



Luis PALACIOS (Dr. Ingeniero Industrial) graduated from Madrid Polytechnic in 1956. He attended the International School for Nuclear Science and Engineering at Argonne National Laboratory.

He worked for Junta de Energía Nuclear in Spain from 1956 to 1973, holding several jobs in the Nuclear Engineering Division and arriving at the position of head of the Division of Planning and Economic Studies. From 1974 he is Technical-Commercial Director of Equipos Nucleares, S. A.

Dr. Palacios has dictated Ph. D. courses at the Madrid Polytechnic and is a member of the Spanish Nuclear Society, where he was its first treasurer.

CONTRIBUTION OF DOMESTIC INDUSTRY TO THE SPANISH NUCLEAR PROGRAM *

L. PALACIOS

BACKGROUND

The economic conditions in Spain by 1960 were appropriate for the inception of a modest nuclear program.

HIGH RATE OF GROWTH

The economy was picking up after a prolonged postwar slump. The population was sizable, about 30 million people, thus providing a good potential market for industrial and service activities.

Electricity was growing at the rate of 11 % per annum, and similar long term growth was predicted since per capita consumption was only about 480 kWh/y.

ENERGY RESOURCES

Resources for generation of electricity were scarce. The economic hydroelectric resources had been tapped to a large extent over the previous decades. Operation of the hydro plants, limited by the available rainfall, was being optimized for peaking duties by the construction of hyperannual dams and additional generating units.

Coal resources were available, but exploiting them was costly due to the structure of the mines. High-sulfur lignites were also available.

- Oil and gas were inexistent, although modest exploration was being conducted on and offshore.

INDUSTRIAL STRUCTURE

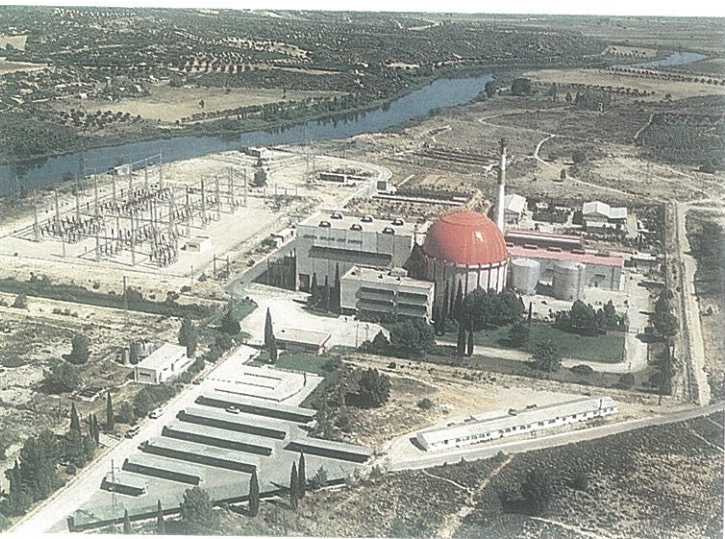
The country had the basic industrial structure on which a nuclear industry could be developed.

- Electrical utilities that had started producing electricity for public consumption in 1875 had the necessary size and skilled personnel to accommodate the then 100-300 MWe nuclear units.
- The scientific and technical community, trained at Universities and Polytechnic Institutes, had a good level. Exchange programs with other countries over the previous decade had provided access to the rapidly advancing nuclear sciences and technology. The Junta de Energía Nuclear, created in 1951, had started promoting technical and experimental activities in the nuclear field and provided a basis for regulatory activities.
- Industry, which had achieved a notable status during the 20's and 30's, had recovered from the postwar recession and had been considerably modernized through its participation in the construction of fossil-fired stations and chemical plants. Engineering firms had been created that incorporated the necessary skills for tackling complex, multidisciplinary projects. Most equipment manufacturing plants were relatively old but new tooling was being added and some brand new plants built with modern machines and methods.

