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REVIEW OF CERTAIN ASPECTS OF KOREA POWER DEVELOPMENT PROGRAM

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ACKNOWLEDGEMENT

This report was made possible by the cooperative attitude of personnel of the Korean Government and Korea Electric Power Company (KEPCO). KEPCO personnel provided information to answer the many questions relating to plant cost, schedule, and economic evaluations. This needed help is much appreciated. A list of meetings and personnel is presented in the Appendix.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

BACKGROUND OF STUDY

An overview assessment of issues of costs and schedule associated with the implementation of the Nuclear Power Program in Korea was performed at the request of the World Bank. The scope of the evaluation considers the major factors that impact on electrical generation cost and the main assignment was to assess plant capital cost. Information was provided by personnel from the Korean Government and the Korea Electric Power Company (KEPCO).

The major findings are presented in Section 5 and Section 6: Section 5 assesses the construction cost and schedule, and Section 6 provides comments and observations on the Power Development Program and on the methods used in planning.

The basic approach used to evaluate cost was to assess the major elements that contribute to plant cost and to analyze the factors that impact on the major cost elements. Information from KEPCO personnel and the USA construction experience was assembled with focus on the major cost elements and the factors that drive these costs elements.

MAJOR FINDINGS

A summary of the main findings of the study is presented in the groupings: (A) General Findings Relating to Plant Construction Cost, (B) Comments on Economic Planning Models and (C) Comments on Power Development Program.

(A) General Findings Relating to Plant Construction Cost

1) The forecast of construction schedule and cost have sound basis and good controls.

   Some schedule completion dates are tight and schedule slippage on some plants is likely to occur - for example, a 12/82 startup for Unit #2 will be difficult to meet. There is high probability, however, that schedule performance will be good and slippages are expected to be small. A similar conclusion is made with regard to plant cost forecast.

2) Schedule is the most important cost impact item within the control of KEPCO, and schedule is receiving priority attention at all levels of management.

3) KEPCO is effectively using construction management support from Bechtel, and is using Bechtel methods and techniques to monitor and control schedule and cost.

(B) Comments on Economic Planning Models

1) The economic models being used by KEPCO for economic evaluations associated with planning provide comprehensive and disciplined evaluations of the cost items for the different generation facilities. KEPCO uses a computerized planning program which was developed by TVA and ORNL and which uses an extensive list of relevant inputs. KEPCO also uses the ORCOST-II model for construction cost estimates. More use of the actual experience from the construction of Korean plants should be used as inputs to planning, rather than averages from the construction experience of the developed countries. This requires means for planning to access construction cost information on a routine

and timely basis.

2) Current KEPCO contracts provide no real basis or incentive to measure labor productivity in terms of manhours per construction unit. Over the long term, knowledge of unit productivity may prove useful. Near identical plants and construction management controls can use the learning phenomena to improve unit productivity on repeat units for both directs and indirects. The similarity of the Korean plant designs and infrastructure of supply and construction may offer some opportunity in this area.

(C) Comments on Power Development Program

1) The forecast of electric load demand may be optimistic and is an item of concern. Also, the system load factor is reduced from 72.5% in 1982 to 66% in 1991 in the forecast. Excess capacity could result from either a lower demand (i.e., lower than forecast) or a better load factor. These forecasts should be carefully examined.

2) Efforts to shorten construction schedules for nuclear plants should be considered. A shorter schedule has benefits to cost and also permits program implementation on the basis of a shorter forecast. The assumed feasibility of a shorter schedule is based on: demonstrated performance before 1970 and in the early '70's, comparison with coal plant construction schedule, and the demonstrated construction capability of Korea.

3) The March 1982 Power Development Plan presents a comparison of generation cost of Ko-Ri #1 against generation cost of the other existing facilities. The results, while interesting, have no meaning for planning of facilities. A comparison of generation

cost from nuclear and coal plants for future years should be presented, as this is meaningful to facilities planning. While the generation cost favors nuclear, the margin appears to be in the range of 5% to 30%.

Plant capacity factor (CF) is also an important cost input. The plan uses 65% CF, which is reasonable (average CF for PWRs in 1981 was 62.2%). It is also feasible to consider higher CF as some utilities consistently do significantly better than the average. For example, the average CF for three Swiss plants in 1981 ws 88.5%.

4) The basic planning position of nuclear and coal for most new facilities is sound. Also, nuclear is likely favored on the basis of economics and logistics associated with the supply of fuel. The cost of generation from nuclear is somewhat lower than that from coal when the current planning inputs are used. It is noted that power generation cost from nuclear is more sensitive to the capitalization charge as nuclear capital costs are higher. Schedule, interest rates, capitalization structure (i.e., funding), and plant capacity factor are all important to generation cost and these factors may change.

