KOREAN EXPERIENCES ON NUCLEAR POWER TECHNOLOGY

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Hwasup Kim , Maengho Yang
Korea Atomic Energy Research Institute

ÖZET

Bu makale, Kore'deki, CANDU ve PWR yakıtının tasarımı ve imalatı ve nükleer buhar sağlama sisteminin tasarımı ve yapımı gibi, nükleer güç teknolojisinin yerli gelişim p·ogramının başarısını anlatmaktadır. Başarı, yabancı firmalardan yapılan başarılı teknoloji transferi ile ve nükleer güç projelerinin tasarım ve mühendisliğinde, araştırma/geliştirme faaliyetleri çerçevesinde, insan gücünün verimli kullanımı ile sağlanmıştır. Teknoloji transferini başarılı bir şekilde gerçekleştirmek için, efektif işbaşı eğitim ve tasarım dökümanlarının, bilgisayar kodlarının transferi ile birlikte tasarımda işbirliği kavramı benimsenmiştir.

Kore'nin nükleer güç programındaki başarılı gelişmeler, kısa sürede, nükleer güç üretim kapasitesinin hızlı bir şekilde artması sonucunu doğurmuştur ve nükleer enerji elektrik fiyatını % 50 kadar azaltarak ulusal ekonomiye katkı sağlamıştır. Nükleer enerjinin Kore'nin gelecekteki elektrik üretiminde önemli bir rol oynaması beklenmektedir.

Şimdi Kore ileri nükleer teknolojiye doğru adım atma aşamasındadır. Ulusal elektrik sisteminin genişletilmesi planı 2006 yılına kadar 18 yeni nükleer santralın yapımını içermektedir. Bu bağlamda, ulusal nükleer teknolojinin yeterliliğini artırmak için, uzun süreli (1992-2001) ulusal araştırma/geliştirme programı belirlenmiştir. Bu maka'əde, Kore'deki nükleer teknoloji gelişim programının geleceği de kısaca anlatılmaktadır.

ABSTRACT

This paper describes the outstanding performance of the indigenous development program of nuclear power technology such as the design and fabrication of both CANDU and PWR fuel and in the design and construction of nuclear steam supply system in Korea. The success has been accomplished through the successful technology transfer from foreign suppliers and efficient utilization of R§D manpower in the design and engineering of nuclear power projects. In order to implement the technology transfer successfully, the joint design concept has been introduced along with effective on-the-job training and the transfer of design documents and computer codes.

Korea's successful development of nuclear power program has resulted in rapid expansion of nuclear power generation capacity in a short time, and the nuclear power has contributed to the national economy through lowering electricity price by about 50 % as well as stabilizing electricity supply in 1980s. The nuclear power is expected to play a key role in the future electricity supply in Korea.

Now Korea is under way of taking a step toward advanced nuclear technology. The national electricity system expansion plan includes 18 more units of NPPs to be constructed by the year 2006. In this circumstance, the country has fixed the national long-term nuclear R§D program (1992-2001) to enhance the national capability of nuclear technology. This paper also briefly describes future prospects of nuclear technology development program in Korea.

INTRODUCTION

In 1960s, Korea drove economic development policies concentranting on the reconstruction of national industries. To achieve the goal, energy supply was found to be critical, because of the shortage of energy resources. In this circumstance, Korea, suffering from lack of energy resources had to depeng on the import of oil. As a result, oil dependency on energy supply increased rapidly from 12.1 % in 1965 to 57 % in 1975 to meet the increase of energy demand. Meanwhile, Korean government conducted a long term electric system expansion plan under the assistance of IAEA in 1973, which recommended the introduction of nuclear power.

A couple of oil crises in 1970s was painful to Korea and greatly hurt Korean economy, and this caused the change of Korean energy policy from heavy dependence on oil to diversification of energy sources, including nuclear energy. Acompanying de-oil energy policy and rapid growth of electricity demand, nuclear power program has rapidly expanded with special emphasis and the first NPP started its operation in 1978.

To accomplish a goal for self-reliance of nuclear technology, the detailed strategy has been built. The success of development in CANDU fuel fabrication, the first project for self-reliance by KAERI through several years of R§D efforts, gave us a confidence to meet a goal for self-reliance.

The success of development in the nuclear power technology in Korea may be summarized by 3 points, first, favorable situation of nuclear world market in 1980s, second, lack of other energy resources in Korea, and third, the efforts of Korean government and nuclear scientists and engineers. Depression of the world nuclear industry in 1980s, which was caused by the TMI accident and revelant public anti-nuke-movement, provided a buyer's market and make it possible for Korea to have a great opportunity of transfering technology by technology-transfer agreement with NPP suppliers. As mentioned above, Korea is suffering from lack of natural energy resources, therefore she has to import most of energy resources abroad. Furthermore nuclear power itself is a technical and economical energy if we can manage the technology. In Korea, there is much well-educated manpower sufficient to carry out nuclear technology self-reliance program. Many Korean nuclear scientists and engineers, who had been actively engaged in oversea's nuclear research or engineering, were drawn to make a key role in nuclear power technology development with direct participation into the nuclear power projects as R§D manpower.

So far, nine nuclear power plants are in operation, and five units under construction (see Table.1). Nuclear power has been supplying about half of total electricity generation since 1989. With increasing nuclear electricity generation, the sales price became lowered down remarkably as shown in Figure. 1, keeping lower price compared with other countries (Table.2). Future Korean energy policy will be focused on: energy security, environment protection, economical improvement and competitiveness in the world market.

