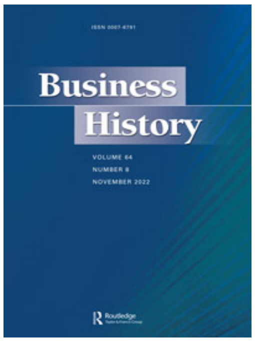

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Nuclear engineering and technology transfer: The Spanish strategies to deal with US, French and German nuclear manufacturers, 1955–1985

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ABSTRACT

We analysed the process of construction and connection to the electrical grid of four Spanish nuclear power plants with different financial and technological foreign partners: those of Zorita (PWR by Westinghouse), Garoña (BWR by General Electric) and Vandellós I (GCR by EDF) (belonging to the first generation of atomic plants and producing electricity from 1969–72) and that of Trillo I (PWR by KWU, connected in 1988). These four examples allow us to observe how the learning curve of nuclear engineering and the acquisition of skills by Spanish companies evolved. Progressively the domestic industry achieved higher levels of participation, fostered by the Ministry of Industry and Energy. When the atomic plants under construction were paralysed by the nuclear moratorium of 1984, and several other projects were abandoned by the utilities along the way, Spain had developed an industrial sector around the fabrication of service components and engineering for nuclear power plants to compete internationally.

KEYWORDS
Technology transfer; multinationals; turnkey projects

1. Introduction

At the end of the 1950s and beginning of the 1960s, the industrial sector in the U.S. made the construction of thermal plants producing nuclear power technically viable. From an economic and financial perspective, these large companies, led by the U.S. government, concluded a cycle of research and technological development that had consumed very large amounts of capital to unlock this new source of energy from nuclear fission. The time had come to profit from the investment. The opportunities for the nuclear power industry in the immense American market laid the foundation for its export to international markets that had few competitors at the time (Rubio-Varas & De la Torre, 2017). The European industrial powers (the United Kingdom, France and West Germany) were still very far from the capabilities achieved by the American multinationals. This was recognized by Euratom when it was founded in 1957 (Armand et al., 1957). As if this technological superiority was not

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enough, the institutions that regulated nuclear energy internationally since 1945 granted the control over enriched uranium to the U.S. and the Soviet Union. This was the fuel for the type of reactor that finally prevailed. The post-war phase of protecting nuclear secrets was replaced by a dissemination phase. The peaceful uses of the atom became one of the banners of Cold War diplomacy. Access to this new technology that promised 'endless prosperity' had to be given to 'friendly' countries, which included the developed economies and those still in the process of development (Drogan, 2016; Hewlett & Holl, 1989; Krige, 2006).

Throughout the sixties, nuclear power underwent the passage from the laboratory to the market. Until 1980, thirty countries began building and operating commercial nuclear reactors. One hundred were built within the United States by five North American manufacturers (General Electric (GE), Westinghouse (WESCO), Babcock & Wilcox (B & W), Combustion Engineering and Atomics International). Meanwhile, the Soviet Union would build another fifty reactors in its territory and in the countries of its political orbit. Yet the global sales of nuclear reactors constituted a tight market. Just about one hundred reactors were sold internationally between 1955 and 1980 (excluding sales by the Soviet Union), the rest were built domestically. By the early 1980s, a dozen companies competed with the U.S. multinationals supplying the core elements of the reactor. But only a few of them could export projects beyond their own borders (see Table 1), in part because the U.S. multinationals that exported nuclear projects - GE and WESCO – had the full support of the U.S. economic diplomacy and the financial assistance of the Export-Import Bank (Rubio-Varas & De la Torre, 2017).

The construction and operation of nuclear power plants was a complex and hazardous technological challenge, within the reach of only a few countries. In fact, initial forecasts by American industry expected that few economies would be able to receive this new energy paradigm. But it could be a great business opportunity. Prior to the sale of a nuclear power plant, one had to evaluate the importing country's capacity for receiving this almost unknown technology (technological absorption capacity) in terms of the country's macroeconomic expectations (economic and financial capacity), the electricity production and consumption system (electrical grid), and the level of industrial development (Drogan, 2016).

None of these three characteristics presaged the emergence of General Franco's dictatorship as one of the global nuclear industry's main clients. However, Spain become an outstanding apprentice among a small group of developing countries that travelled the

Table 1. Competitors with the U.S. for nuclear contracts circa 1980.

Country	Vendor(s)
West Germany*	Kraftwerk Union
	Babcock/Brown-Boveri
France*	Framatome/EDF
USSR*	Atomenergoexport
Sweden*	ASEA-Atom
Japan	Mitsubishi
	Hitachi
	Toshiba
Canada*	Atomic Energy of Canada
Italy	Ansaldo
	Fiat/Breda/Sopren

Sources and notes: Holliday (1981, p. 4).
*These five countries received orders for nuclear power plant exports.

path towards nuclear deployment, including Argentina, Brazil and Mexico in Latin America and India, South Korea and Taiwan in Asia. Spain was a pioneer among the early comers.

Between late 1968 and 1972, three commercial nuclear power plants were successfully connected to the Spanish electrical grid and laid the foundation for a very ambitious commitment to nuclear energy and industry. The Spanish utilities envisaged more than 20 reactors to be in operation before 1985, which exceeded that planned by France, Japan or South Korea during the same period. In the early 1970s, American and European multinationals described the Spanish nuclear programme as the model to be followed by other countries in the international market (Nuclear Engineering International, 1972). In fact, two countries stand out as major clients for nuclear power reactors ordered internationally from 1955 to 1980: Spain with orders for 19 reactors and Japan with 15 (Rubio-Varas & De la Torre, 2016, p. 251).[1]

In the nuclear market pre-Chernobyl, Spain is an exceptional case: it combines a large number of supplying countries (USA, Germany and France) with a large number of alternative nuclear technologies (PWR, BWR and GCR). While other importing countries experimented with a variety of nuclear technologies (Italy and Japan also imported and connected three different types of reactors), they had fewer suppliers: Italy had only two supplying countries -UK and USA- while Japan only imported reactors from the USA. For its part, South Korea imported reactors from three different countries (the USA, France and Canada) but only two types of reactors (PWR and PHWR).[2]

In the pages that follow, we will analyse how was it possible for a country with a low level of industrial development to relatively quickly and successfully gain the knowledge and understanding of a complex and expensive technology purchased abroad. The main objective is to analyse how a developing country's private electricity companies were able to build and connect nuclear power plants during the launch phase of this new form of energy, thus taking its place among the pioneers of its worldwide dissemination. The present study is particularly interested in considering the evolution of this knowledge and skill acquisition process in order to obtain a greater degree of responsibility in the management of nuclear power plant projects. This technological model, imported first from the U.S. and France and subsequently from West Germany, represents a successful experience by a nascent industry that created a business ecosystem with state support. It was a story parallel to the European industrial powers' entry into the nuclear age under an idea that Euratom applied in 1957, which may be applied to the Spanish case: '*scientific and technological knowledge can be borrowed, but industrial capacity one must create oneself*' (Armand et al., 1957).

From a historical perspective, our research addresses key issues in the economic and management literature, basically, how developing economies catch up with development countries and how organizations learn and develop the capabilities which led to create a competitive management. Industrial policy was decisive in this regard, since it established a path based on the objective of increasing participation by Spanish industrial and engineering firms in nuclear power plant construction. Thus, they would be '*learning by doing*' from the American and European multinationals.