5) The economic evaluations should give consideration to all cost elements for nuclear and coal. Examples of items to consider are: decommissioning cost of the plant, fuel cost for storage or disposal, ash disposal, special facilities for coal transport.

1.0 INTRODUCTION

The purpose of this report is to present information and judgements based on an overview assessment of issues affecting costs and schedule associated with the implementation of the Nuclear Power Program in Korea. This assessment was requested by the World Bank.

The scope of the evaluation considers the major factors that impact on electrical generation costs. The main focus is to provide an overview assessment of the forecasted capital cost and schedules of the nuclear plants to be constructed as part of the Korea Power Development Program. The comparison of production cost of nuclear and thermal is also addressed. Information was provided by personnel from the Korean Government and KEPCO. A list of meetings and persons visited is given in Appendix I.

The basic approach used to evaluate cost was to assess the major elements that contribute to plant cost, and to analyze the factors that impact on these major cost elements. The analysis considers the construction experience of the USA, and information provided by KEPCO on their construction cost experience. Also considered are the methods used to manage the Korean nuclear power program and schedule.

While the basic assignment from the World Bank was to address construction cost and cost control methods, comments are provided on the cost numbers and methods used in the Planning Division. Judgements are also offered on the Power Development Plan.

The report is organized as follows. The Executive Summary provides an overview of purpose, approach and findings. The text of the report provides supporting background and discussion.

2.0 EVALUATION FACTORS

This section covers: the major cost elements that comprise plant cost; the factors that impact on these major cost elements; and the principles and approachs for controlling costs. A later setion assesses the Korean Nuclear Projects in context of the format presented in this section.

2.1 Major Cost Elements

Total plant cost can be dissected for analysis in a number of different ways. The approach used in this evaluation was influenced by the contractural arrangements. The major cost elements are:

- o Equipment cost of the total plant (direct cost)
- o Construction cost of construction material and labor (direct cost)
- o Engineering, project management, and construction management costs (indirect cost)
- o Interest

Escalation is not listed as a major element per se; it is an inherent and important part of the basis cost elements, however, and is a basic factor which drives the actual cost incurred. The basic factors that determine actual cost are briefly addressed as background to later sections that deal with assessment cost and cost methods.

2.2 Major Factors that Influence Cost

~~A principal factor~~ in assessing the cost of the projects is the nature of the contracts. For example, in principle a firm price "turnkey" contract that covers all items of cost, and provides comprehensive warranties, with no provisions for escalation, uniquely determines the cost of the project. (Note: As used in this discussion, the term "cost" relates to the cost to KEPCO - independent of the actual cost to the suppliers and contractors). While some of the contracts are "turnkey" type, escalation provisions will influence the final cost. In recent years, escalation and interest have become large contributors to total plant cost. This was caused by very long construction schedules in an economy of rapid inflation and high interest rates. Schedule is the main item within the purview of KEPCO's control - the contract provisions are largely set. Another area that impacts on cost is design and project changes; change control management is also within the purview of KEPCO controls. This evaluation focused on the major items discussed above.

2.3 Principles and Approach for Cost Control

Schedule is the primary item of cost control for the Korean contracts. Schedule delays increase the cost contribution from both escalation and interest. It is noted that while schedule is important to plant cost, the first priority should be safety and quality assurance. Assurance of quality and safety need not be compromised to maintain schedule. Maintaining schedule with quality requires a sound program for quality assurance and project management. The Korean program should strive to utilize the experience of the USA, Canada, and France to implement quality assurance and to control schedule cost.

The other items that need to be controlled are: indirect costs and design and project changes.

2.4 Highlight Features of Contracts, Provisions and Project Status

Table I shows a summary of the Nuclear Power Program

The contract for Units #1 and #2 for the Ko-Ri plant are of the "turnkey" type with Westinghouse (W). These units are at the Ko-Ri site and have the same supply infrastructure: W is the reactor supplier; the G.E. Co. (UK) is the turbine/generator supplier; Gilbert Associates is the Architect Engineer (AE); and W is responsible for construction. Ko-Ri #1 has been in operation since April 1978. Ko-Ri #2 construction is about 84% complete and scheduled for operation in December 1983.

Units 5, 6, 7, and 8 have the same supply infrastructure, except that the turbine-generator equipment is furnished by G.E. Co. (UK) for units 5 and 6 and by W for units 7 and 8. W is the reactor supplier for all units and Bechtel is the AE. KEPCO is responsible for overall construction. Bechtel provides support for construction management.