Table.1 - Nuclear Power Plants in Operation and under Construction in Korea

No	Name	Type	MWe	Comm. Oper. Date	Remarks
1	Kori 1	PWR	587	1978.4	In Operation
2	Kori 2	PWR	659	1983.7	
3	Wolsong 1	PHWR	679	1983.4	
4	Kori 3	PWR	950	1985.9	
5	Kori 4	PWR	950	1986.4	
6	Yonggwang 1	PWR	950	1986.8	
7	Yonggwang 2	PWR	950	1987.6	
8	Ulchin 1	PWR	950	1988.9	
9	Ulchin 2	PWR	950	1989.12	
10	Yonggwang 3	PWR	1000	1995.6	Under Construction
11	Yonggwang 4	PWR	1000	1996.6	
12	Wolsong 2	PHWR	700	1997.6	
13.	Ulchin 3	PWR	1000	1998.6	
14	Ulchin 4	PWR	1000	1999.6	

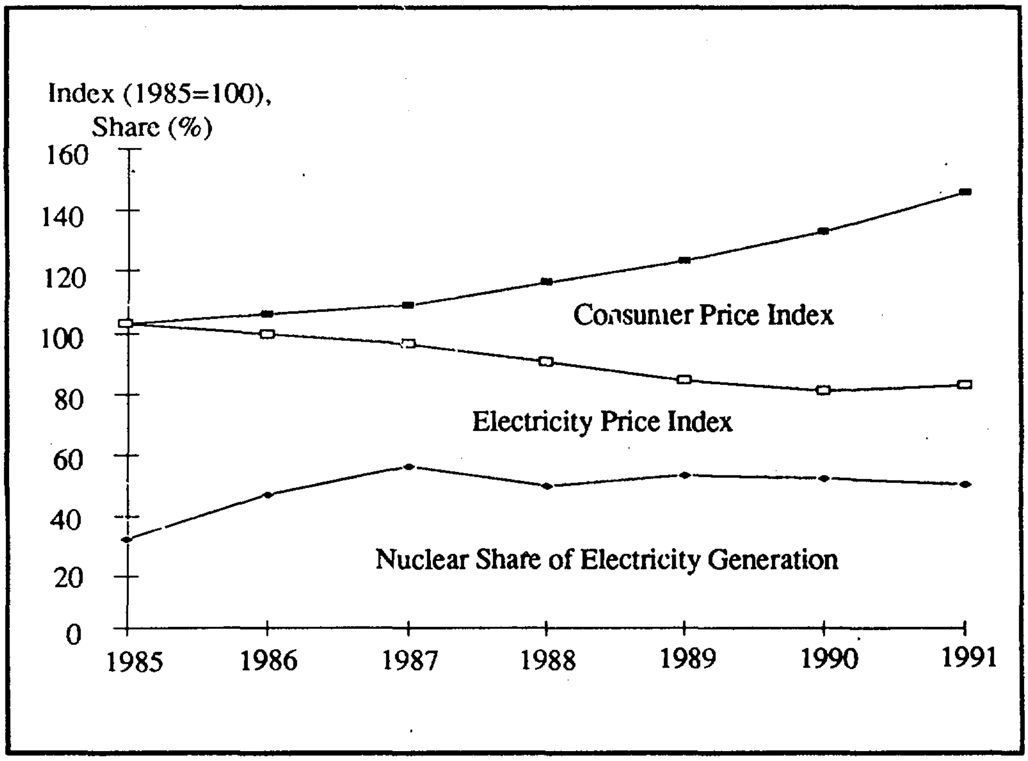

Figure. 1- Consumer Price Index, Electricity Price Index, and Nuclear Share of Electricity Generation

Table. 2- Comparison of Electricity Price between Korea and other Countries (1991)

Country	USA	Korea	Taiwan	France	Japan
Electricity Price, Won/kWh	49.76	52.94	64.29	71.87	116.94

In spite of rapid increase of electric power generation over last 30 years in Korea, per capita electricity consumption is still as low as about one third of Japan, and one sixth of USA as shown is Table. 3. This implies that further expansion of power generation capacity may be necessary for the nation's industrial developments and the improvement of living standards. According to recent long term electricity plan by Korean government, more 18 units are sopposed to be introduced construction (to be doubled in capacity scale) by the year 2006 (Figure 2). This accounts for 37 % of the total installed capacity, and about 50 % of total electricity generation.

Table. 3- The Comparison of Electricity Consumption per Capita

Country	Korea	Taiwan	UK	France	Germany	USA	Japan
Year	1990	1989	1988	1989	1989	1989	1989
Electricty Consumption per Capita kWh	2,435	3,689	4,813	5,609	6,334	10,958	5,792