Within the different phases of a nuclear project (Figure 1), we aim at understanding the strategies at a specific moment in time: the project development and the construction phases. The exercise proposed is simple. The goal is to estimate how much this nascent industry matured through the participation of Spanish companies in the operation of the nuclear programme. Hence, this study provides a comparative history of the execution of four of the ten nuclear projects eventually connected to the grid. In Spain, the story of the

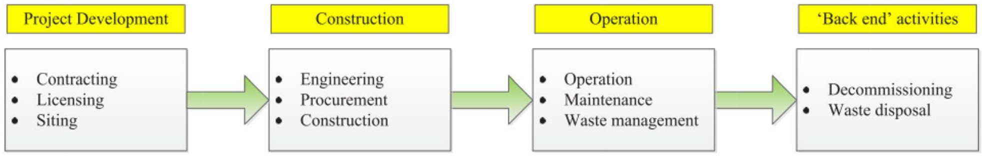

Figure 1. Typical project cycle for a nuclear new build.
Source: IAEA (2017:4).

sector occurs in a three-phase timeline. The first generation of nuclear power plants was connected to the grid between 1969 and 1972, the second generation was connected between 1973 and 1981, and the third and last generation was connected in 1988, four years after the nuclear moratorium decreed by the government. Thus, the pioneering examples of Zorita, Garoña (De la Torre & Rubio-Varas, 2018b) and Vandellós I (Sánchez-Sánchez, 2017), which belong to the first generation (Romero de Pablos, 2019), are compared with that of Trillo I (Sanz Lafuente, 2017), the last nuclear plant connected to the grid in Spain. These nuclear projects contributed to the learning processes among multinationals, promoters, and local manufacturers, managers and engineers but with differences given the timeframe and the nationalities of the multinationals taking the project's lead. We analyse how a developing country was able to develop its own engineering and nuclear equipment manufacturing industries in a record time (knowledge-intensive, technologically-challenging sectors) with different actors (the State, engineers and managers, and firms and businessmen).

The article is organized in four sections plus this introduction. The second section provides some basic characteristics of the institutional framework and the industrial policy in which the nuclear programme was deployed in Spain. The process of executing the four power plant projects is detailed next, bearing in mind the relationships established between suppliers and purchasers of nuclear technology, the implications of the selected technology and the role of chief executive officers (CEOs) in the endeavour's success. The third section analyses levels of knowledge transfer and learning by Spanish nuclear engineers based on increased local participation in the engineering processes for building a nuclear power plant. Finally, some conclusions are offered.

2. The Spanish nuclear race: industrial policies and business strategies

The studies regarding the processes of technology transfer to developing countries contend that the key to success lies in the efficient access of the promoters to '*engineering knowhow*'. Directed by foreign engineering firms, companies in the host country have the opportunity to quickly absorb learning processes (Frewer & Altvater, 1977; Kaynak & Wells, 1990; Lamoreaux et al., 1999). Designing very capital-intensive large-scale infrastructure and/or industrial plants requires companies capable of assuming responsibility for the design, construction and management of the mega-project, in addition to the transfer of learning processes related to a new technology to its customers. Namely, the imported technology must be efficiently assimilated and thoroughly comprehended by the receiver. By the end of the project, the promoter must be able to manage and operate the activities of the new industrial plant, and even improve processes and products (Niosi et al., 1995). In any case, it is useful to distinguish between the 'ability to use' and the 'ability to produce technology' (Tell et al., 2017). The construction and commissioning of a nuclear power plant is a clear example of this progression.

A distinct characteristic of the nuclear sector is that the time that elapsed between the theoretical tests of the atom and its industrial applications was exceptionally brief. In less than a decade, it had moved from the laboratory to the marketplace. A technology scarcely tested on a commercial scale set out to capture markets without sufficient empirical evidence regarding what the appropriate technological path could be. The market offered a diverse range of reactors, capital equipment and cooling systems (linked to the type of fuel and moderator), while the research centres continued to test new prototypes. To receive this technology transfer, it was essential for the host country to have a trained scientific community and a group of companies capable of taking on this challenge (Hewlett & Holl, 1989). Possibly the only certainty for the importing nations was that nuclear projects were difficult to finance without international capital participation.

For reasons related to the dictatorship's military-industrial complex, between 1948 and 1958, the Spanish government laid the foundation for the institutional framework that was to shape the nuclear power plant programme. On one hand, the Nuclear Energy Board (*Junta de Energía Nuclear - JEN*) developed a staff of experts to manage the country's uranium resources and their future industrial applications in power plants. Some of these scientists were trained in European laboratories, although most scientists were trained in American laboratories (Rubio-Varas & De la Torre, 2018). On the other hand, the private electricity companies that handled the supply of the Spanish market and the industrial manufacturers quickly concluded that this new form of energy would generate business activities to be undertaken by the private sector. Managers and engineers were trained for that challenge. Consequently, political and business leaders in Franco's Spain wanted to be among the economies that were pioneering commercial nuclear energy at a historical moment when the frontiers of knowledge were expanding rapidly (De la Torre, 2017; De la Torre & Rubio-Varas, 2016). However, some uncertainties regarding what reactor model and fuel type (enriched uranium vs. natural uranium) should be selected still persisted in the early 1960s.[3]

This choice was extremely significant because it created a path of dependence on the connections between regulators, experts, businessmen, managers and *policy-makers*, namely, between the laboratories, industries, promoters, institutions and foreign multinationals supplying engineering services and large capital equipment. The imported technology that was selected had to align with the maturity level of the host economy and influenced the learning processes for building and, above all, maintaining a commercial power plant in operation. All of the actors agreed that a great opportunity had opened up for the industrial development of nuclear equipment and that it also required a high degree of specialization. One of the methods for this strategy to be successful was the formation of joint ventures with engineering firms and consultants in the receiving country such that the local partner could assimilate the new knowledge. Nevertheless, this approach was not adopted at the beginning. The lack of sufficient business capabilities in Spain tilted the multinationals towards a different strategy in the first phase, based on the 'turnkey contract' model (De la Torre & Rubio-Varas, 2018a).

However, the learning curve also depended on political and business variables affecting both the technology sender and the receiver. Thus, from 1959–1964, General Franco's dictatorship opted for an industrial and energy policy very favourable to foreign capital entry in order to accelerate economic development and enhance business capabilities through *'learning by doing'* processes. That opening improved Franco's Spain's financial capacity, and then the Government sought the support of the 'American friend' and also of some European governments. Americans and Europeans began to compete for the Spanish nuclear energy market. The United States' comparative advantages - unbeatable in its industrial and financial terms - began to weaken towards the end of the 1960s. Governments, multinational companies in the sector, and power plant owners all had to respond to a dynamically changing environment in two phases.

The industrial policy applied by Minister López Bravo (1962–1969) managed to build power plants in record time, but with very modest contributions by Spanish companies. Steps had been taken to select manufacturers of capital equipment based on their shareholder structures, but these measures were applied to few contracts. At least, the consultants and engineering firms born in the 1950s were subcontracted and could therefore improve their skills by working with American and French partners. 'Turnkey contracts' provided full control to the primary contractor, who preferred foreign suppliers to Spanish firms to guarantee the high quality required. However, in addition, the Spanish electricity consortia wanted plants connected to the grid as soon as possible so they could start billing electricity to pay their debts and increase dividends; all these goals had been achieved by importing the American and French reactor models. The promoters did not have a priori incentives to improve the capabilities and quality of nuclear equipment of local manufacturers. These investments required significant capital and time to mature, while imports of capital equipment aggravated the chronic trade deficit. These arguments helped to pursue a new strategy starting in 1968 and they continuity in a second phase between 1969 and 1974.[4]

The political will to achieve greater local participation by manufacturers and engineers spring boarded in the first National Energy Plan (*Plan Energético Nacional – PEN*). The new Minister of Industry and Energy, López de Letona (1969–1973), had a direct knowledge of the electronuclear lobby since he was on the Board of Counselors of the electricity company most involved in the nuclear power business - the Unión Eléctrica Madrileña [UEM].[5] His activities in government were aimed at obtaining greater commitments from electricity utilities, as principal promoters of the nuclear program, with the industrial and services opportunities for Spanish companies. The institutional strategy had five broad elements (De la Torre, 2017):

1. launch a programme of privately owned and managed nuclear power plants as ambitious as those of France, Japan or West Germany (22 GW before 1985);
2. use the public National Industrial Institute (Instituto Nacional de Industria - INI) holding company to lead a first-class industrial group that would manufacture excellent-quality nuclear equipment, with private sector participation and associations with foreign technology multinationals [Equipamientos Nucleares, ENSA];[6]
3. with American technical support, guarantee the supply of 'made in Spain' nuclear fuel to all future power plants through a new company owned 60 per cent by the state and 40 per cent by the major utilities [Empresa Nacional del Uranio SA, ENUSA];[7]
4. provide a new arsenal of financial support measures for nuclear promoters (tax benefits, import tariff relief and direct subsidies);

5. and no less important, grant a greater role to Spanish public and private engineering firms through the intensive use of joint ventures with foreign and domestic companies. The public sector merged its own firms into INITEC, whereas in the private side, Empresarios Agrupados was formed to assemble the Urquijo financial group's technical and industrial services firms.[8] Each would increase their capabilities by collaborating with the foreign engineering companies supplying the primary equipment for the plants.

