5.4 are taken into account.

These average figures are as of 1991~1992 and can be compared with the average in Japan in 1990 in the table. Looking at fuel consumption, the Iranian average of 1,100 Mcal is 70% higher than the 653 Mcal for Japan, while electricity consumption in this country is 30% higher than that in Japan. The specific consumption of energy including both fuel and electricity in cement manufacturing in this country is 63% higher than that in Japan. These figures imply that the potentials of energy conservation in cement manufacturing in this country is substantially high.

Specific energy consumption in cement manufacturing in this country, however, is not ranked among the highest in the world. It is almost the same level as that in the U.S. and the U.K., as can be seen in the table.

Table 5.6 Estimated Specific Energy Consumption in Cement Industry in I.R. Iran

	Specific energy consumption			Remarks
	Fuel (Mcal/t-cl)	Electricity (Kwh/t-cl)	Total (Mcal/t-cl)	
Tehran Cement				
No. 1 Factory (6 kilns)	1,118	132	1,230	In 1991
No. 2 Factory (1 kiln)	970	117	1,070	"
Soufian Cement				
No. 1 & 2 kilns	1,250	110 (*)	1,350	(*) per ton of products. In 1992
No. 3 & 4 kilns	800	120 (*)	900	(*) per ton of products. In 1992
Ourmia Cement	947	113	1,040	In 1992
Estimated average	1,100	123	1,200	
Average in Japan	653	95	735	In 1990
" Germany	713	115	813	"
" Korea	741	107	833	"
" France	748	109	841	"
" U.S.A.	986	148	1,112	"
" U.K.	1,045	129	1,156	"

(ii) Measures for Energy Conservation

a) Introduction

We consider individual technical measures for energy conservation in cement manufacturing in this section of the report. In considering the measures, seven (7) basic technologies for energy conservation mentioned in 5.2.1.1-(ii) and three (3) categories of measures mentioned in 5.2.1.1-(iii) are referred to.

b) Measures in category 1.

In cement "manufacturing, improvement of fuel combustion" and "prevention of heat loss" are main measures specified in category 1. More specifically, the following fall under category 1.

(1) Adjusting fuel/air ratio in the kiln to improve fuel combustion.
(2) Prevention of leakages of high-temperature burned gas, air, and clinker from the kiln and other equipment.
(3) Prevention of inflow of cool air into the kiln and other equipment.

Additionally, the following are important measures in category 1 if they require no large investment;

(4) Repairing refractories in kilns.
(5) Repairing pipes and ducts.
(6) Removing moisture from materials and/or properly controlling their grains.
(7) Preventing clinker and cement from dispersing within the factory.

c) Measures in category 2.

The most effective measure in this category is to convert the existing wet-type kilns and dry-type kilns including the Lepol kilns into SP kilns or NSP kilns. As mentioned already, the conversion will significantly decrease specific energy consumption in cement manufacturing. There are nine (9) wet-type kilns and fourteen (14) dry-type kilns other than SP and NSP in this country as of 1991. If they are converted into SP or NSP kilns, a considerable amount of energy savings can be obtained.

Secondly, power generation utilizing waste heat has a large effect on energy saving. For instance, it is reported that 450~500°C gas is wasted from an SP kiln in Tehran Cement's No. 2

factory; this can be used for generating power (450~500°C is considerably higher than the 320~350°C in Japanese cement factories).

These measures - converting kilns into SP or NSP kilns and power generation utilizing waste heat - correspond to a basic way for energy conservation described in 5.2.1.1-(ii)-d), which is "the recovery of waste heat." In comparison, the following are measures corresponding to 5.2.1.1-(ii)-g) which is "the improvement of conversion from electricity to power";

(1) Installing a preliminary crushing mill in the finishing process.
(2) Introducing inverter systems for controlling the rotations of fans, blowers, pumps, and other equipment.

A preliminary crushing mill is a roller-type mill which is installed with an existing ball-type crusher for the preliminary crushing of cooled clinker, and consumes about twenty (20) per cent less electricity than the conventional way of crushing.

In general, electricity is consumed in proportion to the third power of the rotations of fans, blowers, pumps, etc. Therefore, controlling their rotations according to power demand is very effective for saving energy. Inverter systems have been introduced for controlling the rotations in many factories and plants in Japan, and it is supposed that introducing the system in cement factories in this country will also be very effective for saving energy. It is reported that introducing inverter systems result in electricity savings of 20~50 per cent in Japan, 20 per cent in the U.S., and 40 per cent in Europe.

Finally, the improvement of efficiency of clinker coolers in NSP kilns has been sought as one of the measures in category 2. This technology is said to be the last factor for improving efficiency of NSP kilns. Some systems for improving the efficiency of clinker coolers have been developed and commercialized, but there are still problems to be solved before they can come into wide use.

d) Measures in category 3.

The most effective measure in this category is to replace existing kilns with SP or NSP kilns. The average life of cement kilns is estimated to be 25~30 years including the prolonged period gained by conversion. In this country, many kilns were constructed before 1970 or 1975, according to

Table 5.4, and will be replaced with SP or NSP kilns in around 2000.

Secondly, introducing roller-type crushers in the finishing process as well as in the raw material preparing process can also save energy. Replacing a ball-type vertical crusher with a roller-type vertical crusher will result in one-fourth less electricity consupmtion in both of two processes.

Finally, the fluidized bed furnace has been developed as an energy saving cement kiln. The furnace has such advantages as less dispersed heat, improved cooling efficiency, and less electricity consumption due to smaller movable parts, and will use a maximum of around ten (10) per cent less energy than the NSP kiln. This furnace, however, is considered to be suitable for producing smaller amounts of many kinds of cement products or for automatic production, and may therefore be used as one complementing SP or NSP kilns used for large-scale production.

(iii) Technical Potentials of Energy Conservation in Cement Manufacturing

According to experience in the cement industry in Japan after "the first oil crisis", the effects of energy conservation using measures in category 1 is estimated to be 30 - 50 Mcal (3.2 ~ 5.3 liter of fuel oil equivalent) /t-clinker. This is equivalent to 2.5 - 4.2 per cent of the current s.e.c. in the industry presently in I.R. Iran, which is 1,200 Mcal (126.3l)/t-cl.

Table 5.7 shows factors which decreased the specific energy consumption (s.e.c.) in the cement industry in Japan. As can be seen in the table, introducing SP or NSP kilns in the burning process contributed significantly to decrease the s.e.c. Three-fourths of the decrease (180 Mcal/t-cl) achieved during the period from 1973 to 1977 was contributed by such measures including the increase in the utilization rate of these kilns.

Table 5.7 Analysis of Factors Decreasing the S.E.C. in the Cement Industry in Japan

(Unit : Mcal/t-cl)

	1973 -77	1973 - 80
Preparing materials	15(8.3)	19(8.0)
Burning(*)	163(90.6)	214(90.3)
Conversion to SP, NSP kilns	132(73.3)	170(71.7)
Decrease in s.e.c. of SP, NSP kilns	17(9.4)	26(11.0)
Decrease in s.e.c. of other kilns	20(11.1)	16(6.8)
Unidentified	-6(-3.2)	2(0.8)
Finishing and others	2(1.1)	4(1.7)
Total	180(100.0)	237(100.0)

(*) The s.e.c. of kilns are as follows. Figures in parenthesis show shares of clinker production.

	1973	1977	1980
SP, NSP	854(48.9)	820(80.9)	800(88.6)
Others	1,233(51.1)	1,130(19.1)	1,095(11.4)
Average(Total)	1,048(100.0)	879(100.0)	835(100.0)

Source : IEEJ

In addition to the measure, such measures as ① improvement in preparing materials, ② decrease in air leaks in equipment, and ③ improved insulation were adopted in this period in Japan. The effects of these measures are included in "Decrease in the s.e.c. of SP, NSP kilns" and "Decrease in the s.e.c. of other kilns". Since main measures in existing kilns in this period are those in category 1, almost all of the effects of the latter taken during the period from 1973 to 1977 can be safely said to be those achieved by category 1 measures including ① - ③ above. Furthermore, the effects of the former is estimated to include those of measures in category 1 to a certain degree.

Additionally, if we take into account the effects of measures in other processes and measures taken on SP and NSP kilns during the period from 1978 to 1980, it can be said that the effects of measures in category 1 totaled at least 30 - 50 Mcal/t-cl in the cement industry in Japan.

It is estimated that measures in category 2 and 3 can achieve energy conservation of 196 Mcal (20.7 l) / t-cl. 106 Mcal(11.2 l) comes from the conversion and replacement of kilns, as can be seen in Table 5.32 below, and 90Mcal(9.5 l) from measures other than the conversion and replacement except for " fluidized bed furnace ", which will not be commercialized by 1999, as can be seen in Table 5.31 below.

The s. c. c. in the cement industry as a whole is estimated to be 928 ~ 938 Mcal / t - cl in 1999, if the s. c. c. in newly - built plants is 900 Mcal / t - cl in 1999. Accordingly, the s. c. c. in the cement industry in I. R. Iran can be improved technically by 22 ~ 23 percent in the next five years.

5.2.1.3 Sheet Glass

(i) Present Status of Energy Consumption

a) Demand and supply of sheet glass

Demand for sheet glass in the Islamic Republic of Iran is slightly more than 200,000 tons per annum, around three-fourths (160,000 tons) of which is produced domestically. Accordingly, import is estimated to be 40,000~50,000 tons per annum.

b) Production of sheet glass

There are four (4) sheet glass manufacturing companies in this country. The largest manufacturer is Ghazvin Glass Company, which has the capacity of manufacturing 120,000 tons of sheet glass per annum, followed by Abguineh Glass Company.

	Production Capacity (tons/year)	Lines
Ghazvin Glass	120,000	4
Abguineh Glass	100,000	3
Saveh Jam Glass	70,000	1
Iran Glass	20,000	1
Total	310,000	

c) Energy consumption in sheet glass manufacturing

There are several steps involved in manufacturing sheet glass -- mixing, melting, refining, forming, annealing, and cutting (Fig. 5.4).

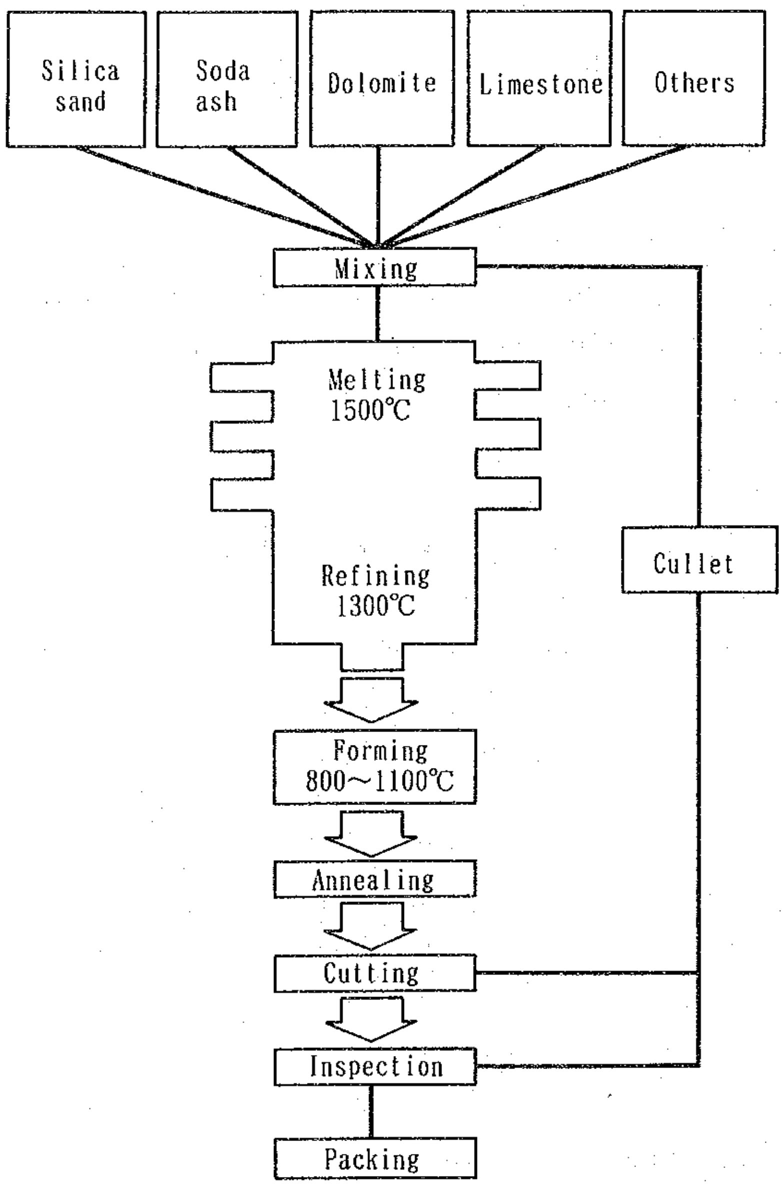


Fig. 5.4 Production Process of Sheet Glass

In the mixing step, silica sand, soda ash, limestone, dolomite, etc. are mixed, and an appropriate amount of cullet is blended with the mixture.

The composite material is charged into the smelting furnace which is kept at about 1,500°C, where the material is heated and melted by the radiating heat of flames in the upper space. Then, the molten material is clarified and its bubbles are separated.

In the next step, the temperature of the molten material is adjusted to be suitable for forming. Sheet glass is formed by the drawing process, the roll-out or rolling process, and the float process. The drawing process includes the Fourcault process, the Pittsburg Pennvernon process, and the Colburn process (Fig. 5.5). In both Ghazvin and Abguineh which the study team visited, the Colburn process is utilized.

Formed glass then goes into the annealing step so that there is no thermal strain left in the product. After annealing, the glass is cut, checked, and packed.

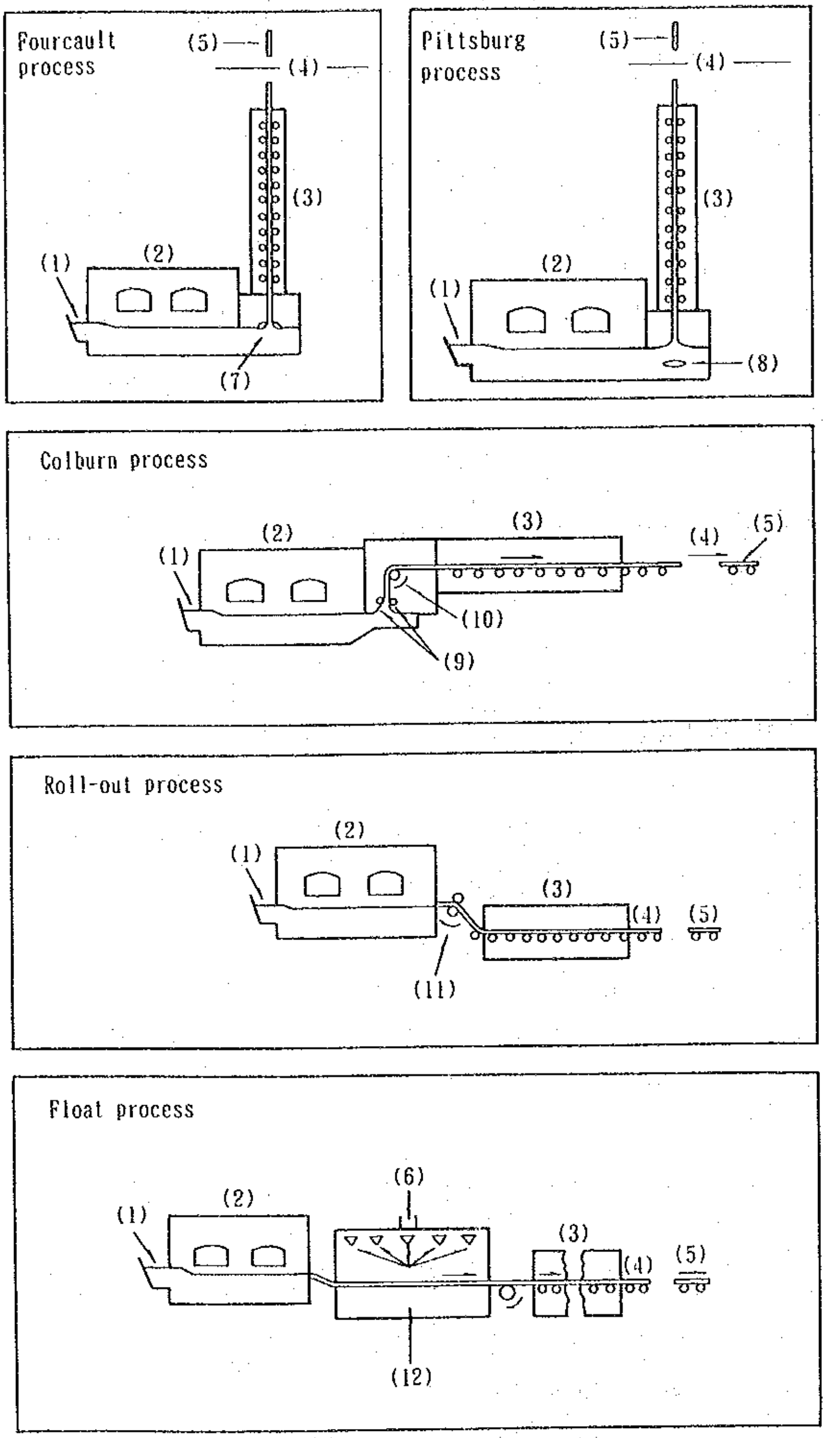
What energy is used in each step of the manufacturing process? In the mixing step, electricity is used for the crushing, mixing, and moving of materials. Fuel oil or natural gas is used for heating the materials in the melting step. In the forming and annealing steps, electricity is used for moving the molten glass and LPG or natural gas for annealing. Ghazvin Glass Company has a plan to install the float process as the fifth line of glass manufacturing in the near future, in which electricity will be used for heating in the float bath.

Finally, electricity is used for moving glass in the cutting and packing steps.

Looking at energy consumption by step in a glass manufacturing factory, ninety per cent of total heat consumption is accounted for by the melting step where materials are heated at a temperature of 1,500°C - 1,600°C. Electricity consumption is rather small, which is five to seven per cent of total heat consumption in glass manufacturing factories in Japan.

d) Specific energy consumption in sheet glass manufacturing

Fuel consumption per ton of manufactured glass is estimated to be 5,000 Mcal and 4,000 Mcal



(1) Materials
(2) Melting furnace
(3) Annealing furnace
(4) Cutting
(5) Product
(6) Float bath
(7) Debiteuse
(8) Draw bar
(9) Knurl roll
(10) Bending roll
(11) Mold roll
(12) Molten metal

Fig. 5.5 Various Processes for Manufacturing Sheet Glass in Ghazvin Glass and Abguineh Glass, respectively. A corresponding figure is less than 3,000 Mcal in Japan, which means there is a large potential of energy saving in glass manufacturing in the Islamic Republic of Iran.

(ii) Measures for energy conservation in sheet glass manufacturing

a) Measures in category 1

Main measures in category 1 in glass manufacturing are the prevention of leaks of hot air and steam, and the management of combustion like in cement manufacturing. More specifically, the following measures can be recommended:

(1) Repairing the wall of melting furnaces
(2) Adjusting fuel/air ratio in melting furnaces.
(3) Preventing materials from scattering out of manufacturing lines.
(4) Reducing broken glass.

b) Measures in category 2.

Measures in category 2 for melting furnaces are as follows:

(1) Heat insulation

Since costs for repairing melting furnaces is substantial in glass manufacturing, the furnaces are often not insulated in order to prolong their life to the extent as possible. In fact, the study team was explained when it visited Ghazvin Glass Company that it was much more important for the company to prolong the life of refractories installed with melting furnaces because they were imported and very expensive. Even "simple" insulation by installing one seam of silica stone refractory, however, is desirable measure in this category for saving energy.

(2) Recovery of waste heat

The waste heat of exhaust gas is usually recovered to preheat secondary air because a melting furnace is heated to high temperature and generates hot exhaust gas, and either a regenerator or recuperator is used as a waste heat recovery unit. Some of the furnaces, however, are not installed with these units in glass manufacturing factories in the Islamic Republic of Iran. Installing recuperators is recommendable for recovering waste heat from melting furnaces. In addition, power generation utilizing waste heat is also recommended.

(3) Reducing fuel/air ratio for the proper management of combustion

The study team observed that some of the furnaces were operated under excess air. In order to control the volume of air more accurately, a computer can be employed.

(4) Increased use of cullet

The energy used for melting materials can be reduced by increased use of cullet and limestone as materials, providing that product quality is not adversely affected. (In some furnaces of Abguineh Glass Company this device has already been introduced.)

c) Measures in category 3

(1) Installing a more insulated melting furnace

It is recommendable that when an existing melting furnace is scrapped, it is replaced with a more insulated furnace with 3 to 4 seams of refractories installed.