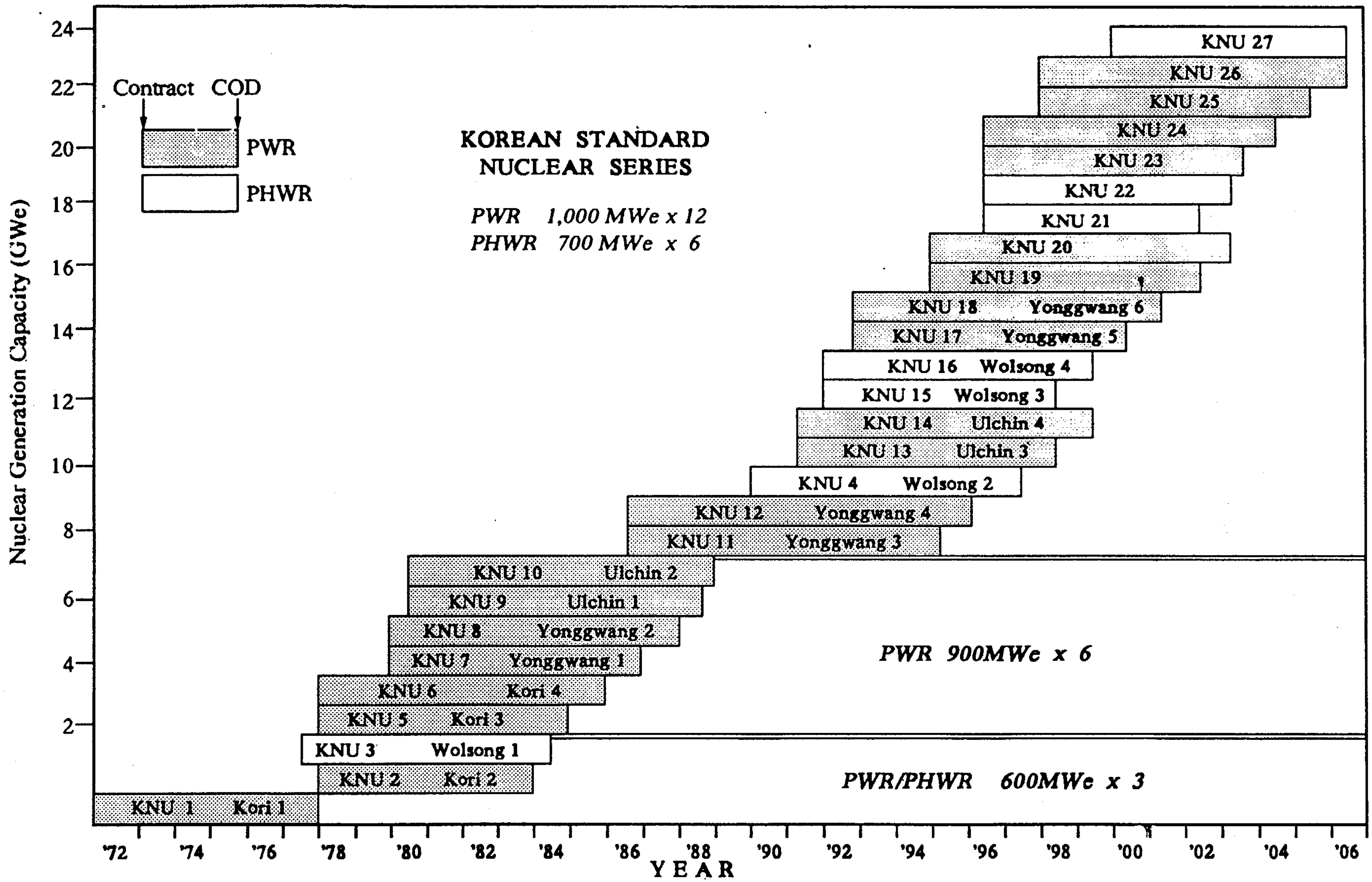

Figure 2. Korean Nuclear Power Program

The national long-term nuclear R§D program initiated last year, has been established to support the national nuclear power program aiming self-sufficiency of nuclear energy supply, and to enhance technical capability to compete with nuclear-advanced countries by the year 2000's.

DEVELOPMENT OF NUCLEAR POWER PROJECTS

Korea has nuclear R§D experience more than thirty years. Until the early 1970s, nuclear R§D was mainly focused on radioisotope researches and applications as well as basic research using research reactors introduced in 1960s and 1970s. Then, nuclear infastructure and manpower in Korea were not matured enough to accommodate the large scale power reactors.

Nuclear power projects have been accelerated due to the past experiences of two worldwide oil shocks in 1970s because Korea is insufficient of oil, gas, or other natural energy resources. KEPCO (utility) ordered nine nuclear power projects (8 PWR and 1 CANDU) under these circumstances.

Among them the first three nuclear units were carried out based on turn-key base contracts with foreign suppliers, which can be categorized as the first phase. As Korean nuclear infrastructure was not yet matured, construction projects were managed entirely by foreign vendors with the limited contrubution to civil engineering made by Korean company. Gradually some of organizations such as KOPEC, KHIC, KEPOS including civil engineering companies were established for nuclear power industrialization.

In the second phase projects, a component approach contract was adopted, under which KEPCO took responsibility of the projects and construction management as well as the startup of the plants. This phase covered six units of 950 MWe PWR NPPs, Kori 3 & 4, Yonggwang 1 & 2 and Ulchin 1& 2.

SELF-RELIANCE FOR NUCLEAR FUEL

1) Localization of CANDU Fuel Fabrication : Possibility of Self-reliance

KAERI, with its qualified manpower and research facilities including research reactors, started CANDU fuel localitazion project since 1980.

A pilot scale nuclear fuel fabrication facility has been built and operable since 1978 at KAERI. Using this facility KAERI has performed fundamental researches on CANDU fuel manufacturing technology. In 1981, government and KEPCO agreed to develop CANDU fuel fabrication technology as a national project. After two years, KAERI developed Uranium conversion technology (AUC) and prototype fuel bundles. Out-of-pile tests to verify the mechanical and material integrity of the fuel were performed at KAERI facility, which was constructed by domestic industry and designed and instructed by KAERI. Subsequent in-pile tests for several prototype fuel bundles were carried out successfuly at the NRU reactor in Canada with the cooperation of AECL.

Finally KAERI decided to extend its efforts to commercialize CANDU fuel fabrication technology. Thereafter 408 bundles of fuel were loaded successfully into the Wolsong unit 1 with governmental approval from 1984 to 1986. And since July 1987, full core of the Wolsong plant began to be commercially loaded with KAERI made fuel. Through years of efforts to develop CANDU fuel fabrication technology and construction of the commercial scale plant, our self-reliance program in nuclear power technology could be established with confidence.

Success in CANDU fuel fabrication drew the attention of government and based on that confidence we could challenge to localize PWR fuel design and fabrication.

