

Korea's Nuclear Past, Present, and Future

by Dr. Chang Kun Lee



Courtesy of Korea Hydro & Nuclear Power Co., Ltd.

Korea's Yongwang nuclear complex with six reactors.

A founder of Korea's nuclear program tells how Korea began nuclear research as a Third World nation after World War II, and within 50 years developed into an industrial powerhouse, supplying 27 percent of the nation's electricity by nuclear power.

One day in 1958, Mr. Walker Lee Cisler made a courtesy call on Dr. Syngman Rhee, the Korean President. Mr. Cisler, one-time CEO and Chairman of the Chicago-based Commonwealth Edison Company, had helped to rehabilitate the electric grids of Europe in the post-war period, under General Dwight Eisenhower, the Allied Forces Commander.

The meeting between the two men was reported in the press, and we

As the chairman of KEPIC, the Korea Electric Power Industry Code Committee, for the past 15 years, C.K. Lee has mobilized and managed 350 engineering professors and professional engineers dispatched from six engineering-related academic societies. KEPIC's 2005 edition consists of five parts contained in 83 volumes or some 27,000 pages, about 3.2 meters thick. Dr. Lee is also a former Commissioner on the Atomic Energy Commission of South Korea, and a former chairman of the International Nuclear Societies Council.

This article is adapted from Dr. Lee's book-length presentation at the Summer Institute of the World Nuclear University, held in Korea in August 2007. A previous article, "A Nuclear Perspective from Asia," appeared in the Winter 2002-2003 21st Century.

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Walker Lee Cisler, the Atoms for Peace ambassador, helped Korea and other nations move into the nuclear age.

can imagine the conversation as having proceeded along the following lines:

President Rhee asked if any radical measures were available that could be undertaken to address the problem of chronic power shortage in Korea. Mr. Cisler answered:

“Well, there is a way, Mr. President. It’s a somewhat difficult option perhaps, but nevertheless worth trying.”

“And the option is?”

Mr. Cisler took out a wooden box from his brief bag. “An energy box of this small a size with uranium fuel can, under the right conditions, undergo a fission reaction, and generate an energy equivalent of 100 freight cars loaded with coal or a big tanker filled with petroleum.”

“Wow!,” marveled the Princeton Ph.D. President who, admittedly, was not a physicist. “How is that possible?”

“You see, Mr. President, uranium atoms when split will release energy some 3 million times more than what fossil fuel can in terms of weight. We are talking about nuclear energy here.”

“Is this something that we Koreans can harness to resolve our energy problems?”

“Of course,” Mr. Cisler said emphatically.

“What would be involved for us to get started?”

“Well, this energy source would not be easily extracted from the ground like coal or oil but, rather, it will be squeezed from the human brain, insofar as it involves technological manipulation and prowess. It’s new technology-based energy for which you will need many high-quality scientists and engineers. Nurturing capable, dedicated manpower will be key for the task.”

“Thank you, Walker! And when do you suppose Korean people will start benefiting from this thing you call nuclear energy?”

“Probably in two decades,” was Mr. Cisler’s prediction.



Dr. Syngman Rhee, the first Korean President (right), at the ground-breaking for the first nuclear reactor in Korea, a research reactor. Rhee pursued an Atoms for Peace program, to take his nation into the 21st Century.

True to Mr. Cisler’s prediction, the Korean nuclear industry began supplying nuclear-based electricity to the nation as of July 20, 1978, exactly 20 years after the Rhee-Cisler meeting. And another 20 years later, Korean nuclear power plants, accounting for some 20 percent of total power-generating facilities, were supplying roughly 40 percent of the nation’s power needs at very low-priced rates.

The Nuclear Sector and How It Began

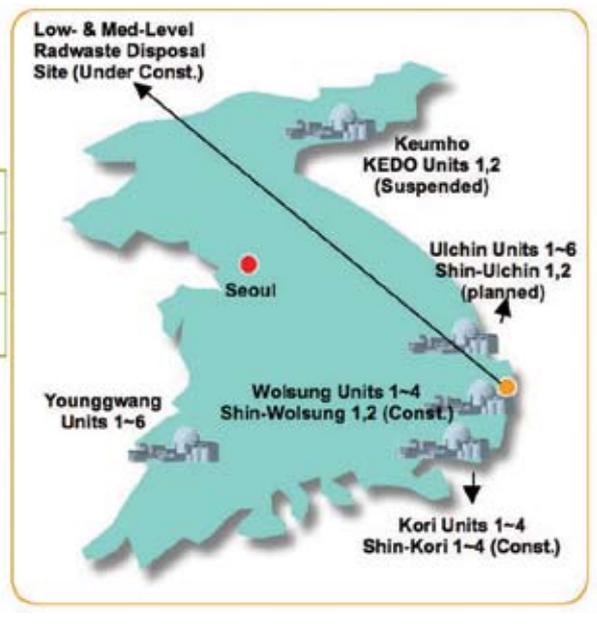
Korea has 20 operating nuclear power reactors deployed at four sites, with a total capacity amounting to 17,716 megawatts, which is 27 percent of the total generating capacity (65,560 MW), supplying 39 percent of the nation’s power need in 2006. Six additional units (6,800 MW) are under construction, and two others (2,800+ MW) are currently in the planning stage.

We believe that the nuclear share in the fuel structure of total power generation will gradually increase in the forthcoming years. To be precise, today’s 27 percent nuclear share will increase to 29 percent by 2020.

The cost of electricity generated from the Korea Electric Power Corporation’s coal-fired plants, hydro-plants, oil-fired plants, and LNG-fired plants was 1.42, 2.19, 3.0, and 3.45 times than that from nuclear power plants in 2006 (Figure 2).

Figure 1
STATUS OF NUCLEAR
POWER STATIONS
IN KOREA

In Operation	20 Units 17,716 MW
Under	6 Units 6,800 MW
Under Plan.	2 Units 2,800 MW



Under the framework of KEDO, the Korea Energy Development Organization, the Republic of Korea started to construct two Korea Standard Nuclear Power Plant, 1,000 MW-class pressurized water reactor units in North Korea, but the construction of these reactors was suspended for politico-diplomatic reasons, especially the reckless nuclear bomb development and its test by North Korea.

When World War II ended, the installed capacity of power generation facilities on the Korean peninsula totalled 1,921 megawatts. Of this, North Korea accounted for 88.5 percent, while the south, with twice the population, had merely the remaining 11.5 percent of capacity, comprising mostly small, inefficient facilities.

The legacy of Japanese colonialism meant that until 1945, there were only 205 Korean university graduates in the entire country who had been educated at four-year-course institutes of higher learning in Japan and elsewhere. In fact, regular universities were not established in Korea until the end of World War II, except for one (the predecessor of Seoul National University), which was newly founded in Seoul primarily for the education of Japanese students.

There was a handful of graduates of European and American colleges. Korea's Third World status at this juncture in history can be seen in the fact that South Korea could claim fewer than

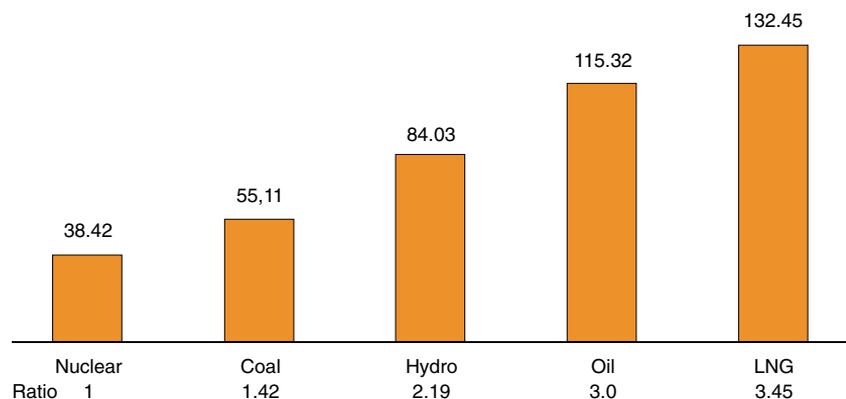
100 college graduates with science and engineering degrees in the immediate years following World War II. These engineers and science professionals would soon become pivotal technocrats for running the country. Such intellectual manpower shortage was the result of Japan's obscurant policy for the colonial Korea.

