NUCLEAR FUSION: THE POLITICAL ECONOMY OF TECHNOLOGY IN FRANCE AND GERMANY

by
Kim O'Neil

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Director: Professor Jeanne Laux

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ABBREVIATIONS

AEE	Agence pour les économies d'énergie
AEG	Allgemeine Elektrizitätsgesellschaft
AFME	Agence française pour la maîtrise de l'énergie
AGF	Arbeitsgemeinschaft der Grossforschungseinrichtungen
Andra	Agence nationale pour la gestion des déchets radioactifs
BMFT	Bundesministerium für Forschung und Technologie
BWR	Boiling Water Reactor
CCFP	Consultative Committee for the Fusion Programme
CEA	Commissariat à l'énergie atomique
DEMO	Demonstration Reactor
DM	Deutsche Mark
EC	European Community
ECSC	European Coal and Steel Community
EdF	Electricité de France
EEC	European Economic Community
EFR	European Fast Reactor
Euratom	European Atomic Energy Community
FBR	Fast Breeder Reactor
FhG	Fraunhofer Gesellschaft
HTR	High-Temperature Reactor
ICT	Information and Communication Technologies
Interatom	Internationale Atomreaktorbau GmbH
IPP	Max-Planck-Institut für Plasmaphysik
IT	Information Technology
ITER (CDA)	International Thermonuclear Reactor (Conceptual Design Activities)
JET	Joint European Torus
JRC	Joint Research Centre
KfK	Kerforschungszentrum Karlsruhe GmbH (Karlsruhe Nuclear Research Centre)
KWU	Kraftwerk Union
LMFBR	Liquid Metal-Cooled Fast Breeder Reactor
LWR	Light Water Reactor
MF	Millions de Francs
MOF	Ministry of Finance
MWe	Megawatts
NET	Next European Torus
NPI	Nuclear Power International
PWR	Pressurized Water Reactor
R&D	Research and Development
SERENA	Société europeéenne pour la promotion des systèmes de réacteurs rapides au sodium
SNR	Schneller Natriumgekühlter Reactor
THTR	Thorium-Hochtemperaturreaktor

CHAPTER ONE

INTRODUCTION

After the nuclear boom of the early 1970s, a general downturn of the nuclear industry began in the mid/late 1970s. The reasons for such a downturn are multifold and usually centre on considerations of energy pricing and resource economics. The downturn may also be attributable to miscalculations in terms of energy forecasting, whereby the predictions of the 1970s exceeded the realities of the 1980s. The decreasing price of oil in the 1980s and the continued abundance of available uranium resources, also, to a certain extent, called into question advanced nuclear technology, such as fast breeder reactors (FBR), which are considered to be more fuel (uranium) efficient than Light Water Reactors (LWR).

This thesis argues, however, that political and technical difficulties, as they relate to the commercial nuclear fission-based industry, have been central to the nuclear industry's woes. Despite the fact that industrialized countries, such as France and Germany, have reacted at the national and international levels, in an effort to resolve problems such as radioactive waste disposal and reactor safety, technical and political difficulties due to the complexity of nuclear technology and public opposition to nuclear power have continued to plague the nuclear industry. At the same time, however, as the nuclear industry suffered from technical uncertainties and was a target of public opposition, governments became increasingly involved in the industry, especially in research and development (R&D), as of the 1970s and 1980s. One of the purposes of this thesis is to explain this apparent contradiction, i.e. on the one hand, a failing industry, and on the other hand, the increased willingness on the part of governments and firms to implicate themselves politically, financially and technologically, through new industry-government relations and international collaboration.

1.1 The Main Argument Presented

The central argument of the thesis is as follows: The continued support for the nuclear industry, despite political opposition and technical difficulties regarding nuclear fission, centres on nuclear fusion, a fundamentally different type of nuclear energy. Nuclear fusion R&D not only aims at offering a long-term alternative to nuclear fission but is compatible with new industry-government strategies of international cooperation and integration. These strategies take the form of joint ventures and co-financing and have become central to competitiveness in the global economy. Two main hypotheses follow from this argument: (1) nuclear fusion, based on the assumption that it will provide a commercially viable source of energy, represents a long-term alternative strategy of an industry forced to innovate, in response to political and technical obstacles relating to nuclear fission, and (2) in an industry which has come to rely increasingly on government financing due to high capital costs and financial risk associated with long-term research, nuclear fusion reinforces trends toward international cooperation and integration, corresponding to new industry-government strategies in the area of high technology.