2) PWR Fuel Technology Development: Joint Design Concept

In 1985, upon the success of CANDU fuel design and fabrication at KAERI, the Korean government decided to localize PWR fuel technologies by using KAERI's experiences and capabilities. Thereby KAERI has been assigned for PWR fuel design and engineering while KNFC for fuel manufacturing.

To expedite self-reliance in PWR fuel technology development, two technology inducement contracts were made in August 1985 as shown in Figure 3: one for fuel design technology transfer, between Kraftwerk Union (KWU) of Federal Rebublic of Germany and KAERI; and the other for fuel fabrication technology transfer between KWU and KNFC.

Joint design concept, introduced by KAERI for PWR fuel development strategy, has been found to be useful and efficient in the complete technology transfer. During the joint system design work, KAERI engineers actively participated in the design activities covering all aspects of fuel and core design, and safety analysis. This took place at Erlangen facilities under KWU's responsibility.

For the design of fuel itslef, joint effort with KWU was made in two steps. The first step is called preliminary joint design of which activities are defined as generation of manufacturing related documents and licensing reports. The second step is the final design, that is design of the reload core using the fuel that was determined during preliminary design stage. From May 1986 until March 1988, preliminary design activities for reload fuel assemblies, to be fabricated during 1989, were successfully completed by joint effort of KWU and KAERI engineers. The final design has started in November 1987 in a stepwise manner for Kori unit 2. Now KAERI independently performs design works on the reload cores for all the PWR fuel assemblies.

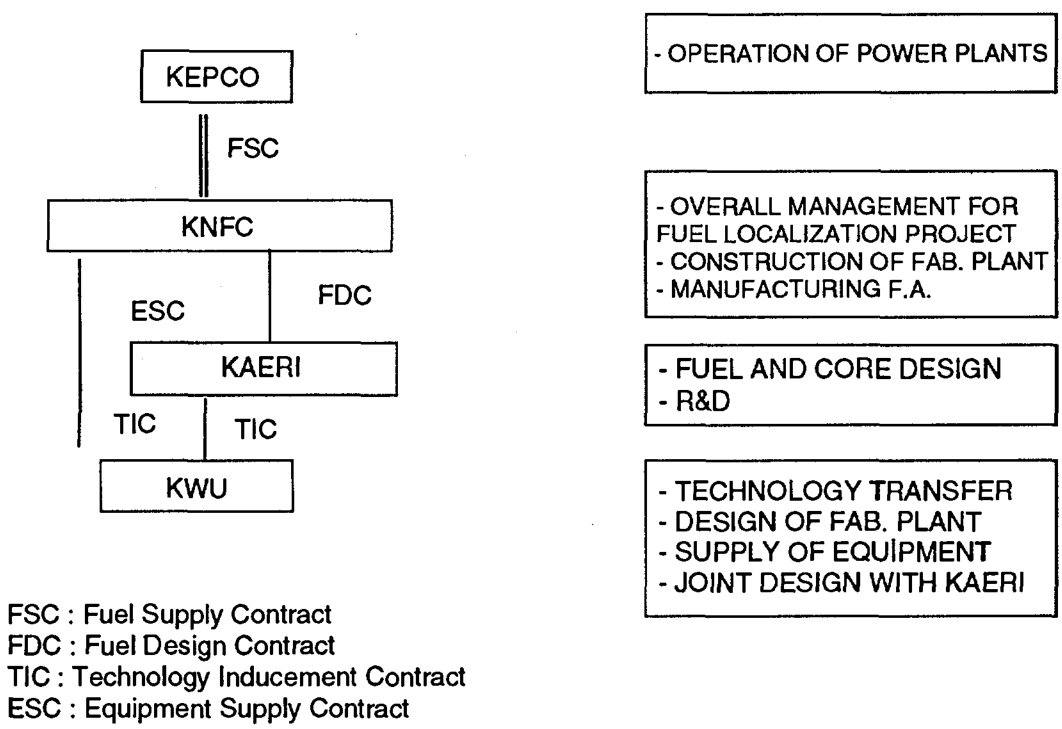

Figure 3. PWR Fuel Project Structure

SELF-RELIANCE OF NUCLEAR POWER TECHNOLOGY

1) Setting of Self-reliance: Yonggwang 3&4 Project

Through three turnkey -and six component- projects of constructing NPPs, some parts of construction, A/E, and hardware manufacturing technologies could be obtained. It was then recognized that software technologies such as fuel design, NSSS design, and engineering were difficult to achieve without indigenous R&D efforts.

Since the early 1980s, in this regard, measures for integration of the nuclear R&D activities with nuclear power projects have taken place to keep close links between the related R&D institutes and industries to accomplish self-reliance goal of nuclear power technology within a short time.

In 1985, Korean government made a milestone decision to implement the national self-reliance policy and divided the role among domestic nuclear organizations for as follows;

Total Project Management: KEPCO (Korea Electric Power Corporation)

Architectural Engineering: KOPEC (Korea Power Engineering Co.)

NSSS/Fuel Design: KAERI (Korea Atomic Energy Research Institue)

NSSS Turbine/Generator Manufacturing: KHIC (Korea Heavy Industry and Construction)

Nuclear fuel Fabrication: KNFC (Korea Nuclear Fuel Co.)

This self-reliance strategy has been applied to the implementation of Yonggwang 3 & 4 project, which was the first project for the third phase. And it has been decided that main contractors from the third phase were to be domestic organizations under KEPCO's responsibility for total project management. Domestic nuclear industries have the initiative as prime contractors with the support licensed technology transfer from the foreign subcontractors for Yonggwang 3&4.

Yonggwang 3&4 Project, initiated in 1987, was a turning point in Korean nuclear history because it enabled to transfer the most matured and state-of-art nuclear technologies, commercially available by then to Korea. This has been the backbone of further development of nuclear technology.