(2) Installing a more efficient regenerator

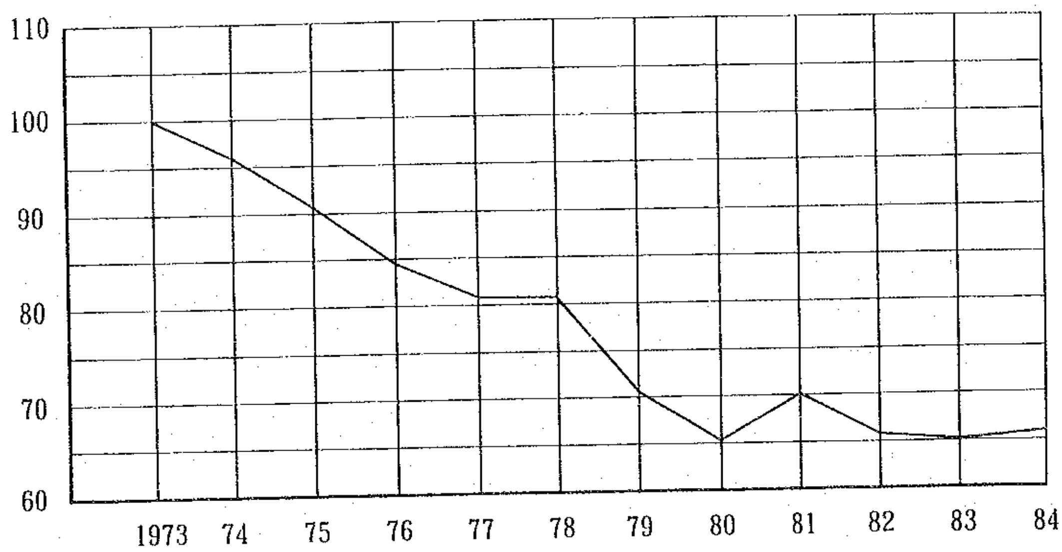
It is also recommendable that a more efficient regenerator is installed when an existing furnace is replaced.

(iii) Technical Potentials of Energy Conservation

Estimates have not been made on potentials of energy conservation in sheet glass manufacturing achieved by each measure in category 1 mentioned in (ii)-a) above. The potentials of energy conservation by measures in category 1 are, therefore, assumed to be at least around 5 per cent, perhaps much more, by referring to the following experiences.

Fuel consumption per ton of sheet glass was decreased by around 10 per cent in 2 years and by around 20 per cent in 4 years after "the first oil crisis" in 1973 in Japan (Fig. 5.6). It is estimated by experts in the sheet glass industry in Japan that about one-half and one-third of each decrease was achieved by measures in category 1.

Fig. 5.6 Trend of Fuel Oil Consumption for Manufacturing Sheet Glass in Japan



(Source) Japan Sheet Glass Association

Additionally, an experience of one glass manufacturing company in Japan showed that ten to twenty per cent of energy conservation was easily achieved in a south-east Asian country by implementing measures in category 1.

The current specific fuel consumption in the sheet glass industry in I.R. Iran is assumed to be around the same as that in Japan in 1973 which was 4,500 Mcal/t and also the average of those in two plants visited by the study team. If the specific fuel conservation is decreased by five per cent in the Iranian sheet glass industry, the amount of saved energy per unit of annual sheet glass production will be 200 - 250 Mcal/ton-glass.

Finally, experiences in Japan mentioned above show that about five and thirteen per cent of each energy conservation for the two and five years was achieved by measures in category 2 (and 3) after "the first oil crisis". If specific energy consumption is decreased by ten percent in the Iranian sheet glass industry, the amount of saved energy per unit of annual sheet glass production will be 400 ~ 500Mcal/ton-glass.

5.2.1.4 Sugar

(i) Present Status of Energy Consumption

a) Demand and supply of sugar

Consumption of sugar in the Islamic Republic of Iran has been at 1.0~1.4 million tons per annum level in recent years. Around 50 or 60 per cent of total consumption has been produced domestically and the balance imported. Sugar is not exported from I.R. Iran. Looking at the supply side from the mid-1970s to the mid-1980s, it can be seen that supply was almost the same level as in recent years. This fact explains that consumption of sugar was fluctuating at almost the same level as in recent years although the figure of consumption is not available in Table 5.8.

b) Production of sugar

Sugar is produced at thirty-nine (39) factories. As explained in further detail below, sugar is produced from beet or cane. There are 35 beet sugar factories and two cane sugar factories in I.R. Iran. The other two are sugar factories which refine crude sugar imported from foreign countries.

c) Energy consumption in sugar manufacturing

The process of manufacturing sugar is somewhat different between a beet sugar factory and a cane sugar factory. In a cane sugar factory, crude sugar is produced from cane in the first half of the process and is refined further in the second half of the process before becoming the final product. On the other hand, in a beet sugar factory, the final product is produced directly without making any crude sugar as a semi-product.

In manufacturing beet sugar, beet which is the feedstock is washed and sliced. The sliced beet is put into hot water in the next process for its sugar content to be diffused.

Hot water containing sugar produced in the diffusion process is then clarified by adding lime

Table 5.8 Demand and Supply of Sugar in I.R. Iran

(1,000 ton; crude sugar equivalent)

	Consumption	Production			Import	Supply
		Beet	Cane	Total (A)	(B)	(A + B)
1976	—	—	—	(722)	(262)	(984)
1977	—	—	—	(672)	(348)	(1,020)
1978	—	—	—	(580)	(227)	(807)
1979	—	—	—	(593)	(127)	(720)
1980	—	—	—	(595)	(583)	(1,178)
1981	—	—	—	(538)	(667)	(1,205)
1982	—	—	—	(708)	(212)	(920)
1983	—	—	—	(663)	(653)	(1,316)
1984	—	—	—	(633)	(560)	(1,193)
1985	—	—	—	(701)	(573)	(1,274)
1986	—	—	—	(721)	(377)	(1,098)
1987	1,300	464	136	600 (657)	582 (557)	1,182(1,214)
1988	1,150	500	225	725	280	1,005
1989	1,000	460	140	600	381	981
1990	1,200	450	170	620	606	1,226
1991	1,400	—	—	710	672	1,382

(Note) — means "not available".

(Source) An Iranian sugar company for figures in ( ); Japan's Sugar Refiners Ass. for others.

for absorbing impurities and carbone dioxide for carbonating. In some cases, the ion exchange process is used for clarification.

In the next process, the clarified sugar juice is concentrated in the evaporator, and then it is crystallized while being evaporated in a vacuum and by adding fine sugar as the seed for crystallizing.

The crystallized sugar is separated from molasses that still include some impurities in the centrifugal separator, and then dried to become the final product (Fig. 5.7).

On the other hand, pulp produced in the diffusion process is pressed and dried - and sometimes formed - to be used as livestock feed.

In a cane sugar factory, cane which is the feedstock is cut and shredded, and then is compressed for sugar juice to be squeezed out. The diffusion process is also sometimes used for producing sugar juice like in the beet sugar factory.

With regard to clarification, evaporation, crystallization, separation, and drying, basic processes are the same as those in beet sugar manufacturing. Crude sugar which is produced by the process, however, is refined once more through basically same processes mentioned above.

A by-product in the compression or diffusion process, which is called bagasse, is used as a fuel for boilers or as a material for manufacturing paper after being dried.

A large amount of heat is consumed in the evaporating (concentrating) and crystallizing processes both in beet sugar and cane sugar manufacturing. In one of the largest beet sugar factories in Japan, 55 per cent and 35 per cent of process steam generated in two boilers are used for evaporating and crystallizing, respectively. And the boilers consume more than four-fifths of fuel oil in the factory. In another sugar refinery in Japan, which manufactures the final product from crude sugar, consumes 65 to 70 per cent of total process steam in crystallizing.

Heat is also used for drying pulp or bagasse. In addition, coke is fired for generating carbone dioxide in the lime kiln which is used for clarifying sugar juice, although this accounts for only a

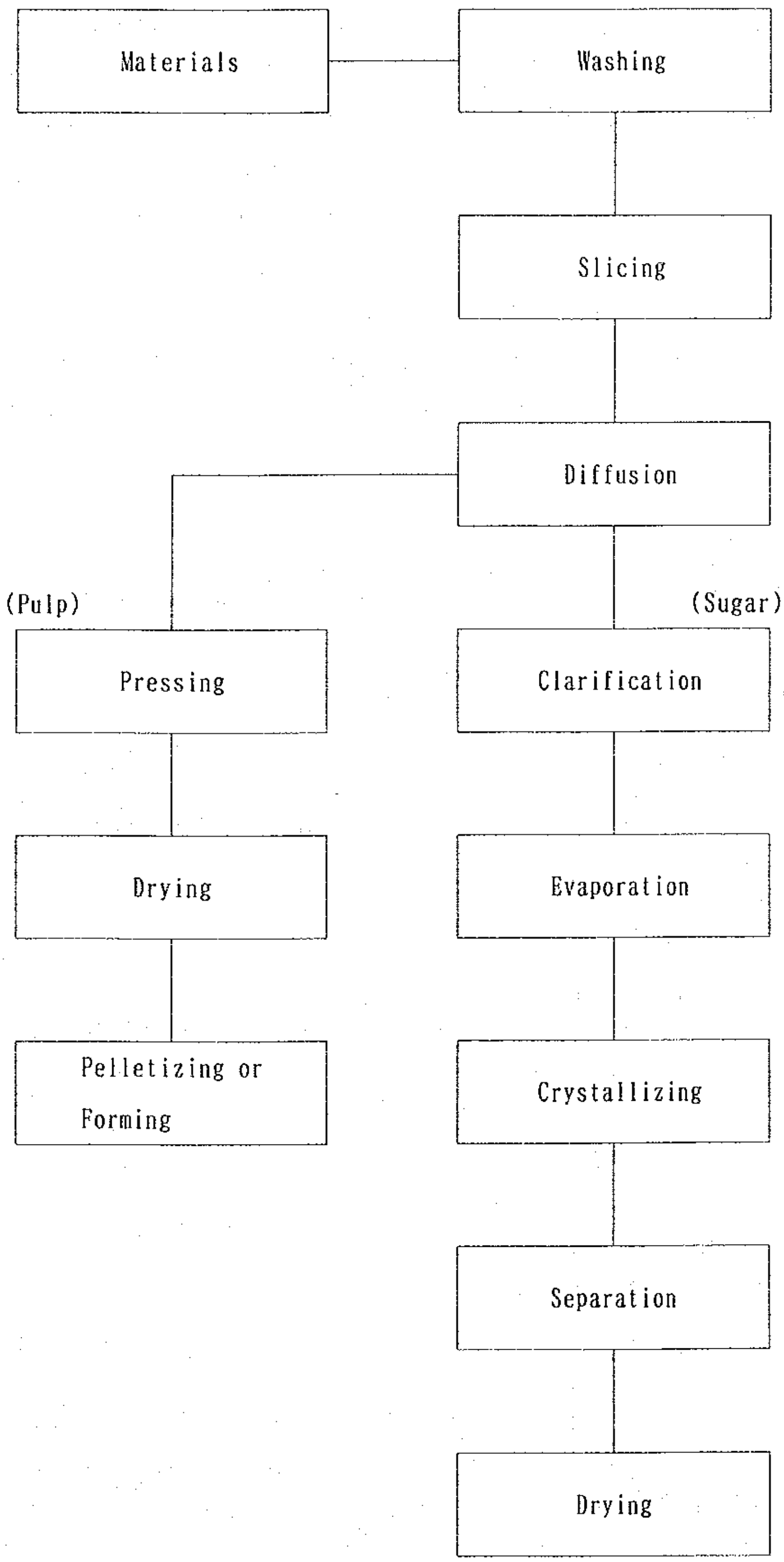


Fig. 5.7 Production Process of Beet Sugar

minor part of fuel consumption in a sugar factory (around 5 per cent in Japan).

Electricity is used for slicing beet and for compressing sliced beet after the diffusion process in a beet sugar factory, and for cutting, shredding and compressing cane in a cane sugar factory. It is also used for operating vacuum pumps, separators, dryers, etc. in sugar manufacturing.

d) Specific energy consumption in sugar manufacturing

The study team visited 3 beet sugar factories, one cane sugar factory, and one sugar refining factory. Figures in Table 5.9 are estimated by utilizing data and information available from the visits to the factories.

Table 5.9 Specific Energy Consumption in Sugar Manufacturing Industry in I.R. Iran

	Fuel* (ℓ/t)	Electricity (Kwh/t)	Remarks
Varamin Sugar Refining	382	301	In 1991. Refining
Haft Tappeh Cane Sugar	750	n.a.	In 1991. Cane sugar
Khorasan Sugar	877	480	In 1992. Beet sugar
Sabet Fariman Sugar	815	n.a.	In 1992. Beet sugar
Torbat-e-Jam Sugar	530	308	In 1992. Beet sugar
Average in Japan	500	250**	In 1990. Cane sugar
Examples in Japan	330~380	170	In 1992. Beet sugar

* Heavy fuel oil equivalent (per ton of refined sugar)
** Estimated

Specific fuel oil consumptions in beet sugar factories in the Islamic Republic of Iran are in the range of 530 l/ton-sugar to 880 l/ton-sugar, which can be compared with 330~380 l/ton-sugar in some beet sugar factories in Japan. Electricity consumption per ton of beet sugar is 310 Kwh and 480 Kwh in this country, while one of the largest beet sugar factories in Japan mentioned above consumes only 170 Kwh/ton-sugar.

In manufacturing cane sugar, 750 l/ton-sugar is used in Haft Tappeh Cane Sugar Company, which can be compared with the average figure of around 500 l/ton-sugar in Japan.

These figures show that a large volume of energy saving can be expected in sugar manufacturing in the Islamic Republic of Iran.

(ii) Measures for energy conservation in sugar manufacturing

a) Measures in category 1

As mentioned above, a large volume of low pressure steam is used for evaporating and crystallizing in sugar manufacturing. Therefore, it is usual that boilers are installed for feeding steam not only to evaporators and crystallizers but also to turbine generators for onsite power generation.

For boilers, the proper management of combustion is important as a measure in this category. The prevention of steam and drain leakage from pipes and ducts is also a measure which can be recommended. The insulation of pipes, ducts and others is also recommendable.

As a measure for manufacturing facilities, reducing water used in crystallizers is very important from the viewpoint of saving heat by decreasing vaporized water. In manufacturing beet sugar, the proper maintenance of slicers is important because slicing beet as thin as possible results in energy-saving through increasing the yield of sugar products.

In addition, scattering or leakage of feedstocks and semi-products from production lines should be prevented.

b) Measures in category 2

For boilers and generators, the following measures are recommendable:

(1) To install economizers and air preheaters for heating process water and air for burning by recovering waste heat from boilers.

(2) To install equipment for recovering drain from evaporators and crystallizers.

(3) To install a steam accumulator for leveling boiler load.

(4) To install measuring machines for the proper management and monitoring of fuel and electricity.

For manufacturing facilities, the following measures can be recommended for category 2:

(5) To install equipment for pre-concentrate sugar juice before putting into crystallizer.

(6) To install a churner in crystallizers for making crystallization more efficient.

(7) To install equipment for recovering waste heat from vapor in crystallizers to make hot water.

Additionally, it is recommendable for saving electricity that an inverter system be introduced in order to control the rotation of blowers, fans, and pumps.

c) Measures in category 3

Varamin Sugar Refining Factory which the study team visited is sixty years old. Here, a water tube boiler was operated, the efficiency of which was estimated at less than sixty (60) per cent. The replacement of old boilers with low efficiency can be recommended. In general, the following measures are recommendable as those for this category:

(1) To replace horizontal-type slicers with drum-type ones in beet sugar factories.

(2) To replace the compressing process with the diffusion process in cane sugar factories.

(3) To install evaporators equipped with more stages when existing ones are replaced.

(4) To replace tube-type heaters with plate-type ones which can utilize lower temperature steam.

(5) To install more efficient compressors (not vertical but horizontal ones, for instance) in beet sugar manufacturing.

(iii) Technical Potentials of Energy Conservation in Sugar Manufacturing

Estimates have not been made on potentials of energy conservation in sugar manufacturing achieved by each measure in category 1 mentioned in (ii)-a) above. The potentials of energy conservation by adopting measures in category 1 are, therefore, assumed roughly around five per cent, taking into consideration the experiences in other industries in Japan which were involved in this study.

However, data and information on measures in categories 2 and 3 on newly-built plants have not been enough for estimating the technical potential of energy conservation in this industry as a whole.

5.2.1.5 Iron and Steel

(i) Present Status of Energy Consumption

a) Demand and supply of steel

Consumption of finished steel products was 7.4 million tons in 1991 in I.R. Iran, according to the International Iron and Steel Institute (IISI). Production of pig iron was around 2 million tons in 1991, which shows that one fourth of steel consumption is supplied by domestic iron and steel mills, where steel is produced from iron ore.

Table 5.10 Demand and Supply of Steel in the Islamic Republic of Iran (Unit: 1,000 metric tons)

	Production of Pig Iron	Import of Semi-finished and Finished Steel Products	Consumption of Finished Steel Products
1982	220	3,114	3,577
1983	240	4,392	5,015
1984	250	3,250	3,979
1985	250	4,532	5,249
1986	250	3,036	3,760
1987	250	4,147	4,876
1988	250	3,100	3,953
1989	250	3,600	4,548
1990	1,267	4,900	6,152
1991	1,952	5,500	7,443

(Source) International Iron and Steel Institute, "Steel Statistical Yearbook 1992," 1992

b) Production of iron and steel

There are three iron and steel complexes in the Islamic Republic of Iran where steel is produced from iron ore. They are Isfahan Steel, Ahwaz Steel, and Mobarakeh Steel. Several steel mills produce steel products from steel supplied by the three complexes.

The three complexes are selected as targets in this study because a large volume of energy is consumed in the process of producing iron from iron ore, as mentioned below.

Isfahan Steel produces iron using the "blast furnace process" in which iron ore is reduced to iron by coke (coal). On the other hand, Ahwas Steel and Mobarakeh Steel produce steel in the "direct reduction process" in which iron ore is reduced to iron by natural gas. Mobarakeh Steel, however, is not expected to be in full operation in the near future. Two other mills visited by the study team can be said to be supplying all of its steel produced from iron ore in this country.

c) Energy consumption in manufacturing steel

(1) Blast furnace process

The process of producing steel products is divided into three main parts -- ironmaking, steelmaking, and rolling.

In the ironmaking process, iron ore is reduced to iron by coke as already mentioned. More specifically, because much of the iron ore comes in the form of fines, it is mixed with coke breeze and pulverized lime and baked into sintered ore in the sintering plant. Coal is converted into coke in a coke oven. Hot metal is produced in the blast furnace from the sintered ore, coke, and fluxes charged into it.

In the steelmaking process, the basic oxygen furnace (BOF) converts hot metal into steel by removing excessive portions of impurities such as carbon, silicon, and sulfur. The molten steel is then solidified into slabs, blooms or billets by the continuous casting process - forms that can be easily rolled during the process that follows.

In the rolling process, slabs and blooms are rolled into products by a series of processes including hot rolling, cold rolling, and surface treatment. The hot rolling process works reheated slabs or blooms on a rolling mill into sheets or plates, shapes, bars or wire rods. The cold rolling process is one that further reduces hot rolled sheets or plates by uniformly rolling them at ordinary temperatures, the purpose being to enhance their properties. Recently, continuons annealing and surface-treating lines have been installed that improve surface quality, durability, and workability of the steel sheets rolled.

Fig. 5.8 shows a typitcal "blast furnace process" in Japan, and Fig. 5.9 shows the producing process and energy flow in the Isfahan Steel Complex. Hot rolled coil and cold rolled coil are not produced in the Complex, as can be seen in Fig. 5.9. In the process of producing the steel products mentioned above, iron making consumes two-thirds or three-fourths of total energy consumed in the whole process. Particularly, the blast furnace consumes nearly 60 per cent of the total, which is carried by coke produced in the coke oven and put into the blast furnace.

At the same time, it should be take into account that coke oven gas (COG), generated in coal being converted into coke and blast furnace gas (BFG), generated from burning coke, are usually used as fuels in the steel mill.

In the Isfahan Steel Complex, COG and BFG are used as fuels for power generation and heating in the rolling process, according to a flow chart of energy which was given to the study team by the Complex.

In the steelmaking process, fuel is consumed in the basic oxygen furnace, which doesn't account for a large part of total consumption (the furnace consumes only about 2 per cent of the total fuel consumption in the typical steel--producing process in Japan). In the Isfahan Steel Complex, natural gas supplied from outside is used in this process. The high-temperature gas is generated in the basic oxygen furnace, where steel is made by spraying oxygen onto the hot metal. The gas -- BOF gas -- is not utilized in the Isfahan Steel Complex.

Finally, in the rolling process, fuels are used for heating the furnaces and electricity as power for the rolling mill.