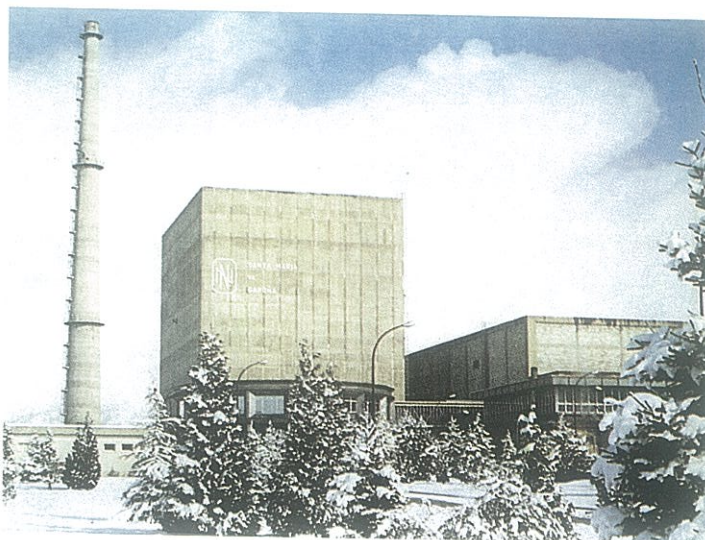
CREATION OF THE INFRASTRUCTURE

The nuclear infrastructure in Spain has been created over a period of 25 years by efforts on all fronts by different participants: Government, utilities and industry.

* This article is adapted, with minor alterations, from a paper presented at the 6th Pacific Basin Nuclear Conference, held in Beijing (China) on September 1986.



CN José Cabrera



CN Santa M.ª Garoña

GOVERNMENT

The Government has played a major role in the creation of the infrastructure, performing the tasks of promotion and regulation, mostly through the Ministry of Industry and Energy, and providing the necessary legislative framework.

THE JUNTA DE ENERGIA NUCLEAR

This Organization, equivalent to the Atomic Energy Commissions of several countries, was created under a different name in 1948 and was given the basic functions of:

- Advising Government on nuclear matters.
- Conducting international relations in the nuclear field.
- Promoting nuclear activities, including the fuel cycle.

- Laying out the regulatory ground rules.
- Training experts.

The major milestones achieved over the years have included:

- The construction and operation of research and experimental reactors.
- The production of radioisotopes.
- The creation of the Institute for Nuclear Studies for postgraduates.
- The development of technology for all phases of the fuel cycle.
- The creation of a Safety Division and the drafting of the Nuclear Act and Regulation.

As the nuclear sector matured in the country, most of these activities have been reassigned.

- The front-end fuel cycle activities have been transferred to the Empresa Nacional del Uranio (ENUSA).
- The Safety and Regulatory activities

have been turned over to the Council for Nuclear Safety (CSN), a newly created organization reporting to Parliament.