The considerations leading to the first hypothesis begin with an observation that the nuclear fission-based industry evolved on the premise that technology would be perfected to cope with inevitable challenges, such as effective radioactive waste management, reactor safety and decommissioning. The industry, however, has been unable to solve many of the problems associated with these activities. In view of such technical difficulties, as well as public opposition to nuclear power in the 1970s and 1980s, the nuclear industry has been forced to pursue alternative strategies in order to ensure the industry's viability. These strategies include the promotion of nuclear fusion. Nuclear fusion is considered to be a safer form of energy because it produces substantially less radioactive waste than fission. As well, if a sustained nuclear fusion chain reaction were achieved (this is one of the goals of basic R&D in the industry at present), fusion could offer a potentially limitless source of energy. Nuclear fusion, thus, would appear more acceptable to the public than nuclear fission.

Regarding the second hypothesis, as of the 1970s, the industry has turned to several advanced technologies, including the FBR and nuclear fusion, the latter being pursued for commercial purposes exclusively at the international level. In the case of the two national industries which will receive special attention in this study, namely France and Germany, cooperation between government and industry at the European level, begun in the 1970s and intensified thereafter, was deemed necessary due to the high capital costs and the risk factor, in terms of the uncertainty of long-term financial returns. New forms of industry-government relations, such as strategic partnering involving knowledge exchanges, have become typical, as governments in the advanced industrial economies react to increasing competition, especially in the high technology sectors, and to the global restructuring of industries.

The thesis does not attempt to explore the wisdom, in terms of social costs and benefits, of the pursuit of nuclear fusion, but rather examines alternatives open to an industry in difficulty and shows how nuclear fusion corresponds to new industrial strategies in the globalization process of the international economy. In order to maximize their technological potentials, government policies in most OECD member countries changed from the predominantly national champion-based, neo-mercantilist approach of the 1960s to greater emphasis on international collaboration as of the 1980s and 1990s. R&D has become a central pillar of policy in high technology sectors and integral to the concept of competitiveness.

Those concepts central to the hypothesis need to be elaborated.

The term "nuclear fusion" is short for thermonuclear fusion, a type of nuclear reaction in which two light nuclei, such as deuterium and tritium, fuse together to form a heavier nucleus. In this process a large amount of energy is released. Fusion reactions are only possible at exceedingly high temperatures. In contrast, nuclear fission is a process whereby a nucleus is split into two parts, including several free neutrons, and gives off large amounts of energy in the form of gamma radiation and heat. Fission occurs spontaneously in certain heavy elements, but in a chain reaction it occurs when a fissile nucleus absorbs a neutron.[1]

"Alternative strategies" are activities by governments and firms in order to ensure or enhance the viability of the nuclear industry. Such strategies are characterized by (i) industrial innovation in the form of R&D activities aimed at improving existing nuclear technology or introducing new technology, which includes the promotion of alternative energy sources, in particular, in the context of this thesis, nuclear fusion, (ii) new industry-government relations characterized by knowledge-sharing, an increased role on the part of governments, on the national and international levels, as well as, in some cases, (iii) new marketing arrangements. Such strategies are aimed at optimizing a firm's or country's competitiveness in the international economy.

The nuclear industry, in the large sense, encompasses a wide range of activities, including reactor engineering and manufacturing, fuel cycle, utilities operation, defense materials production[2], radiation technology and R&D[3], the latter being the main focus of this thesis. In the context of the European Community (EC) Framework programme[4], basic industrial R&D is focused on the development of industrial technology, which describes the current development stage of nuclear fusion.[5]

For the purposes of the thesis, the actors central to the nuclear industry are both state and private sector actors. We identify those government decision-makers who, for the most part, are responsible for policy-making and the corresponding agencies and firms (state-owned or private), which are primarily executors of technology policy, but in some cases, are also part of the decision-making process.

In France, these actors include the President, the Prime Minister and the Ministers of Industry and Finance at the governmental level and the state agency, Commissariat à l'énergie atomique (CEA), the state-owned Électricité de France (EdF) and Framatome, a partially state-owned company.