In the third phase, division of reponsibilities for the domestic nuclear organizations participating in the nuclear self-reliance program is summarized in Table. 4. Presently these organizations are well specialized and earning great reputation in the nuclear fields.

In addition, EPGCC (Electric Power Group Cooperation Council) was being operated among the nuclear power organizations for balanced development and coordination of participating organizations. Since nuclear power projects are incorporating a broad spectrum of technologies, it is necessary to gather a consensus on the directions of nuclear power technology development. EPGCC made great contribution and still keeps an important role on implementing the national policy of nuclear technology development through sufficient discussions and debates at workshop.

Table 4. Summary of Prime Contractors for Yonggwang 3 & 4 Projects

Technology	Prime Korean Contractor	Foreign Subcontractor	Remarks
NSSS/FUEL	KAERI	ABB-CE	Joint Design
Turbine/Generator	KHIC	General Electric	
Architect Engineering	KOPEC	Sargent & Lundy	

KAERI has been designated to be responsible for NSSS system design and engineering technology development through the participation in the Yonggwang 3&4 nuclear power projects since 1985. This decision was made by the Korean government to use elite nuclear R&D manpower of KAERI for the development of sophisticated software technologies on NSSS, through which self-reliance in nuclear power technology could be effectively achieved.

Combustion Engineering (C-E) was selected to supply NSSS hardware, fuel and NSSS system design of Yonggwang 3&4 projects to the domestic prime contractors, KHIC, KNFC and KAERI, respectively, as shown in Figure 4. For an effective technoolgy transfer of NSSS system, a joint system design contract was made between KAERI and C-E. Both praties share 50-50 manpower participation in the NSSS system design and engineering works, while C-E retains the final products warrantly and performance. This provided KAERI with maximum opportunity in gaining the real project experience with guaranteed quality, schedule commitment, and cost kontrol measures.

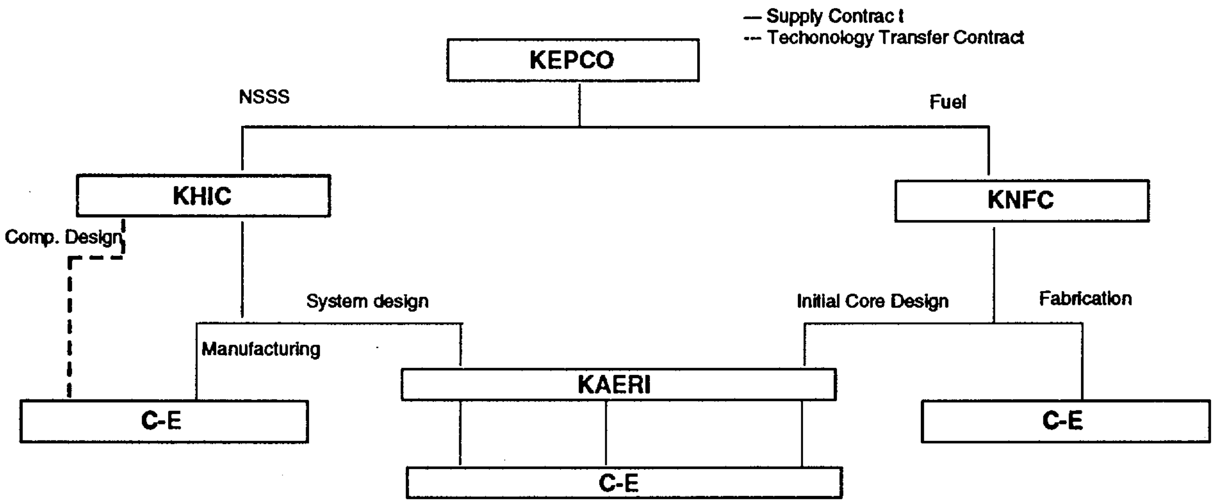

Figure 4. Contractual Relationship of Yonggwang 3&4 Projects

This approach was chosen based on the confidence gained from the success of the previous joint design experience with KWU on the PWR fuel project. The joint design team of KAERI was dispatched to C-E Windsor office and has been carrying out NSSS system design and engineering works with C-E engineers. Since the early 1989, the NSSS design center has moved from C-E Windsor site to KAERI Daeduk site. This means NSSS system design work of Yonggwang 3&4 project was to be carried out mainly by KAERI engineers under C-E technical supervision at KAERI site. The second vehicl to the techonogly self-reliance on NSSS system design comes from the technology transfer agreement between C-E and KAERI. Through this agreement, KAERI received all the technology of NSSS system design and engineering from C-E, as well as project management for commercial PWR that has been devloped.

Participation of KAERI engineers in the ongoing nuclear R&D program of C-E is also included in the technology transfer agreement. New R&D area and the need have been identified through joint R&D meeting betveen KAERI and C-E. The result of joint R&D will be applied to the next two PWR projects.

2) Standardization of Nuclear Power Plant: Ulchin 3&4 Project

Ulchin 3&4 are the first project where KAERI has played the leading role in NSSS design. During the design work KAERI introduced several advanced features such as rapid depressurization in feed and bleed capability of pressurizer.

The Ulchin 3&4 will be served as the first of Korean Standard Nuclear Power Plants (KSNPP). Subsequent PWR plants are expected to follow this design concept, gradually adopting advanced design features incorporating which were come out of US ALWR program.

The Korean standardization program was formulated in 1983 with the purpose of responding to the need for a stable and reliable electricity supply in the 1990s and early in the 21st century. This program was carried out in three distinctive phases from 1983 to 1991 in parallel with the self-reliance program;

- Feasibility study on the basic concept to be approached in the first phase
- Identification of candidate design to be optimized, meeting the requirements of standard plants in the second phase.
- Development of the design concept for Korean Standard Nuclear Power Plant with Yonggwang 3&4 as a reference plant in the final phase.