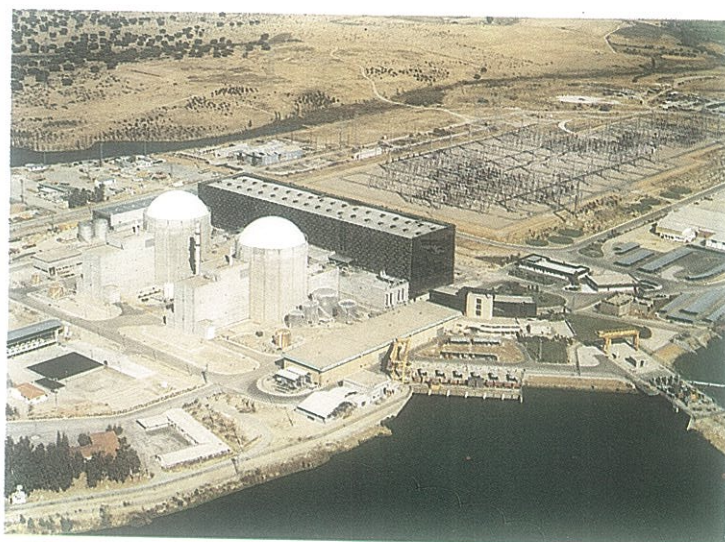
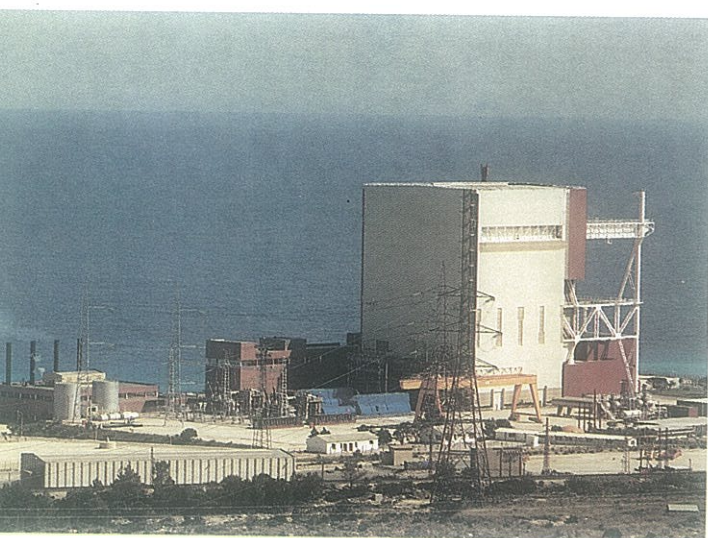
- Waste Management activities are now the responsibility of the Empresa Nacional de Residuos Radiactivos (ENRESA), a crown company which is funded by taxes levied on electricity receipts.

The JEN's main activities are now devoted to High Energy Physics, Fusion and Alternative Energies.

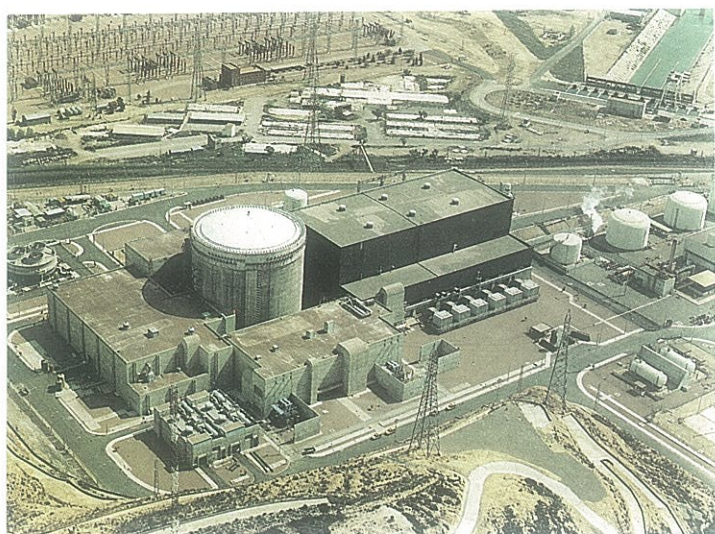
THE ELECTRICAL UTILITIES

The electrical utilities have responded to the challenge of the surging electrical demand over the years. Overall, they have maintained their structures but have grown in size. There are now 21 utilities belonging to 6 groups that

CN Vandellòs I



CN Almaraz I y II



CN Asco



CN Cofrentes

account for 90 % of the market and 3 groups that supply 7 %. 70 % are privately owned, and 30 % are public. All of them are members of the association called Unidad Eléctrica, S. A. (UNESA) that has the following functions:

- Coordination of utilities for rate studies, planning of new facilities, financial matters, nuclear efforts.
- R and D.
- Promotion of uses of electricity.

The integrated operation of the grid, previously under the control of UNESA, has now been transferred to REDELECTRICA, a newly created company with public control.