In Germany, governmental actors include the Ministry for Research and Technology, the Economics Ministry, the Ministry of the Interior and the Länder (federal state) governments, as well as Siemens/Kraftwerk Union, a private firm established in 1977 and private utilities, such as the Rheinsiche-Westphälische Elektrizitätswerke (RWE), Vereinigte Elektrizitätswerke Westfalen AG (VEW).

Political and technical obstacles are factors directly affecting the nuclear industry which influence both its public acceptability and technological evolution. Political obstacles refer to public opposition in the form of protests and overt opposition to nuclear power and government policy. Technical obstacles signify problems of a technical nature related to nuclear fission.

International cooperation reflects inter-nation collaboration, joint ventures and agreements in the high technology sector and include new forms of exchanges, such as strategic partnering.

The thesis undertakes a comparative case study across time, from 1970 to 1992, of public policy, as it relates to the nuclear industry in France and Germany. France and Germany have been selected as advanced industrial countries with a major role in the world nuclear industry, which have fundamentally different state systems, i.e. policy traditions, institutions and rules and norms.

Yet, despite their different state systems, in both countries government support of the nuclear industry has remained crucial and both have chosen to reinvigorate the nuclear industry through R&D to advance the nuclear fusion option.

Although the thesis centres on one industry and is often somewhat technical, in terms of the social sciences, its topic is in fact central to current themes in International Political Economy (IPE) literature, such as the internationalization of the economy, global industrial restructuring, strategic partnering and the role of government in fostering competitiveness. Such themes, which have been developed by political economists from the United States, Europe and Canada, will be recalled here by reference to the work of Krugman, Michalet and Mytelka.

Strategic trade theorist, Paul Krugman, suggests that as of the 1970s, traditional theories of comparative advantage have been challenged by the emergence of specialized, knowledge-intensive sectors, where trade based on classical assumptions, i.e. that each country has unique advantages, in terms of climate, culture, skills, etc., in comparison to other countries, bears little relevance to the current competitive reality.[6] Instead, Krugman highlights international specialization, behind which technology would appear to be the driving force, and innovative industrial organization, aimed at optimizing an actor's potential on global markets, as being key factors in the new international economics.[7]

Charles-Albert Michalet, French author of a classic text on the world economy, underscores the internationalization of finance, capital, production and technology in order to show how firms now create value-added through new forms of investment and strategies which assume a single global economy rather than a set of national economies.[8] In his discussion concerning multinational corporations, Michalet contends that the decentralization of production beyond the boundaries of the nation-state have significant repercussions in the international economy. Such decentralization, he argues, leads to the "opening" of economies and has a profound influence on traditional forms of trade and the circulation of capital.[9]

Among the new strategies of the 1970s and 1980s and, of particular interest to this study, is strategic partnering, which is well analyzed by Lynn Mytelka. Here, agreements are made among independent firms. They involve knowledge-production or the sharing of activities in the context of new production processes or in the management of inter-firm contractual relationships, for example, and sometimes, when the future competitive position of the firm can be improved, long-term planning.[10] Mytelka's notions are similar to the Harvard business economist, Michael Porter, who considers strategic investments to be those which may affect the underlying structural traits of an industry which determine profitability.[11]

Our focus on a high technology industry to understand changing public policy follows an established tradition. There exists, as Henry Nau, author of National Politics and International Technology, attests, an intimate relationship between politics and technology.[12] The thesis examines this interdependent relationship by looking at the central role of R&D in the nuclear industry. As technology and "knowledge generated by firms through R&D and experience" now appear to be a driving force of competitiveness[13], it is not surprising that governments are assigning higher priorities to R&D, thus explaining, in part, the apparent contradiction we noted at the outset, between the failing nuclear industry and increased government support for it. These trends are not restricted to the nuclear industry but also apply to other high technology sectors, such as Information and Communication Technologies (ICT). A detailed analysis of one high technology, nuclear fusion, in the context of the nuclear industry, as presented in this thesis, may thus contribute insights to students of comparative public policy and international political economy.

