ENERGY TRANSITION AND ENERGY-RELATED R & D NEEDS AND PRIORITY AREAS IN KOREA

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I. Introduction

This paper is to review the major directions of energy transitions in the economy in the past two decades, examine the interrelations between energy and the economy, overview the energy prospect for the country in the future, and identify major policy issues that have been faced and expected to be confronted by the country. The paper will also discuss major policies of the government attempted to solve the problems and contributions of the policies to the energy transition. Finally, the paper will attempt to identify energy-related R&D needs and priority areas for the country.

The paper was prepared on the basis of the literature survey. For reference, a bibliopraphy of principal works reviewed and relevent to the subject of this paper is attached at the end.

II. Economic Development and Energy Transition

1. Economic Growth and Changes in Energy Demand

The rapid growth of the economy and changes in its structure have accelarated the growth for energy demand and caused significant changes of the demand in Korea in the past two decades. The gross domestic product in real terms grew at an average rate of 9.3% per year during the period 1962–1979, during which real per capita GNP increased also by more than three times. The economy grew at a much lower rate after the second oil shock; in 1980 the real GDP decreased by 3.5% over the previous year and it grew at an average rate of 6.2% per year in the following two years. The political and social instability following the assassination of former president in 1979, extremely poor harvest of the agricultural production in 1980, and the recession of the world economy after the second oil shock were the main reason for the slow down of the economic growth. The economy seems to pick up its normal growth pace again; it grew at

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TABLE 1 Economic Growth and Structural Change of the Korean Economy, 1965–1982

	1965	1973	1979	1980	1981	1982
GDP (100 billion won in 1975 constant price)	3.86	8.50	14.87	14.34	15.37	16.18
Growth rate of GDP(%)[1]		10.4	9.8	−3.6	7.2	5.3
% of primary sector's GDP(%)[2]	39.6	26.2	21.5	17.1	18.6	17.3
% of Manufacturing sector's GDP (%)	17.9	24.8	27.8	29.3	29.9	29.2
% of Tertiary sector's GDP (%)	42.5	49.0	51.9	54.9	52.8	55.0

1) Average annual rate of growth of real GDP between two periods.
2) Calculated on the basis of nominal GDP accrued in the primary sector including mining industry.
Source of data: The Economic Planning Board, *Handbook of Korean Economy 1980* and *Korea Statistical Yearbook 1983*, Vol. 30, 1984.

TABLE 2 Sectoral Growth and Export Structure of Korea, 1965–1982

	1965	1973	1979	1980	1981	1982
Sectoral Growth Rates						
Primary Sector[1]		3.5	4.6	−20.7	21.0	3.4
Manufacturing Sector[2]		21.2	15.9	−1.1	7.1	3.9
Tertiary Sector[3]		12.1	8.9	1.9	3.0	6.7
Export Growth Rate[4]		44.2	29.2	16.3	21.4	2.8
Export Dependency[5]	9.5	31.3	32.5	40.2	44.2	43.1
Composition of Manufactured Products[6]	62.3	88.2	90.1	92.3	92.9	93.7

1) Average annual growth of the primary sector's real GDP between the two periods.
2) Average annual growth rate of the manufacturing sector's real GDP between the two periods.
3) Average annual growth rate of the tertiary sector's real GDP between the two periods.
4) Average annual growth rate of commodity export in current value between the two periods.
5) the percentage of the value of commodity export to GNP.
6) Percentage of value of manufactured commodity exported to total value of export.
Source of data: The Economic Planning Board, *Handbook of Korean Economy 1980* and *Korea Statistical Yearbook 1983*, 1984

9.3% in 1983 and is projected to grow at about 8.5% in 1984.

The structure of the economy has changed significantly in the process of the economic growth in the past. The GDP accrued in the primary sector decreased in its relative share, while the proportion of GDP produced by the manufacturing and tertiary sectors increased significantly; the share of the primary sector decreased from 39.6% in 1965 to 17.3% in 1982 and that of the manufacturing sector increased from 17.9% to 29.2% in the same period.

The central driving force of the Korea economy in the past two decades has been the expansion of the manufacturing production and commo-