ENGINEERING COMPANIES

The increasingly complex job of engineering modern plants has gradually

been transferred from the so called "technical offices" of the utilities to specialized engineering companies similar to the US Architect-Engineers.

These companies acquired a lot of experience during the 1960's through their involvement in the design and construction of chemical and petrochemical plants. Fossil-fired power stations were designed and built by these companies from about 1960 to 1978, with unit sizes increasing from 40 MWe to 500 MWe.

The engineering companies participated in the nuclear plant program from the beginning, taking on jobs connected with the BOP and erection and site management activities. They worked initially with experienced foreign A/E's, but gradually took on the responsibility for complete jobs.

MANUFACTURING COMPANIES

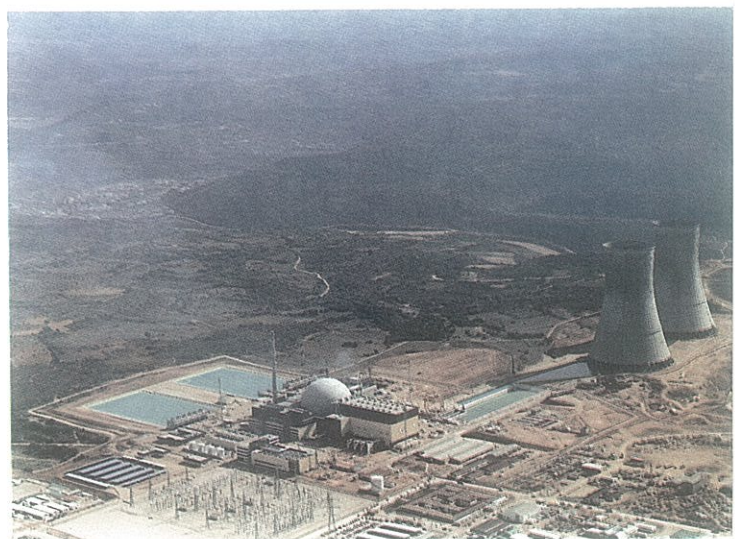
The manufacturing infrastructure of Spain evolved during the 1960's to a point where mechanical equipment, and even more so electrical goods, were built with designs by others, usually under license agreements. At the commencement of the nuclear program, the industry was reorganized on the basis of the existing structure. Major efforts were devoted to this endeavor:

- Investment in new tooling, although existing plants were largely used.
- Acquisition of new technology from experienced foreign manufacturers.
- Training of engineers and technicians.
- Reorganization of company operations along the lines of new Q/A practices.

C.N. Vandellós II



CN Trillo



New plants were built only for very specific purposes, such as manufacture of heavy components (reactor pressure vessels, steam generators, etc.), but the effort to streamline operations of the existing industry was a very worthwhile and fruitful enterprise.

NSSS VENDOR

No basic nuclear design company has been created in Spain. Foreign vendors fill this role in a competitive fashion. These companies operate from domestic offices that have played an important role, mostly in engineering follow up activities and in the promotion of a quality supply industry.

ERECTION AND CONSTRUCTION

The structure of civil engineering companies and mechanical and electrical erection firms was firmly established before the nuclear era and these companies were easily upgraded for nuclear - grade quality work.

FUEL CYCLE

During the 1950's and 1960's, the JEN developed the technology for uranium ore processing to yellow cake. Pilot plants were also built for other phases of the cycle. When ENUSA was created in 1972, patents and know-how were turned over to the new company. Over the years, ENUSA expanded its activities to include exploration of new deposits, construction of an industrial size uranium mill, participation in the EURODIFF enrichment plant, construction and operation of a fuel element fabrication plant and the associated in-core fuel management capacity. ENRESA, created in 1984, is responsible for all back-end phases of the cycle, including storage, transport and reprocessing.