1.2 Background to the Nuclear Industry

The nuclear industry has its roots in military history. The nuclear industry began as an offshoot of submarine nuclear technology and, of course, proved its awesome potential in the bombing of Hiroshima and Nagasaki in 1945.[14] From its inception, however, the nuclear industry has also represented an area of basic

R&D. Interest in nuclear fusion in the late 1920s, as a potential source of energy, actually predates nuclear fission by approximately ten years.[15] Due to the technological complexity of harnessing fusion energy through extraordinarily high temperatures, however, the prospects of nuclear fusion could only be considered a long-term goal.[16] In view of the preceding, at the fourth United Nations Geneva Conference (1971) on the peaceful use of nuclear energy, it was decided that the industry would have to promote nuclear fission, until such time as nuclear fusion could be harnessed.[17]

The real shift from a primarily military-based industry to a civilian one occurred in the 1950s, when the United States and other nations were concerned about intense competition in the area of nuclear weapons in the context of the Cold War.[18] President Dwight Eisenhower decided that the United States could make initiatives that might lead to more stable relationships, based on common ground with the Soviet Union.[19] This in turn led to Eisenhower's Atoms for Peace programme (1953) and a greater emphasis on cooperation in the area of atomic energy.[20] As well, Eisenhower's Atoms for Peace address and amendments to the "McMahon law"[21] permitted the Federal Republic of Germany to participate in the development of atomic energy for peaceful purposes[22], thereby avoiding any independent revival of German military technological capability.

In western Europe, despite the creation of Euratom, the European Atomic Energy Community, throughout the 1950s and 1960s, little collaboration in nuclear R&D took place between EC members, in part due to the predominantly neo-mercantilist tendencies of many nation-states, that is, each sought to develop competitive technologies on a national basis. As well, this absence of cooperation may be explained by the sensitivity of the technologies concerned and their military applications.

A milestone in the history of the nuclear industry occurred in 1969 at the Kurchatov Institute in Moscow, when a team of scientists from the nuclear fusion research laboratory in Culham, England, was invited to verify results the Russians were allegedly obtaining from an experimental tokamak[23], a nuclear fusion prototype, the T3. Toward the end of the year, the Russian claims were confirmed, i.e. temperatures of up to ten million degrees were recorded over times of one tenth of a second, thus representing a breakthrough in nuclear fusion R&D. It changed fusion activities in the world virtually overnight.[24] Discussion soon followed between Britain and the Continent regarding ways of achieving collaboration in nuclear fusion R&D.[25] The first international conference on fusion reactors, held at Britain's Culham Laboratory in September 1969, is traditionally recognized by the scientific community "as marking the beginning of sustained and serious interest in fusion reactor design studies"[26].

France was one of the first countries to react to the Russian tokamak results and plans were made by government and industry to build two tokamaks, namely TFR (1973) at Fontenay-aux-Roses and later, TORE SUPRA (1986).[27] In Germany, the IPP (Max-Planck-Institut für Plasmaphysik) launched PULSATOR, a tokamak project which represented a refined version of the T3.[28] In 1981, Germany also pioneered TEXTOR, an experimental tokamak.

The oil crisis (1973) would add further stimulus to the nuclear energy industry. The expansion of commercial nuclear fission came about as a direct result of the concern of industrialized countries (especially nations in Europe and Japan) regarding their dependence on Middle Eastern sources of oil, 62 per cent of which the known reserves are allegedly located under the Persian Gulf.[29] As John Clarke notes, "[l]ong-term energy supply is an issue that scientists and engineers are concerned with and that politicians can also appreciate..."[30]

By the late 1970s, a view prevailed that, in the long-term, energy supply would be dependent upon one or more of the essentially inexhaustible energy sources, such as nuclear energy, especially fission by breeding and fusion.[31] The oil crisis not only contributed to the launching of a global commercial nuclear fission industry but, as well, provided an impetus for R&D in the area of nuclear fusion.[32] As a result, tokamaks were built in many national laboratories. The Joint European Torus (JET), a collaborative European programme toward a nuclear fusion prototype, which will be central to our analysis, was ratified in 1978. It includes a second and third phase, Next European Torus (NET) and Demonstration Reactor (DEMO), respectively. Over and above the inter-European effort in nuclear fusion, the Reagan-Gorbachev Summit of November 1985 gave political stimulus to international cooperation in fusion, which led, in April 1988, to the International Thermonuclear Reactor (ITER).[33] ITER has the overall objective of demonstrating the scientific and technological feasibility of fusion power.[34]

France and Germany, chosen as the national case studies for the thesis, play a critical role in the nuclear industry and need some elaboration in this introductory chapter.