On Units 2 (and 3) Korea Nuclear Engineering Services (KNE) - a KEPCO owned company - is responsible for the design of the site facilities and participates in the construction management. KNE participation is greater for later units and includes participation in plant design. Construction of Units 5 and 6 for the Ko-Ri Plant is about 65% complete and these units are scheduled for operation 9/84 and 9/85. Construction of Units 7 and 8 for the Young Kwang-Kun plant (another site) is about 17% complete and these units are scheduled for operation 3/86 and 3/87.

Ko-Ri Unit 3, for the Wolsung-Kun plant, is the only unit that is not a PWR; it is a Pressurized Heavy Water Reactor of the Canadian design. The supply infrastructure for this Turnkey type contract is: AECL - reactor supplier, Parsons (British) - turbine-generator supplier, AECL/Canatrom/AC is the AE, and AECLE (Canada) is responsible for overall construction. Unit 3 is scheduled for operation 3/83 and construction is about 97% complete.

Units 9 and 10 are for the Ul Jin site. Equipment supply is from France. KEPCO has overall construction management and the AE (consultant) is Ebasco.

3.0 COST EXPERIENCE AND COST CONTROLS

3.1 Cost Experience

Ko-Ri #1, which has been in operation since 4/78, and Ko-Ri #2, which can be expected to go into operation about 4/83, serve to highlight the variability of costs with time and contract terms. Both plants were furnished by W, and the infrastructure of supply and responsibilities is the same. Unit #2 is about ~~11%~~ bigger than Unit #1, is being built at the same developed site, and by the same infrastructure of participants with benefit of the experience gained from construction of the first plant. These factors could be expected to reduce the unit cost as measured in $/kw by about 5% to 10%. However, the cost of Ko-Ri #1 was $321.8 million, and Ko-Ri #2, which is near complete, is expected to cost about $1.03 billion. This results in a cost (in $ per gross kw(e)) of $548 for Unit 1 and $1585 for Unit 2. This will be discussed more in the next section.

Units 5 and 6 are forecasted to cost $1298/kwe. These units are scheduled to start about 40 and 52 months after Unit 2. The size rating of each of these units is about 46% greater than the rating of Unit #2 and the units are being built at a developed site. These factors should reduce the unit cost ($/kw) about 15%. Even so, considering escalation of the time period of Units #5 and #6, the forecast of $1298/kwe represents an improvement in cost over Unit 2.

The forecasted cost and schedule for the other plants is as shown in Table 2.

3.2 Comparison of Nuclear and Coal Plant Cost and Schedule

~~As noted in the table, a representative construction schedule for a nuclear plant is about 90 months.~~ By comparison, the construction schedule for a typical coal fired plant is about 45 months. The 5 year plan shows schedules for coal-fired plants (500MWe) of: 58, 46, 73, and 55 months for plants coming on line in 1983 and 1984, and 41, 44, 41 and 51 months for plants coming on line in 1988 through 1991. A 500 MW(e) coal-fired plant, equipped with FGD for sulpher control, with a startup date of 4/82 is estimated at $882/Kw, a 900 MWe nuclear plant with a 4/82 startup is estimated at $1391/kw(e).

3.3 Measurement of Construction Progress

KEPCO has a sound program to measure construction progress and to control schedule. The similarity of plants and infrastructure of supply is fair to good. KEPCO uses the Bechtel techniques and process of construction management and KEPCO uses Bechtel support for understanding and implementing construction management. The system is sound and KEPCO is diligent in their application of the process. Work accomplishment is measured for many subtasks. Examples are: the installation of a pipe spool piece, cable pulling, and cubic meters of concrete. The schedule value of a task accomplished also recognizes degree of difficulty. The reported schedule completion is believed to be reliable as the basis is sound, detailed, and objective. A sample of an overview of schedule completion by work tasks is shown in Table 3 for the Ko-Ri #2 plant. This summary tabulation is generated from extensive detail of sub-tasks.

3.4 Basis for Korean Cost Estimate

The major cost elements are discussed in Section 2.1. Schedule control is of primary importance as it impacts on the cost of interest and escalation, and interest and escalation is a large cost item. The indirect costs associated with design, project management, construction management and utility cost is also a sizeable cost account. This account can be expected to be larger today than in 1986, for KEPCO staffing must provide currently for training from Bechtel and other learning costs. Changes in design or other project changes represent another area of potential cost increase. Change control was only briefly addresesd.

One example, a potential contract change, is mentioned. The Korean construction contractors will likely find that the ratio of non-manual labor to manual labor is greater for a nuclear plant than for a fossil plant; the 11% for non-manual labor provided for in their contract is likely low for nuclear construction, and request for contract adjustment might occur.

In summary, the cost forecast are on a sound basis; this does not guarantee that these cost forecast will not be exceeded. The construction management approach does give protection against cost and schedules going out of control.