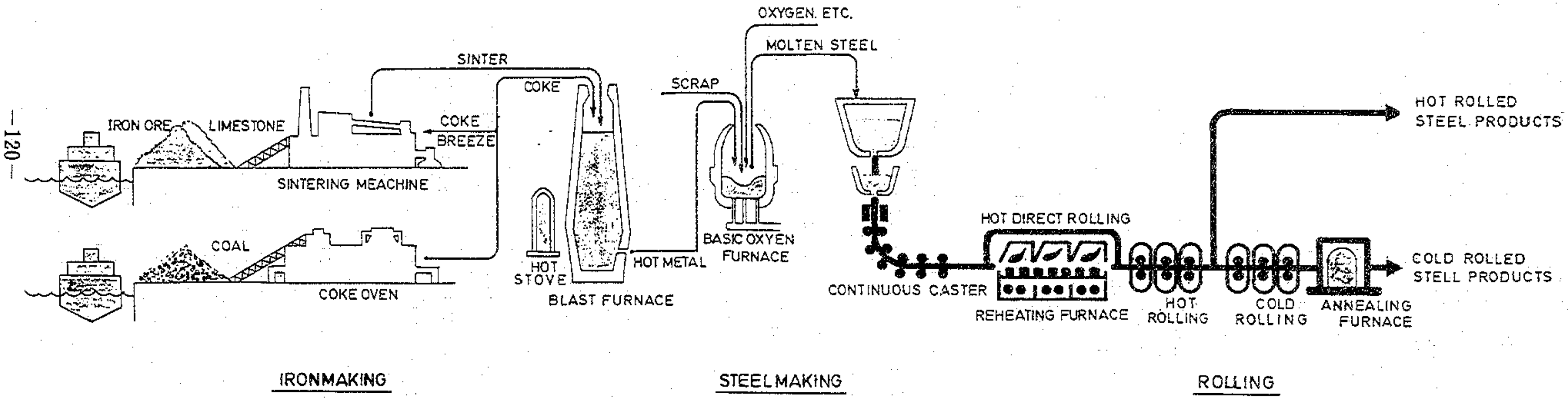
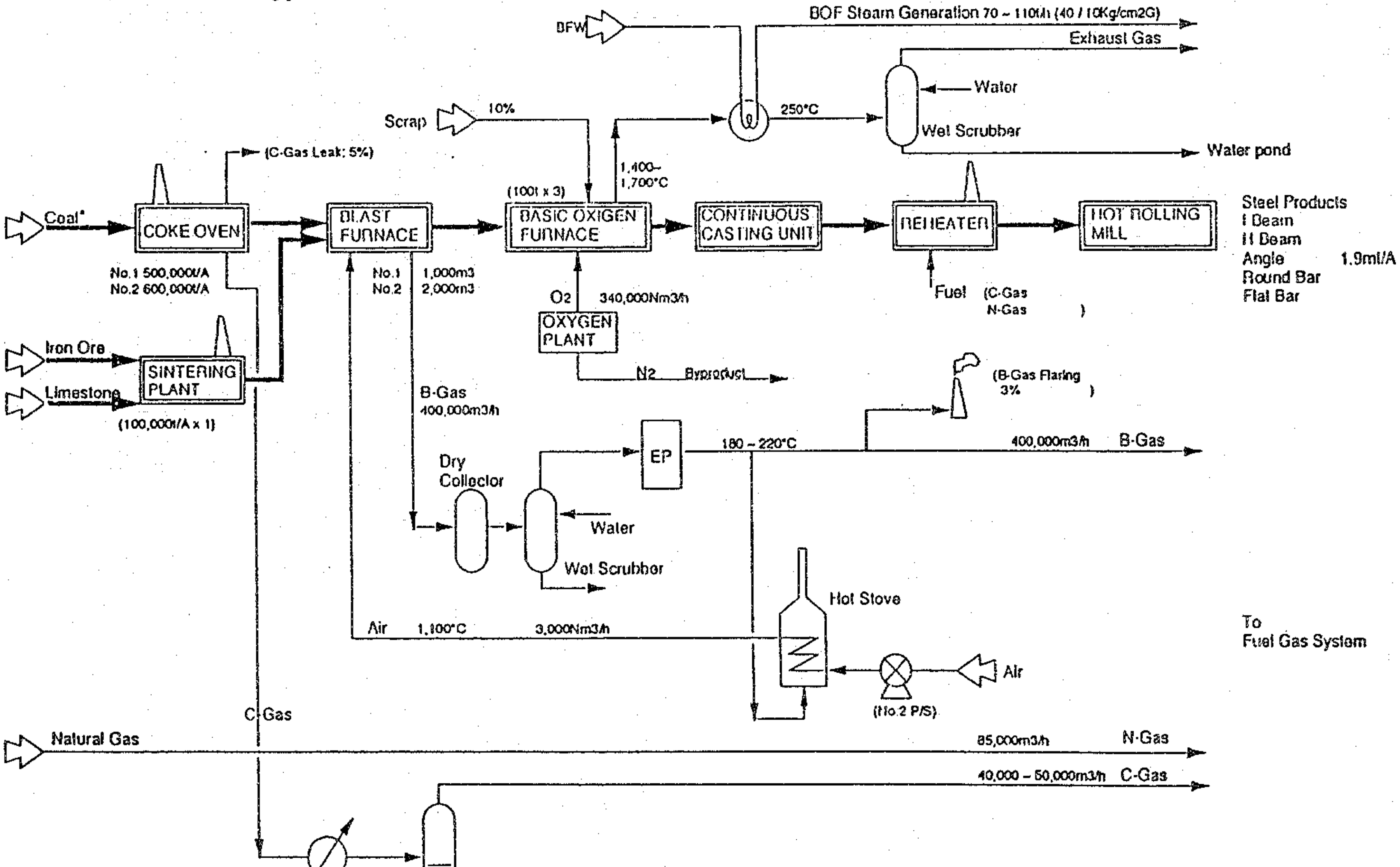


Fig. 5.8 Typical "Blast Furnace Process" in Japan

Fig. 5.9 Energy Flow in Isfahan Steel Mill



Power Consumption 130 ~ 135MW

Power Station No.1 24MW(Generation)
No.2 110MW(Generation)

Steam Generation No.1 140t/h(40Kg/cm2G)
15t/h to Factory at 10BAR and
10t/h Recovery by Condensate
No.2 440t/h(100Kg/cm2G)

Fuel Consumption(m3/h)

N-Gas	16,000
C-Gas	6,000
B-Gas	190,000

Solvent	330t/A
B.T.X.	7,065
Benzole	9,093
Phenole	390
H2SO4	4,700
(NH4)2SO4	18,200
Tar	57,870

* Energy Balance
Coal 85%
N-Gas 15%

In addition, electricity is used for operating blowers, fans, compressors, etc. as kinetic energy, for lighting, and in electrostatic precipitators.

(2) Direct reduction process

This process has been adopted in many countries which produce natural gas, and Ahwaz Steel and Mobarakeh Steel produce iron in this process in the Islamic Republic of Iran.

In these complexes, pellets are manufactured from iron ore in the pelletizing plant and are put into the reduction furnace to be converted into iron (Fig. 5.10).

There are several types of direct reduction processes. In the Ahwaz Steel Complex, three types of direct reduction plants - Purofer, MIDREX, and HYL - have been adopted. Among them, the HYL direct reduction plant is still under construction. Fig. 5.11 shows the production process and energy balance of the MIDREX direct reduction plant which is playing a major role in the Complex.

For steelmaking, the electric arc furnace is installed in the Complex. As can be seen in Fig. 5.11, the Complex doesn't have any rolling process facilities.

Looking at energy consumption by process, the ironmaking process accounts for a major part also in the direct reduction process. Nearly 95 per cent of total energy consumption is consumed in ironmaking in this Complex, as it does not have rolling process facilities.

d) Specific energy consumption in steel manufacturing

According to Table 5.11, specific energy consumption in the Isfahan Steel Complex is 10.3 Gcal/ton-molten steel, which is estimated to be the figure as of 1991. This includes electricity consumption, which is estimated to be 585 Kwh/ton-molten steel (503 Mcal/ton-molten steel). The specific energy consumption of 10.3 Gcal/ton-molten steel can be compared with 5.7 Gcal consumed in an integrated steel plant in Japan in 1991. There is also a big difference between the figures on specific electricity consumption for I.R. Iran and Japan.

Fig. 5.10 AHWAZ STEEL COMPLEX

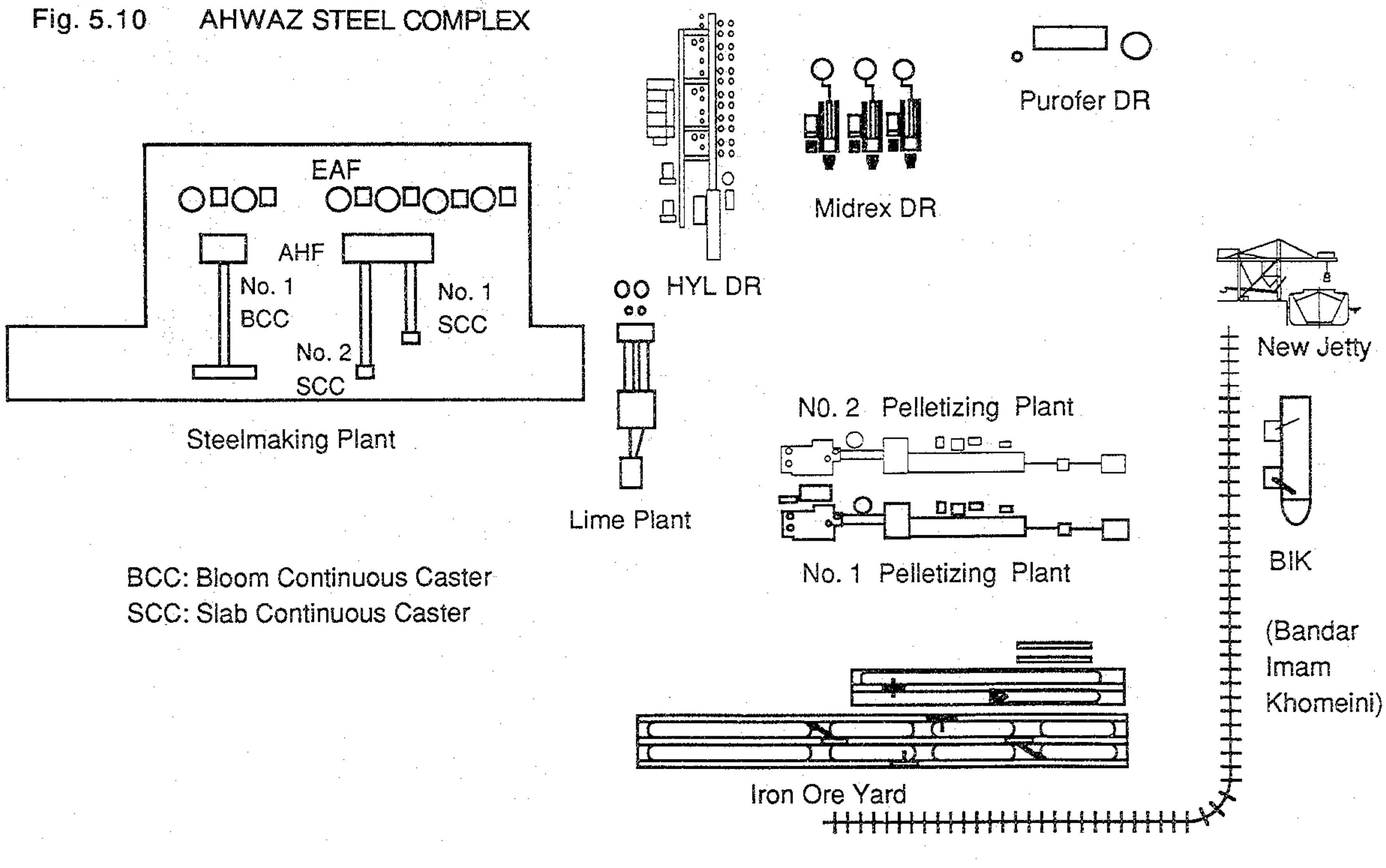


Table 5.11 Specific Energy Consumption in Iron & Steel Industry in I.R. Iran

	Total (Gcal/t-ms)	Fuel (Gcal/t-ms)	Electricity (Kwh/t-ms)	Remarks
Isfahan Steel	10.3 (5.7)	9.8	585 (450～480)	In 1991
Ahwaz Steel	3.43	2.82 (2.39)	711 (650)	In 1992

(Note) (1) Figures in ( ) mean those in Japan for Isfahan, and those planned by the factory for Ahwaz.
(2) Ms means molten steel.

In the Ahwaz Steel Complex, specific fuel consumption is 2.82 Gcal/ton-molten steel and specific electricity consumption is 711 Kwh/ton-molten steel in 1992, assuming all the steelmaking is done in the MIDREX process. The Complex planned its specific fuel consumption be 2.39 Gcal/ton-molten steel and specific electricity consumption 650 Kwh/ton-molten steel for 1992. Therefore, at least about ten (10) and fifteen (15) per cent of energy saving, respectively, could have been achieved.

Fuel consumption per ton of molten steel in the Purofer plant was more than 30 per cent higher, but electricity consumption more than 30 per cent lower, than those in the MIDREX plant. In spite of this fact, the MIDREX plant can be commended at least from the viewpoint of energy conservation because fuel consumption is much larger than electricity consumption in steel manufacturing.

(ii) Measures for Energy Conservation

a) Measures in category 1

Main measures in this category are the proper management of combustion and the prevention of high-temperature gas and steam from leaking in steel manufacturing, like in other manufacturing industries.

In manufacturing steel by the blast furnace process, the following measures can be recommended for category 1 :

(1) Proper management of combustion including that of the fuel/air ratio in the coke oven, sintering plant, blast furnace, and boiler.
(2) To improve the insulation of the various kinds of furnaces and boilers.
(3) To prevent cool air from entering the furnaces and boilers.
(4) To improve the insulation of pipes and ducts.
(5) To prevent steam and gas from leaking out of the pipes and ducts.

In manufacturing steel by the direct reduction process, measures mentioned above can be adopted as far as they are applicable.

Additionally, the proper procurement of equipment and parts is necessary for the higher utilization of plants which results in energy conservation. For instance, it was reported that process gas compressors in the Ahwaz Steel Complex could not be fully maintained because they were lacking in parts. (This kind of measure is also recommended for steel manufacturing by the blast furnace process.)

b) Measures in Category 2

Many of the measures in this category in steej manufacturing by the blast furnace process come under 5.2.1.1-(ii)-d) -- "recovery of waste heat". The following are measures by which the blast furnace top pressure recovery turbine (1) attains the largest energy savings rate in terms of cost/ benefit ratio, followed by the converter (basic oxygen furnace) waste gas collecting unit (2).

(1) Blast furnace top pressure recovering turbine (wet type)
(2) Converter waste gas collecting unit
(3) Coke dry quenching unit (CDQ)
(4) Blast furnace top pressure recovery turbine (dry type)
(5) Sealed-type converter waste gas collecting unit

There are also the following measures which are categorized as basic ways other than 5.2.1.1-(ii)-d).

(6) Hot charge rolling
(7) Coke oven humidity controlling unit
(8) Continuous annealing line

For electric arc furnaces in the Ahwaz Steel Complex, the following measures are recommended, among which (9) is especially important.

(9) Scrap pre-heating unit
(10) Water cooling wall
(11) Improvement of sealing the opening of the electric arc furnace.

Finally, recuperators have already been installed for recovering waste gas to preheat air and fuel in this Complex.

c) Measures in category 3

In steel manufucturing by the blast furnace process, the introduction of the newly-developed direct iron ore smelting production process is one of the measures in this category that is to be introduced in the future. It is estimated that this process will result in a significant level of energy conservation -- 300~600 Mcal/ton-crude steel -- equal to twice or three times the effect brought about by introducing the continuous casting process. The introduction of this process can be expected during the period of our study target (~2021).

In addition, as one of the measures in this category, we should take into account another innovative process also now under development, which is called semi-solid processing -- a process that will eliminate reheating furnaces and hot rolling mills.

In steel manufacturing by the direct reduction process, the installation of the direct current electric arc furnace is another measure in this category.

It is also worth considering that pig iron produced in the direct reduction furnace is input directly or continuously into the electric arc furnace. As can be seen in Fig. 5.12, the sensible heat loss of pig iron accounts for more than 70 per cent of total loss. Accordingly, preventing the loss will lead to a considerable amount of energy saving.

In addition, focusing on the Ahwaz Steel Complx, the following countermeaures are worth considering:

The first is to shut down the Purofer direct reduction plant. There are a few Purofer-type plants which have been established in the world. Among them the plant in the Alwaz Steel Complex is only plant of its kind which is still in operation. It is reported that the plant is not so efficient and suffering from many problems in its operation. For reference, the consumption of natural gas per ton of steel products was 351 Nm^3 in the Purofer plant, which can be compared with 293 Nm^3 in the MIDREX plant. The difference between these figures shows that shutting down the Purofer plant and operating the MIDREX plant at a higher rate would be highly effective in terms of energy saving.

Secondly, it may be necessary for the HYL plant construction plan to be revised. In the plan, three (3) HYL plant units will be installed in the Ahwaz Steel Complex although HYL Process-1, which the Complex is determined to construct, is the oldest one among the HYL Processes and existing HYL Process-1 plants are reported to have been operating neither efficiently nor a high utilization rate. Our suggestion is that if the No. 1 unit now under construction is not operating efficiently after its completion, the construction of No. 2 and No. 3 units should be cancelled and the No. 1 unit rebuilt to a more efficient MIDREX plant.

Thirdly, it is recommended that the Ahwaz Steel Complex also be an integrated steel complex. As mentioned already, blooms and slabs produced in the Complex are transported to other mills to make finished steel products because the Complex is not equipped with rolling process facilities. From the viewpoint of energy conservation as well as higher productivity, it is desirable for the Complex to be integrated.

Finally, the improved system of recovering scrap in this country and a higher utilization of scrap will result in lower electricity consumption for steelmaking in the electric arc furnace, not only in the Ahwaz Steel Complex but also in other complexes or plants. This measure may have to be categorized under "category 4", instead of "category 3".

(iii) Technical Potentials of Energy Conservation in Iron and Steel Making

The iron and steel industry in Japan achieved energy conservation of 624 Mcal per ton of crude steel in the period from 1973 to 1980, 55 percent of which was accounted for by measures in category 1. By IEEJ's estimates, the effects of energy conservation during this period by category are as follows:

	(Mcal/t-c)	(%)
Category 1	341	55
Category 2 and 3	283	45
Total	624	100

Furthermore, Nippon Steel Company estimated that the company achieved its 10.4 percent of energy conservation during the period from the first half of FY1973 to the first half of FY1978, 55 percent of which was again accounted for by measures in category 1.

Thus, the effects of energy conservation achieved by measures in category 1 were 300 - 350 Mcal/t-c for a few years after "the first oil crisis".

According to Isfahan Steel, Iran's s.e.c. in 1991 was 10,300 Mcal/t-c in the iron and steel industry (blast furnace type), compared to 5,407 Mcal in Japan in 1973. Such a large difference in the s.e.c. between the two countries suggests us that the effects of the measures in category 1 would be much larger than 300 - 350 Mcal/t-c in I.R. Iran.

In addition, the following measures in category 2 which are supposed to be implemented at a comparatively early stage will bring about an energy conservation rate of 46.4 ~ 59.01 (fuel oil equivalent), according to Table 5.36:

. Blast furnace top pressure recovery turbine (wet),
. Converter waste gas collecting unit,
. Coke dry quenching unit (CDQ),

. Hot charge rolling,

. Cake furnace humidity - controlling unit.

In the Ahwaz Steel Complex, the difference in the s.e.c. between the plan and actual results was 10 - 15 percent in 1992, as mentioned above. The difference can be narrowed by decreasing the acutual results, which will be mainly achieved by measures in category 1.

5.2.2 Energy Conversion Sector

5.2.2.1 Thermal Power generation

(i) Present Status of Energy Consumption and Loss in Power Generation

a) Demand for electricity

The sales of electricity in 1991 increased from 14,345 GWH in 1978 to 49,175 GWH in 1991 in the Islamic Republic of Iran.

The largest consumer of electricity was the residential sector, followed by the commercial and industrial sectors in 1991 (Table 5.13).

b) Power generation

The installed capacity of generating power was 18 GW in 1991, of which 15 GW is owned by the Ministry of Energy (MOE) and 3 GW by others.

Looking at the total installed capacity by power source, 55 per cent is accounted for by steam turbine, 27 per cent by gas turbine, and 12 per cent by hydro power in 1991. Thus, fossil fuels are playing a big role as fuels for power generation (Table 5.14 and Table 5.15).

Table 5.13 Sold Energy by Consuming Sector

(GWH)

	1967	1978	1989	1990	1991	Compounded Average Increase (1991/1967)(%)
Residential	473	3,862	15,791	17,344	19,128	16.7
Commercial	271	3,464	10,867	11,930	13,609	17.7
Industrial	504	5,877	8,466	10,220	10,637	13.5
Others	213	1,142	4,832	5,613	5,801	14.8
Total	1,461	14,345	39,956	45,107	49,175	15.8

(Source) MOE

Table 5.14 Installed Generating Capacity of MOE

(MW)

Year	Hydro	Steam	Gas Turbine	Diesel	Total
1967	309	343	84	198	934
1972	804	746	172	372	2,094
1978	1,804	1,719	2,887	614	7,024
1987	1,827	7,155	3,492	837	13,311
1988	1,914	7,475	3,489	803	13,681
1989	1,953	8,086	3,600	803	14,442
1990	1,953	8,086	3,940	824	14,803
1991	1,953	8,086	3,940	869	14,848

(Source) MOE

Table 5.15 Energy Generation in MOE

(GWh)

Year	Hydro	Steam	Gas Turbine	Diesel	Total
1967	658	732	56	396	1,842
1972	3,528	2,513	265	564	6,870
1978	6,249	6,316	3,928	893	17,386
1987	8,390	25,360	7,305	1,499	42,554
1988	7,311	26,968	8,146	1,350	43,775
1989	7,522	33,056	6,974	1,173	48,725
1990	6,083	38,836	8,723	1,254	54,896
1991	7,056	41,947	9,463	1,244	59,710

(Source) MOE

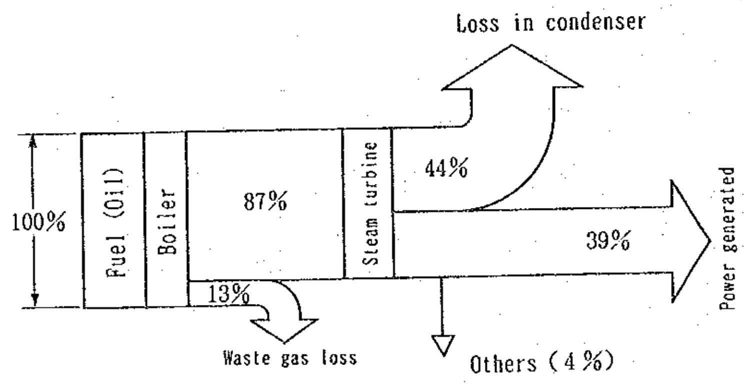
c) Own consumption and loss in thermal power generation

Thermal power generation by steam turbine, gas turbine, and diesel engine -- steam turbine in particular -- is targeted in this study. The reasons are that saving particulaly oil as well as gas, is an important task in power generation and that power generated by steam turbine accounts for two - thirds of the total power generation in I.R. Iran (1992). Power generation by combined cycle system has not been achieved yet in this country, although power plants of this system are under construction.