The state of underdevelopment was so dire that the U.S. military deputy governor, Charles Helmick, was led to comment in 1948: "Korea can never attain a high standard of living. There are virtually no Koreans with technical training and experience required to take advantage of Korea's resources and effect an improvement over its recent rice economy status." Amplifying this view, Helmick added,

"When the U.S. occupation forces withdrew and stopped sending in supplies that south Korea needed, it would be reduced to a bull-cart economy and some 9 million non-food producers will face starvation."

After World War II, the southern part of Korea, which had embraced millions of refugees from the north, Japan, Manchuria, and China, had only 11.5 percent of the nation's power-generation facilities and was able to supply no more than 4 percent of its electricity requirements. So, the south was at the total mercy of the north for power supply.

Figure 2
RELATIVE COST OF ELECTRICITY BY FUEL
(Based on rates paid by KEPCO in 2006)



Nuclear is the least expensive fuel. The most expensive, liquid natural gas, is 3.45 times the price KEPCO paid for nuclear. Costs are shown in won, the Korean currency.

Electricity Demand in Korea

The growth rate of electricity supply in the past was extremely high: 23.2 percent per annum in the 1960s, 15.5 percent in the 1970s, and 11.2 percent in the 1980s, which were good indications of rapid industrialization in those periods, the so-called the Economic Miracle Era. In current years, it has been 4.6 percent per annum, but it will decrease to 1.8 percent in 2011-2015, and then to 1.0 percent in 2016-2020. This downhill trend will be attributed to the rapid shift of GDP's main contributor from heavy industry to the commercial sector, *inter alia*, the service industry, that is now skyrocketing in Korea.

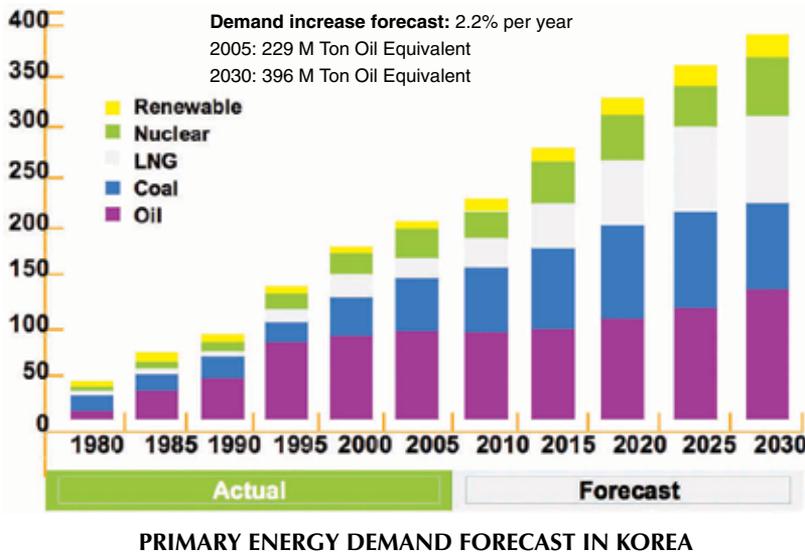
It is estimated that the electricity demand in 2020 will amount to 478,555 million kWh, which will be 1.4 times the consumption in 2006 (248,719 million kWh). The electricity share out of the total amount of energy consumption in Korea will gradually increase with time, in such a way that it will increase to 19.4 percent in 2020 compared to 16.6 percent in 2005.

The total primary energy demand in 2005 was 229 million Ton Oil Equivalent (TOE), and it is estimated to be 396 million TOE in 2030. In the years up to 2030, demand increase forecast is presumed to be about 2.2 percent per annum. The

increase in demand for petroleum and coal will be low, but that for liquid natural gas, nuclear, and renewable energy will be relatively high because of environmental concerns.

In terms of energy demand by sectors, the industrial and transportation sectors will show slow increase, while that of the commercial sector will make a rapid increase, because of the mushrooming growth of the service industry.

The annual growth rate of electricity in Korea was always higher than the nation's annual GDP growth rate, in the period of 1999 through 2006. For instance, the annual electricity growth rate in 2005 was about 6.5 percent against 4.2 percent GDP growth rate in the same year. But the two growth rates levelled off, to be the same, 4.5 percent, in 2006.



North Korea brought the south to its knees by abruptly cutting off the power supply to the south on May 14, 1948, causing crippling blackouts and widespread brownouts throughout the nation. The U.S. Military Administration brought in power supply barges—*Jacona* (20 megawatts) and *Electra* (6.9 MW), and later *Impedance*, to the South Korean ports, to meet the urgent need.

That abrupt power cutoff was actually a prelude to the main knockout punch: The north struck on June 25, 1950, beginning the Korean War.

Under the pretext of homeland unification, the northern regime attacked the south, and the result was a total destruction of all cities and towns in every nook and cranny of the Korean peninsula. What industrial plants and factories that had been there, were laid to waste, and the northern regime's kidnappings and selective killings, especially of educated Koreans, further bled the nation. The war exacted a terrible toll from the already impoverished population, and further scarred the national psyche, which was already hurting from 35 years of colonial subjugation under Japan.

However, where once ashes smoldered, now stands a vibrant

and dynamic nation, with aspirations toward becoming an important player in the global economy. Where war once raged, now stands a thriving economic engine putting out state-of-the-art high-tech software and hardware products, including those in the nuclear sector. And out of the detritus of war was born the Korean nuclear industry. Over the years, the Korean nuclear community has had to face many challenges. And yet, it has thrived. I will summarize here Korea's nuclear power projects in view of the past and present perspectives, and a hopeful future.

The Early Days

President Rhee would have been heartened by the sight of some 15 engineers and scientists, mostly in their late 20s and garbed in military uniforms, voluntarily putting their noses to the grindstone at weekend seminars on nuclear technology, from 1955 onward. The textbook we used was Raymond Murray's *Introduction to Nuclear Engineering*, which was copied for the seminar participants by a typewriter and manual printing kit, and these seminars, conducted in a warehouse-like room, were begun some four years before Mr. Cisler admonished the Presi-

dent in the Blue House about the importance of manpower training for developing nuclear energy.

For about 10 years, beginning in the 1950s, college graduates were dispatched abroad to receive basic training in nuclear technologies, including radioisotope applications. The main incubator was the U.S. government-funded Atoms for Peace program. Of the young trainees, 127, representing 57 percent of 237 total, were sent overseas and many went to the United Kingdom through funding from the Korean government. Given the penurious conditions of the time, with so many Koreans still going hungry and in tattered clothes, city streets pullulating with war-wounded and orphans, and government coffers perennially empty, the commitment to spend the scarce foreign exchange resources on educating these young Koreans was an extraordinary step, and reflected the Korean nation's eagerness for new technological know-how and its wish to quickly rehabilitate the war-ravaged country.

These foreign-trained technical personnel later became the core of the Korean nuclear community, and preached the nuclear gospel all through the early, empty, wilderness years. Of course, many, perhaps a third of the total, were lost through leakage as they opted to remain in the countries where they had received training, to work there either in industry or in academia. This was a phenomenon experienced by many other less-developed countries at the time, and much discussed later under the rubric of the "brain drain."