France is one of the few countries in the world which has committed itself to nuclear fission as a main source of commercial energy. After having developed an independent nuclear strike capability for national defence in the 1960s, one of the underlying reasons for France's pursuit of nuclear fission in the early 1970s was its lack of fossil fuel resources (with the exception of uranium reserves) and its dependence on foreign sources of oil, primarily from the Middle East. Approximately 70 per cent of France's electricity is generated by nuclear power (1989/90).[35] France is involved in all phases of the nuclear fuel cycle and is also a major international exporter of energy to the United

Kingdom, Belgium, Germany, Switzerland, Italy and Spain.[36] In 1990, EdF exported approximately 46 billion kilowatts per hour (kWh) to neighbouring European countries.[37] France has conducted R&D in the area of nuclear fusion as of 1959. As indicated, the CEA, France's state-owned nuclear agency, pioneered TFR and TORE SUPRA (the latter being the first superconductor in the world), and is a key player in JET.

Germany launched its commercial nuclear industry for reasons similar to France, i.e. energy security. Excluded, due to its defeat in World War II, from any national military programme, Germany gained much of its technological know-how through the Atoms for Peace policy from the United States. In less than fifteen years, however, after nuclear energy had been introduced in Germany, German industry was in a position to compete world-wide, becoming independent from its original licensors.[38] Approximately 31 to 32 per cent of Germany's electricity is generated by nuclear power (1989/90).[39] Germany is a key actor in terms of nuclear R&D and has reputed research centres in Garching (IPP), Jülich and Karlsruhe and hosts research activities regarding ITER at the IPP.

Finally, given the premise of the first hypothesis, that nuclear fusion may be seen as a safer form of potential, long-term, commercial energy, in relation to fission, a few remarks on this technology are needed. Nuclear fusion entails the fusion of deuterium with tritium. Unlike radioactive uranium used in nuclear fission, deuterium for fusion occurs naturally in the form of "heavy water" from the sea, the amounts of which are considerably greater than those of uranium or thorium used in commercial nuclear fission.[40] A recent Report issued by the European Commission on Energy, Research and Technology (1991), highlights the differences between nuclear fission and fusion, such as the energy potential represented by nuclear fusion and its relatively minimal radioactive waste by-products, i.e. approximately one to two times less than in a fission reactor.[41] At the same time, however, the report underscores concerns with respect to nuclear fusion, such as its engineering feasibility, environmental impact and the significant amounts of money being spent on R&D in the area, as opposed to other energy alternatives.[42] Yet, one would presume that nuclear fusion is safer.

The choice to invest in R&D to support nuclear fusion involves other considerations besides safety, in the view of the industry itself. A persuasive explanation of technology choice is advanced by H. Frewer, a former Member of the Board of the Kraftwerk Union (KWU), Germany's nuclear giant, prior to its merger with Siemens. In terms of the relationship between the political and technical dimensions of the nuclear industry, Frewer contends that the long-term viability of the nuclear industry has mainly depended on improved energy efficiency, maximization of capital costs, increased reliability and safety, and enhanced public acceptability.[43] Each successive phase of nuclear technology builds on the experience of the former, as more advanced systems are introduced. Frewer's analysis begins in the 1960s/70s with the prototype and demonstration plants of approximately 600 megawatts (MWe), and progresses through the first and second generations of nuclear reactors, which include the pressurized water reactor (PWR), the boiling water reactor (BWR), the heavy-water reactor (HWR) and the advanced gas reactor (AGR) (first generation) and, the advanced light water reactor (ALWR), the high-temperature reactor (HTR) and the European Fast Reactor (EFR) (second generation). The third generation includes nuclear fusion technology, expected to reach maturity only after 2030. Depending upon its scientific and engineering feasibility, fusion could, in Frewer's model, be part of the ongoing substitution process, in terms of offering more advanced technology.[44] For a graph indicating the cycles and possible sequences of development phases of nuclear power plants, see Figure 1.

1.3 Chapter Outline

The presentation of the problematic and the data used to examine the hypotheses take the following format:

Chapter One, after providing a general introduction to the thesis, gives the reader some background information on the evolution of the nuclear industry, including the inception of the commercial fission-based nuclear industry in France and Germany.