Steam power generation is a power generation system in which thermal energy created by burning fuel in the boiler generates high-temperature and high-pressure steam to be injected into a steam turbine where the energy is converted to mechanical (rotating) power that drives the power generator.

Figure 5.11 gives an account of the main factors contributing temperature loss and the rough proportions of temperature loss due to each factor in steam power generation. Fuel which has the therm of 100 and is input to generate steam loses 13% of the therm as waste gas loss in the boiler. Then, 3% as mechanical loss and 44% as thermal loss in the condenser are lost in the turbine. Thus, the balance of around 40% is used for power generation in the generator. In other words, about 60% of input energy is lost in steam power generation.

Fig. 5.11 The Thermal Account of Steam Power Generation(Oil fired; 600MW)



Additionally, a certain part of generated electric power is used for kinetic power and lighting the power plants. This is referred to as in-house consumption of electric power which usually totals les than 10 per cent of generated electric power(3 - 7 percent in Japan).

The balance, which is power generated subtracting losses and in-house consumption in power plants, is distributed to the general consumer. Accordingly, the amount of input energy (fuel) per one unit of electric power which is sent out of power plants is the indicator for the efficiency of consuming energy (fuel) in the plants. However, "gross fuel rate" or "fuel rate at the end of power generation" for thermal loss and "auxiliary power ratio" for in-house consumption are used very often as its indicators. Their definitions are as follows:

$$\text{Gross fuel rate} = \frac{\text{fuel consumption (l or kg)}}{\text{power generation (kWh)}}$$

$$\text{Auxiliary power ratio} = \frac{\text{in-house consumption}}{\text{power generation}} \; (\%)$$

d) The specific energy consumption in thermal power generation in I. R. Iran

The thermal efficiency in thermal power plants in I. R. Iran, which was 23 per cent in 1967 and 27 per cent in 1978, increased to 31 per cent in 1992, which means that the gross fuel rate decreased from 0.399 and 0.342 in 1967 and 1978 respectively to 0.249 in 1992 (Table 5.16).

The auxiliary power ratio was 5 per cent in 1991 for all power plants including the types other than thermal power (Figure 5.12).

For comparison, the gross fuel rate and auxiliary ratio were 0.227 and 4.7 per cent, respectively in thermal power plants in Japan.

Table 5.16 Generation, Heat Rate and Thermal Efficiency

Year	Generation of Thermal Units (GWh)	Heat Rate (kcal/kWh)	Thermal Efficiency (%)	Gross Fuel Rate (l/kWh)
1967	1,149	3,792	22.7	0.399
1972	3,342	2,975	28.9	0.313
1978	11,137	3,250	26.5	0.342
1987	34,164	2,837	30.5	0.299
1988	36,465	2,816	30.5	0.296
1989	41,203	2,754	31.2	0.290
1990	48,813	2,785	30.9	0.293
1991	52,654	2,753	31.2	0.290
1992	63,782	2,363	31.1	0.249

(Source) MOE

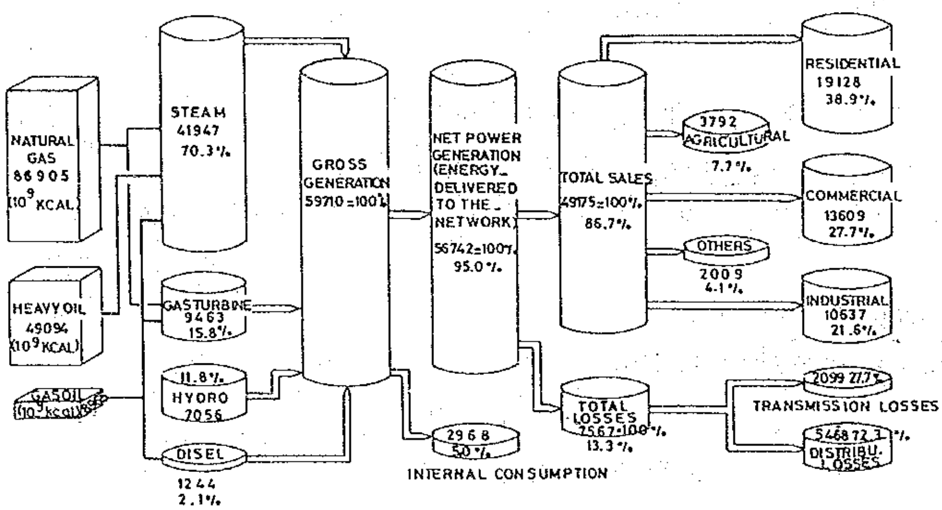


Fig. 5.12 Balance of Electric Energy in 1991(GWh)
(Source) MOE

(ii) Measures for Energy Conservation in Existing Thermal Power Generation

a) Introduction

Measures for energy conservation are considered in this section "Energy Conversion Sector." Here, the definition of basic ways or technologies for energy conservation and the categorization of measures are the same as in the section on "The Industry Sector" (See 5.2.1.1).

Accordingly, eight basic ways of energy conservation are kept in mind and measures are categorized into three groups.

In the energy conversion sector like in the industry sector, certain parts of the overall process are target where measures for energy conservation should be taken.

In steam power generation, energy loss in the condenser accounts for 44 per cent and waste gas loss in the boiler for 13 per cent of the total, as mentioned above. Therefore, if energy conservation is highly effective in these processes, it will bring about a large reduction in losses in the whole generation process.

First, maintaining a vacuum at a designed level in the condenser is critical for loss reduction. There are several factors that inhibit the creation of a vacuum state in the condenser, among which the most influential is soiled cooling tubes, where steam sent from the turbine is condensed through emitting heat to sea, river, well water flowing. The soiling can be cleaned by the "reverse flow of water" or using brushes and balls.

Secondly , in order to reduce waste gas loss in the boiler, it is very important that excess air ratio be decreased (air ratio should be maintained at a proper level), that it be maintained within the limits in which fuel is burned properly to the extent possible, and that the temperature of waste gas occurred be lowered as much as possible to the limit below which low-temperature corrosion of the boiler is not desirable.

Thirdly, in order to reduce mechanical loss in the turbine, introducing (installing) highly efficient turbine blades and proper steam sealing in machines and equipment, and low variable pressure operation of the boiler during operation are important measures for achieving optimum operation.

The following are measures for energy conservation in thermal power generation as those categorized into 3 groups taking into consideration the above important targets.

b) Measures in category 1

First, the following measures are recommended for boilers:

1) To increase combustion efficiency by improving air ratio.
2) To reduce the temperature of waste gas.
3) To enhance insulation efficiency.
4) To improve maintenance of air pre-heater.
5) To remove ash on the outer wall of boiler-tubes.
6) To operate boilers at variable pressure.

Secondly, following measures are recommended for turbines:

1) To maintain a vacuum state in the condenser.
2) To maintain the efficiency of cooling towers.
3) To repair any corrosion and damages on turbine blades.

Moreover, the study team observed in the power plants it visited that measuring machines had often not been well maintained.

In gas turbine power plans like the Ray power plant located near Tehran, optimizing the operation of many gas turbines installed - what gas turbines should be operated to achieve the highest efficiency as a whole in a power plant, and how? - is considered one of the most important countermeasures. The executives of the Ray power plant have already started to consider this issue in collaboration with outside experts.

c) Measures in category 2

First, the following measures are recommended for boilers;

1) To prevent air leakages (to seal air pre-heater, for instance).

2) To improve the heat transfer element of the air pre-heater.
3) To install equipment to decrease starting loss.

Secondly, the followings are recommended for turbines:
1) To install highly-efficient blades.
2) To improve the operation system of turbine values. (In Japan,this measure is often taken together with 1 above)
3) To install a cleaning device in the condenser.
4) To install a vacuum pump with the condenser instead of a steam air ejector as an air extraction device.

In addition, to adopt variable types of fans and pumps is one important measure for reducing power consumption.

In diesel engine plants, adopting a co-generation system (a combined heat and power system) will enable the utilization of waste heat from diesel engines and therefore lead to energy conservation.

Finally, in gas turbine power plants, the installation of a hardware(computers and others) is desirable to optimize the operation of many gas turbines.

d) Measures in category 3

Measures in this category are usually taken when existing machines and equipment are scrapped at the end of their lifetime. There are two kinds of measures to be taken on such occasions.

One is the case in which more efficient machines and equipment including boilers and turbines are "built," although their basic processes have not been changed or revised. In steam power generation, the two options are to install a high-pressure draft boiler for low O_2 operation or to introduce a variable pressure one - through boiler to increase its efficiency when operating with lower load.

In the Ray power plant, replacing gas turbines manufactured by a European manufacture with more efficient types is one way of inplementing such a "scrap and build" measure which should be taken in the future.

Another case is one in which already improved processes are adopted to the extent that finance, land, fuels, and other related factors are available. The combined cycle is such an improved process for thermal power generation, and this has already been adopted in some electric power projects in the Islamic Republic of Iran. Fuel cells, which are forecast to be commercialized five to ten years from now, can play an important role as a power source - particularly as a scattered source - because natural gas will be fired in them (although the system is not for thermal power generation).

(iii) Technical potential of energy conservation in existing thermal power plants

a) Measures in category 1

Well-organized data and information to show us the quantitative effect of measures for energy conservation in existing power plants have not been available. Therefore, a quantitative approach has been taken by referring to some examples available in Japan.

Table 5.17 shows the examples of energy conservation measures in category 1, the costs of which are zero or negligible, and their effectinveness in Japan. The scale and capacity factor of plants are shown in the table as they are important factors determining the quantitative effect of energy conservation in the plants.

It can be seen in the table that energy saved by the measures which were taken after "the first oil crisis" is in the range of 0.069 - 0.829 (fuel oil equivalent) per mWh of power generated. Energy saved by "Improvement in method for cleaning the condenser", which proved to be the second most effective as seen in the table, is equivalent to 6.9 per cent of own consumption in the plants. And "Optimization of time in cleaning the condenser" could save a large amount of energy. In boiler - related measures, a large effect could be accomplished by those for air pre-heaters.

The effects (saved energy) total 4.954 l per mWh if we add up all of them except for "Variable pressure operation (2)" -- this contradicts with "Variable pressure operation (1)" but others are not thought to contradict with each other -- and "Improvement in air ratio" -- the effect of which includes that of measures in category 2. If this amount of energy can be actually saved, around two per cent of

Table 5.17 Examples of Measures in Category 1 and their Effects in Thermal Power Generation in Japan

Measures(in the order of implementation)	Year(*)	Installed Capacity of Power Generation	Capacity Factor	Saved Energy	
				Per Power Generated (fuel oil equivalent)	To Auxiliary Power
		(MW)	(%)	(l/mWh)	(%)
<Boiler-related>					
Improvement in air ratio(**)	1980	750(375×2)	63.2	0.483	3.4
Operation at variable pressure(1)	1980	500(250×2)	30.4	0.710	6.8
Improvement in soot blower steam injection device in air pre-heater	1981	750(250×3)	45.8	0.343	3.4
Change in minimum air	1982	350(359×1)	34.7	0.241	2.1
Efficient use of heating steam in air pre-heater	1982	1,200(600×2)	57.4	0.829	9.7
Cut in temperature of waste gas	1982	1,120(220+450×2)	20.7	0.196	1.5
Operation at variable pressure(2)	1983	700(350×2)	29.0	0.163	1.4
<Turbine-related>					
Increase in the speed of flow in condenser	1982	900(450×2)	23.3	0.069	0.5
Optimization of time for cleaning condenser	1982	375(375×1)	60.0	0.518	0.5
Efficient use of extracted steam in turbine	1983	1,200(600×2)	60.0	0.453	5.5
Improvement in method for cleaning condenser	1989	500(250×2)	82.2	0.822	6.9
<Others>					
Saving of power for fan by improving gas damper control system	1980	1,125(375×3)	55.2	0.152	0.2
Rationalization of auxiliary machines and equipment operation	1982	2,550(250+325×2+ 450+600×2)	53.8	0.194	2.1
Saving of power for pump by cut in cooling water in boiler	1983	1,031(156+375+500)	22.0	0.427	3.5

(*)Year when a measure was implemented. (**)Including measures in category 2.
(Source)ECCJ

energy conservation will be achieved by the measures (Gross fuel rate was 249 l per mWh in 1992 in I.R. Iran as mentioned already).

In addition, it should be taken into account the fact that the measures in the table above would be taken in the second or third stage, not in the first stage in category 1. In other words, we can assume that there are many other measures which should be taken as elementary or primary ones, according to our observations during our visit to the power plants.

For instance, "Improvement in air ratio" in Table 5.17 partly includes measures in category 2 (including the replacement of the monitoring device) as well as those in category 1 (including daily monitoring and the exchange of burner tips in the boiler). In I.R. Iran, however, more elementary or primary measures such as surveysto find out whether or not there are air leakages at the bottom, corners, window - boxes, and doors of boilers, and sealing them if any leakages are found (it is expected that many leakages will be found) should be carried out in the first stage of measures in category 1.

Further, vacuum degree can be increased significantly in the condenser by more proper checking and maintenance. Data obtained when the study team visited the Montazer Ghaem, Tabriz, and Ramin power plants - particularly those for the former two - suggests us that a large amount of energy (fuel oil) can be saved by increasing the vacuum degree in the condenser (Table 5.18). In the Montazer Ghaem power plant, the vacuum degree was 586mmHg (23.0 in.Hg) at the time of the visited in August, 1993 while the designed level of the vacuum degree was 697 mmHg (27.4 in.Hg = 2.50 in.Hg-abs) according to a plant brochure. If the vacuum degree is improved (increased) by 111 mm Hg, which is the difference between the designed and actual levels, 2.896 l/mWh of fuel oil will be saved.

This estimate is made on the assumption that if the vacume degree is increased by 1mmHg, saved fuel oil will be $1{,}550 \times 10^3$ kcal/h, which is equivalent to the amount of fuel oil saved when a vacuum degree of 697mmHg is changed by 1 mmHg in a turbine with a capacity of 375 MW (See Figure 5.13). However, the amount of fuel oil saved is estimated to be much lager than the figures above, considering the following two facts - turbine capacity at the Montazer Ghaem power plant is 1 56 MW (much smaller than 375 MW) although any curve is not shown for the capacity in the figure;

and each curve is going up to the right. In this regard, savings are estimated to be much closer to an actual one in the case of the Tabriz power plant because its capacity is 387 MW and calculation is made by using 1,400 $\times 10^3$ kcal/h as the savings for the change of 1mmHg based upon the curve of 375 MW in the figure. Anyway, we can conclude that increasing the vacuum degree to the designed level will bring about a significant degree of energy conservation.

Table 5.18 Current Vacuum Degree in Condensers and Possible Saving of Energy in Three Power Plants Visited by the Study Team

	Montazer Ghaem	Tabriz	Ramin
Installed Capacity (Commissioning Year) (MW)	156 (1972) 156 (1972) 156 (1974) 156 (1974)	387 (1986) 387 (1989)	300 (1979) 300 (1983)
Main Fuel	Fuel Oil	Fuel Oil	Natural Gas
Capacity Factor(1992) (%)	72.0	53.3	64.6
Gross Fuel Rate(*) (1992)(A) (l/kwh)	0.263	0.248	0.224
Vacuum Degree in Condenser (mmHg)			
(1) Current	586	700	737
(2) Designed	697	724	747(***)
(3) (2)-(1)	111	24	10
Possible Saved Energy(**)(1992)(B) (l/MWh)	2.896	0.812	n.a.
B/A×100(%)	11.0	3.3	n.a.

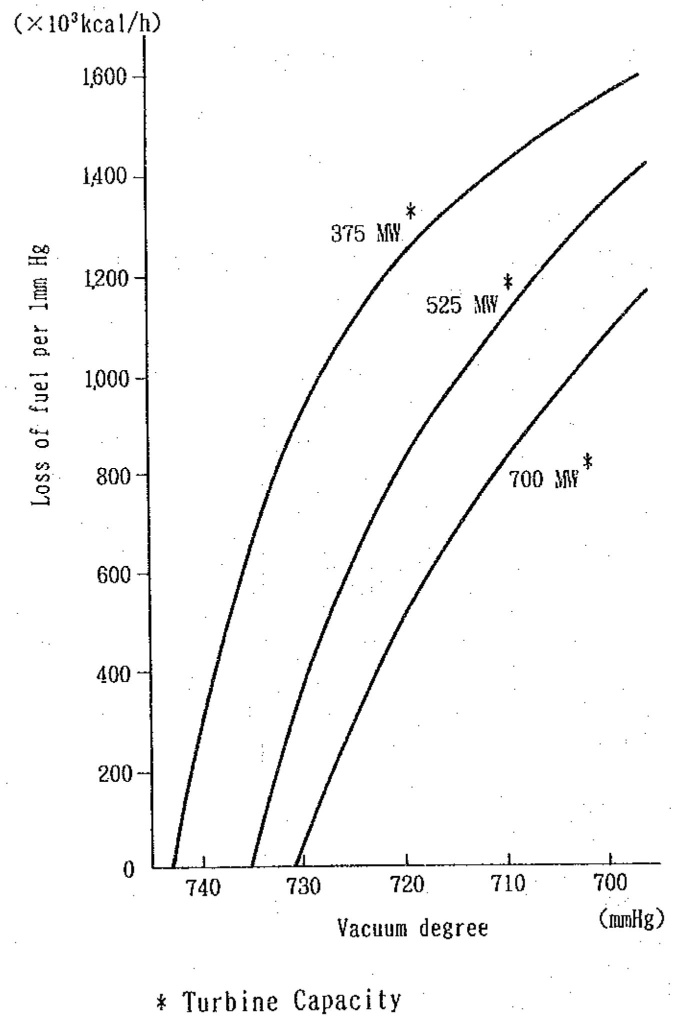
(*)l-fuel oil /kWh-power generated. Calorific Value of fuel oil is 9,500 kcal/l

(**)Meaning energy which can be saved if current vacuum degree which was observed at the visit of the Study Team is improved to designed one.

(***)Estimated

(Source)Annual Report of MOE(Persian); Others

Fig. 5.13 Changes in Fuel Loss due to Changes of 1 mm Hg in Vacuum Degree by Turbine Capacity



(Source) ECCJ

Furthermore, it was explained when the study team visited the Montazer Ghaem power plant that the reason why the pressure and temperature of steam were well below the designed levels was the corrosion of water tubes in the boilers. If that is the case, fuel consumption can be reduced by improving the pressure and temperature through proper maintenance of the tubes.

All of thermal losses shown in the above three examples cannot be recovered only by measures in category 1 which do not require high costs. However, such measures can contribute significantly to reducing the losses at least in the former two examples, that is "Improvement in air ratio" and "Increase in vacuum degree in the condenser". If we can make an estimation based upon the actual measures taken in Japan and the present status of energy consumption in I.R. Iran, it dose not seem so unreasonable for us to conclude that measures in category 1 which do not reqduire high costs can achieve 3 - 5 per cent of energy conservation in thermal power generation in I.R. Iran.

b) Measures in category 2

The actual measures in category 2 and their effects in Japan are shown in Table 5.19. "Improvement in efficiency of turbine brades" is the most effective among the measures shown in the table, by which 6.000 l/mWh of energy was saved, meaning 1 per cent increase in thermal efficiency. It is also worthy of noting that this amount of saved energy is as large as half of total auxiliary power, and that it was accomplished at as low a capacity factor as 38 per cent, as can be seen in the table.

This measure is followed by "Improvement in method for cleaning the condenser (to install cleaning device)", by which 2.081 l/mWh was saved, equivalent to 12.8 per cent of total auxiliary power. This measure, in which the cleaning method was improved by installing a ball cleaning device, has the effect of energy conservation that, together with that of the measure mentioned above, is a figure one place larger than even the largest in category 1.

The same thing can be said for two measures for boilers, that is "Cut in the temperature of steam at the outlet of the boiler" and "Cut in gas leakages in the air pre-heater (improvement in sealing)".

If all measures in the table are implemented in I.R. Iran, saved energy will total 11.882 l/mWh and the gross fuel rate be reduced by 4.87 per cent.

c) Measures in category 3

As mentioned already, there are two kinds of measures in this category. The first is to introduce more efficient machines and equipment which are basically of the conventional types or processes.

Table 5.19 Examples of Measures in Category 2 and their Effects in Thermal Power Generation in Japan

Measures(in the order of implementation)	Year(*)	Installed Capacity of Power Generation	Capacity Factor	Saved Energy	
				Per Power Generated (fuel oil equivalent)	To Auxiliary Power
		(MW)	(%)	(l/mWh)	(%)
<Boiler-related>					
Cut in spray in boilers reheater	1978	750(375×2)	69.9	0.436	3.1
Cut in gas leaks in air pre-heater (Improvement in sealing)	1980	125(125×1)	27.5	1.070	2.1
Cut in temperature of steam at the outlet of boiler	1981	220(220×1)	30.0	1.903	10.5
Cut in temperature of waste gas	1983	1,200(600×2)	60.0	0.253	3.0
Recovery of boiler drain	1983	1,031(165+375+500)	22.0	0.082	0.6
<Turbine-related>					
Improvement in efficiency of turbine blades(Conversion)	1980	175(175×1)	38.0	6.000	49.1
Improvement in method for cleaning condenser (To install cleaning device)	1982	350(175×2)	88.1	2.081	12.8
<Others>					
Improvement in cooling water system	1981	500(500×1)	81.5	0.057	0.4

(Source)ECCJ

Such a kind of boilers, turbines, generators, and others will be "built" when old, existing ones are to be "scrapped".