The brain drain turned out in retrospect to be really a blessing in disguise, because these professionals kept on sharpening their exper-

tise in the host countries only to be tapped later on, when they returned home to join the nuclear projects in full swing, bringing with them much-needed cutting-edge technological skills. Where earlier appeals to patriotism and homesickness had insufficient drawing power, a tangible project commensurate with a suitable posting could pull these ex-pats back home, and thus reverse the brain drain. The material conditions had to be right for the natural reversal of the brain drain.

It goes without saying that those trained in Britain favored a gas-cooled reactor, while the beneficiaries of Uncle Sam's largesse agitated for a light water reactor. Since U.K.-produced gas-cooled reactors were already deployed in Italy and Japan at that time, the British model enjoyed a winning edge at first. A dogfight ensued, pitting the one competing model against the other and involving financial, technical, political, and diplomatic interventions. Ultimately, though, the pro-American camp prevailed, and delivered a coup-de-grâce to the efforts of the allied European consortium. In hindsight and from a long-term

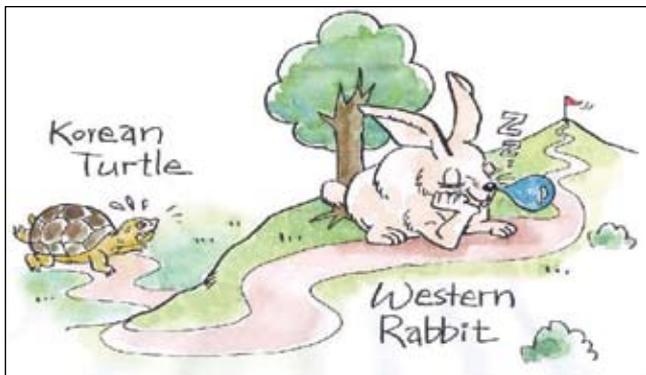


Left: After years of Japanese occupation and then a brutal war, Korea was a devastated country in the early 1950s. Here, civilians in flight during the Korean War.

Below: A recent night scene of Seoul City, with illuminated buildings, the sports facility, and city streets.

National Archives and Records Administration





waste, after some 18 years of contentious bickering over several different possible locations. At least, we were fortunate to avoid a Yucca Mountain-type debacle seen in the United States over site selection.

The Hare and the Turtle

The Western nuclear hares sprinted way ahead, just as the Korean turtle was crawling to the starting line. Over the decades, the world witnessed a successful transformation of nuclear energy applications from swords to plowshares, that is, from bombs to power-generating plants such as CANDU in Canada, LWRs in the United States, and gas-cooled reactors in Europe. Even when it owned zero hardware, the Korean turtle still assiduously prepped for the future by learning the basic software. We were fortunate in that the cream of the Korean academe and industry came knocking at our door: Probably, many were muttering “open sesame” and hoping for a quantum leap both in their status and in the country’s industrial clout.

The recent scenery looks like that depicted in the cartoon, where the Western hare is taking a nap and snoring loudly under a big tree on the hillside, and just coming within the range of the turtle’s sight. Yet the Korean turtle still keeps crawling toward the high mountain.

It is common knowledge that a turtle enjoys a longer life than a hare, although the turtle’s pace is slow. So far, we have pursued a step-by-step route in nuclear technology development. The most important knowledge we had at the very beginning was the self-knowledge that we did not have anything and we knew nothing. We started, indeed, from scratch.

perspective, this was a fortunate development, I must say.

Later, it was adjudged, however, that the light water reactor was too light for us, so a decision was made to add more weight to our overall nuclear system by supplementing it with a heavy water nuclear machine. Thus, we became the only nation in the world with a mix of light and heavy water reactor types—that is, until China came along and followed our footsteps.

These days, four pressurized heavy water reactors are in full operation at the Wolsung site. The name Wolsung, literally meaning Moon Castle or Lunar Citadel, has a poetic and romantic resonance. When the CANDU reactor was introduced to Korea, some wits were commenting that whereas the PWR was akin to an unexciting *de jure* wife, the CANDU at Wolsung was surely like a beloved concubine with whom one could discuss high art and literature and write lofty poetry together under the moon-lit castle.

With the introduction of CANDU, the 2+1 nuclear reactor strategy was developed in Korea under the direction of Dr. Kyung Ho Hyun, the former president of KAERI, the Korea Atomic Energy Research Institute. This called for twin units of the PWR, plus one CANDU, in that combination. Intensive R&D work led later to the DUPIC (Direct Use of PWR spent fuel In a CANDU reactor) concept, for simultaneously saving natural resources and reducing radiation waste volume. On the other side of the coin, it can be nothing but a spread-too-thin drawback of a nation’s technological potential if a small country like Korea should launch into the pursuit of two reactor types from the beginning.

After long pondering and in-depth study, the Korean nuclear community decided to pursue a one-reactor-type strategy, that is, the PWR alone. The deployment of CANDU reactors was terminated with the fourth CANDU unit at the Wolsung site. This CANDU site is scheduled to have new family members bearing different nomenclature: the Westinghouse APR 1400 (Advanced PWR Reactor 1,400-MW-class) and a radioactive waste management center.

To the great collective relief of the Korean nuclear community, Wolsung also has finally been selected as the disposal site for low- and medium-level radiation

Period	Projects	Main contractor	Implementation method
1960s	Research reactor	Foreign suppliers	Cradle, spoon-feeding, technology learning by eyes and ears
1970s	Kori #1,2 Wolsung #1,2,3,4	Foreign suppliers	Turn-key contract
1980s	Kori #3,4 Younggwang #1,2 Ulchin #1,2	Foreign suppliers	Non-turnkey and component approach
1990s	Younggwang #3,4 OPR1000	Domestic suppliers	Component approach, but foreign firm responsible for design, supply, and performance
2000s	Ulchin #3,4 Younggwang #5,6 Ulchin #5,6	Domestic suppliers	Component approach, domestic firm responsible for design, supply, and performance
2000s	Shin-Kori #3,4 (APR1400) and henceforth	Domestic suppliers	System upgrading; looking for foreign markets

Table 1
NUCLEAR POWER PROJECTS VS. TIME

Table 1 (p. 33) shows in chronological order our development path with respect to nuclear projects.

Training and Work Performance

The Korean nuclear sector has long regarded manpower training as priority Number 1. The training (and subsequent retraining) of a top-notch nuclear engineer in Korea usually costs an amount equivalent to his body weight in gold. The amount comes to about 50 percent of the cost incurred in training a full-fledged pilot in the Air Force and in the aviation industry, and much less than that for an astronaut training, yet it is a big burden on the project director, especially insofar as most of the training must be undertaken far in advance.

Because of this, we sometimes jokingly refer to a good nuclear engineer as “Mr. Gold.” And, as you know, the most common last name in Korea is Kim which means gold. We deploy many “Mr. Golds” in planning, design, manufacture, construction, operation, maintenance, inspection and safety analysis for nuclear projects, along with many more “Mr. Silvers” and “Mr. Coppers” in supporting roles who man our laboratories, offices, and plant sites.

Many of our “Mr. Golds” and their supporting cast put in 12-

hour workdays and seven-day work weeks. It has been carried out in a pattern of Monday-Monday-Tuesday-Wednesday-Thursday-Friday-Friday work. Senior members in our nuclear sector have a sort of intimate feeling toward a convenience store entitled Seven-Eleven, which connotes from 7 o'clock in the morning to 11 o'clock at night.

Our plant managers sometimes resort to non-traditional methods to focus the minds of their staffs. A manager by the name of Young Suk Huh, for example, packed off his men to a Marine Corps training camp to toughen their physical and mental endurance. Even those who were initially reluctant to join the camp later expressed their great satisfaction at having completed the tough training, saying that they are now better prepared for difficult tasks and challenges at work.

In January 2007, 29 of KOPEC's new recruits were sent straight to a Marine Corps camp to put them in tiptop shape (KOPEC stands for Korea Power Engineering Co.). All the new recruits of KAERI, the Korea Atomic Energy Research Institute, headed by Dr. Chang Kyu Park, were also sent to a Marine Corps training camp for tough drill.