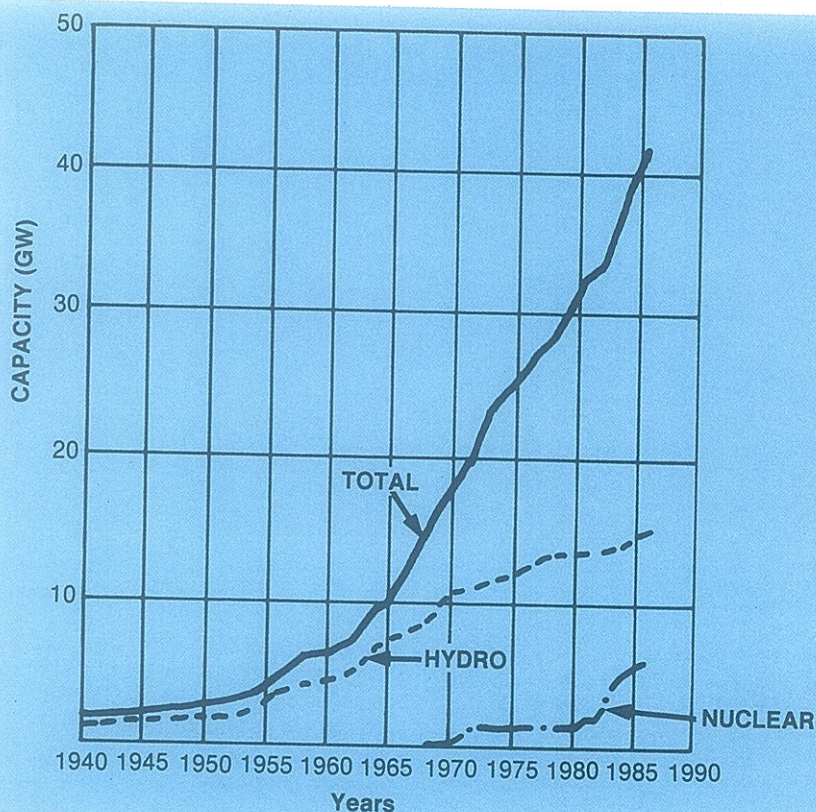
EDUCATION AND TRAINING

The large number of Scientists and engineers that are necessary for the ambitious Spanish program have been trained at Universities and Polytechnic Schools, plus the Institute of Nuclear Studies referred to above.

Special mention should be made of the training and simulation center operated by the firm Tecnatom, where operators for Spanish and a good number of foreign plants have been trained.

OTHER INDUSTRY

A host of companies have been created to meet other specialized needs of nuclear plants, such as in-service inspection, maintenance, retrofits, waste handling, special consulting services, etc.



FI Creation of the Infrastructure. Installed capacity.

ELECTRICAL MARKET AND NUCLEAR PROGRAM

As stated earlier, the decision to go nuclear was prompted by an increasingly heavy demand and the scarcity of resources.

Over the years of rapid economic expansion (from 1960 to 1974, the GNP grew at an annual accumulative rate of

7.5 % per year), electricity demand grew at the rate of 7.2 % per year. The per-capita consumption has grown from 483 kWh in 1960 to 3070 in 1986.

The installed capacity has evolved from a hydro-dominated structure in 1960 to a situation where hydro is reserved for peaking and the load is met by nuclear and domestic coal-fire units. Table I and Figure I contain the evolution of the capacity.

Table II and Figure II summarize the growth of electric generation from 1960 to 1986. The shifting role of hydro energy and the rapid growth of the nuclear component are apparent. The large hydro capacity (further expanded recently with pump-storage units) has been a boon in later years to accommodate large coal and nuclear units supplying the base load.

In 1986, the nuclear units have produced more than 29 percent of the total, close to the European Community average.

The location of the nuclear units can be seen in figure III. The legend clarifies which units are in operation or under construction and sites that are approved but construction permit pending.