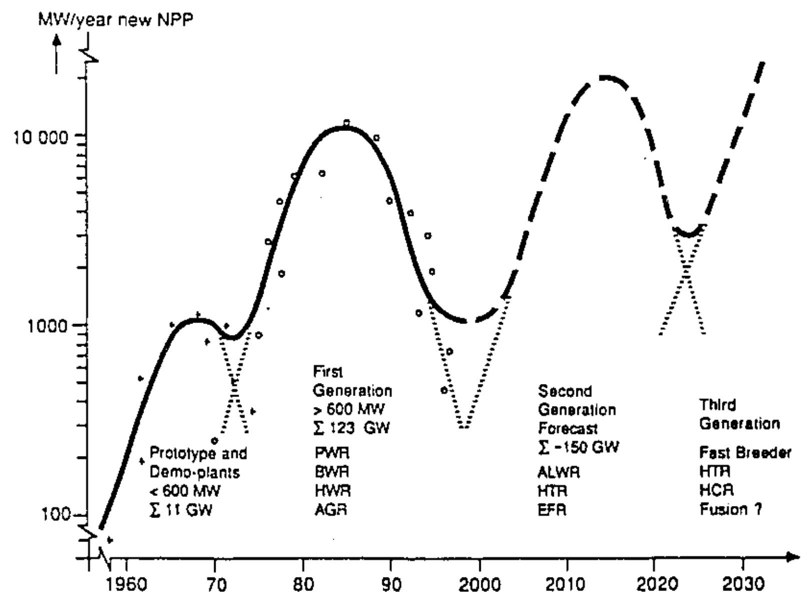

FIGURE 1

Current and Envisaged Development Phases of Nuclear Power Plant Technology in the European Community

Source: H. Frewer, "Future Challenge of Nuclear Power in the European Community," Nuclear Europe Worldscan (Journal of the European Nuclear Society), no. 1/2, January/February 1990, p. 72.

Chapter Two investigates the hypotheses by reference to the French state system and its impact on public policy, especially in light of public opposition to nuclear energy and technological constraints. Regarding the evaluation of the first hypothesis, we will first assess public opposition and then examine technical difficulties in France, relative to commercial nuclear fission. In this instance, industry and government responses, the latter in the form of official reactions and moves toward more "transparent" public policy, will be examined. As well, the improvement of existing nuclear technology and/or the introduction of more advanced systems will be investigated. With respect to the second hypothesis, by examining actions by firms and governments and official government statements, new priority areas, such as the salience of R&D and new industry-government arrangements, will be identified. In particular, the European Fusion Programme, a long-term cooperative project of member states of the EC in the field of nuclear fusion, including JET and NET, will be examined. The nuclear fusion option is presented as a more publicly acceptable alternative, in contrast to the commercial fission-based industry, and France's commitment to nuclear fusion, in terms of its support for R&D projects, is highlighted.

Chapter Three reexamines the hypotheses by reference to the German state system and follows a similar format to Chapter Two. As well, a similar methodology will be used to evaluate the two hypotheses. Despite the fundamental differences between the two state systems, the German case also highlights the central role of government vis-à-vis the industry and the thrust toward international cooperative and collaborative projects.

Chapter Four extends the analysis of the second hypothesis by examining the evolution of the shifts in French and German policy, away from the "national champion" approach by states in the 1950s and 1960s to European international collaboration as of the 1970s. A detailed explanation of the emergence of international R&D in the nuclear industry, as well as in other high technology sectors, draws on the work of Sharp, Krugman, Mytelka and others, in order to articulate the new criteria for industrial success in the global economy. The chapter then focuses on the European Fusion Programme.

Chapter Five summarizes the findings in the thesis as they relate to the two hypotheses. Based on these findings, some broader conclusions are drawn with respect to the role of the nation-state in the changing international political economy.

Chapter One Notes

1. Definitions adapted from "Nuclear Definitions," Ontario Hydro, Toronto (sheet).

2. Such is the case for some countries only, like France

3. Description based on the definition of "nuclear industry" in John F. Hogerton, The Atomic Energy Deskbook, New York, Reinhold Publishing, 1963, p. 338.

4. pluriannual programmes for designated periods in the context of the European Community

5. Aid Element of Government R&D Contracts, Report to the Commission of European Communities, Luxembourg, Office for Official Publications of the European Communities, 1991, p. 7.