Another unique training procedure had reactor operators and technical crew at a Buddhist temple for meditation sessions and

A Fair System of Electricity Rates

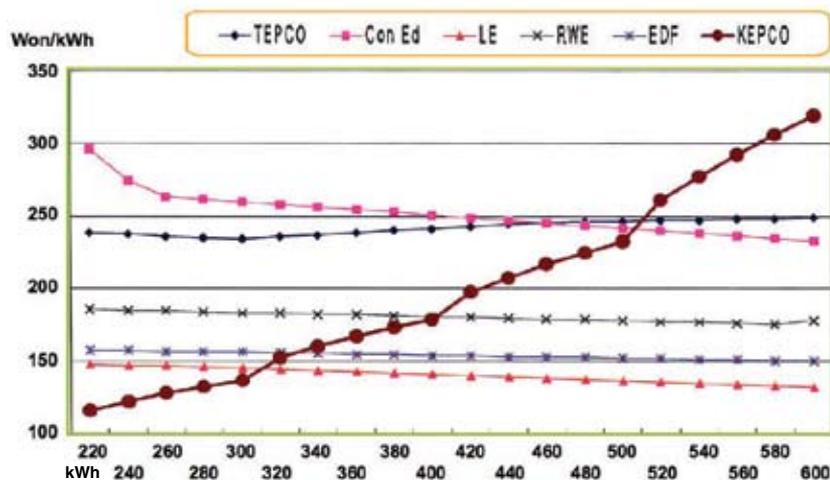
Unit electricity rates in Korea are lower for the poor and higher for the wealthy—the opposite of the rates in many other places. The figure shows the unit electricity rate (in won) imposed on residential customers at six selective electric utilities in the world. Two utilities show distinctive features: One is Con Ed, where the unit electricity rate is 295

won/kWh when its consumption is 220 kWh, while the rate goes down to 240 won/kWh if the consumption is 600 kWh. This means that a high unit rate is imposed on smaller consumers, while there is a low rate on larger consumers.

The other is the Korean case, where the unit electricity rates are opposite to Con Ed: There are low unit rates to smaller users (poor people), and high rates to larger customers (rich people).

For instance, the electricity rate imposed on rich people living in deluxe houses consuming much electricity is about 2.8 times the unit electricity rate imposed on lesser users of electricity, who may be poor people. Please bear in mind that the electric bill to the high-income bracket may be insignificant, but it can be a financial burden to the poor and needy.

Therefore, I strongly recommend this Korean system to the Electricity Commission (Board) or government authorities of other countries, which may thus suppress electricity consumption by self-regulated mechanisms in the luxurious residential sector, as well as indirectly mitigating the financial burden of poor families, whose purses are now squeezed by the electricity bill.



UNIT ELECTRICITY RATES IMPOSED ON RESIDENTIAL CONSUMERS PER kWh AT SELECTED UTILITIES

Two singularities are evident: KEPCO's rates are the lowest for the small users and highest for the large consumers, while Con Edison's rates are the highest for the small consumers, and lower for large consumers.

for open-minded discussions with the reverend monks. This idea was also strongly opposed by employees at first, for many reasons, but especially on religious grounds. However, Mr. Suk Chun Suh, the director of the Wolsung plant site, who introduced this training methodology, was able to assuage the initial skepticism and persuade the employees to give it a try. The success of his persuasion was attributed to his non-religious attitude and atheistic inclination. The meditation training had a good effect, and made these employees sharper mentally to tackle work, especially in stressful emergency situations.

Such intensive and extraordinary training has resulted in a good harvest, that is, in the tangible form of operating performance of power reactors, that has been above a 90 percent capacity factor over the past seven consecutive years, and a 15 percent better capacity factor than the world average over the past two decades. In comparative terms of investment and return, pre-investment for manpower training in timely manner can be a lucrative venture.

The improved revenue as the result of having achieved a better capacity factor of our 20 power reactors can be calculated as \$9 billion in 2004, \$8 billion in 2005, and \$8 billion in 2006.

The physical protection of nuclear facilities has long been a focal point of concern for the Korean nuclear community. Our sense of vulnerability was driven home especially hard in the aftermath of North Korea's bloody acts of rampaging terrorism during the 1970s. Just to mention two cases: There was the massacre of 17 dignitaries, such as several cabinet members of the Korean government in Rangoon, Myanmar (Burma). (The terrorists were targeting the President and nearly got him, too.) And, there was the blowing-up of the Korean Airlines plane carrying some 120 Korean workers who were returning home from construction sites in the Middle East, simply to jeopardize the 1988 Seoul Olympiad.

Because of the terrorist behavior of the North Korean regime, we in the south have had to strengthen and constantly upgrade the protection features for our national security assets, including nuclear facilities. Long before the Sept. 11 disaster, North Korean threats made us sensitive to a possible Al Qaeda-type attack on our critical installations, including nuclear power plants. In response, we have had to put in place extra-security shields and monitoring, and we are confident that our nuclear installations can be run safely and efficiently, free from these external menaces.

From 1984 to the end of 2004, the price index of general commodities in Korea saw a rise of 184.8 percent. During this same period, the electricity price index rose by only 5.4 percent. The availability of relatively cheap electricity in Korea, which is the result in large part of the excellent performance in power generation, especially from nuclear reactors, is the main contributive factor to this benefit. Korea's electricity sector has managed to maintain a top-class standard in power supply quality, both in voltage and in frequency stability terms, meeting 99.99 percent of requirements.

However, we do not bask in self-congratulatory complacency

Table 2

ACTUAL CONSTRUCTION PERIODS AND TARGETS
(In months)

Project	Target	Record
YGN* Units 3, 4	64	63, 67
Ulchin 3, 4	62	61, 73
YGN 5, 6	58	59, 61
Ulchin 5, 6	56	58,55
Shin-Kori 1, 2	53	
Shin-Wolsung 1, 2	53	
Shin-Kori 3, 4	58	

*YGN = Younggwang Units

with this high performance; we think that there is still room for further improvement. We should be able to squeeze out even better productivity, for example, by working on our relatively long overhaul and maintenance periods.

Construction Innovations

When it comes to construction periods, Korea still lags behind those of the nuclear hares. The construction repetition of the same reactor capacity with identical design has always resulted in shortening the construction period by a few months per project. The construction periods for the ongoing Shin-Kori and Shin-Wolsung projects are presumed to be 3 months less than that of the previous project (Ulchin No. 5,6); that is, from 56 to 53 months. All the reactors listed in Table 2 are 1,000-MW pressurized water reactors, except for Shin-Kori 3 and 4, which are of the PWR 1,400-MW-class, or the so-called APR 1400 type.

One thing we are satisfied with is the improving trend in this area. As we climb the learning curve with ever more projects under our belt, the construction periods are getting shortened: for instance, from 64 months for the YGN (Younggwang) 3,4 project, to 56 months for the more recent Ulchin 5,6 project (Table 2). Through further performance-enabling incremental breakthroughs, we think that in time we can reach the construction period target of under 4 years per project.

Korean shipbuilders have been able to develop an innovation that has meant great savings in time, manpower, cost, and space at the job site. The novel procedure involved fabricating modules offsite, and then bringing them together for assembly at the dock site, whose availability was at a premium. This modularization technique was a straight borrowing from the construction experience at one of our nuclear plants, where the calandria (reactor core) of the CANDU reactor was fabricated nearby in advance and then transported by rail track into the containment building.

And Korean shipbuilders are now using such modularization technology on land to assemble container ships that are 200 meters long and 15 stories high, before towing them out to sea on rail tracks. Korean shipbuilders use the word "block" instead

of “module,” which is the terminology used in our nuclear community. The shipbuilders have steadily stepped up the size of the block unit from a 500-ton block to more than 2,000-ton gigablock so as to optimize shipbuilding work and to shorten the construction time.