The promoter thus began to play a more committed roll in the overall management of the projects, namely, establishing more direct control that should stimulate the two main areas of activity: the nuclear components industry and engineering services. A good example of this strategy was the 1972 alliance of all the major electricity companies in taking over majority ownership of Tecnatom, the top nuclear engineering firm for training simulators, safety, maintenance, and operations development. That was one of the keys to the progress of the second and third generations of nuclear power plants. Each of the promoters had their own engineering firm in order to gain control over the execution of projects in favour of the national companies.

In fact, any attempt to measure the so-called 'local participation' is controversial. The available data come from aggregated estimates by regulatory authorities and by the nuclear lobby. The intention was clear - to demonstrate the success of this strategy to 'Spanishize' the nuclear programme. These numbers can only be validated or discredited by accessing primary data sources. For now, they will be used to explain the level of success of this industrial policy, while clarifying several methodology questions and using some technical reports.

The government rules required the power plants acquired a certain percentage of equipment manufactured in Spain, starting with 50 per cent established in 1969 by the National Electric Plan and increasing to 60 per cent in 1972, 65 per cent in 1977 and so on. This plan addressed the so-called *'mixed manufacturing system'*, which sought to replace imports of entire pieces of equipment (tested since 1960 by applying tariff discounts) by importing only 'parts or components not manufactured in Spain'. This would '*facilitate the transfer by foreign manufacturers of their licenses and knowledge*' to 'local' industry. The Ministries of Industry and Commerce would be in charge of controlling this infinitely bureaucratic process for all aspects of capital equipment and would also be subject to the evolution of markets.[9] Fluctuations in exchange rates or final prices unsettled by inflation affected cost accounting during the first oil crisis while the second generation of nuclear power plants was in full swing. In any case, this mixed manufacturing mechanism did produce an increase in the establishment of multinational subsidiaries or in technical assistance agreements between Spanish and foreign companies. This addressed the requirement for the percentage of product manufactured in Spain, although technological dependence on foreign entities persisted.

What do the numbers compiled by the sector suggest? Evaluated as a whole, a priori, it was a successful experience. According to the numbers in Table 2, the level of 'local participation' of 43 per cent in the first stage (1964–72) increased to 67 per cent in the second (1972–82) and 81 per cent in the third (1977–1988). To explain this data, it is necessary to 1) explore the intrahistory of four of nuclear the power plants and 2) analyse the evolution and achievements of the learning and technology transfer processes.

Table 2. Evolution of Spanish industry's participation (in %) in nuclear power plant construction from 1964–1988.

	1964–72	1972–82	1977–88
1. Civil works	70	100	100
2. Nuclear equipment	25	50	71
3. Assembly	83	100	100
4. Engineering	60	80	90
5. Staff training*	–	80	100
6. Other services**	–	80	90
7. TOTAL	43	67	81

*Includes training for plant start-up.
**Logistics and transportation for heavy equipment.
Source: Pascual (1981).

3. Nuclear technology suppliers and buyers: from laboratory to the marketplace

The Spanish electricity businessmen soon expressed their interest in taking over the atomic business. Fully aware of the industrial and financial challenge involved, the large companies, privately owned in Spain, decided to join together in two consortia to build power plants (CENUSA and NUCLENOR). The two consortia covered approximately three quarters of the Spanish electricity market. The leaders of these firms possessed a great deal of information about the United States' export strategy, the international legal framework, and the Euratom plan for developing the nuclear industry in Europe's Inner Six.[10] In addition, these business leaders were confident that the Spanish economy would soon be liberalized to facilitate access to the international market for nuclear energy-related goods and services.

That change occurred from 1959–1963. By then, the nuclear lobby had a voice in the Spanish Atomic Forum (*Foro Atómico Español*), and the design of the first two commercial power plants was well advanced, with a third plant to be added. The focus was on supplying electricity to those parts of the country with rapidly expanding populations, urban areas, and industries. The urban areas of Madrid, Bilbao and Barcelona had levels of electricity consumption that year after year exceeded even the most optimistic demand forecasts (Figure 2). To meet these needs, the electricity companies had been investing in high-voltage distribution infrastructure. Meanwhile, American nuclear businesses had facilitated some institutional and business agreements that included U.S.-based training of Spanish technicians as managers and nuclear engineers, a new profession at the time. This collaboration came to fruition through JEN, which had also extended to its counterparts in France, the United Kingdom and West Germany. This was in addition to exchanges with international nuclear organisms. The overriding need was to train personnel capable of operating a nuclear power plant.

3.1. Selection of a technology partner

Appendix 1 includes summarized information of the four power plants that will be analysed. Focusing on the so-called 'first-generation' plants (the Zorita, Garoña and Vandellós I plants), one common feature is that all three were developed under 'turnkey' project contracts. However, they chose different reactor technologies that, in turn, used different types of fuel (enriched uranium for Zorita and Garoña, natural uranium for Vandellós I). The Trillo I project

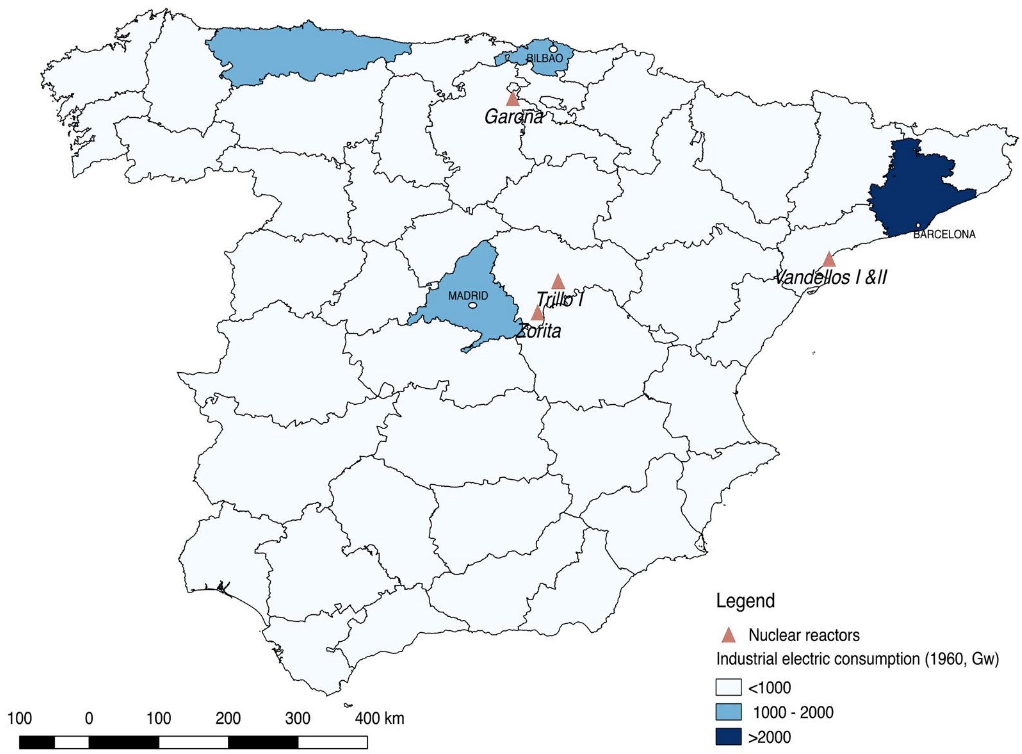

Figure 2. Industrial electricity consumption by province in 1960 and location of the four nuclear plants discussed.
Source: Own elaboration based on data by Ministerio de Industria (1961, p. 16–17).

represented some important innovations. It was the first bid in Spain won by the German nuclear industry (after losing for almost a decade to American proposals). Trillo was developed under a joint venture. In general, each project's choice of technology depended mainly on the promoters and their various existing relationships with suppliers. Since the late 1940s, Spanish electricity producers had purchased equipment abroad for new thermal (coal or oil) and hydroelectric plants. Since 1949, bilateral agreements were in place with France for the exchange of electric power on both sides of the Pyrenees (Viguié, 2014). Some of the utilities were in turn shareholders of the multinationals' subsidiaries for electricity generation machinery and instruments that had been active in Spain since before the civil war. Similarly, the foreign presence in some boards of the big Spanish electricity and industrial companies strengthened the business network that existed prior to nuclear sales.[11] That was one of the advantages of Westinghouse and General Electric (GE) in winning the Zorita and Garoña contracts, besides being the two most competitive commercial nuclear power giants.