4.0 COMMENTS ON KOREAN COST SITUATION

4.1 Major Cost Elements

The major cost elements are as discussed in Section 2.1. These are discussed in context of KEPCO cost as compared to cost to a U.S. utility.

The equipment for the nuclear boiler and the turbine-generator plant is purchased outside of Korea. The cost of this element is expected to be slightly more for KEPCO then the cost to a utility in the U.S. The same comment applies to those construction materials purchased outside of Korea. The cost adder for overseas sales is associated with increased overhead costs of the supplier.

The cost for construction labor is likely to be less for KEPCO than for most U.S. utilities. The Korean labor rate is less than that of the U.S. and the labor productivity is likely equal or better than many regions of the U.S. The experience factor, of course, favors the U.S.

The indirect account of design, project management, and construction management is difficult to assess at this stage. With experience, the KEPCO cost may be lower than for the U.S. utility. At this stage, Korea must provide for learning, training, and significant Bechtel support. It is prudent to provide adequate staff and support in this account until Korea has established a proven record of performance.

Interest cost are determined by interest rate and cash flow. KEPCO has been able to obtain very favorable interest rates. Schedule is the key to controllling cash flow and KEPCO is giving schedule a high priority.

Finally, the contracts for equipment, material and labor provides for escalation. The escalation of the equipment and materials purchased abroad is tied to the escalation indices of the supplying country, and the escalation index of construction material and labor from Korea is tied to Korean indices. It is noted that consumer prices in South Korea increased about 54% (Asian Wall Street Journal, Wednesday - 7 April 1982) over the 20 months 1/81 through 8/82. Recent cost indices show a definite slowing of inflation. Schedule control is important to the control of escalation cost ultimately incurred.

4.2 Comments on Schedule

The benefits of a short construction schedule have been emphasized. The forecasted schedules for the Korean plants are believed to be realistic and appear to represent tight targets. Further analysis of schedule performance is needed to identify the true determinants of incurred schedule. It may be that the hold-up is often the software (i.e., design releases for construction). A brief discussion in support of this speculation is presented in Section 6.3.

5.0 DISCUSSION OF FINDINGS - CONSTRUCTION COST AND SCHEDULE

5.1 Discussion

In recent years the construction cost of nuclear plants have generally exceeded the forecasted cost, and often by large amounts, and this is cause for concern. The KEPCO forecast of cost of their nuclear plants is based on contract prices, forecasted escalation and sound management controls. Loans provide for interest at generally favorable rates. Two of the units now in construction are on the basis of "turnkey" type contracts for equipment, while the other units are based on contracts for equipment, material, and construction. Escalation is included in the contracts and interest rates have been established. Interest and escalation represent a large element of plant cost, and schedule slippage would cause an increase in total interest and escalation cost. KEPCO has made schedule a high priority item and schedule receives attention at all levels of management.

KEPCO has a sound program to measure construction progress and control schedule. KEPCO uses the Bechtel techniques and process of construction management, and KEPCO is using Bechtel support for understanding and implementing construction management. The system for measuring construction progress is sound and KEPCO is diligent in their application of the system. The system provides for measurements of many sub units such as placement of pipe spool pieces or electrical terminations.

KEPCO does not have the responsibility for construction management of Units 2 and 3 - these are on the basis of "turnkey". Ko-Ri #1, now in operation, was also built as a "turnkey" job.

5.2 Representative Items of Cost Within Control of KEPCO

As noted above, schedule is a key cost control item, because schedule impacts on the cost of interest and contract escalation provisions. Interest and escalation have become a major item of cost - especially for the long construction schedules of nuclear plants. Also as noted above, KEPCO is diligent in the management of schedule and uses the proven methods of Bechtel as a tool to implement schedule measurement and controls.

Design changes and contract changes must also be managed. Some items of change can be expected, and some of these will add cost either directly or through schedule delays. Changes must be expedited effectively to maintain schedule and must be controlled to assure quality and safety. An approach which enhances the achievement of both of these goals will take time to evolve. A cumbersome approval system can hurt schedule. An uncontrolled system can hurt safety and quality. A balanced system must be evolved.

The "indirects" of design, project management, and construction management is within the KEPCO purview of cost control. The KEPCO approach is sound. It provides for Bechtel support in a way which gives KEPCO first hand experience with benefit of a proven system and proven construction management (i.e., Bechtel). Adequate staffing and support in this area is a prudent investment to control cost and schedule. In the future it may be feasible to reduce the level of this cost account.