A friend of mine, Dr. D.S. Shin, who is known as the godfather of the Korean shipbuilding community, has been involved in this block-assembly project as a naval architect. He said the other day that a dozen pieces of gigablocks for a 300,000-ton oil tanker are now assembled at dock in 26 days—the world-record in shipbuilding history.

Because of these assembly techniques, a 300,000-ton oil tanker is built at a Korean shipyard within seven months from the first cutting of steel plate to the final launching of the tanker out to the sea. He said further improvement in block unit system, assembly work, and construction time is being pursued. The construction time of the same tonnage tanker at the shipyards in other countries is said to be in the range of 1 to 2 years, but it is becoming shorter each year.

Another time-saving technique can be learned from steel structure assembly work at the construction site of high-rise buildings. The conventional method has been to first dig out the ground, fabricate the underground steel structure, and then start assembling the steel structure above ground.

My kid brother, a structural engineer, was the first to adopt a new technique in this area, the so-called “Top-Down” method, wherein steel frame assembly work proceeds above ground and below ground simultaneously. By relying on this simultaneous assembly work, he usually saves 20 percent of the steel structure assembly time.

I think it is now time for the nuclear sector to benchmark the above shipbuilding technology and steel-frame assembly techniques so as to shorten the construction time of nuclear power plants. In a nuclear power plant, a one-day delay in the construction stage now equals more than a \$1 million dollar loss to its operator.

Key Issues in Nuclear Project Development

In my view, the main lessons learned from Korea’s nuclear project development experience can be summarized as follows:

• Long-term Planning and Its Implementation

In Korea, the long-term nuclear power development program was drawn up in the early 1960s, when electric power was in short supply, and the nation’s total electric grid was too small to accommodate even the smallest nuclear power plant unit. But there was a consensus among the ruling elite, as well as among the public, that the dire power shortage problem had to be tackled by whatever measure necessary, and nuclear power was considered a breakthrough solution.

Over the years, the original development plan was modified a number of times to be consonant with the progress of reactor commercialization in advanced countries. In time, Korea’s role flipped from that of a recipient to one of a supplier of nuclear

technology. The remarkable transformation took three decades of toil, sweat, brainpower, and the mobilization of many dedicated people in the industry.

• Continued Training of Good-Quality Manpower

When our nuclear power development program was in the conception stage in the late 1950s, Korea was just emerging from a devastating civil war. People were in tattered clothes and hungry, the government coffers were near-empty, and the streets were full of begging orphans, destitute widows, and limbless ex-soldiers.

Yet there were young Koreans whose audacious dream for the nation involved nuclear power, those who looked to nuclear energy to rehabilitate the war-torn nation, as well as to nurture their careers. It was with the recruiting of these people (most of them had just completed their mandatory military conscription duties) that the Office of Atomic Energy and KAERI were established.

In order to attract and retain the best-quality manpower, KAERI kept its salaries at an extraordinarily generous level of 300 percent of that for ordinary government officials. Through government and U.S. funding aid, a number of young scientists and engineers had already been sent abroad to receive basic training in nuclear technology. These foreign-trained cadre constituted the original core of KAERI’s personnel.

New recruits to KAERI were given basic training. After that, many were sent abroad for additional training, which, on average, lasted one year. In accordance with the old adage, “strike while the iron is hot,” new trainees were constantly sent to seminars and workshops, in addition to participating in the in-house training courses organized by the seniors.

The oldest and the most active nuclear training center is the one that was established at KAERI, and it has been the delivery clinic, incubator, nursery, kindergarten, and school for Korean nuclear personnel as well as for those from abroad. In the year 2005, KAERI’s Nuclear Training Center (KAERI-NTC) offered 36 domestic courses to 1,580 persons and 9 international courses to 116 foreign individuals, and it managed one international seminar attended by 122 participants. The courses conducted in the year 2005 include: Radioisotope Utilization Technology, Radiation-Hazards Protection, IAEA/KOICA Training Course on Nuclear Power Policy, Planning and Project Management.

Since the NTC’s dormitory capacity can accommodate 48 trainees at maximum, participants in larger courses must be lodged in outside hotels. The Nuclear Training Center of KHNP is better furnished and well equipped, and it is sometimes open to international courses.

In addition, each power station has its own training center furnished with respective simulators and experienced faculty members. KOPEC, the Korea Power Engineering Company, an architect-engineering firm responsible for the design of nuclear power plants; KEPOS, a power plant maintenance company; KINS, the nuclear regulatory and licensing agency; and other



The Korean King, his cabinet members, and subjects witnessing the first electric light lit at his majesty's Royal Palace on March 6, 1887. William McKay, an American engineer, installed the electric bulbs at the royal palace in Seoul, 7 years and 5 months after Thomas Edison's invention of the electric bulb. The bulbs arrived some 2 1/2 years after the order for them had been placed. Nevertheless, April 10 was later promulgated as the official Electricity Day in Korea in recognition that the general populace began benefiting from electricity as of that day in 1890.

outfits operate these training centers.

- **Technical Backup by R&D**

Because the nuclear sector is a knowledge-based industry, the technical problems encountered usually call for technical expertise for resolution. When problems arise, the quickest solution is to resort to foreign consultants and engineering companies. This approach, however, can be costly, time-consuming and, above all, it will not engender the local accumulation and accretion of technical expertise that should result from working on various problems and issues.

Given all this, it is best to adopt a do-it-yourself approach wherein a technical group is empowered to tackle the various problems that will inevitably arise. This technical group, however, can only succeed if there is an effective R&D backup that can be called in to help address the most intractable of problems.

Again, dedicated and high-quality research manpower is a prerequisite for the success of the local go-it-alone approach. The nuclear-related organizations in Korea operate in-house training centers and research centers for the technical upkeep and innovation of their employees and new recruits. Some organizations offer evening classes on specific topics to their members, either by inviting outside experts or professors and/or in-house professional seniors. In the case of reactor operators, one of six shifts is always sent to a training center, while another shift is deployed to a technical evaluation & maintenance group at the site.

Securing top-notch expertise is the prime measure for bringing forth the vitality of our industry and eventually bringing

about the next nuclear renaissance. To this end, continued changes toward innovation and betterment will be the key words that describe the nuclear community of today. It is the growth engine that powers our future technology, keeping our caliber always at the competitive edge.

- **Step-by-Step Development of a Technological Self-Reliance Capability**

In the sciences, we sometimes see quantum leaps in understanding and radical shifts in paradigms; for example, the revolutionary shift from Newtonian science to quantum physics. The philosopher of science Thomas Kuhn wrote about such paradigm shifts. In engineering, however, advancement tends to be incremental in nature, and the gradualist *modus operandi* is the way to go. Here, the persistence of a turtle, moving at what appears to be a glacial pace, is often the guarantor of sure success. It is the small details and constant improvement in all areas, like developing capable and experienced personnel and honing in-house engineering and R&D capability, which will make or break a nuclear power project. And such capability cannot be willed into existence overnight; it has to be the result of years of gradual accumulation and accrual of know-how, and constant training and re-training of personnel.

Our experience tells us that the most cost- and technology-effective way of implementing the first one or two nuclear power projects is to rely on a turn-key contract, structured in such a way as to ensure maximum deployment of local input (ensuring on-the-job training for locals and transfers of know-how), while the supplier still shoulders all the responsibility from alpha to omega. The other side of the coin is that the recipient must keep

his eyes wide open to the work progress and completion and, through surveillance, inspection, and testing, must confirm that the supplier's work conforms to the expected level. The recipient must be a constant watchdog.