There were also clearly political factors that explain the selection of the supplier. The network of contacts established with American nuclear agencies, the State Department and Exim Bank had pursued from the very beginning an opening-up of the Spanish market to the technology of U.S. multinationals. The JEN test reactor and the Zorita and Garoña plants were manifestations of the programme's Americanization. Policy also played a role in the Vandellós I plant. The intervention of G. López-Bravo, the Minister of Industry, was critical for enabling private companies to participate in the initially state owned Spanish-French company called Hispano-Francesa de Energía Nuclear SA (HIFRENSA), created to manage Vandellós I project. Meanwhile, the French government's nuclear energy-related marketing sought to show off 'the grandeur' of its exporting capabilities to the rest of the world by selling its first reactor manufactured by Électricité de France (EDF) and the French Atomic Energy Commission (*Commissariat à l'Énergie Atomique - CEA*). Despite this, the two private firms that participated in the consortium, Fuerzas Eléctricas de Cataluña SA (FECSA) and Hidroeléctrica de Cataluña SA (HECSA), did not hide that they 'were suspicious of French technology and preferred American reactors' because of its lower costs and better prospects (De la Torre & Rubio-Varas, 2018b; Romero de Pablos, 2019; Sánchez-Sánchez, 2017). Similarly, the U.S. Atomic Energy Commission's 1974 decision to temporarily suspend exports of enriched uranium ended up helping the Germans win the Trillo I contract (in addition to other technical and financial factors) (Sanz Lafuente, 2017). In every case, the economic diplomacy of some governments supported these transactions and facilitated the negotiation of contracts and access to external financing. Personal relationships also played a key role.

3.2. The role of the CEOs

Part of the success must be attributed to those who led the power plant projects. Their professional careers exhibit some common features and interesting nuances. Engineers by training, they led each project by taking on the multi-purpose functions of managers at the highest levels of management and administration. The CEO had to establish political and institutional contacts with national and international governments and nuclear energy entities, negotiate the commercial and financial aspects of the contract (responsible for heavy equipment and fuel purchases, and securing bank loans), and sometimes participate in the design and supervision of plant logistics (De la Torre et al., 2018). These engineers periodically visited foreign nuclear agencies and laboratories; received management training; toured nuclear component factories; participated in trade fairs and academic events; dealt with heads of state, ministers, bankers and multinational directors; evangelized for the new era of nuclear energy; and sat on the boards of other companies.

With some interesting nuances, the profiles of the four managers who led the four nuclear projects we analyse exhibit some common features that explain why their roles were essential.

All of them were effective managers associated with one of the three large nuclear energy consortia (Nuclenor, Cenusa and Hifrensa), with financial partners that represented some of the country's largest banks (especially Banco Urquijo and Banco Hispano-Americano, which participated in three of the four power plants studied). In fact, the Urquijo Group acted as the pioneer of the business and ended up becoming the great promoter of the Spanish nuclear program. The careers of MacVeigh[12] at Zorita, G. Cortines[13] at Garoña and Hernández-Rubio[14] at Trillo I reveal technical backgrounds rooted in the industrial capital of engineering. All three had first-hand experience with the technological advances that were unfolding in the United States and Western Europe. They had participated in the large hydroelectric civil works and collaborated in some infrastructure projects connected to the Defence Agreement with the United States. Above all, they shared the conviction that the nuclear development would create an unprecedented industrial sector in Spain. The first two were among the main advocates for Spain's Atomic Forum lobby and led new companies in the nuclear energy business, including the engineering consultancies Tecnatom and Eptisa, in addition to Ibernuclear SA, which aimed to compete in the enriched uranium market. In 1969, Hernández-Rubio ended up assuming the management and presidency of the Electric Union of Madrid (*Unión Eléctrica Madrileña - UEM*), becoming the factotum and main contact for the Germans in the Trillo I project.

Before taking over the Vandellós I project, Durán-Farell was a civil engineer who had gained experience as an efficient manager of the industrial and energy companies belonging to Banco Urquijo and Banco Hispano-Americano in Catalonia. His reputation and activism catapulted him into multiple management roles in that region. As an engineer in hydroelectric dam construction, he held managerial responsibilities until being appointed CEO and ultimately president of HECSA. In 1961, he undertook the challenge of reviving Catalana de Gas y Electricidad SA, which enabled him to interact with French energy entrepreneurs and technocrats. As an executive of Maquinista Terrestre y Marítima SA since 1963, he signed an agreement with the Swiss firm Brown Boveri to manufacture machinery for thermal power plants and received capital investments from American engineering firm Foster Wheeler Iberia SA. The Barcelona Chamber of Commerce and Industry and the *Círculo de Economía*, among other institutions, allowed him to raise investment capital and develop personal relationships with many medium and large entrepreneurs of the Catalan business world.[15] In short, Durán was a type of manager strongly linked to financial capital and multiple development-related investment opportunities in which political connections with the Franco government were common. He even attempted once to be named Minister of Energy.

3.3. Project execution: from turnkey projects to joint ventures

In brief, all of the projects had to follow the same path (Figure 3): once the initial phases of design, location identification, selection of the supplier of the technological model and negotiation of permits, and securing loans and signing contracts were completed, the basic infrastructure and the main and auxiliary buildings were erected. Next was the mechanical and electrical engineering, in parallel with determining the logistics for receiving and installing the large nuclear equipment (reactor, pressure vessel and turbo generator).

These tasks prepared everything for the nuclear engineering, which was the most complex activity because it consisted of receiving the fuel core, loading the reactor, fine-tuning the instruments and testing the nuclear fission chain reaction. This all led to the last step of transmitting power to the electrical grid. Throughout all of these activities, training was conducted for the staff of engineers and operators responsible for the last stage, starting up the plant to perform safely and effectively for final delivery to the promoter. Many of these tasks were being conducted for the first time in Spain and had a steep learning curve. Spanish technicians received training in domestic and foreign laboratories and in the power plants of suppliers already operating in the United States, France and Germany (or in Italy, where GE had already built a nuclear power plant). As soon as possible, they transitioned to the plant they were building and continued their learning.

The time elapsed between the start of construction and commercial energy generation was relatively fast for the first-generation plants, in contrast with the pace of the second- and third-generation plants (Figure 4). Trillo's project took more than ten years to complete, whereas Zorita took less than half that time. Vandellós I took slightly more than six years and

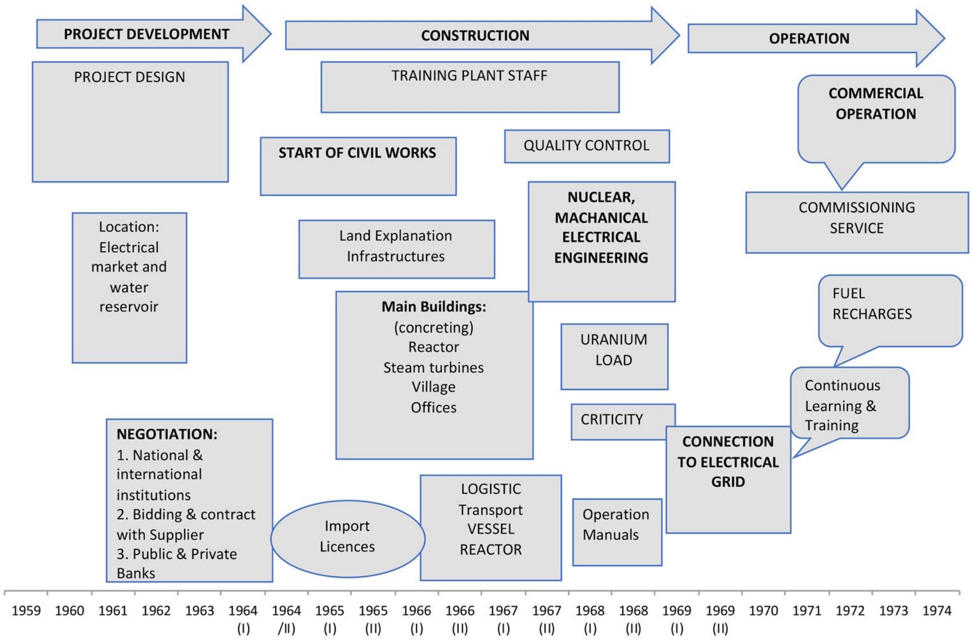

Figure 3. Phases of the construction and commercial exploitation of nuclear power plants in Spain. *Source:* Own elaboration.