5.3 Summary of Finding - Cost and Schedule

KEPCO furnished schedule and cost information for the nuclear plants (see Tables 1 and 2 for a summary) in the Korean Power Development Program. Some schedule completion dates are tight and some slippage is likely to occur on some plants - for example, a 12/83 startup for Unit 2 will be difficult to meet. There is high probability, however, that schedule performance will be good, and if slippages occur, they are expected to be small. A similar conclusion is made with regard to plant cost forecast. Additional comments on the overall Power Development Program and on the planning methods used to develop cost follows.

6.0 COMMENTS ON POWER DEVELOPMENT PROGRAM

While the basic assignment from the World Bank was to address construction cost and cost control methods, comments are provided on certain economic aspects of the Power Development Program.

6.1 Economic and Cost Models

The economic models used by KEPCO for planning provide comprehensive and disciplined evaluations of costs. KEPCO uses a computerized planning program called WASP (Wien Automatic System Planning Package) which was developed by TVA and ORNL. Inputs to the model include: system loads, existing generating facilities, future units, unit maintenance requirements, reserve requirements, and financial data (i.e., unit costs, fuel costs, cost of capital and inflation rate). KEPCO also uses the ORCOST-II computer code to estimate the cost by cost account, e.g., structures, nuclear boiler, etc.

More use of actual experience from the Korean plants recently constructed and under construction needs to be used as inputs to the excellent modeling analysis which the planners are doing. Construction cost vary over a wide range. KEPCO planners use the cost experience of the developed countries, but these published numbers are averages. Each nuclear plant has been a story in itself, and Korea will have its own capabilities and experiences and these numbers should be used for inputs into the model. This will require means to access these numbers from the construction organization on a routine basis.

The economic models used by planning should include all elements of cost (this statement does not imply that they do not). In particular, consideration should be given to the cost of decommissioning the plant, and to all elements needed to complete the fuel cycle that is planned. Inclusion of all elements pertains to coal and nuclear.

6.2 Generation Cost Comparison of Nuclear and Fossil

The March 1982 report by KEPCO entitled "Status of Nuclear Power Program in Korea" presents a comparison of production cost of electricity from Ko-Ri #1 with current production cost from thermal (oil and coal) plants. A highlight of the comparison follows:

	Ko-Ri #1	All Existing Thermal
Capacity Factor (%)	56.3	57.2
Fixed Charged + O M (mills/KWH)	28.67	13.85
Fuel Cost (mills/KWH)	2.77	56.40
Total Gen Cost (mills/KWH)	31.44	70.25

While the above numbers are of interest and represent actual cost, the comparison is not meaningful for system generation planning. Ko-Ri #1 capital cost, in $/KWe, is about 1/3 (see Table 2) of the forecasted capital cost of nuclear Units 2 and 3. Also, the nuclear fuel cost are considerably lower than today's cost.

KEPCO planning has evaluated the economics of the generating facilities using the methods mentioned previously. A summary comparison, in 1982 dollars, of generation cost for nuclear and coal is as follows:

	Coal 900MW(e)	Nuclear 900MW(e)	Nuclear 1200MW(e)
Fixed Cost (mills/KWH)	18.2	25.1	21.1
Fuel Cost (mills/KWH)	25.7	7.5	7.5
Total (mills/KWH)	43.9	32.6	28.6

The coal capital cost is based on provisions for sulphur pollution control. The coal fuel cost are based on contract price for bituminous coal from Australia. KEPCO used a capacity factor of 65% for nuclear and 60% for coal, and a yearly fixed charge rate of 14.13% for coal and 11.51% for nuclear. Use of the same fixed charge rate and CF should bring the power cost within 10% of each other for the 900MW(e) size.

The basic conclusion is that generation cost from nuclear and future coal would be much closer than the comparison of nuclear Unit 1 generation cost with existing generation cost. The best choice for the bulk of future generation is nuclear and coal. The economics favor the nuclear plant. The nuclear power cost are more sensitive to capacity factor and fixed charged rate because of the higher capital cost of nuclear.

6.3 Construction Schedule of Nuclear vs. Coal

The Korean experience and forecast show a construction schedule for the nuclear plant about twice that of a coal fired plant. The cost impact of schedule is large. To date, the Korea Power Development Program has benefited from very favorable interest rates.

It is suggested that KEPCO investigate means to shorten the nuclear construction schedule* from the current forecast of about 7 1/2 years. Nuclear plants were being built in the U.S. on shorter schedules prior to 1970 and in the early seventies.

Examples include:

San Onofre 1	436 MWe	32.9 months
Yankee-Rowe 1	175 MWe	28.3 "
Ginna	470 MWe	41.6 "
Robinson 2	700 MWe	42 "
Palisades	805 MWe	31.8 "
Point Beach 1	497 MWe	45.1 "

Also the Tsuruga plant 357 MWe in Japan was constructed in about 43 months, and reached commercial operation five months later.