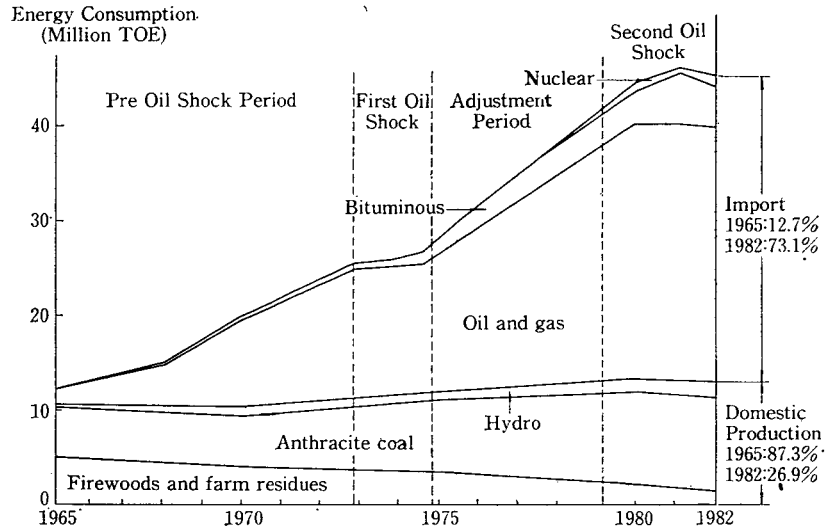
dity export. The nominal value of export increased by 125 times during 1965–1982. Since the rate of growth of the export far exceeded that of GNP growth, the economy's dependence on foreign trade had increased rapidly: the ratio of export to GNP increased from 9.5% in 1965 to 43% in 1982.

The phenomenal economic progress has accompanied significant changes in the energy sector. Total energy demand has almost doubled in every ten years in the past two decades. It increased from 10,346 thousand tons of oil equivalent (TOE) in 1962 to 45,974 thousand TOE in 1982, an average rate of increase of 7.7% per year during the period. The increase in the demand has far outpaced increases in the supply from the domestic sources so that the country's import dependence of energy increased from 9.5% to 73.1% during the period. Also a very rapid transformation has developed in fuel mix of the supply from low to high quality energy sources: The proportion of firewoods and agricultural wastes decreased from 51.7% to 5.3%, while that of petroleum products increased from 9.8 to 58 %: the proportion of anthracite coal also decreased from 36.8% to 21.4% during the period. The proportion of electricity in total final demand increased from 4% in 1962 to 22.1% in 1982.

When the whole period of 1962–1982 is divided into oil shock and and non oil shock or adjustment-to-oil shock periods, the GDP elasticity of energy demand was distinctively different from period to period. In the pre-oil shock period of 1962–1973, GDP and total energy demand grew at almost the same rates so that the GDP elasticity of total energy demand was close to one. In 1974 and 1975, the economy grew at a slightly lower rate than the preceeding years, but the energy demand grew at a much lower rate (1.7% in 1974 and 6.0% in 1975) so that the GDP elasticity was 0.2 in 1974 and 0.74 in 1975 [13] . During the adjustment to the first oil shock period (1975–1979), the economy seemed to recover fully from the oil shock and grew at an average rate of 10.6% per year. The energy demand in this adjustment period, however, grew even at a faster rate than the GDP growth resulting in higher GDP elasticity than the pre-oil shock period. The GDP elasticity reduced very significantly again after the second oil shock: it was -0.42 in 1980, 0.62 in 1981 and -0.03 in 1982. Growth rates of both GDP and energy demand in the post second oil shock period were much lower than those of preceeding years, but the growth rate of energy demand reduced more than the rate of the economic growth [13].

The sectoral shares of energy consumption of the country has also changed significantly in the last two decades. Energy demands in the inudstry and transportation sectors have increased at a faster rate than the average growth of total energy demand so that the proportion of energy consumed by these sectors have increased over the years, while the proportion of energy consumed by the residential and commercial sectors

FIGURE 1 CHANGES IN TOTAL ENERGY DEMAND, FUEL MIX, AND ENERGY IMPORT OF KOREA

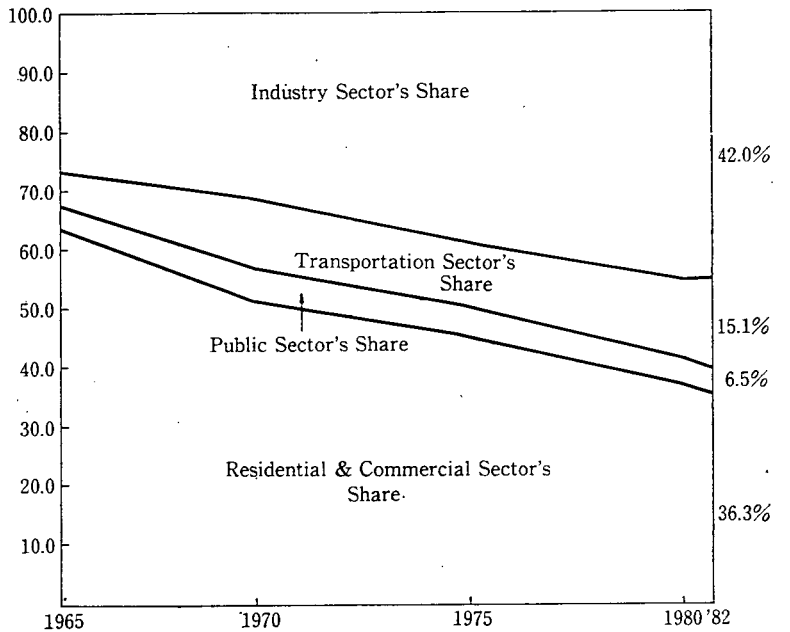


decreased over time [13].