Garoña almost seven years. A series of strictly technical factors can explain these differences. The most basic factor is the size of the plant and the speed with which the productive power of the reactors was expanded throughout the 1960s. The 153 MW capacity of the first plant was tripled by the following two plants (460 and 480 MW, respectively), whereas Trillo's capacity (1,030 MW) was in turn more than double that of those plants. Additionally, the initial size of all the plants was increased between the design phase and the bidding process. This was the product of an industry that very quickly moved laboratory innovations to the commercial stage and of engineers convinced that it was a simple problem of scaling. The prudence demonstrated by UEM in selecting a small commercial reactor that first enabled the learning process for a later leap to more powerful reactors was supplanted as soon as Zorita was connected to the grid in 1968 using a more ambitious alternative. The promoter was already anticipating two 1,000 MW reactors, the so-called Zorita II and III plants, which were superseded by Trillo's project shortly thereafter.

The American and French strategies of executing 'turnkey' projects facilitated compliance with deadlines, although it constrained the learning process of Spanish engineering firms, if we compare it with the results in intensity of learning that the joint ventures would generate in the next phase. In addition, the use of components manufactured in Spain was less than desired. There could be no other way. In 1965, Spanish manufacturers were not able to produce high-technology capital equipment of the required quality. Additionally, that type of contract provided full control to the reactor supplier, who only subcontracted local companies for the civil engineering services and the mechanical and electrical assembly under the supervision of a foreign partner. As such, these circumstances relegated the Spanish consultancies to less important tasks.

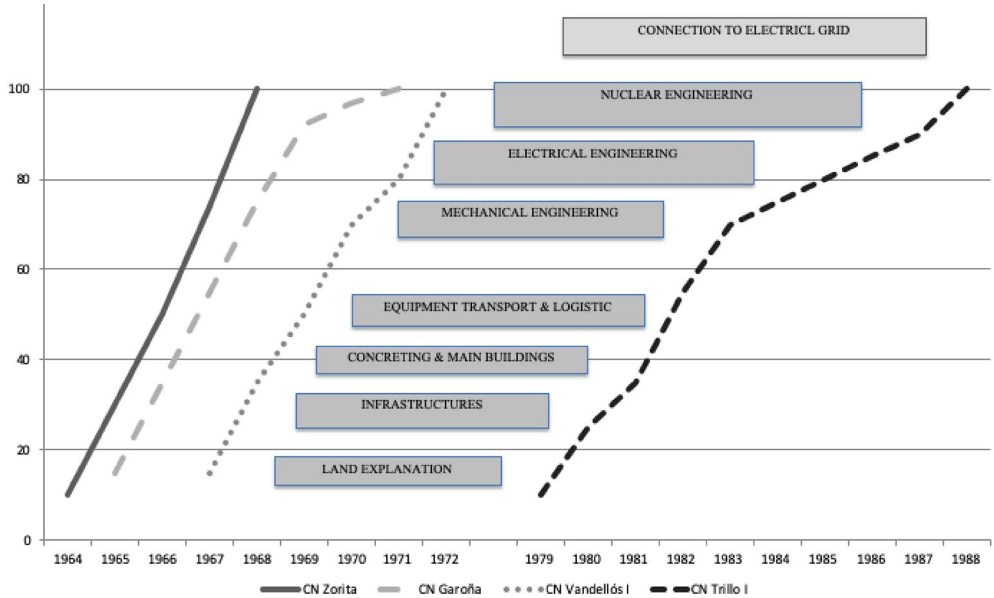

Figure 4. Execution time of the works in the Spanish NPPs, 1964–88 (accumulated percentage).
Sources: Own elaboration. De la Torre and Rubio-Varas (2018b); Sánchez-Sánchez (2017); Sanz Lafuente (2017).

The most conventional form of the 'turnkey contract' was implemented in the plants located in the Basque Country and Catalonia. GE decided that all phases of the Garoña project would be managed by GE Technical Services and by Ebasco, whose lead engineers specialized in nuclear services. The French strategy for Vandellós I was similar, although the Societé pour l'Industrie Atomique (SOCIA) consortium included a very diverse conglomerate of large construction, engineering and capital equipment firms. The Groupement pour l'Industrie Atomique (Indatom) and the Societé d'Études et d'Entreprises Nucléaires (SEEN) coordinated the project execution.[16] In both cases, the primary equipment and the fuel core was assigned to American and French firms, respectively. Subcontracts with 'Spanish' firms (civil engineering, supplying electrical and mechanical equipment) were mostly with the Spanish subsidiaries of these same companies or with local firms receiving technical assistance from the supplier.

However, the approach differed in Zorita by granting a more important role to Spanish engineering firms. The promoter managed to get Westinghouse to trust that Tecnatom, a newly created consulting firm associated with UEM and Banco Urquijo, could be on site, participating in an admittedly minor role in all project phases with the support of the American company, Bechtel. A more ambitious goal was achieved through this minor participation, turning the Zorita power plant into a learning centre for engineers and operators.[17]

In terms of final cost per megawatt of electricity, Table 3 reflects reasonably well the difficulties inherent in achieving economies of scale between the two American and the French plants. Although they are the same size, the French reactor's nuclear power was 25 per cent more expensive than GE's power. However, the Garoña plant was 64 per cent over budget, compared to a 36 per cent budget overrun for Vandellós I.

Table 3. Size, cost per MW and distribution of planned financing in the Spanish Nuclear power plants discussed.

	Zorita NP (1964–68)		Garoña NP (1967–71)		Vandellós I NP (1967–72)		Trillo NP (1980–88)	
Installed Capacity	150 MW		460 MW		480 MW		1.000 MW	
Cost/MW	0.20 (0.27)		0.11 (0.20)		0.19 (0.25)		0.72 (not data)	
Initial financing	*mill $ USA*	*%*	*mill $ USA*	*%*	*mill $ USA*	*%*	*mill $ USA*	*%*
Nuclear equipment	19.0	62.3	70.7	76,9	26.2	50.1	451,1	61,9
Fuel	5.5	18.0	12.1	13,1	18.7	35.7	223,6	31,1
Engineering services	6.0	19.7	9.0	9,7	7.4	14.2	52,8	7
Total	30.5	100	91.9	100	52.4	100	727,5	100

Note: In parenthesis the final costs per MW.
Source: AHEBE, IEME, Operaciones financieras, Cj. 1885 y 1973. Memorias de Hifrensa (vv. aa.), Archivo Municipal de Trillo. *Unión Eléctrica S.A. Anteproyecto 1974.* Box 87. Siemens Archives 54 Li/319 KWU-Report (1981). März 1981, n° 34. *Partnerschaft grossgeschrieben*. Pag. 2. De la Torre & Rubio-Varars, 2018a), Sánchez-Sánchez (2017) and Sanz Lafuente (2017).