The Korean construction industry should be able to come closer to the early schedule performance of the nuclear industry. KEPCO should determine the true schedule constraints and strive to alleviate these. It may be that schedule could be shortened by improving the process for the release of documents (drawings, specs, etc.) for construction. It is noted that the writer did not investigate the schedule constraints and the feeling that software may be the constraint (as opposed to the construction capability) is speculative; in any case, a shorter schedule is supported by early performance of the nuclear industry and the current record of the Korean construction industry.

* As used in this tabulation, construction schedule is from start of excavation to start of fuel loading.

In summary, schedule is an important driver of nuclear cost. The nuclear plant is recognized as being more complex to construct than the coal plant, but the ratio of about 90 months to 45 months (nuclear/coal plant construction) can likely be improved. The program should strive for: (1) completed "front end" of licensing, construction controls, design, standards and quality assurance and (2) a shorter construction period.

6.4 Comments on Load Demand Forecast and Future Facilities

The methods used to forecast the electrical load demand were outside the scope of the investigation. The following comments are based totally on the writer's opinion and should be treated accordingly. The projected rate of electrical demand may be optimistic. The average/year of the five year growth rate in GWH gross generation* for selected periods is summarized below:

	Period	Avg GWH/hr	Ratio
A	1971-76	2515	
B	1976-81	3418	B/A = 1.359
C	1981-86	5486	C/B = 1.605
D	1986-91	9336	D/C = 1.702

The percentage growths are:

Period	% Growth	Compound Growth Rate-%
1971-76	2.193	17%
1976-81	1.739	11.7%
1981-86	1.682	11%
1986-91	1.690	11.08%

* Using numbers from Operation Results in 1981 and Power Development Program; February 1982.

A compound growth rate of 11% will be difficult to sustain as the load base grows. This effect is illustrated by comparing the average growth rate/year that is required to achieve these compound growth rates (see first tabulated summary above).

In 1981, the power sales by service sector for Korea was 16.75% residential, 14.66% commercial and public services, and 65.59% industrial. (Approximate numbers for U.S.: 33.5% residential, 23.8% commercial, 39.1% industrial, and 3.6% other). Load demand growth depends heavily upon industrial growth as the industry sector accounts for a large part of the base. The industry growth will depend upon the general world economy. Price of electricity can be expected to influence residential growth and price has doubled* in two years. The various users should be analyzed.

In summary, the forecasted electrical demand may be optimistic. A detailed model which builds the forecast based on an analysis and summation of the users is worth considering. It is also noted that the forecast of peak load factor increases at a faster rate than the forecast of gross generation (GWH/hr); this happens because the Load Factor changes from 72.5% in 1982 to 66% in 1991. The reason for the lower load factor is not apparent. An optimistic forecast of electrical demand could result in excess capacity. Should this happen, the nuclear plant capacity should be used as much as possible in order to enhance economics.

* This was deduced by taking the ratio of sales/generation and normalizing the number to 1.00 for 1979; the normalized ratio for 1980 is 1.58 and for 1981 is 2.0.

6.4 Plant Capacity Factor

The planning is based on a nuclear capacity factor of 65%. This is a reasonable number (PWR's averaged 62.5% in 1981). It is noted that some utilities, however, achieve better capacity factor. (For example, in 1981 the average capacity of three Swiss plants was 88.5%.) The incentive for good capacity factor is especially high for the nuclear plants. For example, a CF of 85% vs. 65% would reduce capital charge by 5.9 mills/KWH . The operation and maintenance cost would be reduced about 30% and the fuel cost by a few percent.

APPENDIX I

LIST OF MEETINGS AND PERSONS VISITED

6 April 1982 - Arrival in Seoul

7 April 1982 - General background discussions. Meetings : Infrastructure Planning Division (EPB) and Bureau of Electric Power (MER). Personnel: Tae-Yon Kim (Director - Infrastructure Planning Div.), Sung-Jin Kim (Assistant Director), Se-Jong Kim (Director - MER), and Sa-Woo Hong (Deputy Manager Power Planning Dept. - KEPCO). Also Hyun-Kyn Roh (KEPCO), and Young-Soo Lee (KEPCO).

8 April 1982 - Review of Electric Power Development Plan and cost models used in planning. Suk Lee (General Manager Power Div. - KEPCO), Soon-Byong Lee (Section Chief, Power Development Div. - KEPCO), and Sang-Hyun Yoon (Assistant Manager Power Planning Section - KEPCO).

9 April 1982 - Meetings with KEPCO officials at the Ko-Ri Construction site. Discussed cost and schedule. Sang-Kee Park (Deputy General Manager Nuclear Power Generation Dept. - KEPCO), Moo-Sun Lee (Chief, Project Control Section), Im-Huan-Jo (Unit #2 construction).