The manufacturing sector is the largest consumer of energy in the economy. It alone consumed 46% of total energy consumption of the country in 1982, which used to be 20% in the early 1960s. The sector consumes not only the largest portion of total energy supplied, but also more of expensive commercial energy than the cheap non-commercial energy. In 1982 the sector consumed about 67% of total electricity produced and 31.4% of total oil consumption of the country. The rapid growth in energy demand of the sector has been attributable largely to the fast growth of the sector's output and the structural changes of the sector from a less energy-intensive to a more energy-intensive heavy chemical industry structure. The fuel mix of the industry sector has also changed drastically in the past two decades. The share of coal decreased from 46% in 1965 to 28% in 1982. Coal now consumed by the sector is mostly for coking coal used in steel mill and coal used in other processes in the sector is less than one percent of total energy consumption of the sector. In contrast, the share of pertroleum products and electricity had increased considerably from 19.1% and 20.3% in 1965 to 39.8% and 32.4% in 1982 [13, 20].

The share of energy consumption of the transportation sector increased from 6% in 1962 to 14.5% in 1982. The rate of growth of the demand for passenger and freight transport has far exceeded the rate of the growth of the economy in the past two decades. Total number of vehicles increased by more than 20 times. The number of passenger cars grew even

FIGURE 2 CHANGES IN SECTORAL ENERGY SHARES



faster; at an average rate of almost 20% per year, an equivalence of 35 times increase in twenty years. The number of cars and demand for energy of the sector is expected to grow in the foreseeable future at a fastest rate among all sectors of the economy [13, 18, 27].

The share of energy consumption of the residential and commercial sector decreased from 63% in 1962 to 36% in 1982. A relatively slow rate of increase in the demand for energy of the sector is a major reason for the decrease in the share, but fuel switch from less efficient to a more efficient fuel sources is further reason for the decrease. A more than 70% of energy consumed in the sector was supplied by firewoods and agricultural wastes in 1962, but the non-commercial sources supplied only 17% of total energy consumption of the sector. Still a more than 60% of the sector's energy demand is comprised of coal briquettes made of domestically produced anthracite. The importance of anthracite as a fuel source for the residential and commercial sector, however, is expected to decline rapidly as level of income increases and coal is substituted by petroleum products, electricity, and LNG [1, 3, 17, 18, 27, 30].

2. Energy Transition

The Korean economy underwent three energy transitions in the last two decades: the first transition was from firewoods and agricultural

wastes to anthracite coal during the first five-year economic development plan period (1962–1966): the second transition was characterized by replacement of coal by oil during the period 1967–1979. Since the second oil shock, a new transition from oil to different mix of imported fuels has been under way.

Up to early 1960s, firewoods and agricultural wastes were the principal source of energy supply in Korea: it alone supplied 60% of total energy requirements of the country in 1960. However, these non-commercial energy sources were not only inadequate, but also unable to supply the raidly growing energy demand during the first five-year economic development plan period. Because of the indiscreet deforestation in the past, mountains became extremely denuded by early 60s. Hence the government decided to launch a nation-wide reforestation program and in substitution to promote increases in domestic coal production, for which the government enacted the "Provisional Coal Development Law" in 1961 and encouraged the consumers to replace firewoods by anthracite coal by keeping coal price low with government subsidization. Both reforestation and coal promotion programs had been extremely successful, resulting increases in coal production in two fold from less than 6 million tons in 1961 to 12 million tons by 1966.

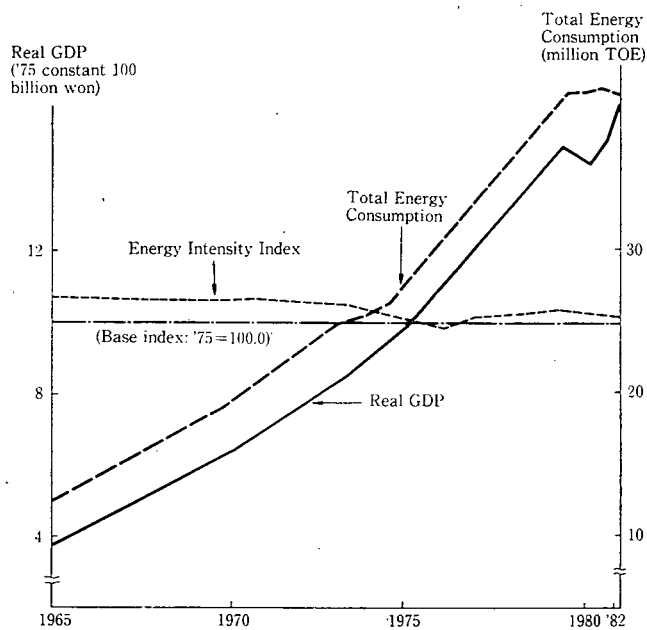
Pace of economic growth and urbanization had been accelerated since the second five-year economic development plan launched in 1967: the manufacturing sector had grown at an average rate of 22% per annum during 1967–1973 and the share of urban population increased from 34% to 45%. Domestic coal production could no longer suffice the increasing demand for energy in the manufacturing and urban residential sectors, resulting in severe shortages of coal briquettes in late 60s. In the second phase of energy transition, oil replaced anthracite coal and by early 1970s oil supplied more than 50% of total energy requirements of the country. try. The petroleum refinery plant, established first in 1964, had been expanded aggressively during this second phase and large quantities of heating oil were imported from abroad to meet immediate needs. The substitution of petroleum for coal had been successful due among others to secure procurements of crude as well as petroleum products at a cheap cost. This coal-to-oil substitution had resulted in a remarkable increase in oil share(from 16.6% in 1966 to 55% in 1973) and drastic decrease in coal share (from 46.2% in 1966 to 29.5% in 1973).