Thermal efficiency in thermal power generation is 31.1 per cent in I.R. Iran, while that in steam power generation 38.8 per cent in Japan (at the end of power generation and in 1992). From these figures, we can conclude there is a wide difference between thermal efficiency in thermal power generation in the two countries, despite the fact that there is a difference in the scale per unit of thermal power generation system between the two, and that power generated by gas turbines and diesel engines accounts for one-third of the total in I.R. Iran, while power generated in steam power plants accounts for almost all of the total in Japan, including that in plants of combined cycle system. If we can conclude this, the first kind of measures in this category mentioned above will accomplish a significant degree of effectiveness in energy conservation.

Secondly, if old and existing machines and equipment are "scrapped" and those of new processes or types "built" after overcoming constraints including finance, land, etc., this will be highly effective in terms of energy conservation.

In the combined cycle system fueled by natural gas, about 44 per cent of thermal efficiency has already been accomplished in 1,100 ℃ class gas turbines, and the efficiency is forecast to increase to about 47 per cent in 1,300 ℃ class gas turbines and later to about 50 per cent in 1,500 ℃ class gas turbines.

Introducing fuel cells utilizing natural gas can also contribute to increasing thermal efficiency in power generation, although fuel cells don't belong to thermal power generation. The thermal efficiency is forecast to be higher than 50 per cent in some types of fuel cells.

5.2.2.2 Petroleum Refining

(i) Present Status of Energy Consumption in Petroleum Refining

a) Demand for and Supply of Petroleum Products

Demand for petroleum products increased from 5.7 million B/D in 1980 to 9.4 million B/D in 1991. Middle distillates - kerosene and gas oil (or diesel fuel oil) - account for a major part of the demand (54 per cent in 1991) (Table 5.20).

Petroleum products, mainly the middle distillates, have been continuously imported although the domestic production of petroleum products has been expanding since the end of the war.

b) Petroleum refining

Refining capacity (crude distillation) increased from 585,000 B/D in 1986 to 954,000 B/D in 1992. There were 7 refineries as of the end of 1992, and the Arak refinery started partial operation recently (Table 5.21).

c) Own consumption of energy in petroleum refining

Petroleum refining is a process in which various hydrocarbon compounds in crude oil are processed into fuels and other useful products. Main products processed in petroleum refining are listed below, from lightest to heaviest.

- Liquid Petroleum Gases (LPG - ethane, propane, butane, and others)
- Gasoline (naphtha)
- Aviation jet fuel
- Kerosene
- Gas oil (Diesel fuel oil)
- Heavy fuel oil
- Petroleum coke
- Asphalt (Bitumen)

In addition, refineries often produce lubricants and petrochemicals such as ethanol, styrene, ethyl chloride, butadiene, methanol, etc.

Table 5.20 Production and Consumption of Refined Products ('000 b/d)

A-Production

	1989	1990	1991
Gasoline	105.2	118.9	—
Kerosene	74.5	82.6	—
Distillate fuels	196.4	229.2	—
Residual fuels	211.3	230.9	—
Others	65.8	78.0	—
Total	653.6	739.6	853.2

B-Consumption

	1989	1990	1991
Gasoline	119.9	131.0	148.1
Kerosene	118.3	129.3	150.6
Distillate fuels	264.7	289.3	350.1
Residual fuels	198.5	216.9	222.0
Others	77.1	84.3	64.4
Total	778.5	850.5	935.0

(Source) OPEC, Annual Statistical Bulletin 1991

Table 5.21 Refining Capacity ('000 b/d)

Existing Refineries	1986	1992	1994	1996(2)
Abadan(1)	—	260	390	500
Tehran	200	220	240	240
Isfahan	220	280	365	365
Tabriz	80	99	110	110
Shiraz	40	40	40	40
Kermanshah (Bakhtaran)	25	35	35	35
Lavan	20	20	20	20
Total	585	954	1,200	1,310
New Refineries Arak	——	——	150	300
Bandar Abbas	——	——	232	232
Grand Total			1,582	1,840

(1) Destroyed during the war.

(Source) Arab Oil and Gas Directory, 1993

There are four main processes in petroleum refining, which are separation (distillation), conversion (cracking), reorganization (reforming), and finishing (treating).

In distillation, the hydrocarbons in crude oil are separated from one another. The heated crude oil is fed into atmospheric distillation columns (towers) where it is broken down into its constituent hydrocarbons on the principle that the various hydrocarbons boil at different temperatures, and then the lighter fractions of separated hydrocarbons are sent to various conversion and finishing processes. The heavier high-boiling-point products are sent to a vacuum distillation unit for further separation where they are broken into fuel oil and asphalt, lubricant, and other fractions.

Cracking is used to convert heavier, lower-value hydrocarbons into lighter, higher-value ones. Catalitic cracking is used to convert intermediate distillates (equivalent to kerosine and gas oil) into gasoline. Hydrocraking is used to convert highly aromatic hydrocarbons, which severely degrade the catalysts used in catalytic processes, into high-octane gasoline and aviation jet fuel. Finally, the thermal cracking method is used to convert low-grade residual oils into gasoline, gas oil, and coke, and to reduce the viscosity of heavy fuel oil. More specifically, gasoline, gas oil, and coke are produced from vacuum residues (asphalt and heavy fuel oil fraction) by the coking method, and the viscosity of heavy fuel oil is reduced and gas oil is produced by the visbreaking method.

Reforming, an extension of the cracking process, is used to raise the octane number of gasoline. Octane ratings are enhanced by reorganizing hydrocarbon molecules, principally by changing their structure. Reforming can be accomplished by the thermal method, but catalytic techniques have made them obsolete. Alkylation, isomerization, and polymerization processes are those belonging to catalytic reforming.

Finally, treating processes are used to remove detrimental components from petroleum fractions. Hydrotreating is the most widely used finishing process.

The next question is the proportion of energy (fuel) used in the main processes mentioned above. The proportion of energy (fuel) used in the petroleum refining processes varies from one case to another, as Dr. P. Schenk of Royal Dutch Steel Group made his proposal in the late 1960s that a proper or appropriate amount of "energy consumption and loss" should be calculated in order to promote energy conservation in refineries because, for instance, fuel used in crude oil distillation was 25 per cent of the total in one refinery and 80 per cent in another as mentioned later. The share of electricity is usually very small (Oil and Gas International, March 1968).

Generally, less energy is used in distillation and more in cracking and reforming in the U. S. . According to a study done by the Office of Technology Assessment, the U.S. Congress, distillation accounts for 23 per cent of the energy used in refining. Of this, atmospheric distillation accounts for 16 per cent, and cracking accounts for 13 per cent, reforming 30 per cent, treating 17 per cent, and others 17 per cent ("Industrial Energy Efficiency", August 1993). The share of distillation here is close to the smallest figure which Dr.Schenk mentioned in 1968.

On the other hand, the weight of distillation process is generally higher in the composition of refining processes in I. R. Iran, as we can see in refineries which are not equipped with other facilities than crude atmospheric distillation units, like in the Kermanshah and Lavan refineries. Although detailed data are not available, distillation can be estimated to be larger and cracking and reforming smaller in I. R. Iran than in the U. S. in the composition of energy consumed in each process of refining.

Now, let's look at the shares of types of energy input into petroleum refining. Table 5.22 shows the shares of fuel input (liquids, gas, and solids generated in a refinery are usually used as fuels for in-house consumption) and electricity bought. The share of fuel is very large, and can be compared with the small share of electricity (1～3 per cent) in Japan, while electricity accounts for about 10 per cent in the U.S. or in the Shell group. While there is a difference in the share of electricity, it is common in all cases that the share of fuel is as high as 90～99 per cent. 55～70 per cent of energy consumed as fuel is used in heating furnaces which generate process heat used in distillation, cracking, and other processes. And 25～45 per cent is used for generating steam which is supplied to steam-driven facilities including turbines and generators.

Around half or more of energy generated by fuel is lost for cooling products in the final stage of refining. About 50 per cent is lost for cooling products in the case of a refinery in the U.S. shown in

Table 5.22 Consumption Share of Power Bought and Fuel Used in Petroleum Refinery

Refineries	Survey Time	Power Bought	Fuel Used	Share of Process Heat and Steam(Fuel=100)	
				Process Heat	Steam
(1)A refinery in Japan	1976	3	97	55	45
(2)B refinery in Japan	1974	1	99	53	47
(3)A Oil Company in the U.S.A.	around 1975	10	90	72	28
(4)Average refinery in Shell Group(except for North America)	around 1980	9	91	56	44

(Source) (1) ECCJ, "Annual Report: The 5th Edition" ,1980(Japanese)
(2) Aizawa,M.. "Energy Conservation by Technology in Oil Refinery" November 1982.
(3) Shiroko,K.,et.al., "Energy Conservation in Petroleum Refineries, -Current Status and Future Trends-" (Chemical Economy & Engineering Review,November 1976).
(4) "Optimization of Energy Consumption in Refineries" ,The Sekiyu, November 1981(Japanese)

Table 5.22 above, and the share is reported to be nearly 60 per cent in the case of a refinery in Japan (ECCJ "Annual Report 1982"). Accordingly, it is very important from the viewpoint of energy conservation for refineries to reduce such heat loss as much as possible through improving and reinforcing the method of heat recovery.

d) The specific energy consumption in refineries (in-house consumption and energy loss per unit of crude throughput)

The study team visited the Tehran and Tabriz refineries among the refineries shown in Table 5.21. Data given to the team show that in-house consumption and energy loss was 7.2 per cent of crude throughput in the Tehran refinery (in January, 1993), and 8 per cent in the Tabriz refinery (the latest figures as of the visit in July, 1993).

In addition, in-house consumption and energy loss in all refineries in I. R. Iran was 8.0 per cent in 1989 and 6.2% in 1990, according to the International Energy Agency's statistics.

The proper or appropriate rate of in-house energy consumption in petroleum refining depends upon the composition of refining facilities. As mentioned in c) above, the rate of in-house energy consumption is usually higher in the U.S., where a higher share of cracking and reforming capacities - the latter in particular - in total refining facilities is characteristic compared with refineries where the weight of distillation is higher. What is more, in-house energy consumption is larger in refineries which are installed with anti-pollution devices such as de-sulphurization and other units, as can be seen very often in Japan.

Looking at the composition of facilities or processes, the proper rate of in-house energy consumption is thought to be generally lower in I.R. Iran than that in the U.S. and Japan because the weight of distillation is larger in I.R. Iran, as mentioned above. In this connection, in-house consumption is 5 per cent in the U.S. and 6.3 per cent in Japan, according to IEA (in 1990).

Some methodologies for estimating the proper in-house consumption in refineries has been developed for the purpose of accelerating energy conservation. According to a methodology using the concept of "the complexity" of petroleum refineries, the proper rate is estimated at 5 - 6 per cent in the

Tabriz refinery, and about 5 per cent as the average in all refineries in I.R. Iran (Note).

(Note) The methodology using the concept of "the complexity" was introduced by W.L. Nelson (Oil and Gas Journal, March 7, 1975 and other issues). Among others, there are "Refinery Energy Factor" which was developed by W.P. Thomson, partly depending upon W.L. Nelson (Oil and Gas Journal, January 2, 1978), "CEL Index" which was developed by P.Schenk as mentioned already, and "Energy Guideline Factor" which was used by the EXXON Group of companies (Proceedings of the Tenth World Petroleum Congress, 1979).

(ii) Measures for Energy Conservation in Existing Facilities

As mentioned on measures for energy conservation in thermal power generation, it is necessary for us to confirm the main targets for measures in petroleum refining.

First, it is important to maintain a proper air ratio in heating furnaces and boilers for the efficient combustion of fuel for generating process heat and steam.

Secondly, another very important measure is to recover heat as much as possible in the process of cooling products where around half or more of energy generated by fuel is lost. It is necessary to cool products at the final stage because they still hold much heat after finishing a series of refining processes and their temperature is too high to be sent to storage tanks. Water coolers or air coolers are installed as heat exchangers. To recover heat which will otherwise have been lost in the coolers is the purpose of this measure.

Thirdly, the efficient utilization of steam, prevention of air leakages, and recovery of condensate as much as possible are measures which can bring about a high rate of energy conservation.

Fourthly, it is recommended that machines and equipment are well insulated in order to prevent heat loss for process heat as well as steam.

Finally, recovering energy in the form of gas -- recovery of off - gas and recovery of heat from waste gas -- should also be noted.

These measures are usually taken step by step in existing plants -- first, proper operation and maintenance, and then, improvement in machines and equipment (conversion, addition, etc.).

Tracing experiences on "Improvement in air ratio" as an example in Japan, the first step was proper monitoring or measuring. Since this is done using an analytical device, installation or repair will be necessary if this device is not installed or is out of order in the plants in I. R. Iran. The next step was controlling air supply (it is the work of the operators to control damper, air register, others by hand), and preventing air leakages. (For this purpose, materials such as aluminum tape, asbestos yarn, etc. are used. The installation of stopcocks on burners as well as the improvement check-windows are also necessary). After taking these measures mainly in category 1, low O_2 burners, the automatic damper control system, and others were introduced.

The followings are main measures, classified into three categories.

a) Measures in category 1

The followings are recommended as countermeasures in this category in existing refineries:

(1) Furnace and boiler efficiency improvements through improved control and maintenance, including checking and adjusting their fuel/air ratio.

(2) Heat containment with improved insulation.

(3) Steam system improvements including repairing leaks and traps, reducing consumption, and recovering condensate.

(4) Operational improvements on existing equipment such as cutting back on distillation column reflux rates.

(5) Shutdown of some operations such as power-consuming devices when not needed.

(6) Better heat recovery through a program of monitoring and cleaning heat exchangers.

b) Measures in category 2

The followings are recommended as measures in this category:

(1) Improved heat integration including waste heat recovery from process steam, heat

exchanger optimization, and distillation optimization

- To install heat exchangers in the atmospheric distillation unit, catalytic cracking unit, and others

(2) Improved furnace efficiency including combustion air preheating and steam generation

-To install a waste heat boiler with the heating furnace in the atmospheric distillation unit, vacuum distillation unit, and others

-To install an air preheater with the furnace in the atmospheric distillation unit, and others

-To install an improved damper with the furnace in the atmospheric distillation unit, vacuum distillation unit, and others

(3) Heat containment with additional insulation including insulation on tank as well as equipment and piping

(4) Heat recovery from condensate and waste steam

(5) Energy recovery from high-pressure or high-mass flow streams by using power recovery turbines and gas expanders

(6) Use of high-efficiency rotating equipment

-To install an inverter system in the atmospheric distillation unit, and others

(7) Use of lower-quality fuels such as by-products

-To install a gas holder in the refinery

(8) Proper management of water recycle streams

(9) Reduction of pressure drop in critical circuits including lines, reaction beds, furnaces, columns, and heat exchangers

c) Measures in category 3

One of the most important measures in this category is to install facilities which convert heavy fractions to middle distillates. The installation will contribute to increasing the supply of kerosene and gas oil as well as to reducing the surplus of fuel oil in the Islamic Republic of Iran.

(iii) Technical Potential of Energy Conservation in Existing Refineries

After "the first oil crisis", measures for energy conservation were taken rapidly in many industries including petroleum refining in industrialized countries. These measures involved mainly the proper maintenance and operation of machines and equipment in the first stage, then gradually shifting its focus to the conversion or addition of machines and equipment. Here in this section, the effectiveness of measures for energy conservation are estimated quantitatively by referring to experiences in Japan and other countries.

According to a survey made by the Petroleum Association of Japan (PAJ) in 1979, in-house energy consumption in refineries was decreased by 16 per cent using measures in category 1 and by 7 per cent using those in category 2 (Table 5.23).

Energy saved by measures in category 1 totaled 10l (fuel oil equivalent) per 1 kl of annual crude throughput. However, since the effects which were accomplished by measures taken in 1974~75 were not included in this table, it can safely be said that much more were accomplished actually during the five years from 1974 to 1978. In addition, the measures taken were mainly those whose costs were nil or negligible. Finally, energy saved by measures in category 1 accounted for 82 per cent in 1976, 70 per cent in 1977, and 63 per cent in 1978, being larger than that in category 2.

Measures in category 1 which were highly effective during the period from 1976~1978 are as follows (Figures show the effects in l - fuel oil/kl - crude throughput):

(1) Control of O_2 in heating furnace	2.8
(2) Improvement in storage tank insulation	1.0
(2) Rationalization of steam system	1.0
(4) Improvement in balance of plant operation	0.8
(5) Reflux rate cut	0.6
(5) Recycle gas rate cut	0.6
(7) Improvement in operating conditions	0.4
(7) Injected steam control	0.4
(9) Improvement in heat exchanger cleaning metnod	0.3
(10) Improvement of operation temperature and reaction pressure	0.2

Energy saved by measures in category 2 was 4.6 l (fuel oil equivalent) per 1 kl of crude oil throughput for the period from 1976~78, which was less than half of that in category 1. However, as mentioned for measures in category 1, energy saved by measures in category 2 during the period from 1974~75 is not included in the table. In addition, measures in this category were taken on a full

Table 5.23 Examples of Effects of Measures for Energy Conservation in Petroleum Refining in Japan

	FY1976	FY1977	FY1978
(A) Annual Crude Oil Throughput	246,521	248,587	249,983
(B) Annual Energy Consumption(*) (Fuel oil equivalent 1,000kl)	12,700	12,700	12,341
(C) Energy Saved by Conservation Measures (Fuel oil equivalent 1,000kl) (D+E)(**)	873	2,143	3,721
(D) Energy Saved by Measures in Category 1(**) (Fuel oil equivalent 1,000kl)	715	1,613	2,573
(E) Energy Saved by Measures in Category 2(**) (Fuel oil equivalent 1,000kl)	158	530	1,148
(F) The Specific Energy Consumption without Any measures [(B+C)/A×1,000]	55.1	59.7	64.3
(G) S.E.C. when only measures in category 1 are implemented [(B+C-D)/A×1,000]	52.2	53.2	54.0
(H) S.E.C.when only measures in category 2 are implemented [(B+C-E)/A×1,000]	54.4	57.6	59.7
(I) Rate of Savings (G/F×100)(%)	94.7	89.1	84.0
(J) Rate of Savings (H/F×100)(%)	98.7	96.5	92.8

(*) Increase in energy consumption by installing anti-pollution devices is excluded.
(**) Energy saved in 1977 and 1978 is cumulative one.
(Source) Estimated by IEEJ using data and information compiled by PAJ in February,1979.

scale after this period.

Among measures in category 2, the following are those which had a large effect in energy conservation (The unit used is the same as that for measures in category 1).

(1)	Installing heat exchangers and improvement in their arrangements	0.5
(2)	Efficient use of steam	0.4
(2)	O_2 reduction in heating furnace	0.4
(4)	Installing steam generator	0.3
(4)	Improvement in balance of plant operation	0.3
(4)	Reinforcing insulation	0.3
(7)	Recovery of off-gas	0.2
(7)	Better functioning of steam trap	0.2
(7)	Recovery of hydrogen gas	0.2
(7)	Improvement in controlling method	0.2

Reports on experiences on energy conservation other than the survey complied by PAJ have been issued, as indicated below. The first is the annual survey published by ECCJ, which shows that refineries in Japan could save energy by 9~15 per cent by taking measures in category 1.

The second is a report on energy conservation in the U.S., which concluded after having conducted energy audits at refineries of a certain company that a goal of 10 to 15 per cent in energy saving based on 1971 total consumption was considered feasible in the next four to five years. By early 1975, it had reached about two-thirds of the goal, largely as a result of measures in category 1 (Source is the same as (3) in Table 5.22).

The third is a report prepared by the Shell group, saying that around 20 per cent of energy conservation was achieved in its 33 refineries except for those in North America during the period from 1972 to 1980, and that more than half of it was accomplished by such measures as sufficient management and reinforced maintenance (Source is the same as (4) in Table 5.22).

Experience in Japan and other countries above show that in-house consumption and energy loss in refineries were reduced by 7~15 per cent by taking measures in category 1, and by 3~8 per cent by those in category 2 for a few years after "the first oil crisis". It is needless to say that even if a 10 per cent reduction were achieved using one measure in one case, it does not mean that the same measure will have the same effectiveness in another. The measures taken will vary in content and intensity, and the specific energy consumption in the refineries, before the measures are actually taken, will also differ from each other.

Despite such consideration, it is thought to be correct in concluding that the effect of measures in a certain range would be much larger in I.R. Iran than in other countries. As mentioned already, sufficient maintenance and rehabilitation have not been carried out on machines and equipment in this country because of the war and the shortage of foreign currency, and this is one of the main reasons why we made the above conclusion. The temperature of waste gas from boilers can lead us to conclude that in-house consumption of energy in refineries is much larger in I.R. Iran that in Japan and other industrialized countries. The actual temperatures are shown below, although guidelines for the operation of refineries indicate that the proper temperature is around 120~ 150°C in these facilities.

(At the outlet of)	(Tehran)	(Tabriz)
Heating furnace at atmospheric distillation unit	480°C	340°C
Heating furnace at vacuum distillation unit	480°C	460°C
Boiler	260-370°C	260°C

Therefore, if the same measures in category 1 as those taken in Japan during the period from 19 74-78 are also taken in I.R. Iran, it is highly possible the effectiveness of the measures is larger than the 10 l (fuel oil equivalent) per 1 kl of crude oil throughput that was achieved in Japan. Assuming that current in-house consumption is 60 l - fuel oil/kl - crude throughput and 10 l of fuel oil can be saved by measures in category 1 in I.R. Iran, the rate of energy conservation will be 17 per cent.