Finally, political and institutional factors yet again affected the speed with which the expectations of that first generation were fulfilled. The government granted various legal, industrial, financial, fiscal and commercial concessions to the promoters. The suppliers were eager to win contracts in foreign markets. International safety standards were still relatively weak, but the risk of accidents was deemed to be low. In addition, there was no social opposition where these first three energy installations were located, although there could hardly be any under the dictatorship. The delays in bringing Garoña and Vandellós I online were due to technical reasons (in the criticality and connection stages), since nuclear facilities of that size had never been built before in Europe.[18]

They all enjoyed magnificent financial circumstances. Throughout the 1960s, the strategy of the U.S. suppliers included the support of the U.S. government through the credit for American capital equipment exports provided by the Exim Bank. The credit terms included low interest rates and amortization that started when the nuclear power plant began producing and selling electricity. The equipment and facilities not of American origin were covered with loans from the private banking sectors of the exporting countries and from local banks associated with the electricity companies (Chase Manhattan and Banco Urquijo for the Zorita plant and the GE Technical Services finance company and the banking consortium of Banco Bilbao, Banco Vizcaya, Banco Santander, Banco Español de Crédito and Banco Central for the Garoña plant). The French government applied a similar approach for Vandellós I, paying for a financial package that supplied the almost entire installation with French equipment and services. Meanwhile, third parties turned for financing to the Smith Barney consortium in the U.S., bonds issued by the electricity companies and, to a lesser extent, the Urquijo-Hispano Group.

Trillo I epitomized that strategy of continuous training and '*learning by doing*', in addition to the change in contract type. However, why did this plant take comparatively longer to build? Along with the problems of scaling the industrial and engineering processes (Ross & Staw, 1993), the political, institutional and financial factors were very significant in this case. The microhistory of this nuclear plant coincides with profound changes in nuclear management in Spain and other countries since the mid-1970s. The advent of democracy in Spain meant that nuclear energy had to be debated and regulated under new terms that incorporated the governance changes required by the IAEA. The creation of the Nuclear Safety Council (in 1981) involved reviewing and validating the programme, establishing new protocols and bureaucratic processes that were stricter than before. Safety regulation and management had become more demanding than it was before the Harrisburg accident and was tightened up even further afterwards. The IAEA safeguards (signed by Spain but which did not apply to French supplies) and Nuclear Non-Proliferation Treaty (which Spain only signed in December 1987) led to stricter controls over international sales of nuclear components for peaceful purposes to importing countries, due to the risk of military re-use. In addition, perceptions of nuclear-related risk had fomented anti-nuclear activism in the West. Finally, municipalities near nuclear facilities demanded financial compensation or, for example, opposed projects to store radioactive waste in their vicinity. Due to the newly regained freedom to unionize, plant workers went on strike to demand salary increases. Added to all of this was the uncertainty created by the nuclear moratorium declared by the Spanish government in 1984. Each one of these factors contributed to delays in the Trillo project (and to delays in other plants under construction in the early 1980s).[19] However, there was an even greater disruptive factor that explains the reason for halting the nuclear programme. The promoters' financial status had clearly deteriorated with the increase in interest rates and a very adverse exchange rate for the Spanish currency. Public banks in the U.S. withdrew from the nuclear power plant development business, creating an opening for public and private financing from Germany. Difficulties in obtaining and negotiating credit also delayed the completion of the Trillo project, the last plant built in Spain.

3.4. The hidden Spanish participation role: the ability to use technology

In any case, these four experiences served to improve the level of participation of Spanish companies in projects led by foreign multinationals (Table 2). However, it remains to be resolved to what extent this success data responded to the ability to use the transferred technology or, more importantly, to the ability to innovate and create technology manufactured in Spain.

The main strengths in the level of 'local participation' were in non-nuclear areas such as civil works (concrete and metal structures for buildings and basic infrastructure), mechanical and electrical assembly, and engineering services for logistics and transportation. The Spanish parent companies had gained these three capabilities in their hydroelectric and thermal megaprojects, in addition to in other very technologically intensive sectors, such as the petrochemical industry, the steel industry and the electrical installations for large infrastructure (airports, ports and railroad networks, for example) (Gómez Mendoza et al., 2007; Torres, 2009 and 2017). This trend continued in the ten years after 1972 and featured a high level of personnel training in Spanish facilities (Allones, 1977). The Spanish engineers of the main consultants explained it correctly. The forecasts for the last period aimed to consolidate these results. However, even though the percentages indicated high relative gains (from 25 per cent to 71 per cent in 20 years), the great weakness was in the amount of Spanish technology in the nuclear equipment. The mixed manufacturing system had managed to increase the nuclear components manufactured in Spain, although with uneven concentrations (Table 4). The Spanish industry had achieved an almost optimal level of participation in the mechanical, electronic, instrumentation and control components of a

Table 4. Spanish participation in the components of a nuclear power plant, 1964–88.

Nuclear Equipment	1964–72*	1972–82	1977–88
2.1. Reactor	5	33	60
2.2. Turbo generator	15	35	45
2.3. Boiler and mechanical equipment	42	74	90
2.4. Electronics, instrumentation and control	40	78	93
Total participation	25	50	71

Source: Pascual (1981) for the second and third generations and the total for the first generation.

Note: (*)The breakouts of the numbers for 1964–72 are estimates by the authors based on Kaibel (1972), Allones (1977), Gutiérrez-Bernal (1977) and Cerrolaza et al. (1977).

power plant. The local participation in the two most complex and critical systems of a nuclear power plant - the reactor and the turbo generator – lagged far behind, although there were some increases.

This situation was expected. The steam generation system was subject to the strictest standards of certification, control and safety to avoid any incident resulting from the production of nuclear energy. The industrial product had to be of the upmost quality to guarantee that the radiation, corrosion and instability of the materials subjected to extreme mechanical and thermal stress worked properly with minimal risk.

This was part of the most complex technology transfer in the history of American industry. From 1956–1968, the American Society of Mechanical Engineers (ASME) developed a manufacturer-specific quality certification code for the 'Nuclear Age' that was rolled out to the rest of the world starting in 1972. Basically, it consisted of three levels of high-to-low quality requirements, known as ASME Code III A, III B and C, and VIII (Asme Website). That same year, E. Kaibel, director of Sercobe (the national association for capital goods manufacturers) acknowledged that the Spanish equipment sector had never manufactured to the specifications required by Code III A, saying that the code was so demanding that they would require a '*massive investment in production, testing and quality control facilities*' and '*considerable organizational changes so as to afford access to these inspection facilities at any stage of production*' (Kaibel, 1972). That is, Spain was still far from being able to manufacture the most complex components. The ENSA factory in Santander was planned to meet that objective, although production had to wait until 1978, with licenses from Westinghouse, GE and Siemens.[20] As such, it would only be able to achieve this quality standard in the third generation of power plants.

The expectations for complying with the requirements of Codes III B & C seemed more achievable. After a decade of deploying the 'mixed manufacturing system', '*it appears that Spanish industry has already built equipment to these standards*', referring to the secondary components of the reactor and turbo generator. Finally, at the beginning of the 1970s, Spanish industry was able to manufacture the other equipment (steam turbines, boilers and mechanical equipment, pumps, electrical and electronic equipment) because Code VIII was equivalent '*to the standard for advanced chemical and petrochemical process plant and conventional thermal power stations equipment*' (Kaibel, 1972). The committed business portfolio reached its maximum with each revision of the Electrical National Plan. Five years later, *Nuclear Engineering International* was once again touting the progress in transferring of this *know how* to Spanish companies. The data reveal the persistence of this industrial duality in the weaknesses and strengths of nuclear equipment developed in the host country (Table 5).

The impact was clearly more positive in terms of the development of engineering services. The participation of Spanish consultants started at a high level. A total of 60 per cent participation in the first generation enabled this participation to grow to 80 per cent and 90 per cent in the next two generations (Table 3, above). In 1977, a group of nuclear engineers from INITEC, Sener and Empresarios Agrupados identified two influencing factors. First, the knowledge and experience gained in other energy facilities (electrical and petrochemical) and in other industrial installations deployed throughout the country during the years of developmentalism were applied in the nuclear sector. Second, strategic alliances with domestic and foreign partners (prompted by the government) enabled engineers to increase their competencies in each project and to rapidly assimilate the transferred technology. (Cerrolaza et al., 1977). How Spanish participation in the first three plants of Zorita, Garoña and Vandellós I was in areas of lower importance has already been discussed. The second generation further extended the close collaboration with foreign suppliers, culminating in the third generation. The Trillo I nuclear power plant was the first project in which the nuclear fission system was wholly assembled by Spanish service firms. In fact, at the end of the 1970s, some of them competed internationally in the nuclear services market. For instance, ENSA manufactured 40 per cent of the heavy components for Trillo and participated in the KWU nuclear projects in Argentina and West Germany in 1981.[21] However, this did not prevent cooperation agreements from being reached.[22]

Table 5. Spanish contribution to Mixed-manufacture Equipment in 1977 by level of quality requirement of the technology (in percentage).