10 April 1982 - Review information and prepare report.

11 April 1982 - Review information and prepare report.

12 April 1982
and
13 April 1982 - Review cost and construction schedules. Review cost planning methods. Sang-Hyun Yoon, Kwang-Soo Lim, and Yoon-Kee Kang.

13 April 1982 - Meeting with Suk Lee (GM Power Development Dept. - KEPCO).

14 April 1982 - Telephone discussion with Bechtel personnel. Meeting with Dai Young Kim (Director General - Bureau of Economic Planning - EPB).

15 April 1982 - Departed Seoul for San Francisco, CA.

EPB - Economic Planning Board
MER - Ministry of Energy and Resources
KEPCO - Korea Electric Power Co.

TABLE 1

Nuclear Power Program

Item / Plant Name	Site	Capacity (MWe Gross)	Reactor Type	Scheduled Operation Const. START ( )	Status	Suppliers & A/E
Nuclear Unit No. 1	Ko-Ri	587	PWR	Apr. 78 (9/70)	In Operation	NSSS, Fuel : W T/G : GEC A/E : GAI
Nuclear Unit No. 2	Ko-Ri	650	PWR	Dec. 83 (5/77)	Under Construction	NSSS, Fuel : W T/G : GEC A/E : GAI
Nuclear Unit No. 3	Wolsung	678	PHWR	Apr. 83 (1/76)	"	NSSS, Fuel : AECL T/G : HPL/CAP A/E : CANATOM CO.
Nuclear Units No. 5 & 6	Ko-Ri	950	PWR	Sep. 84 Sep. 85 (1/78)	"	NSSS, Fuel : W T/G : GEC A/E : BECHTEL
Nuclear Units No. 7 & 8	Yeong-gwang	950	PWR	Mar. 86 Mar. 87 (3/79 and 3/79)	"	NSSS, Fuel : W T/G : W A/E : BECHTEL
Nuclear Units No. 9 & 10	Uljin	950	PWR	Mar. 88 Mar. 89 (4/80 & 4/80)	"	NSSS, Fuel : FRAMATOME, C[illegible] T/G : Alsthom Atlantique A/E(Consultant) : EBASCO
Nuclear Units No. 11 & 12	Not Decided	900 Class	Not Decided	Dec. 89 Dec. 90	Under Planning	Not Decided
Nuclear Units No. 13 & 14	"	"	"	Mar. 91 Dec. 91	"	"

TABLE 2

Nuclear Plants - Summary Schedule & Cost Forecast

Unit Number	Site	Type	Schedule* Months	% Complete**	Est. Cost $/KWe-Gross
1	Ko-Ri	PWR	91	100% (in operation since 78)	550
2	Ko-Ri	PWR	79	83.81	1583
3	Wolsung	PHWR	87	97.5	1670
5 & 6	Ko-Ri	PWR	80 - Unit 5 92 - Unit 6	64.9	1410
7 & 8	Yeong-gwand	PWR	84 - Unit 7 96 - Unit 8	16.63%	1626
9 & 10	Uljim	PWR	95 - Unit 9 107 - Unit 10	6.46%	

NOTES

All cost are in 1982 dollars except for Ko-Ri 1, which started operation 4/78.

* Actual site construction, i.e., ground-breaking to startup

**Through 3/82.

TABLE 4

214 Week ([illegible] - [illegible]) Primary Work Status

과장 ✓

K-2 Project Control Section

Description		Unit	This Week		To Date	Estimated Total Qty	% Completed	Remark
			Schedule	Actual				
Concrete	Structural	M^3	7,235	-	72,785	72,785	100.0	
Misc. Steel Work	Weight	Ton	2.5	3.5	315.8	343	92.0	
Painting	Wall	M^2	220	0	19,270	19,910	96.8	
	Floor	M^2	-	1,054	6,751	10,920	61.8	
Large Bore Pipe	Spool	Spool	2	-	5,056	5,092	99.3	
	Length	L/M	-	-	18,217.2	18,360	99.2	
	Welding	Point	-	22	5,839	5,860	99.6	
	Hanger	EA	139	(94)	7,694	9,632	79.8	
	Valve	EA	1	1	992	1,129	87.8	
Small Bore Pipe	Spool	Spool	-	47	6,585	6,700	98.2	
	Length	L/M	-	115.5	21,738.4	23,307	93.6	
	Welding	Point	442	445	29,402	29,000		
	Hanger	EA	182	218	8,515	9,000	94.5	
	Valve	EA	-	48	3,991	5,226	76.3	
HVAC Duct	Spool	Spool	38	31	4,775	4,900	97.4	
	Weight	Kg	-	2,253	311,824	343,600	90.7	
Cable Tray	Length	L/M	-	12.3	9,323.5	9,400	99.1	
	Hanger	EA	11	8	2,320	2,449	94.7	
Conduit	Length	L/M	1,000	949.2	69,500.2	76,223	91.1	
Cable Pulling	Length	L/M	5,800	4,477.7	568,649.7	564,216	89.6	
	Circuit	Pcs	-	120	8,939	11,500	77.7	
Termination	End	EA	550	251	14,407	23,000	62.6	
	Point		-	1,166	72,725	101,050	71.0	