Confronting the steep increase in oil prices and insecure supply situation of oil in 73/74 oil crisis, the government had taken various restrictive policies to reduce oil consumption. Diversification of fuel sources and conservation were the principal policy changes taken during the third energy transition period. Even though the government intended and took various measures for fuel diversification and conservation right after the first oil shock, they were not very successful until the second oil

shock hit the economy again in 1979. The oil share had continued to increase to reach to 64% by 1979, but the rate of increase of the share during this period slowed down. The energy intensity measured in energy consumption per 1,000 US $ was reduced only marginally (from 1.46TOE in 1973 to 1.41 TOE in 1979). The unsuccessful implementation or the failure of the third transition during this period was due partly to long gestation time of the projects and partly to misjudgement of policy planners for the future development of world oil situation. Even during this period, the principal policy goal of the government was set at pursuing the economic growth and the overall development strategy was to build a strong export-oriented industrial base. The main concern of energy policy, therefore, was to ensure that energy did not become an obstacle to economic growth. As a result, the manufacturing sector had grown at an average rate of 16.8% per year during this period and energy consumption of the sector at 20%, by which the GDP elasticity of energy demand of the sector became 1.2 [6, 10, 12, 13, 20].

The impact of the second oil shock was felt much more gravely than that of the first oil shock and the government has taken positive and stronger policy measures to conserve energy and reduce oil dependence since the second oil shock. Aggressive fuel substitution programs have been promoted for the power and manufacturing sectors. By end of 1983

FIGURE 3 Economic Growth, Changes in Energy Consumption and Energy Intensity



all cement plants in the country switched their fuel from oil to coal. New power plants to be constructed are limited to either coal-fired or nuclear. By the fuel substitution program, oil portion of power sector will decrease drastically from the current 80% level to 15% by early 1990s [6, 13, 18, 19, 27].

Realizing the importance of energy conservation, the government enacted the "Law Governing Rational Utilization of Energy" in 1980. Since the enactment of the new law, various regulatory and incentive measures have been taken to conserve energy. Insulation became mandatory for all new buildings to be constructed since 1980 and financial incentives are provided for insulating existing buildings. Also energy audits are legally enforced for large energy consumers in manufacturing sector and large commercial buildings. Because of all these concerted efforts of energy conservation, the GDP elasticity of energy demand decreased in the 80s as compared with those in 60s and 70s (See Section II.A.) [11, 13, 21, 26].

3. Prospects for Future Energy Demand and Supply

Energy demand in the future will depend in principal on economic growth and improvements in efficiency of energy consumption. Various studies have attempted to project energy demand for the future and the projected demands vary considerably by studies depending on assumptions and models employed [1, 6, 12, 18, 19, 27]. Assuming the average growth rate of the economy 7.5% per year and somewhat more rigorous conservation policies to be taken in the future, total energy demand is projected to be about 1.7 times in 1991 and 2.8–3.0 times greater in year 2001 than that of base year, 1981 [27].

All studies project that due to the limited potential of domestic resource development the import dependency of energy supply of the country will continue to increase and reach to over 90% by year 2001 [1, 18, 19, 20, 27]. The studies also project that due to the substitution from oil to nuclear and coal the oil dependency will continue to decrease to a 30% level by year 2001 from the current level of 58% while the proportion of nuclear and coal will continue to increase.

The industry sector is projected to remain as a largest consumer of energy in the economy as it continues to be a leading sector driving the economic development while the relative importance of the residential and commercial sector will decrease over time. Though the proportion of energy consumed by the transportation sector will remain relatively smaller than those of other sectors of the economy, its share will increase steadily over time [1, 18, 19, 20, 27].