ASME code		%
Code III A	1. NUCLEAR STEAM GENERATING SYSTEM	
Code III A	1.1. Steam generators	35
Code III A	1.2. Vessel	48
Code III A	1.3. Internal parts	58
Code III A	1.4. Pressurizers	62
Code III A	1.5. Main pipework	62
Code III A	2. GENERAL PIPEWORK & FITTINGS	45
Code III B&C	3. STORAGE BATTERIES & BORON INJECTIONS TANKS	75
Code III B&C	4. SPECIAL VALVES (filters, pipework)	54
Code VIII	5. STEAM TURBINES for NPS in 700–1250 MW range	38
Code VIII	6. AUXILIARY STEAM TURBINES	50
Code VIII	7. ELECTRICAL INSTALLATIONS FOR NUCLEAR REACTORS	60
Code VIII	8. ELECTRIC GENERATORS for NPS in 700–1250 MW range	50

Sources: Our own ellaboration by Allones (1977) and ASME website.

4. Conclusions

Sustaining the growth trajectory just described would be very complicated. The Spanish Nuclear planning was affected by international and local changes. Firstly, in 1970s the optimist atomic race was ended. The negative impact started with the Nuclear Non-Proliferation Treaty (from 1968), which restricted cooperation and transfer of nuclear materials to importing countries. Later, the collapse of Bretton Woods (1971) affected the financing model. Shortly after, the oil crisis accelerated the nuclear energy programmes of many countries for a short period of time. The world market became more competitive with the entrance of Europe and Canada's atomic industries in to the race to win new power plants contracts. Governments, multinationals companies in the sector, and private promoters all had to respond to such a rapid changing environment. In addition, the social pressures from social movements pushed companies for the application of new requirements for greater safety measures that increased costs at nuclear plants. This caused transformations in the national and international regulatory framework.[23] Three Mile Island incident (1979) only accelerated this process.

All this meant changes in nuclear policies and in the decisions of the companies. And in both dimensions the geopolitical interests of the great powers and the viability of the atomic business were intermingled. The 'Nuclear Suppliers Group' (USA, Soviet Union, Canada, United Kingdom, France and Japan) was born in order to review the policy for nuclear exports to countries that were not signatories of the NPT after the atomic explosion in India in 1974.[24] Although at the bottom governments were also looking for a coordination agreement in the midst of commercial competition. That was the goal of the supplier conference that took place in London in late 1975.

In other words, the 'Atoms for Peace' model and its market features had sold out by the end of the 1970s. Those who knew it first-hand were the CEOs of the big atomic multinationals. Theodore Stern,[25] Executive Vice President of Nuclear Energy systems, at WESCO, called for a reassessment of U.S. International Nuclear Policy in December 1979. He identified an 'erosion of our position of nuclear leadership' because 'Japan and the European community are continuing to develop nuclear technology and the breeder reactor without the direction (…) of U.S.'. As a result, American allies around the world are becoming sceptical of the U.S. as a reliable supplier for the international nuclear market.

This erosion 'hurts economically and politically' the U.S. interest. It resulted in loss of orders for nuclear facilities to countries who have developed their own capabilities based on U.S. technology. 'Every order of a NP lost to foreign competitor results in 30,000 man-years of employment of U.S. workers lost in 40 different states'. And the American balance of payments adversely affected by the lack of exported orders. All of which was accompanied by a lessening of American ability to develop and lead a consensus of nations in achieving mutual non-proliferation goals and policies. Stern called upon the Carter Administration to reassess its international policy on the energy needs of the world through five major points: 1) Recognize that some countries will need reprocessing of nuclear materials and the breeder reactor sooner than the U.S. will; 2) Improve the NTP Act based on the realities of the world; 3) Strengthen the support of the IAEA and its efforts to improve international safeguards; 4) Insure the procedures established to implement the President's Executive Order 'on the environmental effects of U.S. nuclear reactors exports are prudent, and not another obstacle in our nuclear relations with other countries'; and 5) Develop a reprocessing industry and continue development of the breeder reactor for energy needs, and 'to demonstrate to our allies this nation's commitment to nuclear power as stated by the President'.[26] In any case, the U.S. position had weakened in the face of foreign competition and changes in nuclear diplomacy.

And behind the political and economic problems were also issues of technology transfer and business organization. From the European perspective, the situation was viewed differently and introduced new explanatory factors. French Government was negotiating the sale of reprocessing plants to Pakistan, Iran and South Korea. West Germany nuclear industry was also expanding its business in Argentina and Brazil.[27] It is true that none of those countries that bought nuclear technology was very reliable. Alongside the geopolitical dimension, a competitive shock was taking place.

This was recognized in a secret report by Cyrus Vance, Secretary of State for the Carter government. 'There is virtually universal disagreement with the U.S. Nuclear Nonproliferation Act of 1978, particularly its retroactive provisions.[28] In particular, Euratom countries and Japan felt this policy as an imposition of new conditions for nuclear trade, especially adverse for the advanced atomic industries. 'As suppliers, their support is essential to restrain the spread of sensitive nuclear materials and technology to other countries and deal with would-be proliferators'. Spain was one of them.[29]

From 1977 the industrial crisis directly impacted the Spanish nuclear sector. The collapse in investment was manifested in labour regulations and the bankruptcy records of some companies, which was further exacerbated by the second oil crisis. In addition, Spain's new democratic institutions revised the energy policy (and of the nuclear programme, in particular), bringing a new threat to the nuclear lobby. Meanwhile, financial risk increased due to the heavy debt incurred by the industry. Besides the Government had to solve the non-proliferation problems associated with plutonium on the part of the Spanish military in an effort on nuclear weapons (Velarde, 2016). In 1978 the American State Department concluded that 'Spain's desire for closer ties with Western Europe' and the likely entry into NATO are probable inhibiting factors on any Spanish decision to develop nuclear weapons'.[30] But above all, the further development of Spain's nuclear power program continued of large economic and energy significance in a country that remained dependent on outside sources of nuclear fuel, equipment and transfer knowledge.

In conclusion, the future of the Spanish nuclear program depended on internal and external factors. Meanwhile, companies and engineering companies had learned to handle such complex technology. The 1984 nuclear moratorium by the socialist Government meant a significant reduction in planned nuclear power capacity and a bailout of the utilities that promoted the nuclear projects. Once the nuclear programme reached its apex in the late 1980s, there was no longer any problem in terms of locally supplying services, nor in terms of the mechanical, electronic, instrumental and control installations. As we have shown with the examples of the Zorita, Garoña, Vandellos I and Trillo nuclear power plants, Spain had managed to be competitive in engineering processes, perfecting systems to assimilate equipment and knowledge, on-site training of specialized personnel, development and improvement of safety, and operational maintenance of those facilities.

Twenty years later, in 1998, one of those responsible for the policy of national participation in the nuclear industry, Francisco Pascual, acknowledged that 'in specifically nuclear instruments' a quota of between 15 and 20 per cent of the total had been achieved. A small participation, but 'very important because it had allowed the industrial or service areas to capture and adapt to nuclear quality'.[31] These capabilities are what they had learned from the technology transferred from abroad and the 'mixed manufacturing system'. There was still a weakness in the manufacture of the steam generation system - the hard core of nuclear fission. The clearest proof of this technological ceiling is that a Spanish commercial reactor was never designed or manufactured. In other words, through the strategy followed by Spanish companies and government to deal with the U.S., French and German nuclear manufacturers, Spain managed to develop from the scratch the 'ability to use' but did not achieve the 'ability to produce technology'. However, at least the service engineering companies embarked on a path of internationalization and Spaniards occupied positions of responsibility in the multilateral nuclear organisms.