TI CREATION OF THE INFRASTRUCTURE. ELECTRICAL UTILITIES

EVOLUTION OF INSTALLED CAPACITY (MW)

	HYDRO	FOSSIL	NUCLEAR	TOTAL
1960	4600	1967	-	6567
1970	10883	6888	153	17924
1980	13577	16447	1120	31144
1985	14661	20991	5815	41467
1986	15208	21029	5815	42052

T II

CREATION OF THE INFRASTRUCTURE EVOLUTION OF ELECTRIC GENERATION (%)

	HYDRO	FOSSIL	NUCLEAR	TOTAL GWH
1960	84	16	—	18614
1970	49	49	2	56490
1980	28	67	5	110483
1985	26	52	22	127363
1986	21	50	29	128697

— FOSSIL IN 1986
COAL 48 %
OIL
GAS 2 %

The nuclear program has been implemented in three phases or "generations", which are characterized by the contracting mode, the size of the units and the degree of domestic participation.

FIRST GENERATION (1962-1972)

Three plants make up the first round of orders (see Table III).

All three were contracted with foreign vendors using the turnkey procedure. The role of Spanish industry was limited to the civil work, mechanical and electrical erection and a substantial part of the engineering under the leadership of foreign A/E's. Electrical and mechanical equipment were localized only on a limited basis.

These units are in operation today and achieve an excellent load factor. The Vandellós-I plant is partly owned by Electricité de France. It has the only gas-cooled reactor in Spain.

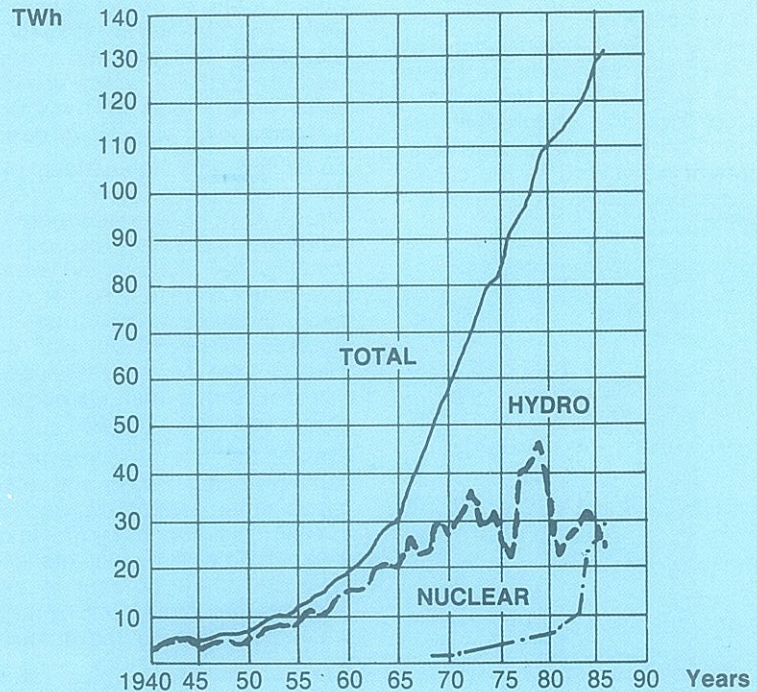
SECOND GENERATION (1970-1982)

In 1969, the first 10-year electric plan with a strong nuclear component was approved.

On the basis of the experience obtained in the construction and initial operation of the first generation units, the Spanish utilities ordered a second round of seven larger units.