Once on the learning curve, the interactive and on-the-job aspects of the projects pushed us quickly up the admittedly steep learning curve, as this chronology shows:

1970-1986: Acquisition of basic technology

1986-1995: Buildup of technological self-reliance capability through project repetitions

1992-2001: Development of next-generation reactors

1999-2006: Enhancement of nuclear power technology with emphasis on core technology development

2007: Basic buildup for nuclear technology advancement and preparations for plant export.

• Construction Management

No manual or textbook on construction management and project scheduling can hope to match the direct tutorial and hands-on involvement of an experienced project manager or a professional project scheduler from offshore, and this is especially true for the very first nuclear power plant construction projects. The experienced foreign professionals can guide the locals on the well-trodden path of power plant construction, saving the locals from having to reinvent the wheel every so often. Repetitive trials and errors can be avoided, and the project can be finished on a timely basis and on budget.

When it comes to hiring outside help, we recommend top-notch consultants, even if it means bigger outlays in fees and salaries. Pennywise and pound foolish is an apt maxim to hearken to here, and we all know how bad consulting advice can lead to millions of dollars in problems to fix down the road.

Korea's first and second nuclear power projects were undertaken on a turn-key contract basis. The suppliers were fully responsible from design to test operation, and the projects were completed within schedule and budget. Korean engineers and technicians were involved in every step of the process, and they were eager to learn and absorb the tangible know-how from the foreign suppliers. The deployment of Korean personnel in every aspect of the project meant, too, that the suppliers could realize a saving in their personnel expenses.

In short, it was a win-win situation for both parties: The supplier could save in personnel deployment, while the buyers' personnel could become proficient in the new technology through on-the-project participation. This on-the-job learning gave us not only new knowledge but also fomented within us a determined self-confidence necessary for confronting the subsequent projects which we, for the most part, carried out on our own.

After the completion of first two turn-key projects of the nuclear power plants in Korea, the construction company dispatched many of its engineers to KAERI for training in nuclear basics and the concept of quality control and quality assurance

systems. Needless to say, this construction company has been the most successful bidder in the public bidding for many subsequent nuclear power plant construction projects. And this particular firm has grown to be one of the top-notch construction-engineering companies in the world market in terms of work progress, quality, and amount of contracts.

When I was an engineering student, I was very impressed with the following lecture from a much experienced professor: It was something to do with the reshuffling scheme of plant managers along with the progress of construction and operation phases of thermal power plants:

CONSTRUCTION PHASES AND THE PREFERABLE CORRESPONDING PLANT MANAGERS

Phase	Plant manager
Site preparation, building	Civil engineer
Equipment installation	Mechanical engineer
From test operation to initial operation for some years	Electrical engineer
After some years of initial operation to the end of plant life	Chemist

The professor stressed the importance of water chemistry and corrosion control of the materials in a power plant time and again, saying that the availability of the power plant is greatly dependent on the control of water quality and the preventive measures against material corrosion. I think that this point is not only limited to a thermal power plant but also to a nuclear power plant as well.

• Measures for Winning Public Acceptance

In any society, one finds ardent supporters for national nuclear projects as well as activists agitating against them. The general public, for the most part, remains unperturbed, neutral, and non-biased. The proportions of each group tend to fall in place in a bell curve.

Professional anti-nuclear people are bold, quick to act, and internationally well-connected. They do not shirk from aggressive tactics. Above all, they are clever with presenting nonsensical data in plausible terms, and they seek to provoke. It is difficult to win a public debate against them since they are quick to counter our arguments with unfounded facts and data. The long and strenuous efforts of the Korean nuclear community to engage and win over these radical anti-nuclear activists through rational discourse have not borne any fruit. All our sincere and time-consuming face-to-face discussions with them have failed totally.

What we have learned is that in order to win wide public acceptance of nuclear power, we must focus on the unthinking general public in the middle: the housewives, students, children and, especially, those in the mass-media, rather than waste our time wrestling *mano-a-mano* with incorrigible anti-nuke activists. A winning campaign will require our total commitment for the long haul, with lots of patience, sincerity, and, of course, uncontested facts and data with

which to present our claims.

Using straightforward and simple language, we must appeal to reason and common sense, and make a case for how nuclear technology can ensure environmental conservation and at the same time provide a stable energy supply for now and for future generations. Hearts and minds must be won over from an early age and one of our long-term strategies is to encode the concept of nuclear energy benefitting human civilization and kindling electric candles for our offspring in textbooks at all levels.

Technological Self-Reliance Capability

In retrospect, Korea's pace toward a self-reliance capability for developing nuclear technology has been slow but persistent over the years. It was fortunate that continued efforts have been dauntlessly employed in step-by-step fashion.

First was the learning process of practical know-how from the mentors, either in the form of training courses at home and abroad or on-the-job training at the sites, and second was the endeavor for developing basic software and hardware technologies. This was followed by the third step, which is the tangible realization of design-engineering-manufacturing as well as system analysis of necessary systems. Here are some of the major footprints regarding the technological development of domestic capability in the nuclear sector.

• CANDU Fuel Development

Technological self-reliance, or so-called technical localization, has been a magic word in the Korean nuclear community. First of the all-out endeavors for the localization commenced with the development of CANDU fuel at Korea Atomic Energy Research Institute in the late 1970s. Our researchers and engineers employed their utmost efforts at this, working 12 hours per day and 7 days a week, around the year.

As the result of their endeavor at home and in Canada, KAERI people succeeded in designing CANDU fuel bundles, and then approached AECL (Atomic Energy of Canada Limited) for the use of CANDU fuel technology. AECL, the Atomic Energy of Canada, Ltd., claimed \$26 million of it.

There were lengthy *vis-à-vis* negotiations between KAERI researchers and AECL staff involving the proprietary information issue. During the negotiation process, Canadians recognized that the very fact that KAERI researchers possessed sufficient CANDU fuel design know-why and know-how, almost everything from its alpha to omega, meant that there was nothing much to be transferred to the technology recipient. As a symbol, however, AECL requested \$1.00 from KAERI for the use of the CANDU fuel design technology.

We still feel extremely grateful to our AECL partners for their generosity in this regard. It was our first step toward the nuclear technology self-reliance avenue.

The second step was the actual fabrication and test-proof of the CANDU fuel bundles. Because it was mandatory for the KAERI-made fuel bundles to be test-proven under the actual op-

erating conditions for their integrity before being loaded into a CANDU reactor, KAERI was obliged to ask AECL for help.

The Korean-made fuel bundles had to be tested at NRU, a materials-testing reactor in Canada. The test fee quoted from Canada was \$3 million, which was, however, far more than what KAERI had in its coffers. In fact, KAERI had only \$0.4 million for it. Eventually, the three-day negotiation between AECL and KAERI was broken off, and the KAERI delegation went out to Montreal Airport to return home in despondency.

But while the Korean delegates were waiting for the boarding announcement, they were abruptly visited by AECL's vice president, who graciously conveyed the word that the Canadian government had authorized AECL to sign the contract for the irradiation of KAERI-made fuel bundles at NRU at \$400,000.

Thus the contract was signed at Montreal Airport on Oct. 5, 1982.

Canada's favor was not limited only to the exceptional reduction of the contract amount but also extended to invisible support for R&D activities in this regard: Under the positive cooperation of Canadian colleagues, three Korean-made fuel bundles were loaded in the NRU reactor for a seven-month test period. During the test period, all kinds of test data were obtained by the measuring instruments of the Canadian laboratory, with the help of Canadian colleagues.

In June 1984, the fully tested fuel bundles were discharged from the NRU reactor, and the result was more than satisfactory.

Our track record attests to the fact that CANDU fuel development was Korea's major march toward the lengthy technological self-reliance path for the development of nuclear software and hardware. The expenditure KAERI put up for CANDU fuel development was merely 0.3 percent of what the Canadian developer had initially invested for this fuel development.