The rate of energy conservation will be 8 per cent in the case of measures in category 2 using the same calculation. Accordingly, it can be said that about 25 per cent of energy conservation can be achieved by taking both measures in category 1 and 2 in petroleum refining in I.R. Iran.

5.2.3 Road Transport Sector

5.2.3.1 Measures for Energy Conservation in the Road Transport Sector

There are many measures for energy conservation in road transportation, including those aimed toward each vehicle as well as those concerning infrastructure for road transport. Here, measures taken toward the improvement of vehicles, vehicle maintenance, and improvement of road transportation systems will be described.

(i) Measures taken by Manufacturers using Automotive Technologies

Energy conservation using automobile technologies have been undertaken by automobile manufactures in industrialized countries from the standpoint of fuel consumption and, recently, of environmental protection.

a) Improvement of Gasoline Cars

It is common to use gasoline engines in passenger cars. Many technologies for reduction in fuel consumption have been developed. Recently, this necessity has been increasing due to environmental pollution by carbon dioxide.

Fig. 5.14 shows the change in fuel consumption by gasoline cars by year, and it shows there has been less improvement in the recent years. The reasons are that every available technology has been employed, and automobiles have therefore become heavy due to the addition of equipment for safety and comfort. The current technologies used for reduction in fuel consumption are shown in Table 5.24. Diesel engines are listed in the table, because diesel engines have better performance in fuel consumption than gasoline engines; diesel engines will improve fuel consumption by 40 - 50% at low speed and 20% at the speed of 120 km/h in comparison with gasoline engines. However, diesel engines create problems of environmental pollution that gasoline engines do not.

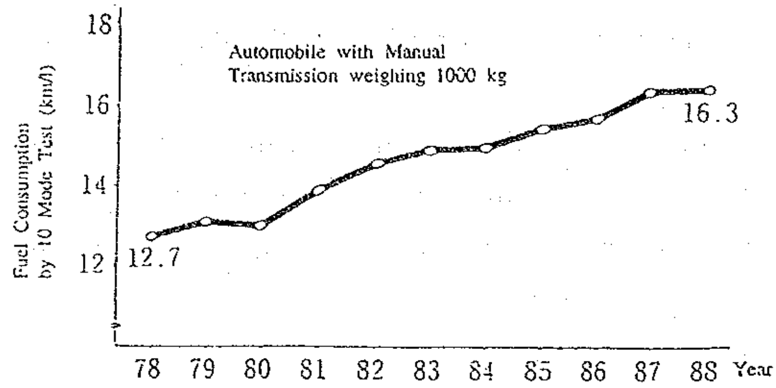


Fig. 5.14 Transition of Fuel Consumption of Gasoline Car

b) Improvement of Diesel Cars

Diesel engines are commonly employed in buses and trucks because of their rate of fuel consumption and durability. Technologies for improvement of fuel consumption in diesel engines have been developed as well as in gasoline engines. Fig. 5.15 shows the changes in fuel consumption in diesel engines.

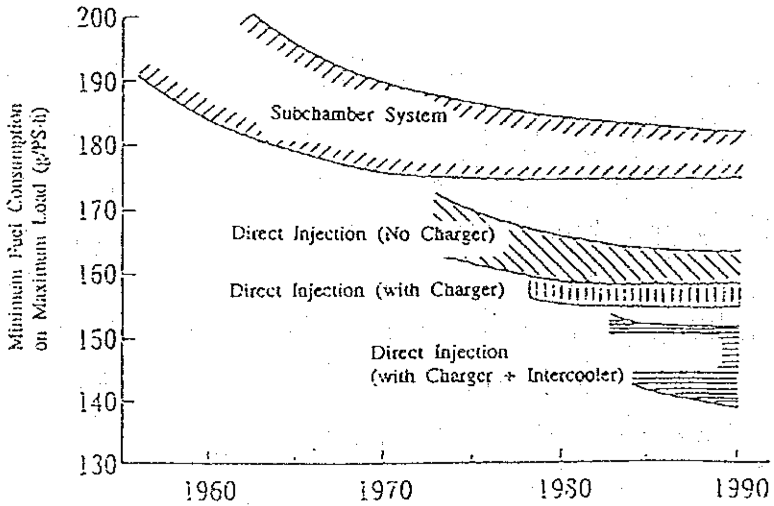


Fig. 5.15 Transition of Fuel Consumption of Diesel Engine for Automobiles
(Source) J. of Traffic Engineers

Technologies for improvement of fuel consumption in diesel engines will be introduced in the future.

(1) Reduction in Heat Loss

Main causes for heat loss are in the exhaust gas and cooling water. The exhaust gas turbo charger is an equipment for the effective use of the exhaust gas. In addition, the charger enhances the power of the engine. For reduction in the loss of cooling water, devices for controling cooling fans and cooling water pumps have been improved.

(2) Effective Use of Energy on Brakes

Since the inertial energy of brakes on buses and trucks is large, that energy can be electrically reused.

c) Use of Alternative Fuels

Some countries including the industrialized are trying to use alternative fuels instead of gasoline and diesel fuel oil for the conservation of energy and prevention of pollution. Fig. 5.16 shows the relationship between energy and automobiles. Improvement not only of alternative fuel-driven automobiles but also of infrastructure such as fuel supply systems will be essential in the promotion of the usage of alternative fuel-driven automobiles.

From the standpoint of energy conservation as well as environmental protection, the usage of energy that does not yield carbon dioxide upon both production and consumption is desirable. Fuels that meet this condition are hydrogen produced from non-fossil fuel sources, biomass, and electricity produced from non-fossil fuel sources.

(1) Electric Vehicles

Nowadays, electric vehicles have been partly put into practical use in industrialized countries. However, they are far from widespread use due to their performance and price. There is a regulation in California in the U.S. that requires 2% of new cars be electric vehicles during 1998 to 2000, 5% in 2001 to 2002, and 10% after 2003.

(2) Natural Gas Vehicles

The driving range of natural gas vehicles is one third or one fourth of gasoline vehicles, but the same technologies as the gasoline engines are applicable to the natural gas engines. In some countries where natural gas is produced, the natural gas vehicles have been used since the 1930's.

(3) Hydrogen-fueled Vehicles

Since it is difficult to store hydrogen, the hydrogen-fueled vehicles are still in the research phase.

(4) Methanol-fueled Vehicles

Methanol is in liquid form at normal temperature. Thus, one advantage of the methanol-fueled vehicle is that its chassis and engine structure are similar to that of gasoline and diesel vehicles. Its driving range is currently half that of the gasoline vehicle, but experiments for practical use have been conducted in industrialized countries.

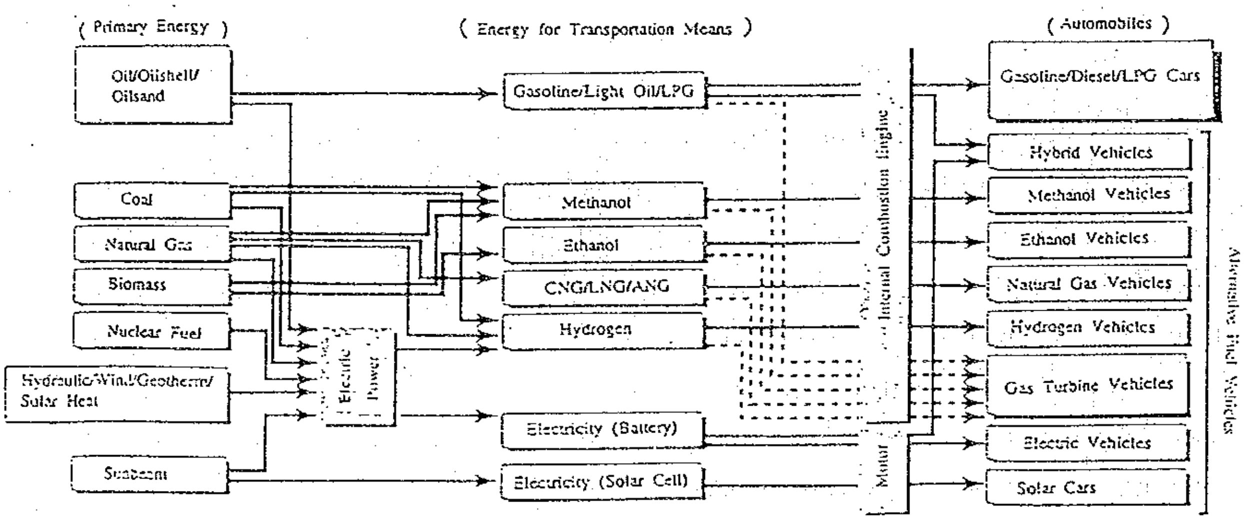


Fig. 5.16 Relations between Energy and Automobiles
(Source) Nissan

Table 5.24 Automotive Technologies for Fuel Efficiency

Parts		Details	Examples
Engine	Improvement of Thermal Efficiency	Improvement of Combustion Chambers	Optimization of Swirls Increase in Compression Ratio Use of Multi Valves Optimization of Port Shapes Variable Valve Timing
		Optimization of Mixing Ratio and Ignition Timing	Lean Burn Electronic Fuel Injection Electronic Spark Advance Improvement of Carburetor
		Improvement of Measures for Exhaust	Catalytic Converter Rhodium
		Use of Diesel Engines	
	Reduction of Loss	Lightening and Reduction of of Friction on Moving Parts	Lightening of Pistons and Valves Variety of Engine Oil Use of Two Piston Rings
		Reduction of Loss in Auxiliary Equipment	Improvement of Fans Electric Power Steering
	Miscellaneous	Reduction of Idling Rotation	
		Fuel Cut on Braking	
Resistance due to Acceleration	Lightening of Vehicles	Use of FF	
		Use of Light Materials	Use of High Tension Steel Use of Plastics for Bumpers Use of Aluminum Cylinder Blocks
	Lightening of Power Train	Use of FF	
		Use of Light Materials	
Running Resistance	Improvement of Rolling Resistance	Use of Radial Tires	
		Improvement of Wheel Bearing	
	Improvement of Air Resistance	Improvement of Body Shapes	Use of Flush Surfaces Use of Spoilers
Loss in Power Train	Transmission	Use of Lock-up in Automatic Transmission	
		Manual Transmission of Five Speeds	
		Electronic Automatic Transmission	
		Continuously Variable-ratio Transmission	
	Differential Gears	Use of FF	
	Air Conditioner	Optimization of Loads on Power Train	Two Way Control Modes Variable Capacity

(ii) Measures involving Vehicle Maintenance by Users

a) Maintenance of Vehicles

Measures for energy conservation that users can practice in vehicle maintenance are as follows:

- engine oil exchange at proper intervals;
- adjustment and cleaning of ignition plugs;
- cleaning of air cleaners;
- maintenance of batteries, and
- proper air pressure of tires.

b) Driving of Vehicles

Fuel consumption also depends largely on the way the vehicle is driven. Table 5.25 illustrates the ways in which energy conservation can be achieved and their effects.

Table 5.25 Driving Method for Fuel Efficiency

Items	Fuel Consumption(Passenger Car of 2 l engine)
Do not start your car with large acceleration	100 cc/10 times
Do not accelerate your car abruptly	50 cc/10 times
Do not load your car with unnecessary stuff	80 cc on run of 50 km with stuff of 10 kg
Do not rev up while stopping	50 cc/10 times
Do not leave the engine idle	200 cc/10 minutes
Make a route plan to your destination beforehand	500 cc on stray driving for 10 minutes
Run at a fuel-efficient speed (40-50 km/h on urban streets; 80 km/h on expressways)	

(iii) Measures involving Automobile Traffic

Measures involving automobile technologies and ways of driving have been described, but the most effective means of energy conservation in road transportation is the elimination of traffic congestion. Fig. 5.17 shows the relationship between average speeds of vehicles and fuel consumption. It shows that the fuel efficiency is proportional to the average speeds when the speed is slower than 60 km/h, and the best fuel efficiency is achieved when the speed is between 60~80 km/h. The figure also illustrates that fuel consumption is improved by 3% every increase of the speed by 1 km/h when the speed is slower than 60 km/h. Nowadays, West Europe, North America and Japan have been developing information systems for automobile traffic as national projects whose purpose is the reduction of traffic congestions, energy consumption, and the promotion of environmental protection.

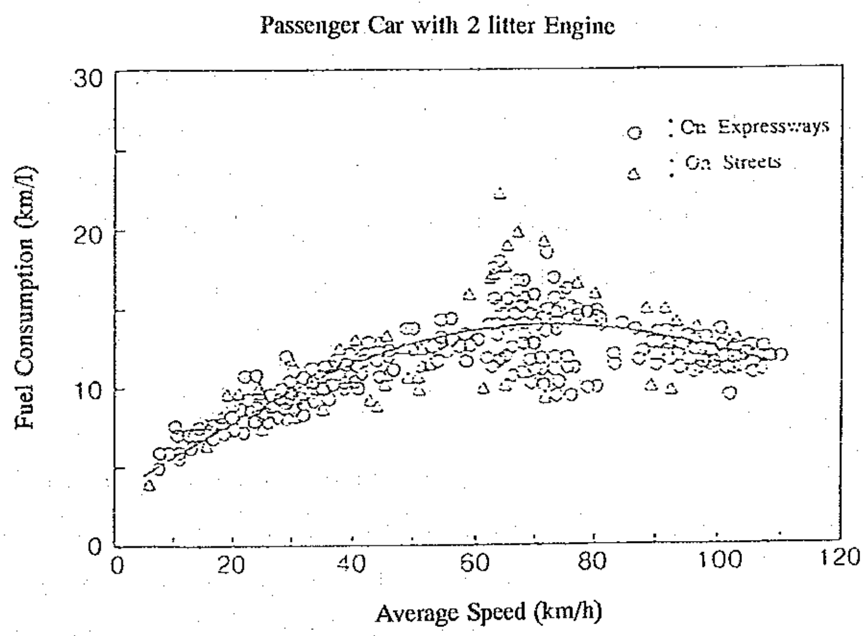


Fig. 5.17 Relations between Fuel Consumption and Average Speed

Here, systems for automobile traffic that have been employed or will be installed in the near future in developed countries are described.

a) Increase in Road Capacity

It is needless to say that traffic congestion will be eliminated by the construction of new roads. However, what should be pointed out is how the present roads can be used more efficient. The following methods are implemented in industrialized countries including Japan.

(1) Improvement of Present Roads

- Organization of Road Networks
- Widening of Roads

Larger road capacity will be realized by increasing the number of lanes on widened roads.

- Elimination of Road Bottlenecks

Intersections are where traffic congestions usually tend to occur, and so the improvement of intersections will decrease traffic congestion. In particular, the installation of right-turning lanes (in Japan) or left-turning lanes (in I.R. Iran) will not block the traffic that is trying to go straight through the intersection. Construction of bridges at large intersections to avoid turning using same lanes will also eliminate congestion. The installation of an additional lane for vehicles driving at slow speeds along ascending roads will also prevent congestion.

(2) Improvement of Automobile Traffic Management

- Efficient Use of Existing Roads

The installation and improvement of traffic signal control systems and traffic information boards will decrease traffic congestion. The installation of reversible lanes, which involves the shifting of the center lines on roads with multi lanes depending on traffic volume during rush hours, will increase road capacity. The construction of parking lots will decrease illegal parking that obstruct a smooth traffic flow.

In Japan, measures for a smooth traffic flow were installed along 72 routes comprising a total length of 1,783 km in 1991. The measures included synchronization of traffic signals, optimal tuning of traffic signal parameters, installation of lanes for right and left turnings. Table 5.26 illustrates the effectiveness of the measures.

Table 5.26 Effects of Smooth Traffic Flow

Items	Effects		
	Before Installation	After Installation	Improvement
Travelling Time (per 10 km)	16 min.9 sec.	14 min.40 sec.	9.2 %
Stopping Times (per 10 km)	4.75 times	3.77 times	20.7 %
Road Capacity	1603.8 veh./h	1710.6 veh./h	6.7 %

- Improvement of Utility of Public Transportation Means

Improvement of squares in front of stations, construction of parking lots for park and ride systems, and installation of bus information systems such as bus locating systems will ease the usage of buses and trains. The installation of bus priority lanes may become an incentive the usage of buses.

- Use of Advanced Technologies

Automatic toll collection on expressways, which the U.S. and Hong Kong have already employed, will decrease congestion at toll gates. Rational management of freight will decrease traffic volume of trucks.

b) Management of Traffic Demands

The management of traffic demands to decrease traffic volume is as important as increase in traffic capacity. The following measures have been put into practical use in developed countries including Japan.

(1) New Ideas for Use of Automobiles

- Increase in Transportation Efficiency

Ride sharing such as car pool and van pool will decrease the numbers of automobiles. In the U.S., there are lanes on freeways exclusively for cars with 2 or 3 passengers. Optimization of routes and locations of buses and trucks will increase the efficiency of this system.

- Time Leveling of Traffic Demands

Introduction of flextime will level the rush hours. Leveling of day-offs will also level the traffic demands.

(2) Introduction of Appropriate Use of Automobiles

- Construction of Cities with Light Traffic Loads

Construction of cities where working places and residential areas are close together will decrease traffic demands.

A city in Brazil is a good example. Curitiba, the capital of the state of Paran in southeastern Brazil, prevents fuel waste and traffic congestion by excellent city planning. Radial express lines reserved exclusively for buses interconnected by interdistrict lines shorten the distances between the working places and residential areas. As a result, the city enjoys one of the highest rates of motor vehicle ownership per capita and one of the lowest rates of fuel consumption per vehicle in Brazil. The citizens use buses for routine urban travel.

- Introduction of Cost Loading

Introduction of road pricing systems which impose on automobiles coming into the city center will decrease traffic volume in the centers. Singapore has already introduced the road pricing system. Some cities in West Europe, where streets are not wide enough, are planning its introduction.

(iv) Intelligent Vehicle-Highway Systems

In Europe, North America and Japan, projects have been undertaken or planned to provide solutions to the automobile traffic issues of accidents, congestion and pollution. As found in PROMETHEUS (Programme for European Traffic with Highest Efficiency and Unprecedented Safety) and DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe) in Europe, IVHS (Intelligent Vehicle-Highway Systems) in North America, and some projects in Japan, their purpose is compatibility of both safety and efficiency of automobile traffic systems by equipping automobiles and roads with intelligence by means of electronics and information processing technologies.

In IVHS projects of North America, the process of system development is defined as follows: First, ATMS (Advanced Traffic Management Systems) including traffic signal control systems are to be materialized, then ATIS (Advanced Traveler Information Systems) including navigation systems will be introduced, and finally AVCS (Advanced Vehicle Control Systems) including driver assistance systems and automatic driving systems will be developed.

Traffic signal control systems have already been installed in many cities to yield much effect in traffic safety and efficiency.

Navigation systems that do not require infrastructure have already been put into practical use. Experiments of route guidance systems with real-time traffic conditions in cooperation with infrastructure were conducted in Japan and Europe, and the results show that the systems are effective in energy conservation. Such systems will be put into practical use in the near future, but they require a tremendous amount of initial investment.

Automatic driving systems are still in their research phase now. Only small parts of the driver assistance systems are currently in practical use. As the automatic driving system has many features as shown in Table 5.27, it has required much research work to be done, but many problems even in the field of technologies still remain unsolved. It will be long before the automatic driving system can put into practice.

Table 5.27 Features of Automatic Driving

Features of Automatic Driving	Effects		
	Increase in Safety	Decrease in Congestion	Energy Saving / Environmental Protection
Early Detection and Operation	Prevention of Accidents	Driving with Small Gap on Narrow Lane Prevention of Delayed Start	Elimination of Congestion
Elimination of Human Errors	Prevention of Accidents	Prevention of Congestion due to Human Behavior	
Certain Operation	Prevention of Accidents		Prevention of Unnecessary Acceleration
Elimination of Effects of Psychology of Drivers		Prevention of Congestion due to Human Psychology	Prevention of Unnecessary Acceleration
Controllability of Individual Vehicles		Driving with Small Gap on Narrow Lane	Elimination of Congestion

(v) Modal Shift

The shift of transportation means of passengers from cars to public transportation means such as buses and railways or of cargo from trucks to railways is called a modal shift. Modal shift can be an effective way of energy conservation.

In 1977, the Federal Bureau of Budget of the U.S. investigated the relationship between energy and urban transportation means including modal shift. Table 5.28 shows a comparison of energy consumption between urban transportation means. The results are not necessarily applicable to individual cases, because the analysis was based on the "average concept," but it does indicate that railways are not necessarily energy-effective.

Table 5.28 Comparison of Energy Efficiency of Urban Transportation Means in U.S.A.

Transportation Means	Operational Energy [cal/capita km]	Line Haul Energy(1) [cal/capita km]	Modal Energy(2) [cal/capita km]
Passenger Car(one passenger)	1723	2227	2227
Psngr Car(mean productivity)	1231	1591	1591
Car Pool	575	742	853
Van Pool(3)	244	316	379
Dial-a-Ride(4)	1517	1928	2698
Heavy Railways(old)	398	485	625
Heavy Railways(new)	560	713	1030
Commuter Railways	411	453	786
Light Railways	587	670	792
Bus	409	442	481

Note
(1) Line haul energy is a sum of operational energy and energy for production, construction, and maintenance of vehicles and infrastructure.
(2) Modal energy is a sum of line haul energy and energy for access and detour.
(3) A ride sharing system with a van of a capacity of 10-12 passengers that employers lease their employees within a same residential area to drive by themselves.
(4) A ride sharing system with taxis responsive to telephone calls under public operation.