In this work, KEPCO (utility), KAERI (NSSS Designer), and KOPEC (BOP Designer keep close cooperation with government support. K-SRED (Korea standard Requirement Document), and K-SSAR (Korea Standard Safety Analysis Report) address new licensing requirements aiming to meet the need for a reliable and stable electricity supply.

Ulching 3&4, which are currently under construction, are the leading plants of KSNPP. Design works on two more KSNPP units of Yonggwong 5&6 are also scheduled to start this year. Without changing the skeleton of the KSNPP design devloped already, plant enhancement and improvements will be made by adopting advanced design features which were not previously employed.

3) Balance of Two Different Reactor Types: Self-reliance of CANDU Technology, Wolsong Projects

The design and construction of additional Wolsong units 2, 3 and 4, after unit 1, which started operation in 1983, is underway at the same site. CANDU reactor deployment will continue as a complementary reactor to balance reactor mix in Korea. Wolsong 2, 3 and 4 have a capacity of 713 MW each. Wolsong 2 started construction in Jan. 1991 and is supposed to start commercial operation in June 1997, while Wolsong 3 and 4 started in Sept. 1992. They are supposed to begin operation in June 1998 and June 1999, respectively, as shown in Figure 5. Wolsong 2, 3 and 4 are referring to Cernavoda nuclear power plant for NSSS and Wolsong 1 for BOP, respectively. Korea is constructing those three units under a unified project management system.

Korea also has a very aggressive strategy to achieve self-reliance of technology for PHWR. Korea is trying to experience and accumulate design skill from the Wolsong 2 project and to accomplish self-reliance for the most of the core technology by the end of Wolsong 3 and 4 project.

Furthermore, Korea is planning to initiate the core design for the PHWR introducing thereafter (temporarily fixed Wolsong 5 and 6) and to apply all the possible features of improved and advanced CANDU technology acquired through the joint research between KAERI and AECL as shown in Figure 6. The strategy will be carried on mainly through the technology transfer contract, made between KAERI and AECL, for the next ten years.

ECONOMIC PERFORMANCE OF NUCLEAR POWER PLANTS

1) The cost and performance of the nuclear power plants

Reflecting its rapid economic development, Korea's energy consumption has quadrupled over the past two decades, particularly because of increase of the demand for electricity. The increase averaged about 16% a year in the 1970s, but fell bact to 9.7% during the recession of the early 1980s. In the past ten years, electricity generation capacity and consumption have increased by more than two and half times, much faster than the total energy demand. The annual growth rates of total energy