III. Impacts of Oil Shocks and Major Energy Policy Issues

1. Impacts of the Two Oil Shocks on the Economy

The steep increase in oil price by the two oil shocks in the 70s had grave adverse impacts on the economy in terms of stagflation and deterioration of terms of trade, trade balance, and balance of payments.

The increase in oil price during the first oil shock had relatively smaller impact on economic growth than the second oil shock period. The economy grew at 8.0 and 7.1% in 1974 and in 1975, but GNP decreased by 6.2% in 1980 and grew at slightly over 5% per year in the following two years. A part of the economic recession following the second oil shock was attributable to other factors such as recession of the world trade, poor harvest of agricultural production, and the political and social instability following the assassination of the former president in 1979.

The rate of inflation was almost in the same magnitude in the two oil shock periods: the wholesale price index had risen by almost 40% in the year right after the two oil shocks, while the consumer price index had risen by 24.5% in 1974 and 28.7% in 1980. The rate of inflation has been in one digit level since 1981, thanks to the recent decrease in crude oil price and the adoption of stabilization policy of the government.

The increases in oil prices in the two oil shocks had severely influenced the position of trade balance and balance of pyament of the country. The volume of crude oil imports of Korea increased from 11.2 million in 1965 to 103.2 million barrels in 1973, an increase of 9.2 times in eight years. In the same period, the oil import bill increased from 23.7 million to 305.2 million U.S. $, an increase of 12.9 times. About 39 percent of the increase in the oil bill during this period was due to increase in CIF price of crude oil and the rest 61 percent due to the increase in volume of import. In 1974 the volume of crude import increased by 9.2 percent over that of 1973, but oil import bill increased by 262 percent over that of 1973. Hence, more than 95 percent of the increase in oil bill in the year was due to the increase in CIF price of oil. During the second oil shock period 1979–1981, the oil import bill increased again by 82%, while the volume of oil import rather decreased by 1.5 percent. Hence the increase in the oil bill was attributed solely to the increase in CIF price of crude oil in this period. Since the second oil shock, both of volume of import and import bill has been declining slightly.

The trade balance has been moving almost exactly to the same direction as the oil bill moves. The trade deficit of the country was 567 million US dollars, which increased to 1,937 million dollars in 1974. Trade balance and balance of payment had improved during 1975–78, but seriously deteriorated again during the second oil shock period. Trade deficit

TABLE 3 CHANGES IN OIL PRICES AND INFLATION RATES

	Pre-oil shock period '65–'73	Oil shock period '73–'74	Adjustment period '75–'79	Second oil period '79–'80	Adjustment period '81–'82
	——average rate of change per year (%)——				
CIF price of crude oil	4.2	102	12.9	72.2	H4.3
Wholesale price index	8.6	41.9	15.4	38.9	4.7
Consumer price index	11.1	24.5	16.6	28.7	7.3

Source of data: EPB, *Handbook of Korea Economy,* 1980 and *Korea Statistical Yearbook, 1983*

TABLE 4 CHANGES IN OIL IMPORT BILL, TRADE BALANCE, AND BALANCE OF PAYMENT, 1965–1982

	1965	1973	1974	1979	1980	1981	1982
Crude oil import (mil. Bbl)	11.2	103.2	112.7	185.5	182.9	182.8	178.4
Average CIF Price (U.S. $/ barrel)[1]	2.12	2.95	9.80	17.96	30.92	35.58	34.06
Crude oil import bill (million U.S. $)	23.7	305.2	1104.8	3330.6	5654.2	6504.2	6075.3
Trade balance (million U.S. $)[2]	9.0	–567.	–2023	–4395.5	–4384.1	–3628.3	–2594.4
Balance of payment million U.S. $)[3]	21.0	390.	–1094	–973.3	–1889.6	–2297.0	-2711.2
Foreign exchange reserve (Mil. U.S. $)	138.	1034	1049	5628.1	6528.1	6794.9	6890.4

1) Weighted average CIF price for the year.
2) Balance of commodity import and export.
3) Overall payment balance except capital transfer.
Source: EPB, *Handbook of Korean Economy, 1980* and *Korea Statistical Yearbook, 1983*

amounted to over 4 billion dollars per year in 1979 and 1980 and then decreased gradually in the following years. The country could manage to overcome the '74 and '75 crises of foreign exchange drainage by leaning on foreign loan. Long-term foreign loans and other borrowings from foreign banks in 1974 amounted to almost 2 billion dollars. In addition, the country had been extremely successful in drawing back oil dollars by exporting construction and other services to the Middle East since the first oil shock.