(Source) U.S. Federal Bureau of Budget

Table 5.29 shows energy efficiencies of urban transportation means in Japan. There are differences from those in the U.S. shown in Table 5.28. This is because the efficiency of road transport in Japan is 2~2.5 times as high as in the U.S., and the efficiency of railways in Japan is 4.8~6.4 times as high as in the U.S. In Table 5.29, the cost for access to railways are taken into account.

Table 5.29 Energy Efficiency of Urban Transportation Means in Japan

	Mean Trips for Urban Commuting [kcal/trip]	Trips by Less-Crowded Railways [kcal/trip]
Railways Only	2408	3612
Railways + Route Bus	3387	4591
Railways +Passenger Car	5674	6878
Railways + Taxi	9654	10858
Route Bus Only	6566	6566
Private Bus Only	3496	3496
Passenger Car Only	22070	22070

(Source) Expressway and Automobiles, 1978

5.2.3.2 Technical Potentials of Energy Conservation

(i) Maintenance and Driving of Automobiles

Campaigns to arouse automobile user awareness on the necessity of routine maintenance and about driving methods are measures for energy conservation that could be carried out at the present time. It will be also necessary to teach drivers to observe traffic rules and driving manners. For example, drivers should learn that illegal parking will decrease the road capacity significantly, and that it will be a cause of congestion.

It is estimated that maintenance of cars in Tehran is not sufficient due to a lack of parts and mechanics. However, a campaign to teach drivers about driving methods to achieve fuel efficiency will be one of the most effective and practical measures for energy conservation.

(ii) Automotive Technologies by Manufacturers

a) Measures involving Improvement of Gasoline Cars and Diesel Cars

Technologies for energy conservation by improving gasoline cars and diesel cars have become widespread in industrialized countries. Therefore, the introduction of modern gasoline cars and diesel cars will have an effect on energy conservation in I.R. Iran in the short term (by 1999) as well as the long term (2000-2021).

Estimating the lifespan of passenger cars in Tehran, they can be categorized into 3 groups: within 10 years, between 10 and 20 years, and between 20 and 30 years. The proportions of cars belonging to each category are 20%, 50% and 30%, respectively. As shown in Fig. 5.17, modern cars probably have at least 30% higher fuel efficiency than the average car in Teheran.

b) Use of Alternative Fuels

Concerning the introduction of alternative fuel-driven cars, it will be possible to introduce natural gas vehicles in the near future in areas where natural gas is produced. Since Iran produces natural gas and its reserve is estimated to be large, it is possible that natural gas vehicles will be employed as a short-term measure.

It will be long before vehicles driven by alternative fuels other than natural gas can be put into practical use.

(iii) Automobile Traffic Systems

The prevention of congestions and increase in the average speeds of automobiles to proper speeds are effective measures for energy conservation. Observations reveal that the average speed of cars in Teheran is 20~30 km/h. If the speed is increased by 10 km/h, it will yield 30% energy conservation. Since the improvement of automobile traffic systems requires the construction of infrastructure, it can not be considered a short-term measure. As measures to be taken in the future, it will be necessary to install traffic signal control systems and introduce frequent radio broadcasting of traffic information.

Measures for the near term are installation of new right- and left-turn lanes at intersections and more lanes at bottlenecks where congestions tend to occur. The installation as well as user awareness will realize a smooth traffic flow.

Sometimes it is a proper measure to prohibit the entry of cars into shopping areas and bazaars where many citizens come together. Here, park-and-ride systems will be employed, where shuttle buses will operate between the shopping areas and parking lots in the neighborhood.

(iv) Intelligent Vehicle-Highway Systems

Intelligent Vehicle-Highway Systems have been partly put in practical use in industrialized countries. Since many of the systems are still in the research phase even in industrialized countries, it will take long before they can be put to practical use in I.R. Iran.

5.3 Estimate of Economic Potentials of Energy Conservation

5.3.1 The Industry Sector

5.3.1.1 Introduction

(i) Estimating Economic Potential of Energy Conservation

The economic potential of energy conservation is estimated according to the model shown in Figure 5.18. The specific energy consumption (s.e.c.) is estimated for each group of existing and newly-built plants in an industry in the coming years, and the weighted average is caluculated to estimate s.e.c. for the whole industry. The difference between the current s.e.c. and future one can be defined as the economic potential of energy conservation in the industry. To explain further, estimates can be made in the following way if related data and information are available.

First, the economic potential is estimated for a certain time-span. For instance, an estimate can be made for the amount of energy conservation achieved in the cement industry by 1999.

Secondly, investments or expenditures for implementing measures and energy prices at a certain time are taken into account in order to estimate the measures' potential as a part of the technical potential which can actually be accomplished. It is needless to say that the economic potential includes the effectiveness of energy conservation which requires no investments or expenditures.

Thirdly, the replacement of old plants is taken into account as one of measures for energy conservation. In other words, the effect of energy conservation accomplished by "scrapping" old plants and "building" new and more efficient ones is included in the economic potential.

Fourthly, it is basically supposed that the best available technologies (BAT) are selected in constructing a new plant, and then the adoption of the BAT is finally determined after considering the financing accrued in its construction. If the financing including the procurement of foreign currencies is very difficult, less efficient technologies will be adopted for the new plant. In addition, current and future energy prices are also taken into consideration for selecting technologies.

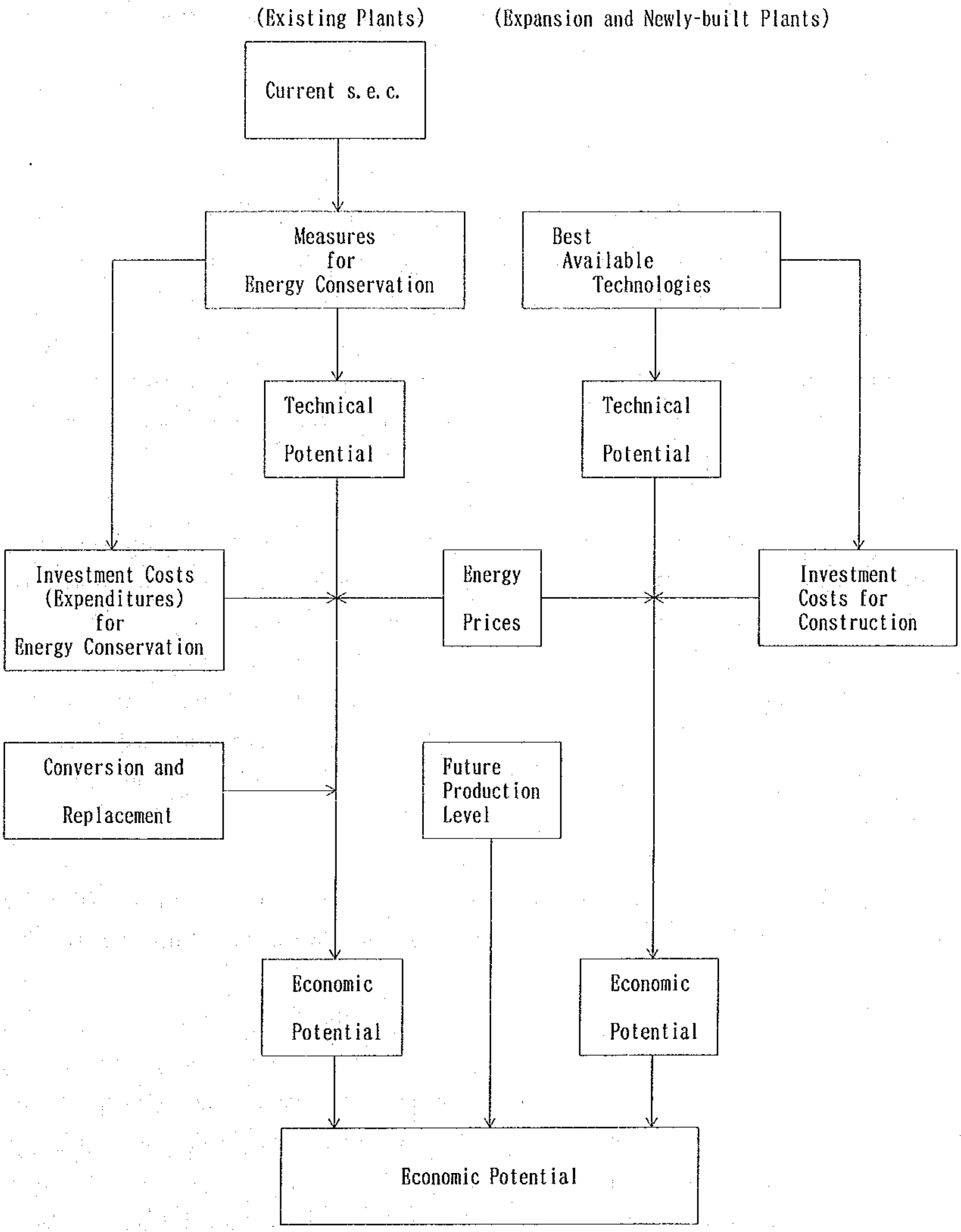


Fig. 5.18 The Model for Estimating Economic Potential of Energy Conservation [In the Case of Industry and Energy Conversion Sector]

Finally, the s.e.c. in an industry as a whole is calculated as the weighted average of the s.e.c. in existing and newly-built plants.

(ii) How to Estimate Investment Costs

Estimating investment costs is one of the most critical tasks in estimating the economic potential of energy conservation. The following issues should be taken into account in making the estimation.

First, what factors are included in "the costs" should be confirmed. In many cases, not only the costs of machines and equipment but also those of construction and materials and in-direct costs including engineering and general management are also included. In some cases, however, only the costs of machines and equipment are included.

Secondly, the differences in costs between different countries and areas should be carefully considered. There would be differences between costs in I.R. Iran and Japan for certain reasons even if the same kind of plant in terms of type and scale is constructed in the two countries.

Additionally, the scale of the plant is an important item which should be considered in estimating costs. The two items mentioned above are, however, emphasized in this study because of their importance in estimating the economic potential and the availability of data and information on them.

All data on investments or expenditures referred to in this study have been those concerning Japan, and they are defined to include the costs of not only machines and equipment but also other items.

The question is how we can estimate the investment costs in I.R. Iran by using data on costs in Japan. The estimation was done on the assumption that the cost of constructing a plant in I.R. Iran would be around twice the cost of machines and equipment in Japan - although it was said they were sometimes more than twice - if the machines and equipment were manufactured and transported to construct the plant in I.R. Iran. Table 5.30 shows the composition of costs of constructing a plant in

I.R. Iran using machines and equipment made in Japan, which some Japanese companies showed the study team as a rough estimate. This shows that the total costs will be around twice that of machines and equipment in Japan even in the case of a refractory plant, if 0.25-0.35 is added as general management costs like in the case of an iron and steel plant in the Table.

Table 5.30 Examples of Investment Costs of Plants in I.R. Iran

[A] Iron & Steel plant

Equipment and machines Transportation to the site Civil engineering Construction	1.00 0.33 0.16 0.24
Sub-Total	1.73
In-direct costs	0.26 - 0.35
Total	1.99 - 2.08

[B] Refractory plant (50,000 tons/year)

	US$ 1,000
Machines & Equipment* Civil engineering; labor; insurance; etc**	Total24,000 (1.00) 16,000 (0.67)
	40,000 (1.67)

* Including transport, supervision of construction, and commission.
** Indirect costs are not included.
(Source) Japanese companies.

Then, it was estimated that the costs of machines and equipment would account for one-third of the total construction costs in Japan (Table 5.31). In other words, according to the estimates made by a Japanese industrial association, the total cost in I.R. Iran would be equivalent to two-thirds of the total cost in Japan.

Table 5.31 Composition of Investment Costs in Japan

(%)

	Chemical	Cement
Machines & Equipment	34	31
Construction and materials	45	52
In-direct costs (including engineering cost)	12	7
General management	9	10
Total	100	100

(Source) Sangyo Kikai Kogyo Kai, 1993

Nevertheless, we used the data on investment costs in Japan for estimating the economic potential of energy conservation in I.R. Iran which had been converted to 1993 prices in real terms. The followings are the reasons for doing so.

First, it is estimated by some of experts in Japan that the cost of constructing a plant in I.R. Iran might be more than twice the costs of machines and equipment in Japan if the machines and equipment for the plant are made in Japan.

Secondly, the costs of machines and equipment made in Japan are generally more expensive than those in the U.S. or European countries, according to influential views in the business circle in Japan.

Thirdly and most importantly, the ratio of the costs necessary for measures in category 1 and 2 of energy conservation to current energy prices in I.R. Iran is not in the magnitude of one and half or two times, but ten or twenty as mentioned later.

For such reasons, we have concluded that using data on investment costs in Japan would by no means lead to the mis-estimation of the economic potential of energy conservation in I.R. Iran.

5.3.1.2 The Economic Potential of Energy Conservation in Cement Manufacturing

(i) Existing Plants

It has already been estimated in this study that the technical potential of energy conservation

Table 5.32 Examples of Investment Costs of Energy Conservation Measures in the Cement Industry in Japan(*)

Measures	Saved Energy per Unit of Clinker Production (fuel oil equivalent) (**) (l/t)	Investment Cost per Unit of Saved Energy (fuel oil equivalent) (Rs/l)	Present Value of Annual Pay-back (***) (Rs/l)
<Category 2>			
Conversion of Lepol kiln to NSP (SP) kiln	15.8～21.1	2,910～2,180	383～287
Power generation using waste heat	5.8	24,830	3,265
Preliminary crushing mill (finishing)	0.6	30,560	4,018
Improvement of clinker cooler efficiency	1.6	n.a.	n.a.
<Category 2>			
Replacement of wet kiln with NSP (SP) kiln	52.6～63.2	7,920～6,590	1,040～870
Roller-type vertical crusher (finishing)	0.9	45,930	6,040
Roller-type vertical crusher (raw material)	0.6	45,280	5,950
Replacement of NSP kiln with fluidized bed furnace	30.0	20,830	2,740

(*) 1993 price. Exchange rate: US$1=¥105=Rs1,750 (As of February 20, 1994)

(**) Calorific value of fuel oil is 9,500 kcal/l.

(***) Present value (P) of annual pay-back to investment cost is calculated according to a formula below.

Initial Investment = $\sum_{j=1}^{n} P \times 1/(1+i)^j$

i: discount rate = 0.1

n: 15 in this case

(Source) Environmental Protection Agency (Japan) totals approximately 230 - 250 Mcal/t-clinker in cement manufacturing in I.R. Iran, and that 30 - 50 Mcal/t-clinker of the potential can be accomplished mainly by the measures in category 1 which do not require significant costs.

On the contrary, the economic potential of energy conservation carried out by measures in category 2 and 3 are estimated to be very limited, at least for the next four or five years. For instance, the costs of "conversion of a Lepol kiln to an NSP (SP) kiln" is estimated to be 2,200 - 2,900 Rs/l-fuel oil and the present value of annual pay-back of the costs is calculated to be 290 - 380 Rs/l-fuel oil, although the costs are the smallest among measures in category 2 (Table 5.32). Implementing the measure cannot be justified because the current price of fuel oil is reported to be 4 Rs/l ex-refinery and around 10 Rs/l as one of fuel oil delivered at consuming plants, and this situation will not be changed significantly in the near future.

However, a large amount of energy conservation can be achieved by the conversion and replacement of old kilns at the end of their lifespan. Generally, it is said that cement kilns have a lifespan of twenty-five to thirty years including prolonged time after conversion. There are three dry kilns and nine wet kilns which were constructed before 1970 and can be supposed to be replaced by or converted to NSP kilns by 1999. In addition, eleven dry-type kilns which were constructed in the 1970s can also be supposed to be replaced by or converted to NSP kilns by 2009.

If the above measures are implemented, the specific energy consumption will be decreased as shown in Table 5.33.

Table 5.33 The s.e.c. in Existing Cement Factories in I.R. Iran

	s.e.c. (Mcal/c-t)
1991	1,200
(category 1)	(-50)
(conversion)	(-4)
(replacement)	(-29)
1999	1,117
(conversion)	(-73)
2009	1,044

(ii) Newly-built Factories

There are many cement factories or plants which are under construction or in the planning stage in I.R. Iran. If all cement plants now under construction start operation by 1999, total cement production capacity will be 108,160 tons per day, which means the capacity will be nearly doubled in eight years. After that, cement production may be increased still further rapidly, say by five per cent per annum. If production capacity increasess at a rate of five per cent per annum, it will reach 176,180 tons per day by 2009.

If the capacity of existing factories remains the same as that in 1991 despite conversions and replacements, its share in the total capacity will be 52.2% in 1999 and 32.0% in 2009 as shown in Table 5.34 (In most cases, the capacity increases when a plant is converted. It is reported that the No. 1 kiln of Kerman Cement Company - dry-type, 300 tons per day - is being converted to SP or NSP and as a result, its capacity will increase to 1,200 tons per day).

Table 5.34 Forecast of Production Capacity in I.R. Iran (Ton/Day)

Year	Production Capacity	Addition	Total
1999	56,460	51,700	108,160
	(52.2)	(47.8)	(100.0)
2009	56,460	119,720	176,180
	(32.0)	(68.0)	(100.0)

The specific energy consumption of newly-built plants are supposed to be much lower than that of existing plants. Looking at the plants the study team visited, the lowest s.e.c. among existing plants is around 900 Mcal/t-c as far as plants we visited are concerned, according to Table 5.6 (No. 3 and No. 4 kilns of Soufian Cement). The average s.e.c. can be expected to decrease to this level in newly-built plants by 1999, and it may reach the 830 Mcal/t-c level, which is equal to that of Korea in 1990 (Table 5.6).

(iii) The Specific Energy Consumption

If the s.e.c. of newly-built plants are 900 Mcal in 1999 and 830 Mcal in 2009, the s.e.c. of the cement industry will be 1,013 Mcal in 1999 and 898 Mcal in 2009 in I.R. Iran, showing an improvement of 16% and 25% compared with the figures for 1991, respectively (Table 5.35).

Table 5.35 Tentative Estimate of the Specific Energy Consumption in the Cement Industry in I.R. Iran (1999 and 2009)

(Mcal/t-clinker)

Year	Existing (A)	Newly-built (B)	Total (Weighted average of (A) and (B))
1991	1,200	-	1,200 (100)
1999	1,117	900	1,013 (84)
2009	1,044	830	898 (75)

However, this magnitude of energy conservation can be achieved only if the following measures are taken by the concerned people.

First, executives and workers in this sector should enhance "morale" to conserve energy even if energy prices are not increased.

Secondly, the most efficient facilities (the best available technologies) should be chosen when expanding and constructing plants.

The estimates above have been made on the assumption that energy prices will not be increased in the coming years. Then, how large will be the economic potential of energy conservation in the cement industry, if energy prices are raised to a certain degree: if, for instance, the current price of about 10 Rs/l for fuel oil delivered at consumer's plants is hiked fivefold? Looking at annual payback as indicated in Table 5.31, we cannot help but conclude that there will be only a very small possibility of measures in category 2 and 3 being implemented on a full-scale.

5.3.1.3 The Economic Potential of Energy Conservation in Sheet Glass and Sugar Manufacturing, and Iron and Steel Making

For these three industries only the economic potential for existing plants are estimated, the main reason being data and information necessary for making similar estimates as for the cement industry have not been available.

As mentioned already in estimating the technical potential of energy conservation in sheet glass and sugar manufacturing, sufficient data and information have not been availble for estimating the effectiveness of measures in all categories 1, 2, and 3 in the two industries. However, it has been estimated that a few per cent of energy conservation can be accomplished technically by measures in category 1. Based on experience as well as data and information on thermal power generation and petroleum refining in Japan, which are mentioned below, we assume that technical potential are at the same time economic as well, and thus the measures to be taken are those which do not bear significant costs.

For iron and steel making, experience in Japan suggest that measures in category 1 can accomplish energy conservation of at least 350 Mcal/t-crude steel in the blast furnace process. For the same reason as for sheet glass and sugar manufacturing mentioned above, we also assumed that this magnitude of energy conservation can be accomplished not only technically but also economically.

The costs necessary for measures in category 2 and 3, which are shown in Table 5.36, indicate that implementing the measures cannot be justified if current energy prices are not increased. In addition, such a situation will not be changed even if the energy prices are increased five times (We could say that only the "sealed-type converter waste gas-collecting unit" is exceptional).

In spite of these estimations, we can forecast a certain degree of economic potential of energy conservation achieved by measures in category 2 and 3 in sheet glass and sugar manufacturing and iron and steel making, if measures, which require no large costs, can be found in these industries like in thermal power generation and petroleum refining as mentioned below.

Table 5.36 Examples of Investment Costs of Energy Conservation Measures in the Iron and Steel Industry in Japan (*)

Measures	Saved Energy per Unit of Crude Steel Production (fuel oil equivalent)(**) (ℓ/t)	Investment Cost per Unit of Saved Energy (fuel oil equivalent) (Rs/ℓ)	Present Value of Annual Pay-back (***) (Rs/ℓ)
<Category 2>			
Blast furnace top pressure recovery turbine (wet)	9.5～12.6	1,228～926	161～122
Converter waste gas collecting unit	21.1～25.3	1,548～1,291	204～170
Coke dry quenching unit (CDQ)	10.5～15.8	7,556～5,021	994～660
Hot charge rolling	3.2	5,833	767
Coke furnace humidity-controlling unit	2.1	3,333	438
Blast furnace top pressure recovery turbine (dry)	1.6	7,292	959
Sealed-type converter waste gas-collecting unit	4.7	496	65
Scrap pre-heating unit (electric arc furnace)	7.4～11.6	90～58	12～8
Continuous annealing line	1.1	61,525	8,090
<Category 3>			
Direct current electric arc furnace	2.0	9,000	1,183
Direct iron on smelting production process	31.6～63.2	11,867～5,934	1560～780

(*)(**)(***) The same as that in Table 5.32.
(Source) Environmental Protection Agency (Japan)

5.3.2 The Energy Conversion Sector

The same method of estimating the economic potential of energy conservation as in the industry sector should be followed in this sector. However, only the potential for existing plants are estimated as was done for sheet glass and sugar manufacturing and iron and steel making because of limited availability of data and information on newly-built plants.