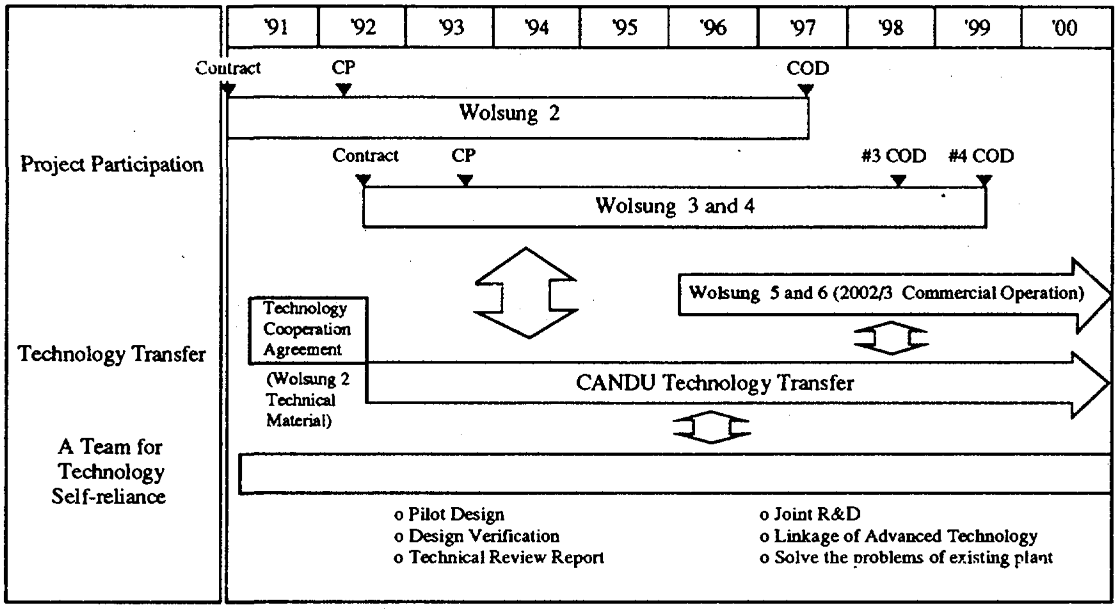

Figure 5. Detailed Plan for Self-reliance of Wolsong NPP

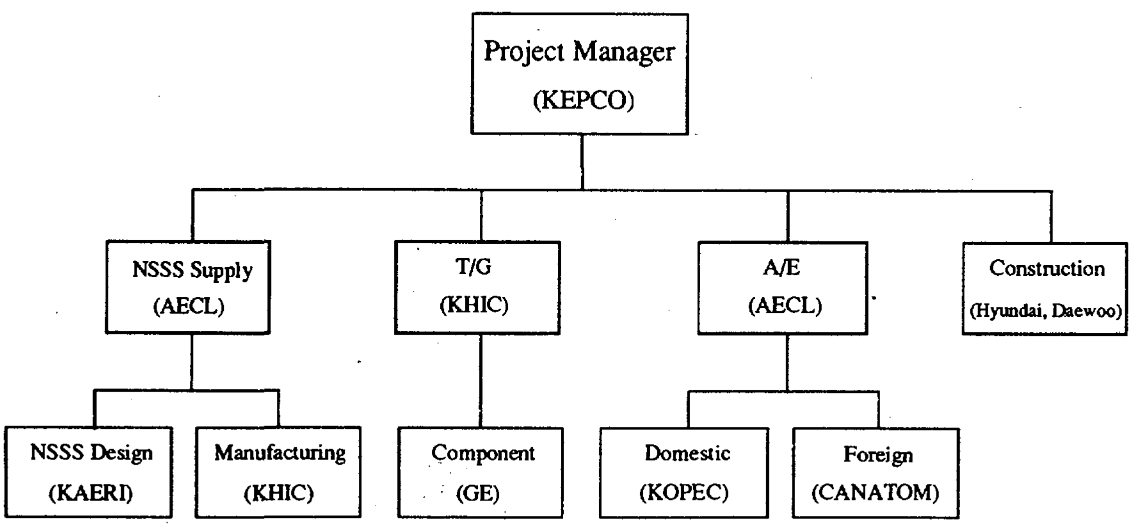

Figure 6. Contract Structure of Wolsong Project

consumption, electricity generation and nuclear energy were 8.1%, 11.4% and 34.0%, respectively. Total nuclear electricity generation in 1991 was more than 56,300 GWh, which accounted for 47.5% of the electricity generation in the country.

The growth rate of installed nuclear capacity is also high in both relative and absolute terms, increasing from 8.5% in 1978 to 36.0% of the total installed electricity generation capacity in 1991. In terms of the sharing with total energy consumption, nuclear power generation increased from 1.5% in 1978 to 13.6% in 1991, as shown in Figure 7.

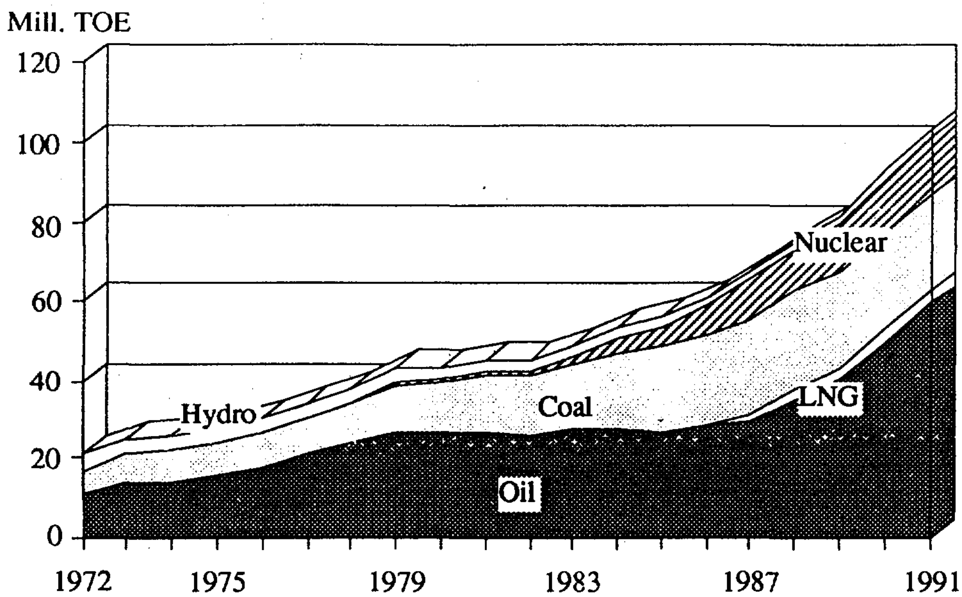

Figure 7. Trend of Energy Consumption in Korea

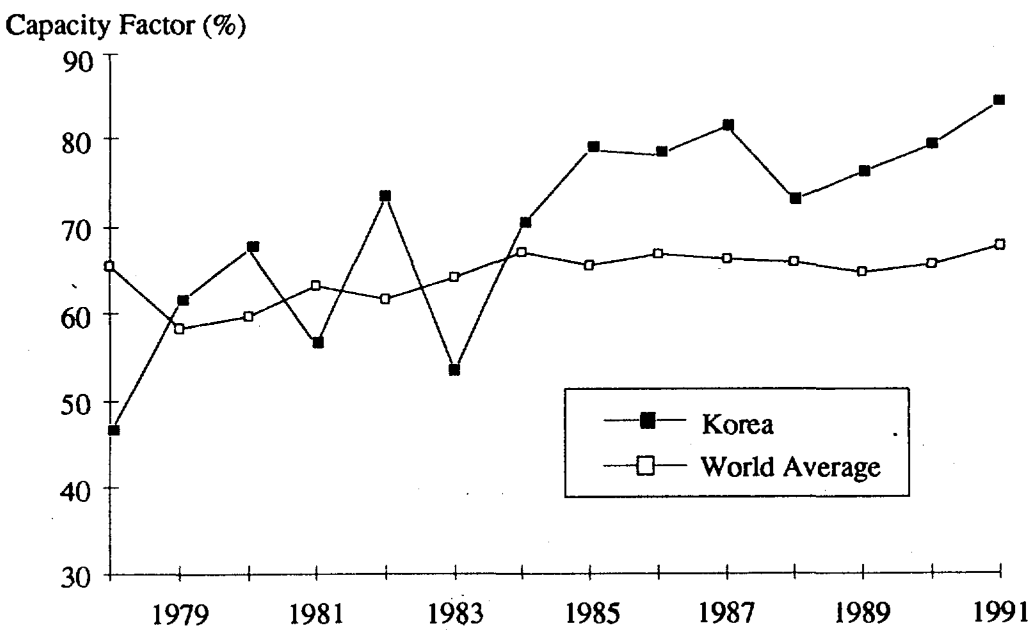

Figure 8. Capacity Factor of Operating NPPs in Korea

Korea has gradually improved nuclear plant performance in trems of the average annual capacity factor of nuclear plants due to accumulated technology and experience. Capacity factor of Korean NPPs improved from 61.3% in 1979 to 84.4% in 1991, showed good performance compared with world average, as shown in Figure 8. In terms of total generation cost, the cost of nuclear power is much lower than those of coal and oil fired generation as shown in Table 5.