• PWR Fuel Development

Of the operating power reactor fleet, 16 out of 20 reactors in Korea belong to PWR type, purchased from two different countries, the U.S.A. and France. Since PWR fuel is made of enriched uranium, the related technical specifications are complex and more stringent compared to other types of fuel. In particular, its design technology is one that cannot be easily mastered. Furthermore, codes and standards applicable to the design, manufacture, inspection, tests, and surveillance of the fuel in these two countries are different in the U.S. and French programs.

In order to jump over this hurdle and to achieve the localization objective at the earliest possible period, with the least amount of expenditure, KAERI ended up with the following conditions for importing technology from abroad:

(1) KAERI should be fully empowered, including in its selection of technology providers. Priority will be given to the degree and contents of the provider's technology-transfer terms from KAERI's perspective.

(2) The contract form will be a joint design between technol-

ogy provider and recipient. However, the responsibility for the integrity of the output will be borne by the recipient.

(3) The construction cost for the fuel fabrication plant to be built at home will be financed by domestic (Korean) sources.

As the result of public bidding, the German firm KWU (Siemens) was selected, because its terms and conditions for technology transfer were most favorable among all bidders. It was agreed in the contract that the training for recipient party's engineers will be carried by on-the-job participation; that is, to deploy trainees at each specialty group and every job site from the beginning. This new training concept was considered plausible and workable because most of the trainees had already been exposed to the fundamental technologies, and the majority of them had a few years of a post-doctorate career. In addition, the Korean trainees at KWU worked more than 60 hours per week with tenacious effort.

At last, the PWR fuel fabrication plant was constructed at KAERI within the budget and time frame. At the same time, the nuclear fuel group became legally independent from KAERI in 1989, and it was named KNFC, Korea Nuclear Fuel Company. At present, KNFC supplies all the necessary CANDU and PWR fuel in Korea. KNFC also fabricates the zircaloy tubing, which accounts for more than one-third of the nuclear fuel fabrication cost.

Korea's Changing Status and Role

Korea has gone through thick and thin, with many challenges, and is the only country in the world, that has transformed its status from an LDC (least-developed country) to a nuclear-developed nation in the past 50 years.

When my generation was young, in the 1950s and 1960s, we were stricken with hunger and cold, clad in tattered clothes, and we usually slept in naturally well air-conditioned rooms without

Figure 3

KOREA'S SMART: A DUAL PURPOSE REACTOR FOR POWER GENERATION AND DESALINATION

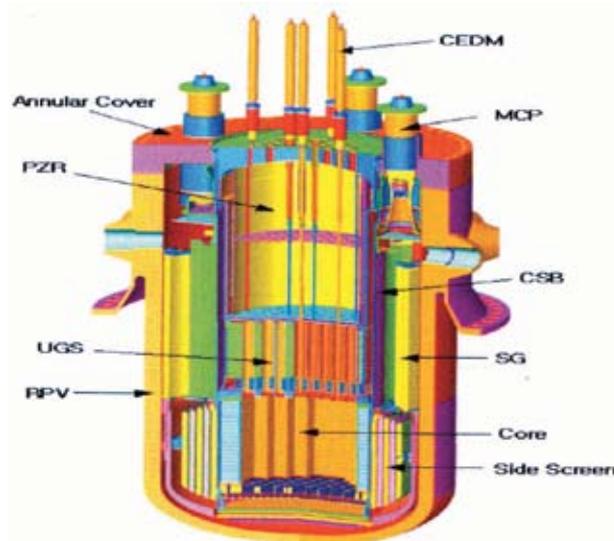
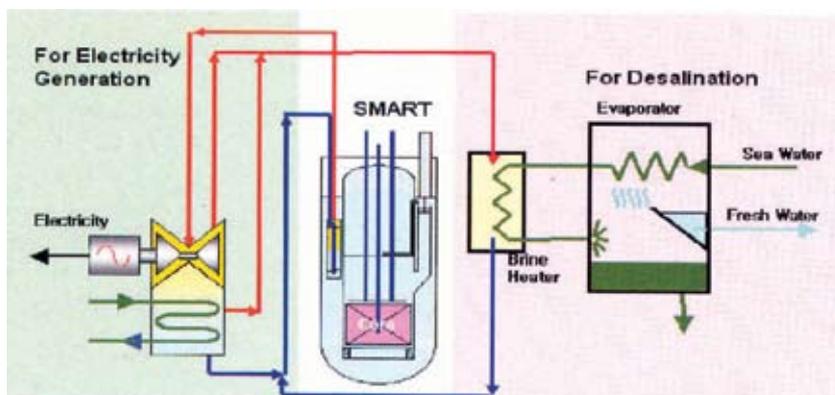
SMART stands for System-integrated Modular Advanced Reactor, designed by the Korea Atomic Energy Research Institute as a 110 MW electric power reactor, enough to meet the demand for electricity and water for 100,000 inhabitants.

Human history is entering a new era, wherein a severe shortage of water is presumed to occur in many parts of the world, as a result of climate changes, rapid population increase, and industrialization. To cope with this problem, KAERI developed SMART, with the blessing of the IAEA and in consultation with a few water-thirsty countries.

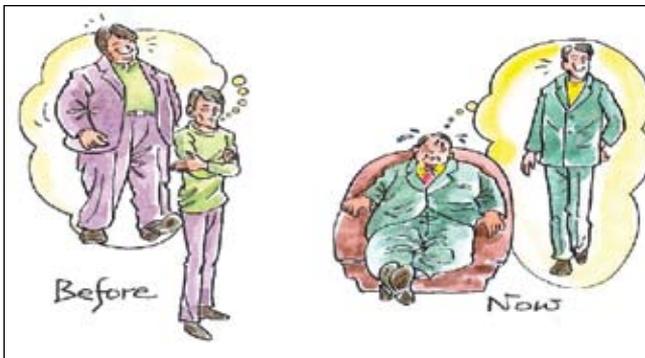
SMART is an integral type reactor with new innovative design features and proven technologies, aimed at achieving enhanced safety and improved economics, by incorporating inherent safety improvement features and reliable passive systems. The improved economics is achieved by means of system simplification, component modularization, construction time reduction by in-shop fabrication and site installation, and increased operating availability.

The low power-density design has a core fueled by uranium oxide, and is proven to provide a thermal margin of more than 15 percent to accommodate design basis transients associated with critical heat flux. The soluble boron-free design provides a strong negative moderator coefficient over the entire fuel cycle and therefore improves reactor transients and load-following capacity. A modular type once-through steam generator has an innovative design feature with helically coiled tubes to produce superheated steam at normal operating conditions.

All major primary components are contained in a single



pressurized vessel. The system pressure is passively adjusted by partial pressure of steam and nitrogen gas filled in the pressurizer in accordance with variation in pressure and temperature of the primary coolant.



beds in the winter seasons. At that time, our hope was how to become affluent, and, in other words, it meant to be fat, preferably being full of nutrition storage under the skin.

These days, in the 21st Century, people desire not to be obese, but to become slim and thin, even wearing intentionally tattered blue-jeans. Thus, people's hopes change with time, and the utmost desire of mankind in the present era is sustainable development along with environmental conservation, and nuclear energy can be one of the major contributors in this equation.

The Republic of Korea joined the Organization for Economic Cooperation and Development in 1997, and also the Geneva Group in 2006. Until last year, Korea's United Nations Base Rate Share had been 1.73 percent, but it was increased to 2.17 percent as of this year, thus becoming the 11th highest among nearly 200 U.N. member states; it corresponds to our GDP or GNP. (The U.N. Base Rate Share of the economic giants, the United States and Japan, is 25 percent and 12.5 percent, respectively.)

IAEA's case study report published recently pointed out that nuclear energy in Korea played a crucial role in realizing Korea's "Economic Miracle." The main contents of the report are:

- Korea's nuclear energy (including RI and radiation) constitutes 2.2 percent added value to its GDP.
- Nuclear technology self-reliance has been demonstrated by the development and deployment of the KSNP, the Korea Standard Nuclear Power Plant, PWR-1000 MW, which is unique in the world.
- Korea is a successful example of national development from an agro-society to a high-tech state that is enjoying several top world commodities in the global market.
- Korea was a "recipient country" when the IAEA was established, but is now a representative "donor country."