5.3.2.1 The Economic Potential of Energy Conservation in Thermal Power Generation

Experience in Japan show that many of the measures in category 1 for thermal power generation can be implemented without any additional costs or with negligible costs. The Energy Conservation Center, Japan (ECCJ) reports that a major part of measures listed in Table 5.17 are those which need no significant costs. Among them, those measures which cost little are shown in Table 5.37. The measures in the table can be justified at current energy prices in I.R. Iran. Accordingly, it is safe to say the technical potential mentioned before — 3 - 5% of current fuel rate — is at the same time economic as well.

Table 5.38 shows some of the measures of energy conservation listed in Table 5.19 on which data on costs are available. Some of these measures can be justified if the prices of fuel delivered at plants are raised approximately five fold but all of them cannot be justified at current prices. If the measures are implemented, saved energy will total about two per cent of the current fuel rate.

5.3.2.2 The Economic Potential of Energy Conservation in Petroleum Refining

Experience in Japan show that many of the measures in category 1 for petroleum refining can be implemented without any additional costs or with negligible costs. The Petroleum Association of Japan (PAJ) reports that all measures in category 1 listed in 5.2.2.2 are those which need no additional costs or whose costs are negligible ones (Table 5.39). As can be seen in the table, the average cost of measures taken during the period from 1976 to 1978 shows that all measures with a few exceptions can be justified at current energy prices in I.R. Iran.

Accordingly, it would be right to estimate that the technical potential mentioned above - about

Table 5.37 Examples of Investment Costs of Energy Conservation Measures in Category 1 in Thermal Power Generation in Japan(*)

Measures	Total Investment (Expenditure)	Saved Energy (fuel oil equivalent) (**)	Investment per Unit of Saved Energy (fuel oil equivalent)		Present Value of Annual Pay-back(***)
	(¥1,000)	(kℓ)	(¥/ℓ)	(Rs/ℓ)	(Rs/ℓ)
Improvement in soot blower steam injection device for air preheater	15	670	0.02	0.37	0.10
Improvement in method for cleaning condenser	314	2,960	0.11	1.77	0.47
Decrease in cooling water in boiler (decrease in power for pumping)	400	930	0.43	7.11	1.89

(*)(**)(***) The same as in Table 5.32 except that "n" in (***) is 5 years in this case.
(Source) ECCJ "Annual Report" each edition

Table 5.38 Examples of Investment Costs of Energy Conservation Measures in Category 2 in Thermal Power Generation in Japan(*)

Measures	Total Investment	Saved Energy (fuel oil equivalent) (**)	Investment per Unit of Saved Energy (fuel oil equivalent)		Present Value of Annual Pay-back(***) (Rs/ℓ)	
	(¥1,000)	(kℓ)	(¥/ℓ)	(Rs/ℓ)	15	20
<Boiler>						
Cut in spray in boiler's reheater	48,390	1,000	48.4	806	106	95
Cut in gas leaks in air preheater (improvement in sealing)	37,210	322	84.5	1,408	185	165
Cut in gas leaks in air preheater	73,940	190	389.2	6,486	853	762
Efficient use of steam for heating air pre-heater	5,330	5,000	1.1	178	2	2
Cut in temperature of steam at the outlet of boiler	16,160	1,100	14.7	245	32	29
Recovery of boiler drain	6,580	163	20.2	337	44	40
<Turbine>						
Improvement in efficiency of turbine blades (conversion)	563,380	3,500	161.0	2,683	353	315
Improvement in method for cleaning condenser (to install cleaning device)	136,000	5,620	24.2	403	53	47
<Others>						
Improvement in cooling water system in generator	3,420	203	16.9	281	37	33

(*)(**)(***) The same as in Table 5.32. 15 and 20 in (***) mean 15 and 20 years.
(Source) ECCJ "Annual Report" each edition

Table 5.39 Examples of Investments of Energy Conservation Measures in Category 1 in Petroleum Refining in Japan (*)

Measures	Investment per Unit of Saved Energy (fuel oil equivalent)(**) (Rs/ℓ)			Present Value of Annual Pay-back(***) (Rs/ℓ)		
	1976(****)	1977	1978	1976(****)	1977	1978
Control of O2 in heating furnace	12.82	3.60	2.51	3.38	0.95	0.66
Improvement in insulation in storage tanks	-	-	1.16	-	-	0.31
Rationalization of steam system	10.61	-	1.71	2.80	-	0.45
Improvement in balance of operating plants	-	-	17.67	-	-	4.66
Cut in reflux rate	-	-	-	-	-	-
Cut in recycle gas rate	1.31	30.83	-	0.35	8.14	-
Improvement in operating conditions	2.41	-	-	0.63	-	-
Control of injected steam	1.02	0.51	-	0.27	0.14	-
Improvement in method for cleaning heat exchanger	-	6.41	19.93	-	1.69	5.26
Improvement of operation temperature and reaction pressure	-	-	-	-	-	-

(*)(**)(***) The same as in Table 5.32 except that "n" in (***) is 5 years in this case.
(****) Including investments (expenditures) for the period of 1974-75.
(Source) Estimated from PAJ's survey made in February, 1979.

17 % of current s.e.c. - is at the same time applicable to the economic potential as well.

The average costs of the measures in category 2 listed in 5.2.2.2 above are as follows (Rs in 1993 per one liter of fuel oil);

1976	42.5
1977	52.7
1978	52.7

In addition, the average cost of each measure in category 2 is shown in Table 5.40. Looking at these data, we can conclude that all measures with a few exceptions can be justified if the prices of fuel delivered at consuming plants are raised approxinately five fold. If these measures are implemented, the effect of energy conservation will total about 3% of current s.e.c. in petroleum refining. It is important to note here, however, that measures in category 2 were implemented on a full-scale after this period in Japan.

Table 5.40 Examples of Investments of Energy Conservation Measures in Category 2 in Petroleum Refining in Japan (*)

Measures	Investment per Unit of Saved Energy (full oil equivalent) (**) (Rs/ℓ)			Present Value of Annual Pay-back (***) (Rs/ℓ)		
	1976(****)	1977	1978	1976(****)	1977	1978
Installing heat exchangers and improvement in their arrangement	999.7	1,066.0	656.2	131.5	140.2	86.3
Efficient use of steam	453.5	239.8	321.4	59.6	31.5	42.3
Cut in O2 in heating furnaces	359.5	246.2	349.6	47.3	32.4	46.0
Installing steam generator	638.8	576.2	935.9	84.0	75.8	123.1
Improvement in balance of operating plants	149.3	741.2	105.5	19.6	97.5	13.9
Strengthening insulation	851.8	732.1	495.6	112.0	96.3	65.2
Recovery of off-gas	453.5	78.6	13.5	59.6	10.3	1.8
Better functioning of steam trap	268.2	221.7	17.2	35.3	29.2	2.3
Recovery of hydrogen gas	113.4	76.1	n.a.	14.9	10.0	n.a.
Improvement in controlling method	110.3	73.5	682.0	14.5	9.7	89.7

(*)(**)(***)The same as in Table 5.32.
(****)Including investments in the period of 1974-75.
(Source:)The same as in Table 5.39.

5.3.3 Summary on Estimating the Economic Potential of Energy Conservation in the Industry Sector and the Energy Conversion Sector

(i) On Measures in Category 1

Being based entirely upon available data, it has been estimated that around 3 - 5 percent of energy conservation can be accomplished by measures in category 1 in many industries targeted in this study while iron and steel making in the direct reduction process and petroleum refining are exceptional in achieving much more energy conservation.

Additionally, if we take into consideration the following facts, we can presume that the economic potential of energy conservation is much larger in these industries.

First, more than 15 percent of energy conservation was accomplished by low-cost measures in category 1 in petroleum refining in Japan. We can presume that there may be more room for energy conservation than the 3 - 5 percent mentioned above in other industries.

Second, only measures in category 1 can create greater energy conservation than the 3 - 5 percent of the current s.e.c. in I.R.Iran, mainly because no measures for energy conservation have been implemented in this country.

Third, many surveys on energy conservation in developing countries by the Energy Conservation Center, Japan (ECCJ) show that 10 - 15 percent of energy conservation can be achieved only by measures in category 1.

(ii) On Measures in Categories 2 and 3

It has been estimated that the economic potential of energy conservation achieved by measures in these categories would be very small if energy prices remain at current levels in this country. However, if the price of energy (fuel oil) for industry is increased fivefold, the economic potential of energy conserved will be 2 - 3 percent of the current s.e.c. in thermal power generation and petroleum refining.

We have not made estimates of the economic potential of energy conservation in the cement, sheet glass, sugar, and iron and steel industries which are based entirely upon available data. However, if the following is taken into consideration, it is reasonable for us to consider that these industries can accomplish 1-2 percent of energy conservation at least when the price of energy at factories is increased around five times.

Generally, there must be cheaper measures in category 2 also in these industries as have been found in thermal power generation and petroleum refining in Japan. More concretely, to strengthen insulation in cement manufacturing and to promote waste heat recovery in iron and steel manufacturing are some examples of such measures which are less expensive than those that show the economic potential of around 2-3 percent.

(iii) For an industry as a whole

Only data on the cement industry is available for estimating the future s.e.c. in an industry. It is estimated that the s.e.c. will be reduced by 16 percent by 1999 and by 25 percent by 2009 in the cement industry in I.R.Iran.

Since the technical potential is estimated to be 22-23 percent by 1999 as mentioned above, the economic potential by the same year is equivalent to 70 percent of it. The main reason why the amount of the economic potential is so large is that existing kilns will be converted to or replaced with SP or NSP kilns as one of measures in category 2 and 3.

No estimates have been made on the economic potential for other industries.

5.3.4 Road Transport Sector

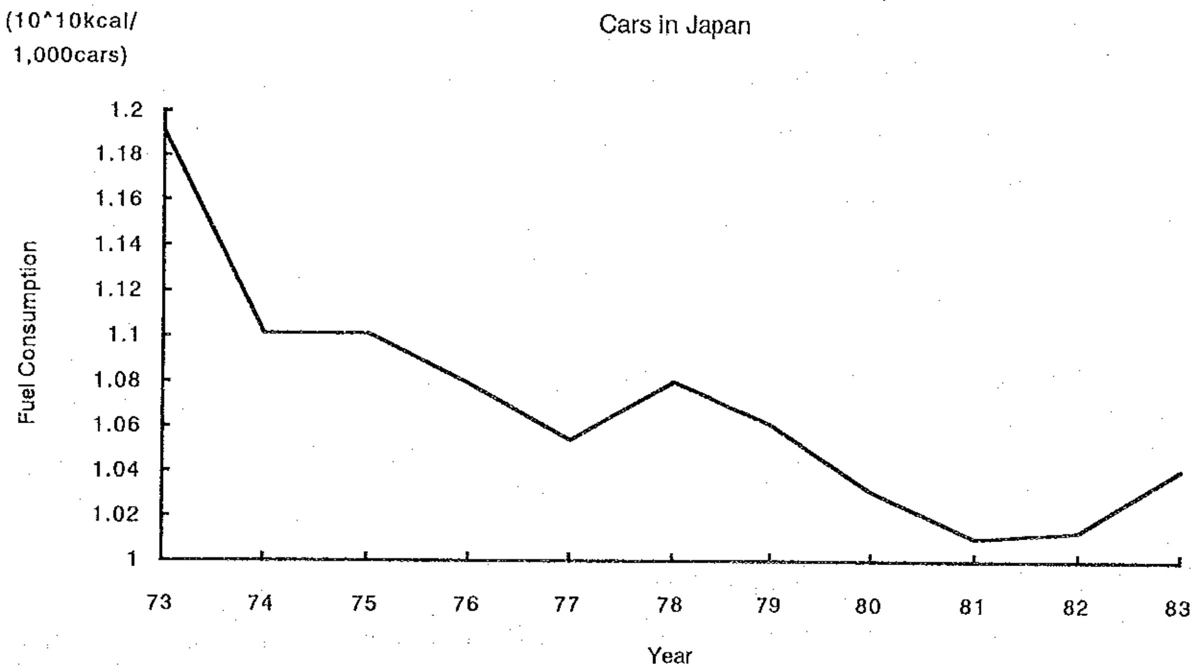
There are also three categories of measures for energy conservation in the road transport sector, implemented by drivers, manufacturers, and governments.

Among the measures, proper driving and proper maintenance of vehicles are implemented by drivers, improvement of fuel efficiency by manufacturers, and improvement of road traffic systems and modal shift by central and local governments.

Economic potentials for energy conservation resulting from each measure mentioned above have not been estimated. Economic potenials for measures in category 1 can be estimated, however.

Fuel consumption per one thousand passenger cars decreased by more than 10 percent for a few years after the first oil crisis in Japan, as can be seen in Fig. 5.19. It is not unreasonable for us to assume that measures in category 1 contributed to a major part of the decrease during the period in which the fuel efficiency of passenger cars was declining, although reduction in driving distance of cars should be taken into account.

Fig. 5.19 Fuel Consumption of Passenger Cars in Japan



5.4 Scenarios for Promoting Energy Conservation

5.4.1 Policies for Energy Conservation

Basic ways for promoting energy conservation as policy measures are classified as follows:

(1) Guidance, advice, and education
(2) Compulsory measures
(3) Instruction
(4) Inducement
(5) Incentives
(6) Detailed studies

The following are examples of guidance, advice, and education:

(1) To establish an Energy Conservation Day and/or Energy Conservation Month
(2) To begin campaign for energy conservation
(3) To set up an Energy Conservation Center which is in charge of the following items:
- Guidance, advice, and education
- Survey and study
- Energy auditing
- Training

The following are examples of compulsory measures:

(1) Closing petrol stations on Fridays
(2) Prohibiting cars from entering a certain areas in large cities

The following are examples of instruction:

(1) To establish standards for evaluating energy efficiency of factories or plants, appliances, and vehicles
(2) To implement energy audit
(3) To provide people, companies, and others with information necessary for energy conservation

The following are examples of inducements:

(1) Pricing policy on energy carriers

(2) Taxation on energy carriers

The following are examples of incentives:

(1) To give tax credits and depreciation allowances to those who invest in energy conservation devices

(2) Make long-term, low-interest loans to those who invest in energy conservation devices

In addition to the ways mentioned above, detailed studies of each sector should be done for implementing concrete policy measures, including the following items:

(1) Collecting and organizing data into a database

(2) Analysis of energy uses at the micro level

(3) Study of detailed measures for promoting energy conservation

(4) Estimate of technical and economic potentials of energy conservation

5.4.2 Scenarios for Energy Conservation

Considering the policy measures shown above as well as economic potentials mentioned in 5.3, the following scenarios can be described as realistic ones for promoting energy conservation in the Islamic Republic of Iran.

5.4.2.1 Scenario for Short Period (1994-1999)

First, among individual measures in existing factories and plants in 5.2 above, some of those in category 1 are considered realistic to be implemented in the industry sector and the energy conversion sector. In the road transport sector, improving driving ways and proper maintenance of cars, both of which should be implemented by drivers with the governments' support, and efficient use of existing roads are considered to be realistic measures in this period.

Second, the adoption of efficient plants and equipment is recommendable in constructing new ones or expanding existing ones as far as their financing is possible. Governments should encourage production of energy-efficient cars (It is reported that the average consumption of gasoline per each car in Tehran is 15 liters per 100 km, which is around twice that in Japan).

Third, the following are policies to encourage individual measures:

(1) Guidance, advice, and education

(2) Compulsory measures, particularly in the road transport sector

(3) Increase in energy prices in the real term

As already mentioned, even a fivefold increase in energy prices may not have a big effect on energy savings made by a major part of measures which need investment costs in the industry sector and the energy conversion sector. However, a much greater increase in price in a short period is too drastic, particularly considering its impact on people's lives.

Measures in category 1 are reasonable ways for industry, energy conversion and road transport sectors to conserve energy.

Finally, detailed studies on energy conservation in each sector should be commended during this period so that their results can be utilized over time.

5.4.2.2 Scenario for Longer Period (2000-2021)

First, future detailed studies can identify concrete policy measures and estimate more reliable figures on the economic potentials of energy conservation including those achieved by measures in the household, commercial, and agricultural sectors, which are not dealt with in this study, as well as those achieved by measures mainly in category 2 and 3 in the industry, energy conversion, and road transport sector, which could not be estimated sufficiently in this study.

Second, we can expect that measures requiring investment will be implemented in existing factories and plants based upon the studies mentioned above.

In the road transport sector, many of measures in categories 2 and 3 also can be considered and implemented along with introducing more efficient cars.

Third, stronger policy measures and financial aid can be considered to support and encourage energy conservation measures and the adoption of more efficient plants, equipment and vehicles.

6. Energy and Environment

6.1 Introduction

6.1.1 Energy and Environment

Energy is indispensable for our modern life and economic activities. Energy systems, however, consume energy resources, impose loads on the environment in different stages of each fuel cycle and create waste. Above all, oil, coal, natural gas and other fossil fuels are closely tied to environmental issues. In combustion, storage and other phases, sulphur oxides, nitrogen oxides, soot and dust, hydrocarbons and other air pollutants are discharged, causing regional air pollution and acid rain.

Fossil fuels also emit carbon dioxide and other greenhouse gases which cause global warming. Methane is emitted in the mining process and leaked in the shipping process. Energy consumption in urban areas sometimes causes heat islands.

As for offshore oil fields, once a major accident occurs, the ocean is seriously polluted like the accident at the North Sea Oil Field. Crude oil spilled in the accidents of huge tankers and ballast water in their cargo holds are also causes for marine pollution.

If we focus on air pollution, environmental pollution associated with energy consumption is classified into following three groups:

(1) Local Air Pollution

Potentially, the combustion of fossil fuels may result in the emission of traditional air pollutants such as soot and dust, sulfur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC) and other chemicals.

Soot and dust which are less than 10 microns in particle diameter are suspended in the atmosphere over long periods of time and are likely to be deposited in the respiratory track or pulmonary alveoli, impacting the lungs, so that environmental quality standards are determined as those for Suspended Particulate Matter (SPM). SOx negatively affects human health, the aquatic ecosystem, crops and forests, and buildings. NO_X mainly stem from the burning of fossil fuels at high pressure. NO_X generates photochemical oxidants, smog and acid precipitation together with sulphur oxides. Ambient levels of SOx and NOx are represented by measured concentration in the air, and their emissions are given as the quantities of sulphur dioxide (SO_2) and nitrogen dioxide (NO_2).

CO interferes with the absorption of oxygen by red blood cells. Volatile organic compounds (VOC) are considered to be the main precursors of photochemical air pollution together with nitrogen oxides. After all, photochemical oxidants are generated by CO, NO_X and HC, which are generated by incomplete combustion of fuels, and poses problems on regional air pollution in conjunction with energy consumption.

(2) Acid Rain (Regional Air Pollution)

The generation of acid rain results from the melting of SO_X and NO_X produced in the combustion of fossil fuels. Acid rain sometimes falls and inflicts serious damage on areas thousands of kilometers away from the source, becoming an international political issue.

(3) Global Warming

Emissions of greenhouse gases (GHGs) such as carbon dioxide(CO_2), methane and chlorofluoracarbons (CFCs) and the other factors including deforestation are cited as factors causing global warming. According to *Policy Options for Stabilizing Global Climate, Feb. 1989, US-EPA,* about 57 percent of all anthropogenic contribution to global warming is due to energy production and consumption, followed by 17 percent by CFCs, 14 percent by agricultural work and 9 percent by changes in land use. CO_2 related to energy consumption is essential in countermeasures to prevent global warming because CO_2 contributes the largest share to the greenhouse effect which potentially effects the climate, sea level and world agriculture.

6.1.2 The Focus and Objectives of the Study

The final goal of this kind of study on energy and environment is to identify individual measures for environmental improvement and to formulate concrete policies, which can support and encourage the measures, in order to reach the targets of environmental preservation. To formulate and propose concrete policies, the following steps are needed.

First, as far as local and regional pollution is concerned, the concentration of environmental pollution as well as the emission of pollutants are surveyed (or monitored) to accurately grasp the current status of environmental pollution by area.

Second, if the current status is deemed undesirable to inhabitants in and around the area, an acceptable or desirable level of environmental pollution is considered to establish a standard, which will be used to regulate the emission of pollutants in and around the area.

Third, in conjunction with setting standards, environmental conservation methods, such as the installation of technical devices, are considered along with the economic feasibility of such methods.

In this study, some data and information on the concentration of air pollution, which have been surveyed mainly by international organizations, have been collected and analyzed, while past and present emissions is estimated.

The acceptable or desirable level of environmental pollution in I.R. Iran has not been studied partly because the Iranian Government is now studying the standard, while the current control system of environment in I.R.Iran has been reviewed.

Measures for environmental preservation on both stationary and mobile sources are studied in order to suggest basic ideas on policies. In addition, the costs or capital requirements of the measures are reviewed to provide policy makers with some data and information for formulating concrete policies.

Finally, based upon studies mentioned above, some considerations on policy measures are made for more concrete ones to be identified for the future.