Table 5. Comparison of Electricity Generation Cost in Korea

Unit : Won/kWh

Yearf	1988	1989	1990	1991
Oil	37.54	32.82	37.88	27.84
LNG	43.95	41.15	40.89	37.44
Coal	29.90	30.99	30.95	30.79
Nuclear	26.63	23.62	23.75	22.62
Hydro	35.22	28.81	23.06	29.24

2) Constribution to the national economy

As pointed out earlier, nuclear energy supplies almost half of the nation's total electriciy consumption. As shown in Table 5, the Korean nuclear program made a contribution to provide a relatively cheap energy in trems of nuclear power generation cost, at least. In particular, this has been realized by substituting nuclear power for expensive imported fossil fuels in generating electricity.

It is, therefore, possible to piont out that the gradual reduction of dependence on imported energy is attributed to the nuclear generation particularly between 1981 and 1987, despite the increase in total energy demand during the same period. It is quite sure that nuclear generation partly contrubited to lowering electricity prices since 1982.

The low electricity price has improved the price competitiveness of exporting goods to help the government export-driven economic policy. The contribution of nuclear power to Korean economy can be summarized as follows: substantial reduction of oil consumption, diversion of capital from energy sector to other manufacturin sectors, improvement of the overall level of industrial technology and price reduction of exporting goods.

NATIONAL R&D LONG-TERM PROGRAM

Korea expects to accomplish self-reliance of commercial nuclear technology by the turn of this century. Besides she plans to link the accumulated technology to self-reliance of advanced nuclear technologies.

For the purpose, Korea triggered the national nuclear R&D long-term program under the cooperation of government, KEPCO,and KAERI. THe prgram has established in 1992, is being conducted along the schedule with ambition. The final goal of this program is the enhancement of technological capability to the level of nuclear advanced countries in the early 2000s and establishment of self-sufficiency in nuclear energy supply.

To perform this program successfully, Korea decided to select strategic key technologies and raise them intensively until they have strong international competitiveness through effective international cooperation and systematic development of basic advanced technologies. For reliable and economic supply of nuclear energy, Korea is making continuous efforts to improve safety and economy, and establish industrial technology standards, etc. The national long-term R&D program has been fixed until 2001 as the first phase. The program to be implemented in two separate lines that are government -and industry- led R&D program. The details of the government -and industry- led R&D program are summarized in Table 6 & 7.

CONCLUSION AND FUTURE PERSPECTIVE

The Korean experiences over the last ten years imply many lessons to developing countries which intend to develop nuclear power technologies by technology transferring from advanced countries in the future. And Korean experiences described so far might be regarded as a good model case for the developing countries in the development of implementing methodoloy, management system, self-reliance policy and manpower training, etc.

However, the success of nuclear technology devlopment program highy depends on the country specific factors such as infrastructure, economic level, manpower quality, and energy resources. Therefore, developing countries pursuing the nuclear technology development should consider all the country specific factors including international relations with advanced countries.

Now Korea is under way taking a step forward advanced nuclear technology. The basic strategy to acquire the advanced technologies is to perform the national long-term nuclear R&D program and the continuous expansion of nuclear power plants. It is hoped to achieve the self-reliance of advanced nuclear technologies in the near future through feedbacak of nuclear power plant projects and R&D program.

Table 6. Summary of Long-Term Nuclear R & D Program led by Government

Fidels	R & D Projects
1. Nuclear Rector Technology	Liquid Metal Reactor Development
2. Nuclear Fuel Cycle Technology	Development of Advanced Nuclear Fuel
3. Radioactive Waste Management	Development of Radioactive Waste Disposal Techonology
	Development of Spent Nuclear Fuel Management Technology
	Development of Fundamental Technologies for Radioactive Waste Treatment
4. Nuclear Safety	Nuclear Safety Research
	Research on Radiation and Environmental Safety Nuclear Regulatory Research
5. Basic Technologies	Development of Advanced Nuclear Materials Development of Advanced Instrumentation and Control Technology Development of Human Engineering Advanced Robotics for Nuclear Industry Development of Laser Technology Development of Atomic Spectroscopy Development of Nuclear Transmutation Techonology for Long-lived Radionuclides Nuclear Fusion Reactor Research Development of Advanced CANDU Technoolgy
6. Radiation/Radioisotope	Radiation Dosage and Cancer Research
Applications	Radiation/Radioisotope Applications

Table 7. Summary of Long-Term Nuclear R & D Program led by Industries

Field	R & D Projects
1. Nuclear Reactor Technologies	Development of Next Generation PWR
2. Nuclear Fuel Cycle Technology	Development of Advanced Fuel for PWRs
3. Nuclear Power Plant Construction Technology	Nuclear Power Plant Construction Technology Development of Codes and Standards for Nuclear Industry Development of a Systematic Technology for Nuclear Power Plants Evaluation of Environmental Impact due to Thermal Discharge from Nuclear Power Plants
4. Nuclear Reactor Operation Technology	Improvement of Nuclear Reactor Safety Improvement of Reactor Operation Technology Development of Operation and Maintenance Technology Developments of Health Physics and Radiation Protection Technology Development of Industrumentation & Control Techonolgy for Nuclear Power Plants Robotics for Operation and Maintenance Plant Life-Time Extension and Decommissioning Technology Establishment of Data Base for Operation and Maintenance