The terms of trade of the country sharply deteriorated in 1974. The import price index had increased from the base of 100.0 in 1972 to 189.2 in 1974, while the export price index had risen to 67.7 in 1974 from 100.0 in 1972. The excess cost to the country in 1974 due to the deterioration in the terms of trade was 898.5 billion won, which was 12.1 percent of the gross national product of the year. Since 1975, the export price index

had been rising at a faster rate than the import price index until 1978 mianly due to stabilized oil and other import material prices so that the terms of trade had been improving during this period. Partly due to the improvement in price terms of trade and partly to the rapid expansion of the volume of export, the income terms of trade of the country continued to improve during 1976–1978. The situation, however, reversed again since 1979 with the second oil shock. Both price and income terms of trade were deteriorated seriousely during 1980–1982.

2. Policy Issues

Virtually, there was no energy issue before the first oil crisis and therefore no energy policies existed in the country in that period. Because relatively inexpensive imports of oil were continuousely available, energy constraints on economic growth were not only minimal, but also import of oil was not felt as a burden to the economy as to its influence on inflation, trade and payment balances, etc. The only energy issue that attracted the government's attention from time to time was the probable shortages of anthracite coal supply, an essential commodity for the general public. More than 90 percent of urban residences were heated by coal briquettes and any shortage of coal supply, especially in winter, could develop into social and political issues. Not only was the adequate and seasonable supply of coal necessary for the living and welfare of the general public, but also proper price and production policies were needed for the welfare of coal miners [3,4,7,8,10,17,24,29]. Other than these, the expansion of petroleum refinery and power generation capacities was major policy issues, which was a problem of capital allocation among alternative uses for economic development rather than energy policy issues [15, 25].

A spectrum of energy policy issues were raised after the first oil shock. The most urgent and immediate issue right after the shock was to secure oil supply to minimize disturbances of the economic acitivity that could be caused by oil shortage. The oil dependency of the country had reached 54 percent by 1973 and without securing the supply of oil, the national economy could have been badly jeopardized. Along with the oil securing measures, the government introduced a series of emergency measure to reduce oil consumption, which was to a certain extent effective but only short-lived. This initial emergency policies and programmes were subsequently consolidated into a more comprehensive national energy policy, the main objectives of which were to achieve economic growth while consuming less energy and reducing dependence on oil [1, 11, 13, 18, 20].

A common and principal goal of energy policy of oil-importing countries since the first oil crisis is to minimize energy cost to the economy. Policy measures to achieve this goal could vary among countries, but can be summarized into development of domestic resources, conservation, and

diversification of fuel sources. Since the first oil crisis, Korea has been pursuing all these three measures in parallel but with differential emphasis to to reduce the energy cost to the economy.

Energy resource endowments of Korea are extremely poor. The only fossil fuel so far identified is anthracite coal, whose proven reserve is estimated as about 600 million metric tons. The current rate of production is about 19 million metric tons per year and the maximum rate of production is estimated at no more than 22 million tons per year. It is known that the production will reach to its peak sometime in late 1980s and will decrease gradually thereafter [1, 4, 17, 18]. A maximum development of all hydro potential of the country will contribute marginally to the expanding energy demand. Not only the relative importance, but also the absolute amount of consumption of non-commercial sources of energy has been declining in the past two decades and continue to be so in the future [1, 13, 18, 19]. The potential for the development and utilization of renewable energy resources such as solar and wind power can hardly be determined at this stage. Technological and economic feasibilities have yet to be proved before its contribution to energy balance can reasonably be estimated [1, 13, 18, 19]. Some uranium reserves have been identified recently, but their qualities are too low to be extracted and utilized economically by the prevailing technologies under the current price relationship [18]. All in all, the contribution of domestic sources to increasing demand will only be marginal if any.

Since the country is extremely poor in energy resource endowments and the development of domestic energy resources is highly limited, a higher priority should be placed on conservation and other policies to reduce the energy burden of the economy. Recognizing these limitations and the severe impacts of the two oil shock on the economy, all the government planning documents have emphasized the importance of energy demand management and placed it on a high priority area in national development plans since 1974. The actual formulation and implementation of the conservation policies and programs had not however, been successfully done especially during the adjustment period of 1975–1979. For example, the GDP elasticity of energy demand did not, decline and the share of petroleum rather increased during this period. This was mainly due to the fact that a higher priority had alway been placed on growth goal so that the growth goal overrided that of the energy conservation. The government tried to achieve the conservation goals largely by the administrative power and mandatory measures rather than by providing incentives and allocating public funds to conservation projects. Whenever available public funds compete between the growth and conservation goals, favors have always been given to the growth at the cost of conservation [11, 12, 13, 21, 26].

A host of problems and issues exist for formulation and implementation of more effective conservation policies and programs, which ranges

from systematic identification and assessment of conservation opportunities for all the sectors of the economy, engineering and economic evaluation of the opportunities and development of new technologies and their adaptation possibilities to problems and issues associated with implementation of the policies and programs.

The fuel diversification policies and programs have been evaluated quite successful in reducing oil dependence of the economy. However, a host of associated problems and issues have arisen with present and future introduction of massive coal import and nuclear reactors. Pollution, ash disposal, and timely build-up of inland transportation network as well as unloading facilities at ports are the major policy issues to be resolved if the massive import of coal as planned by the government to substitute oil is to be realized. Also formulation of deliberate import policy of coal is another major area, for which the government should pay its due attention to minimizing the cost of coal import.