Notes

1. EXIM: Eximbank Programmes in Support of Nuclear Power Projects, Box J11, Folder 2347.
2. The details can be found at the NUCLEUS database of the International Atomic Energy Agency at https://www.iaea.org/resources/nucleus-information-resources. If we extend the analysis to all reactors connected by 2013 no country has ever imported and connected more than three different types of reactors and only China has imported reactors from four different countries (Canada, France, Russia and the U.S.). India is the only other country in the world to have imported three different nuclear technologies (BWR, PWR, PHWR) from three different countries (USA, Germany and Canada). The manufacturing countries experimented with larger number of reactors: Germany built six different types of reactors while in the U.S. five different technologies can be found among the connected reactors.
3. AHBE, IEME, Secretaría, Box 133.
4. NAUK, Foreign and Commomwealth Office [FCO], 91820. The Spanish policy-makers expressed to British delegation that they 'are not interested in the purchase on a turnkey basis' and were 'anxious to rationalize their power programme'. Report October 1968.
5. ASEPI, Ensa, Presidencia, Box. 9516. UEM Council minutes, May 1969. About the industrial policy of the INI at this stage, Martín-Aceña and Comín (1991, pp. 331–333). Before a policy-maker, the engineer López de Letona was an entrepreneur. In 1957 he founded Dimetal, with patents from Westinghouse Brake & Signal Ltd. In 1966 he acceded to the INI Council and was responsible for the industrial policy of the Development Plans. AGUN, ES 3121, Fondo López de Letona.
6. ASEPI, Ensa Presidencia, Box. 5210.
7. ASEPI, Enusa, Box 26, vol. 71 and Box 221.Under study since 1969, ENUSA was stablished in 1972 in order to centralize uranium mining activities, the production of uranium concentrates, the manufacture of fuel elements and the outsourcing and diversification of enrichment services. Industrial enrichment within Spain was ruled out early on due to its high financial and technological costs (both in centrifugation and in gas diffusion).
8. Tecnatom (2007); Álvaro et al. (2018). ASEPI, Auxini, Box 1706.
9. Boletín Oficial del Estado, Decree 2182/1974, of July 20, by which Decree 2472/1967 is modified and Decree-Law 7/1967 is developed on the granting of tariff bonuses for the importation of goods destined to the manufacture of capital goods.
10. The original members of what came to be known as the European Communities were the Inner Six: Belgium, France, Italy, Luxembourg, the Netherlands, and West Germany.
11. For instance, 'the two biggest Spanish manufacturers of electrical equipment Cenemesa and GE Española are controlled by Westinghouse and GE' as major shareholders. NAUK, FCO 91820, Report by British Nuclear Board in July 1968. It was the same case of Siemens in the Badalona thermal plants in 1957. Siemens Archives [SM] 54 Li/319. KWU Reports 1980 and 1981, *Siemens in Spanien*.

12. NAU, AB, 61105, Meeting at UKEA with MacVeigh (1959), AB 38280, Meeting UKEA and Tecnatom staff (1967). ASEPI, Box 4898, Minutes of the Board of UEM (1971). See also Romero de Pablos (2019).
13. ASEPI, Enusa, Box 71. NAU, FCO BOX 55299, Meeting at UKEA, July 1969. See also Ortega (1975) and Romero de Pablos (2019).
14. See Generallandesarchiv Karlsruhe [GLA]Abt, 69 KfK Nr. 455 Wirtz, Karl. Besuch der spanischen Delegation am 8. Juli 1969. ASEPI Speech by the president to the shareholders on the exercise of 1971.20.05.1972. Memorandum of the Unión Eléctrica meeting held 14 November 1972. Box 5048. Politisches Archiv des Auswärtigen Amts [PA AA] PAAA B 72 129507 Westdeutsche Landesbank Girozentrale an den Chef des Protokolls (Auswärtiges Amt) Düsseldorf den 4. Februar 1981.
15. From the newspaper *La Vanguardia* (several years) and Fábregas (2014).
16. Regarding the Vandellós I NP, the negotiation processes can be followed in the Archives Historiques d'EDF-Blois (boxes 890521 and 890522), original contracts are preserved in the Archivo General de la Administración, Alcalá de Henares-Madrid (Industry, boxes 71/8588 to 71/8592), and the evolution of the construction work is textually and graphically described in the *Bulletins of HIFRENSA*, numbers 1 to 13, 1968–1972.
17. In fact, this was recognized by the nuclear sector until its closure in 2006. Being the smallest plant that was built and the first in which equipment was tested, the consortium of the electric companies used Zorita as a continuous training school. Pomar & Sastre (2006) and NAUK, AB 38763, Report Decembar 1973.
18. In France Chinon 3 (400 MW), Saint-Laurent-des-Eaux I (460 MW) were connected in 1966 and 1969. Saint-Laurent-des-Eaux I (512 MW), y Bugey I (540 MW) entered in operation in 1971 y 1972. The four fueled with natural uranium.
19. ASEPI, Box 5550. Minutes of the administrative council of Unión Eléctrica 28.11.1975. KfW Historisches Konzernarchiv 3042/1Exportkredit Unión Eléctrica S.A. (Madrid) Nr. IV/22a.,Nr.IV/22b. Kreditbewilliungsausschusssitzung am 18.11.1975. Historisches Konzernarchiv-KfW -. Charlottestraβe 33/33a, Berlin (Germany).
20. ASEPI, Ensa, Annual Reports, 1972–1989.
21. In fact this supply business to German and Argentine plants reached 80 pr cent of Ensa's turnover in 1983. PAAA B/72 129507 Fernschreiben aus Madrid 13.04.1983. Auswärtiges Amt (Brunner). Hier: Deutsch-spanische Kooperation im Kernenergiebereich. B 72/129507. Betr: KWU-Kernkraftwerksprojekte in Spanien.
22. Radkau (1990). In 1982 the agreement with General Electric was renewed, replacing the old AEG from 1964 that the KWU had inherited in 1973. It was an agreement for the exchange of information on reactor technology, fuel and services. The agreement with Combustion Engineering was from 1972 to 1982 and was extended that same year until 1992.Or, in 1976 Westinghouse, CEA, Framatome and EDF signed a cooperation agreement that was renewed in 1982. Siemens Archives 54 Li/319. KWU-Report April 1983 Nr 38. *Brückenschlag in die Zukunft*, pag. 9–10. KWU-Report 1982 *Weitere Kooperation mit GE und CE* Oktober nº 37; and *Informationen von Kernkraftwerkmarkt 15.1.1982*
23. Between 1970 and 1978 the Nuclear Regulatory Commission multiplied by 15 the control items in each nuclear power plant. Buchwald (1979), p.208.
24. Burr (2014).
25. He was a big expert of the sector. Mechanical Engineer at Foster Wheeler Cº, from 1958 he joined as technical director in the Atomic Department of WESCO. In 1966 he was named general manager of PWR systems division, in 1971 appointed general manager and in 1978 vice president for nuclear energy systems.
26. LASHHC, Westinghouse Electric Corp, Series X, Box 141, WENS Bulletin, 170.
27. French ambassador expressed to Americans if it would be posible to restrict the flow of technical knowledge. NSA, U.S. Embassy Paris telegram 28641 to Department of State, 'French view on Coordination of Nuclear Export Policy', 29 November 1974. Secret. More details of French nuclear exports in Dänzel-Kantof and Torres (2013).
28. Many nations with nuclear power programmes need assured access to uranium, enrichment and spent fuel storage services, reactors and components, and cooperation on dealing with

the problems of nuclear power (e.g. reactor safety, spent fuel storage, waste disposal). 'You did not wish to interfere with the nuclear programs of countries like UK France, FRG, and Japan that have special energy needs'. NSA, Memorandum for The President from Cyrus Vance, Nonproliferation Strategy for 1980 and Beyond, February 1980.

29. 'Since all of the prior contracts involve NPT or equivalent advanced countries (we are hopeful Spain will assume such non-proliferation obligations) and reprocessing in the UK or France, we should remove this torn in our relations'. Ibid
30. NSA, Department of State Report about the 'Dirty Dozen', Broadening Our Approach to Non-Proliferation. The countries included are Argentina, Brazil, China, Egypt, India, Iran, Israel, Pakistan, South Africa, South Korea and Spain. 04 Assitant Secretary of State for Politico-Military Affairs, 17 March 1978.
31. Pascual (1998, p. 20). According to WESCO, the nuclear equipment manufactured in Spain for Almaraz I NP reached 22 per cent of the total. LASHHC, Box 142, WENS Bulletin 101, July 1981.

Disclosure statement

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Notes on contributor

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