In this regard, I have a say: As far as nuclear training is concerned, I was a technology recipient from the IAEA and the United States on many occasions in the 1950s to 1970s. After that, people started calling me a nuclear engineer. In the 1980s-1990s, I was often recruited by the IAEA as a consultant for technical projects, and I presided over many technical meetings as chairman.

Several years ago, the IAEA dispatched me and Dr. John Rundo of the United States to Africa to evaluate the IAEA-supported



projects, to interview former IAEA trainees, and to help the member states in drawing up their national nuclear development program if necessary.

In this connection, it has been customary for the host country to provide the IAEA Mission with a car and chauffeur. Nevertheless, one of the member states did not do it for us. So we had to rely on taxicabs and a rental car. Upon their request one day, Dr. Rundo and I gave a one-hour lecture each to a few hundred participants. At the end of my lecture, I wrote the following words on the blackboard: "We like Africa. We love Africa."

I read it such that we like Africa because of many reasons, and we love Africa from the bottom of our hearts. Then I added the third line: "We need Africa in terms of ah-free-cah."

To this expression, a dignitary sitting at the first line of the audience stood up gently and shook hands with me, saying, "Sorry, we will send car and driver to you from tomorrow."

Research and Development

R&D stands for Research and Development. The scope of R&D has been extended to R&DDD by the addition of Demonstration and Deployment.

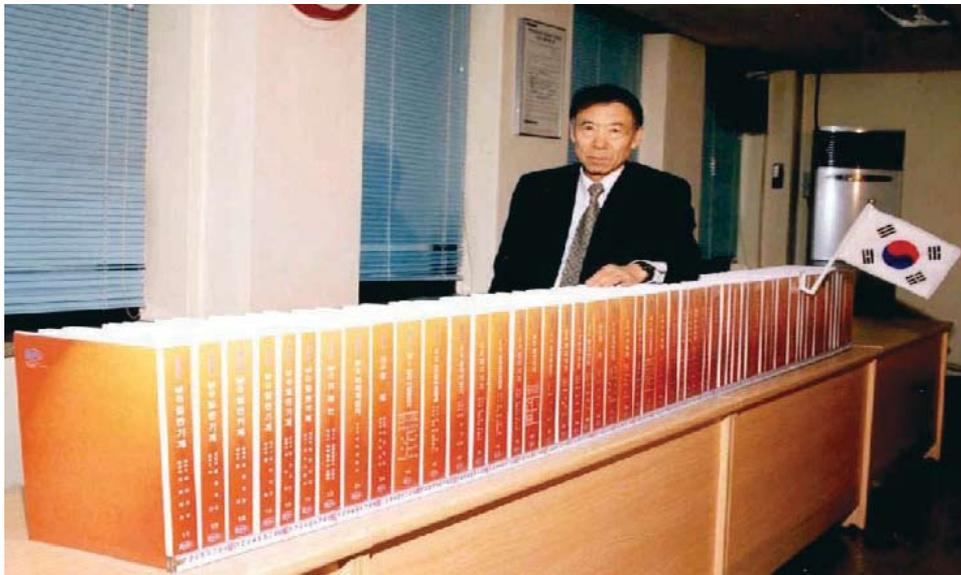
I'd like to introduce a new vocabulary, under the acronym of R&Penta-D, or R&DDDDDD, that is supplemented with Driving (Operation & Maintenance) and Decommissioning. In our business, nuclear personnel must be responsible for carrying out a lifelong caretaker role of facilities, up to the end of their life, that is, until plant decommissioning. That is why I'm proposing to add two more "D"s to R&DDD.

Here are the critical items for our R&D activities:

- Fuel cell and hydrogen production by a nuclear reactor, as well as hydrogen storage and distribution. The high-temperature gas-cooled reactor, HTGR, must be further upgraded and improved in this regard.
- The development of superconductor and electricity storage technologies.
- Wireless transmission of electricity.

At present, Korean researchers announced that they have succeeded in transmitting electricity without a conductor for a distance of 1 centimeter, and NASA researchers have announced that they have accomplished a wireless transmission of electricity between a 1-kilometer gap.

- The development of a fusion reactor. As the international tokamak ITER stands for "way" in Latin, it will yet be a steep



Dr. Lee with the 2005 edition (in 83 volumes), of the Korea Electric Power Industry Code, whose publication he organized and oversaw

and thorny way with lots of engineering and material problems, and such problems must be solved by “Tinkers” rather than “Thinkers.”

- Once I was deeply engaged in the submarine transmission line connection project between Korea and Japan, which spans 200 kilometers. To this end, my friend recruited a cable manufacturer, bank, engineering company, and so on; and actually there was consensus or agreement between the two parties for the implementation of this project, considering the merit that the electricity price in Korea is 45 percent of that in Japan, and that electricity quality in Korea is superb.

Conclusion

As of the end of 2006, the number of operating nuclear power plants in the world was 435 units or 370 gigawatts, plus 26 additional units (21 GW) that are under construction. By 2030, global nuclear power generation capacity will increase to 640 GW, that is 1.73 times the present capacity (370 GW). This means we will have 270 additional gigawatts about 270 more units than now during the forthcoming 23 years, and the nuclear share out of the total installed capacity will augment from the present 16 percent to 27 percent by that time.

Most of the currently operating nuclear units will be either refurbished, life-extended, shut-down or decommissioned by 2030, and all such works will have to be carried out by nuclear professionals. In this context, today’s nuclear students will be called upon to implement these projects, which constitute a tremendous volume of work.

In fact, there are many people and at the same time, there are only a few people. Here “many people” means the general public, who are waiting for the supply of reliable, safe, and cheap electricity; while “few people” connotes the capable and dedicated manpower who can be deployed to meet these require-

ments from the general public. To make a long story short, the future will hold lots of nuclear projects.

Nuclear projects require long lead and construction times, lots of preparatory work, huge capital cost, a variety of numerous dedicated specialists, and, in particular, public acceptance. However, nuclear technology is younger than those of the computer, television, airplanes, and others. It is, therefore, worth participating in its challenges in consideration of the significant potential benefits in the future, looming on the horizon.

One day, Albert Einstein was asked by a newspaper reporter:

“Why can’t we get rid of the nuclear war threat?”

“Because politics is more complicated and difficult than physics,” was his answer. So, I’ll not touch upon these tricky politics here. I’ll wrap up this lecture with the following solicitation: To those who are from countries or organizations without an operating nuclear reactor and with relatively underdeveloped industrial or institutional infrastructures, my message is to go and preach the nuclear gospel even in the wilderness, and win converts and public mandates—that is, carry light to the darkness with nuclear light bulbs

To those who are from countries with aging nuclear facilities and whose nuclear program has been inert for decades, my message is that the Nuclear Renaissance is never a free gift from a merciful and generous Santa Claus, but can only come from unending do-it-yourself efforts and perspiration. Your forebears have already gone down the steep learning curves, and you are already blessed with a font of native original insight for the challenges ahead.

To those who are from countries having steady ongoing nuclear projects and whose operational record has been satisfactory, my message is that your first enemy is the self-complacency that lurks within you. What you desperately need is not complacency but continued complaisance in your daily work! Always be vigilant and innovative. In addition, you have to pay heed to the catch-phrase from the Japanese industry: “Wring your dry rag further and once more, for that last drop.”

In conclusion, you are cordially invited to display your caliber as a robust “Nuclear Stallion” here, there, and everywhere, all the time from now on. In order for me to see your Earth-saving activities and also to clap my hands in applause for your success, I’m going to apply to the Absolute Being for my “Life Extension.”