A host of policy problems and issues have also been raised in associastion with the government plans of massive introduction of nuclear power. Safety, disposal of waste materials, shortage of nuclear engineers and technicians, and accumulation of foreign debt due to increasing loan for the construction of costly nuclear power plants are examples of the issues caused by the massive construction of nuclear power plants.

Another major issues that calls for policy reconsideration in energy field in Korea is the possibility of redirecting the get-away-from-oil policy that has been pursued since the first oil crisis. The major thrust of fuel substitution policy of the country so far has been from heavy oil (mostly bunker C) to coal and nuclear rather than from all petroleum products to other sources, which has resulted in supply glut of heavy oil. The current and projected refinery specification of the country will continue to produce more heavy oil than the country will demand. Supply surplus of heavy oil is also projected to prevail in the world market in coming decade or so, which will suppress its market price. These changes call for reformulation of the present and planned fuel substitution policy of the country [32].

IV. R & D Needs and Priority Areas

The common and principal policy question that has been addressed by all the oil importing countries since the first oil crisis is how to reduce or minimize energy costs to the economy. These costs include not only the direct cost of energy import, but also other indirect costs of the society that are incurred by increases in oil price and interruption of oil import. Policy measures that have been taken by the oil-importing countries to reduce the cost are diverse and vary among countries, but they can be classified into the following three lines; 1) the enhancement of domestic resource development and utilization, 2) energy conservation, and 3) diversifica-

tion and changes in the mix of imported fuel sources. Energy-related R&Ds have been undertaken to support these policy measures.

R & D needs and priority areas in the field of energy can be identified and determined along the three lines of the classification. In case of Korea, the development and utilization of domestic resources is highly limited due to poor resource endowments. The domestic resource development policy had rather been more successful in 1960s than after the oil-shock period. Domestic coal production increased by more than twice between 1962 and 1973, but the increase was only marginal thereafter. Because of smallness of coal reserves and ever worsening mining conditions of coal mines, any improvement in the production technology will contribute marginally to increases in coal production. That is why not much efforts and investment have been put into R & D in this area. The R & D area that needs to be done in this area is the development of utilization technology of domestic coal, especially of low-grade coal. About 20–30% of coal reserved are estimated to have caloric value of less than 3,500cal/Kg, most of which are abandoned unused when produced. Hence technology improvement to either upgrade low quality coal or to design boilers to burn the low-grade coal would contribute greatly to the development and utilization of domestic coal. Also development of more efficient and convenient end-use devices to burn firewoods and agricultural wastes could be a area where a large opportunity exists to use domestic energy resources. The development and utilization of solar energy is another area where R &Ds are needed, but not a priority area. In sum, opportunities and utilization of domestic resources are very meager and hence R & D payoffs of this area are not very prospective.

Energy conservation is a priority area where a largest opportunity and potential is believed to exist to reduce energy costs to the economy. Yet, this is one of the areas where R & D activities are most lacking. An endless list can be prepared for R & D needs in this area ranging from macro policy studies to hard-ware studies on end-use devices, but just defining the R&D needs and priority areas in broader terms would be enough for the purpose of this paper. A systematic identification and estimation of conservation potential for each sector of the economy is the first step and urgent area that needs to be done for formulating sounder conservation policies. Enormous amounts of survey and research works are required, both at macro and micro levels, for the identification and estimation of sectoral conservation potentials. In addition, the followings are research priority areas in the field of energy conservation in Korea:

(1) Energy implication of alternative strategies of economic development of the country.

(2) Evaluation of the effectiveness of the past and current conservation policies and identification of major factors impeding the effectiveness of the policies.

(3) Determination of investment priorities for energy conservation for each sector of the economy.

(4) Formulation of comprehensive sectoral conservation policies.

Along with these policy studies, micro engineering-economic and hard-ware studies need be done to evaluate technical and economic feasibilities of major conservation projects and to develop energy-saving technologies. However, the micro and hard-ware studies are too diverse to meaningfully summarize them.

Fuel diversification and changes in the mix of imported energy to reduce energy costs to the economy have been implemented successfully so far. However, follow-up studies need be done to reevaluate the current fuel substitution policy and to resolve future issues expected to arise as a result of the fuel switch. They are:

(1) Timely and adequate build-up of infrastructure required to unload and transport massive coal imported.

(2) Formulation of coal import policy to minimize the import cost of coal to the country both in the short- and long-run including the determination of alternative import sources, ways of transportation, and ways of procurement such as short- or long-term contract, development import, or spot-market purchase.

(3) Analysis of the environmental impacts of burning massive coal and cost of pollution control.

(4) Environmental and safety issues associated with the massive introduction of nuclear power.