* S/B Pipe Welding, Shop Point (- / -) 16,803/17,300 (97.1%)
* 2nd Stage Concrete (16/33) 5,514/5,624 (98.0%)
* Yard Concrete Work (7 / 5) 972/1,106 (87.9%)
* Piping Support (- / 1.5) 275.5/355 (77.6%)

Description		Unit	This Week		To Date	Estimated Total Qty	% Completed	Remark
			Schedule	Actual				
I & C	Gauge	EA	40	34	658	2,070	31.7	
	Tubing	L/M	500	381.2	18,172.4	23,944	75.9	

Flush & Test

SYS.	# TOP	STATUS
CZ	100-01,02 03	Flush 완료 Flush 진행중
IA	6	Compressor "A" 가동중
WS	14-01 02	Hydro 완료
Aux. Relay Panel		Test 진행중
Motor Operating Valve		Test 진행중
HVAC	746, 721	Test 진행중

Equipment Installation

* Set

L2-SD105PMP : R.B Sump Pump A,B ('82. 4. 1)
('82. 3. 28 Carry - In)

214 week(3 /28 - 4 /3) Secondary Work Status

K-2 Project Control Section

Description		Unit	This Week		To Date	Estimated	%	Remark
			Schedule	Actual		Total Qty	Completed	
Concrete		M^3	-	-	22,670	22,450		
Large Bore Pipe	Spool	Spool	-	-	4,475	4,482	99.8	
	Length	L/M	-	-	-	-		
	Welding	Point	-	31	5,445	5,474	99.4	[illegible]
	Hanger	EA	-	10	2,111	2,142	98.5	
	Valve	EA	-	4	655	656	99.8	
Small Bore Pipe	Length	L/M	165	41	22,412	23,408	95.7	
	Welding	Point	-	-	-	-		
	Hanger	EA	25	43	3,278	3,385	96.8	
	Valve	EA	20	11	1,932	2,018	95.7	
HVAC	Spool	Kg	-	-	11,950	11,950	100.0	
	Pipe	L/M	-	-	4,600	4,600	100.0	
	Strip Heater	Set	-	-	184	184	100.0	
	Unit Heater	Set	-	-	20	20	100.0	
	Bracket	EA	-	-	2,180	2,180	100.0	
Cable Tray	Length	L/M	-	17	20,000	20,000	100.0	[illegible]
	Hanger	EA	-	1	4,328	4,328	100.0	//
Small Power & Lighting System	Conduit	L/M	-	-	9,732	9,863	98.6	
	Wiring	m	-	-	45,000	45,400	99.1	
	Cabling	m	-	-	14,000	14,000	100.0	
	L-Fitting FL	Set	-	-	125	459	27.2	
	L-Fitting IL	Set	-	-	23	187	14.9	

Description		Unit	This Week Schedule	This Week Actual	To Date	Estimated Total Qty	% Completed	Remark
Cable Pulling	'P' Cables	M	-	-	18,064	18,064	100.0	
	'M' Cables	M	-	-	46,030	46,048	99.9	
	'I & C' Cables	M	-	1,320	229,824	257,900	89.1	
	Total	M	-	1,320	293,918	322,012	91.2	
Termination	'P' Cables	EA	-	-	284	284	100.0	
	'M' Cables	EA	-	14	2,824	3,101	91.1	
	'I & C' Cabl	EA	-	309	37,105	40,886	90.7	
	Total	EA	-	323	40,133	43,987	91.2	
I & C	Gauge	EA	-	80	15,901	15,992	99.4	
	Tubing	1/M	-	1	700	900	77.8	

Flush & Test

* Electrical

L.B.S. - Function Test.

F.W. Sys. - Valve Actuator Circuit Function Test.

6.6 KV-VT Circuit Check.

F.W. Sys. - Thermal Over Load Relay Exchange Test.

* Mechanical

F. W. Sys. - LP Heater Side.

Lube Oil Sys. - A.C Pump Running Test.

Seal Oil Sys. - Flushing.

Aux. Boiler - Burner A, C Running.

C.W Sys. - Pump A, B & C Running.