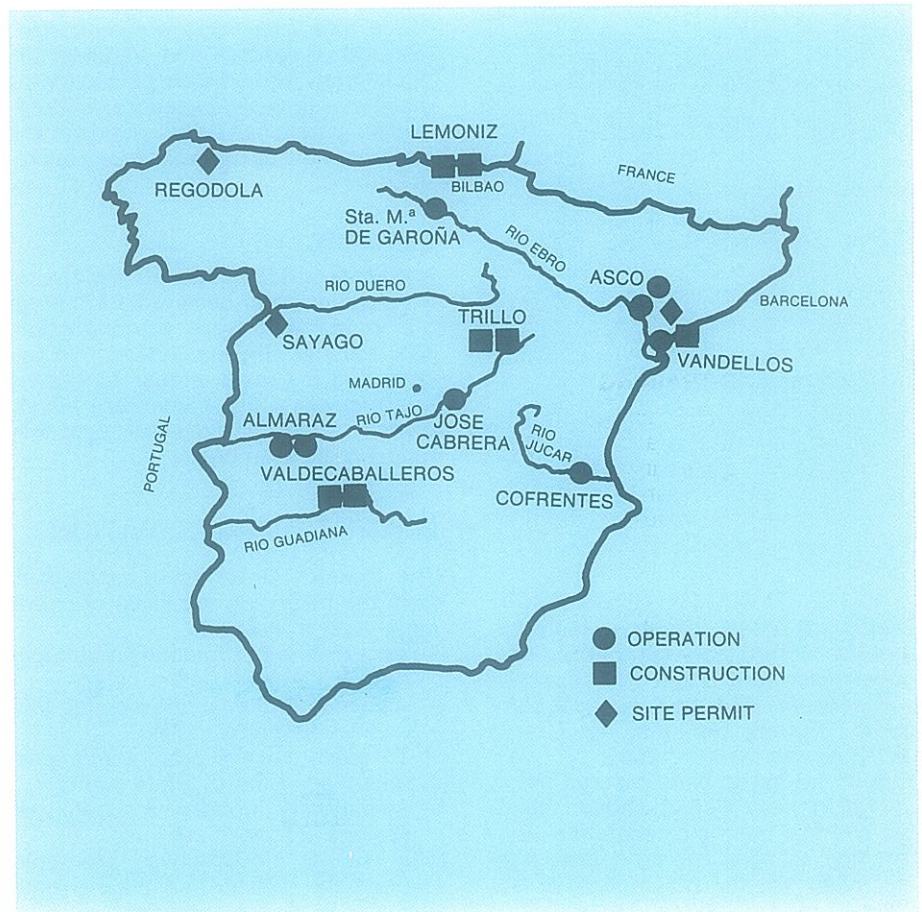
The turnkey concept was abandoned in favor of a system of contracting by packages, under the management of the owners with the help of A/E's.

The NSSS was contracted to foreign nuclear vendors, who supplied the basic engineering and equipment plus erection supervision. They were requested to localize most of the equipment in Spain and, in pursuit of this



F II Creation of the Infrastructure. Electric Generation.

F III Nuclear plant construction. Location of plants



goal, they played an important role in helping develop a nuclear quality industry in the country.

The Balance of Plant was designed by the A/E's working alongside the customers. The Spanish Engineering Companies took over the responsibility for this job (and construction management, to the extent demanded by the customers), with occasional help from foreign A/E's.

T III

NUCLEAR PLAN CONSTRUCTION

FIRST GENERATION

1. Zorita	PWR/W	160 MWe	Jul 68
2. Garoña	BWR/GE	460 MWe	Mar 71
3. Vandellós 1	GCR/France	500 MWe	May 72

SECOND GENERATION (1970-1982)

4. Almaraz 1	PWR/W	930 MWe	Jul 81
5. Ascó 1	PWR/W	930 MWe	Dec 83
6. Almaraz 2	PWR/W	930 MWe	Jan 84
7. Cofrentes	BWR/GE	975 MWe	Nov 84
8. Ascó 2	PWR/GE	930 MWe	Oct 85
9. Lemóniz 1	PWR/W	930 MWe	Uncertain
10. Lemóniz 2	PWR/W	930 MWe	Uncertain

THIRD GENERATION

INCLUDED IN 1983 PEN.

11. Vandellós 2	PWR/W	982 MWe	1988
12. Trillo 1	PWR/KWU	1041 MWe	1988

OUTSIDE 1983 PEN.