(5) Training and provision of nuclear technicians and experts to operate and maintain expanding capacity of nuclear power plants.

Along with the above-listed issues in the field of fuel diversification, the reevaluation of the current get-away-from-heavy oil policy of the country need be undertaken.

BIBLIOGRAPHY

(Arranged in Chronicle Order)

[1] Yong S. Chang, et al., *Projection of Energy Demand and Supply and Policy Recommendations*, Korea Development Institute, 1978.

[2] Ho T. Kim, et al., *Peteroleum Products Rationing Scheme for Emergency*, Korea Institute of Energy Conservation, 1979.

[3] Hyo C. Ham, et al., *Energy Consumption Survey and Residential Fuel Policy*, KIEC, 1979.

[4] Ho T. Kim, et al., *Coal Mining Industry and Coal Pricing Policy*, Korea Energy Research Institute, Dec. 1980.

[5] Hyo C. Ham, et al., *A Study on the Improvement of Coal Marketing*, KERI, Dec. 1980.

[6] Seung Y. Rhee, et al., *Econometric Model of Energy Demand*, Korea Institute of Energy and Resources, Dec. 1981.
[7] Byong W. Yoo, et al., *A Stduy on Coal and Coal Briquette Marketing*, KIER, KE-81P-10, Dec. 1981.
[8] Hyo C. Ham, et al., *Investment Policy for Coal Sector and Residential Policy*, KIER, KE-81P-81, Dec. 1981.
[9] Hyo C. Ham, et al., *A Study on Modernization of Coal Briquette Manufactures*, KIER, KE-81P-4, Dec. 1981.
[10] Ho T. Kim, et al., *Economic and Welfare Implication of Coal Price Subsidization Policy*, KIER, KE-81P-3, 1981.
[11] Ho T. Kim, et al., *Review of Past Energy Conservation Policy and Policy Recommendations*, KIER, KE-81P-25, 1981.
[12] Ho T. Kim, et al., *Energy Implication of Alternative Development Strategy*, KIER, KE-81P-19, 1981.
[13] Ho T. Kim, *Korea's Energy Experiences in the 70s and Short to Medium-term Options Open to Korea*, KIER, KE-81P-33, 1981.
[14] Hoe S. Rhee, et al., *Ecnomic Analysis of Petroleum Refining Industry*, KIER, KE-81P-23, Dec, 1981.
[15] Seung Y. Rhee, et al., *A Study on Electric Tariff Rate*, KIER, KE-81P-34, 1981
[16] Hoe S. Rhee, et al., *Energy Consumption and Environmental Effects*, KIER, KE-81P-24, 1981.
[17] Tae Y. Song, et al., *A Study on Measuses for Coal Production Increase and Its Utilization*, KIER, May 1981.
[18] Republic of Korea/U.S. Cooperative Energy Assessment, Vols. I-IV. Energy and Environmental Systems Division, Argonne National Lab. Sept. 1981.
[19] Eung W. Kim, Ho T. Kim, et al., *The Electric Future of Korea*, Resource Systems Institute, East-West Center, Honolulu, Hawaii, Sept. 1983.
[20] Seung Y. Rhee, et al., *Energy Demand and Supply Planning*, KIER, Dec. 1982.
[21] Sang K, Lee, et al., *A Study on Less Energy-Intensive Industry Structuse*, Dec. 1982.
[22] Byong W. Yoo, et al, *A Study on The Feasibility of Establishment of Coal Distribution Centre*, KIER, KE-82P-35, 1982.
[23] Sang Y. Shim, *A Study on Reorganization of Coal Mines*, KIER Dec. 1982.
[24] Sang K. Lee, et al., *A Study on Coal Pricing Policy*, KIER, 1982.
[25] Yong K. Rhee, et al., *A Study on Petroleum Policy in Korea*, KIER, 1983.
[26] Sang K, Lee, et al., *A Study on Energy Conservation Policy*, KIER, 1983.
[27] Hoe S. Rhee, et al., *Long-Term Energy Outlook and Policy*, KIER, 1983.
[28] *A Study on the Economic Use of the Low Calory Anthracite Coal*, Doe S. Chung and et al., KIER, 1983.
[29] Sang K. Lee, *Consolidation of Coal Mines for Economics of Scale*, KIER, KE-83P-9, 1983.
[30] Sang K. Lee, *A Study on Long-term Strategy for Coal Demand and Supply*, KIER, KE-83P-8.
[31] Ho T. Kim, "Energy and power intensities of manufactured products and factors affecting the changes in the intensities," *Agricultural Research*, Seoul National University, Dec. 1983.
[32] Feredun Fesharaki, Ho T. Kim and et al., *Oil Import Strategy and Refinery Rationalization Policy in Korea*, March, 1984.
[33] Chung N. Whang, *An Analysis of Energy Consumption Structure*, KIER. 1983.