13. Valdecaballeros 1	BWR/GE	975 MWe	
14. Valdecaballeros 2	BWR/GE	975 MWe	
15. Trillo 2	PWR/KWU	1041 MWe	

SITE PERMIT GRANTED

16. Sayago			
17. Regodola			
18. Vandellós 3			

During this phase, industry was upgraded to world-class standards, new companies were created for specialized services, and the fuel cycle company Empresa Nacional del Uranio (ENUSA) was incorporated.

Five of the seven units ordered are in operation today. Construction of the other two has been suspended for non-technical reasons and no definite date has been set for resumption of activities.

THIRD GENERATION (1975)

A third round of orders comprising five units was planned in 1975 or slightly thereafter. Full national participation was intended, in practice about 90 percent, since import of items of a high economic level was always considered.

To achieve this high national participation, a new company, Equipos Nucleares, S. A. (ENSA), was created to manufacture the heavy components for the NSSS of whatever system the utilities would choose. Another new company, Empresa Nacional de Residuos Radiactivos (ENRESA), was also formed to take on the responsibility for the back-end of the fuel cycle and waste management activities.

Two of the five units are in the final commissioning stages and are expected to enter commercial service early in 1988. The other three are suspended with percentage of completeness ranging from a few percent to about 60 percent. Resumption will be authorized when the anticipate demand justifies it.

During this latest phase of nuclear construction, the nuclear industry in Spain has reached maturity. Spanish firms have become exporters of nuclear-grade equipment and services, and technical assistance and transfer of technology to other countries have begun.

Three additional sites are authorized (Sayago, Regodola and Vandellós-3), but although orders were placed for the first two with nuclear vendors, no construction permit has been issued yet and activities have stopped before concrete pouring.

SUMMARY

In summary, 8 units with 5815 MWe are in operation and 7 units with 6871 MWe are in various stages of construction. The 15 units are located on 7 inland sites and 2 coastal areas. 10 utilities are involved. Only 4 units are wholly owned by one utility, the rest being shared by more than one.

DOMESTIC PARTICIPATION

The Spanish Government recognized from the beginning the value of creating a nuclear industry.

- As a means of promoting high technology industry in other fields.
- As a means of ensuring independence from foreign supplies.
- To guarantee the prompt and competent servicing of future plants.
- As a means of obtaining substantial savings in foreign currency.

The nuclear industry was promoted through the established mechanisms available to the Government.

- Use of the old "Preferential Interest" Act that restricted importation of certain items.
- Regulation of Technology Transfer Contracts.
- A new Act covering "Mixed Manufacture" that awarded special benefits, fiscal and otherwise, to firms that undertook the manufacture of equipment incorporating imported sub-components.
- Direct action, when needed, such as the creation of specific entities, using a bidding process.

The increase in domestic participation over the years is shown in Table IV. It is seen that total capacity has been achieved in the fields of engineering, civil works and erection, with the exception of the basic engineering of the NSSS. The equipment has been localized to the practical extent imposed by the availability of raw materials and the economy of scale for some components.

T IV

DOMESTIC PARTICIPATION ACHIEVEMENTS TURNING POINT: THE SECOND GENERATION PLANTS

	DOMESTIC CONTENT (%)		
	FIRST GEN.	SECOND GEN.	THIRD GEN.
TOTAL	42-44	70-80	80-90
EQUIPMENT	24-25	45-55	70-78
ENGINEERING	50-70	75-80	~100
CIVIL	65-75	100	100
ERECTION	80-81	100	100

The process has been successful and has enabled Spanish Industry to be present in the world market.

Countries embarking on similar programs have expressed interest in the Spanish process as being representative of a medium scale industry that, by determination and serious work, has achieved an advanced status, overcoming deficiencies that are not normally encountered in more developed societies. Spanish Industry is of course ready to share its experience with interested parties, helping to orient local industries by advising them regarding successes achieved as an example to follow, and the mistakes made to prevent reoccurrence.