6. Paul Krugman, "Introduction: New Thinking About Trade Policy," in Paul R. Krugman, ed., Strategic Trade Policy and the New International Economics, Cambridge (Mass.), MIT Press, second printing 1987 (1986), p. 7.

7. Ibid., pp. 8-9.

8. Charles-Albert Michalet, Le capitalisme mondial, 2nd ed., Paris, Presses universitaires de France, 1985.

9. Ibid., p. 11.

10. Lynn Krieger Mytelka, ed., Strategic Partnerships: States, Firms and International Cooperation, London, Pinter Publishers, 1991, p. 1.

11. M. E. Porter, Competitive Strategy: Techniques for Analyzing Industries and Competitors, New York, Free Press, 1980, and M. E. Porter and M. B. Fuller, "Coalitions and Global Strategies," in Michael E. Porter, ed., Competition in Global Industries, Boston, Harvard Business School Press, 1986, in Ibid., p. 2.

12. Henry Nau, National Politics and International Technology: Nuclear Reactor Development in Western Europe, Baltimore, Johns Hopkins University Press, 1974, pp. 9-39.

13. Krugman, "New Thinking About Trade Policy," p. 8.

14. Martin B. Zimmerman, "The Evolution of Civilian Nuclear Power," in Richard L. Gordon, Henry D. Jacoby and Martin B. Zimmerman, eds., Energy Markets and Regulation, Cambridge (Mass.)/London (England), MIT Press, 1987, p. 84.

15. Stanley Ernest Hunt, Fission, Fusion and the Energy Crisis, 2nd ed., Oxford/New York, Pergamon Press, 1980 (1973), p. 127.

16. Ibid., p. 127.

17. Karl Winnacker and Karl Wirtz, Atome: illusion ou miracle? L'énergie nucléaire en Allemagne, trans. by Marcel Chabernaud, Vendôme, Presses universitaires de France, 1975, p. 384.

18. John F. Clarke, "Future Directions in Fusion Research," Journal of Fusion Energy, vol. 7 (2/3), 1988, p. 197.

19. Ibid., 197.

20. Ibid., p. 197.

21. After World War II, the so-called "McMahon law" (American) outlined the legal conditions regarding the construction of nuclear power reactors for the peaceful use of nuclear energy (Winnacker and Wirtz, Atome: illusion ou miracle?, p. 53).

22. Ibid., p. 63.

23. The term "tokamak" is of Russian origin, signifies "current + chamber + magnetic field" and represents the basic design of a nuclear fusion prototype being pursued by the EC (E. N. Shaw, Europe's Experiment in Fusion: The JET Joint Undertaking, foreword by J. Teillac, Amsterdam, North-Holland, 1990, p. 13). In a nuclear fusion reactor, the fuel changes its state from a gas to plasma, which is in turn heated and confined away from the vessel walls by magnetic fields. The objective of a fusion reaction is to achieve "ignition", whereby the plasma is hot enough to become self-heating.

24. The above regarding the fusion breakthrough in 1969 is adapted from Shaw, Europe's Experiment, pp. 13-14.

25. Ibid., p. 14.

26. Joan Bromberg, Fusion: Science, Politics and the Invention of a New Energy Source, Cambridge (Mass.)/London (England), MIT, 1982, p. 181.

27. Shaw, Europe's Experiment, pp. 15 and 174-75. A principal concern with respect to TFR, however, was funding (Otto Keck, Policy-making in a Nuclear Programme: The Case of the West German Fast Breeder Reactor, foreword by Robert G. Gilpin, Jr., Lexington (Mass.)/Toronto, LexingtonBooks, 1981, p. 115).

28. Shaw, Europe's Experiment, p. 17.

29. Clarke, "Future Directions in Fusion Research," p. 195.

30. Ibid., p. 195.

31. W. Häfele, J. P. Holdren, G. Kessler and G. L. Kulcinski, Fusion and Fast Breeder Reactors, Laxenburg (Austria), International Institute for Applied Systems Analysis, revised ed. July 1977 (November 1976), p. 1.

32. Arthur Robinson, "L'Énergie de fusion," La Recherche, vol. 14 (142), March 1983, p. 411.

33. IAEA, "General Overview," Nuclear Fusion (30 Years of "Nuclear Fusion" Anniversary Issue), vol. 30 (9), September 1990, p. 1658.

34. K. Tomabechi, "International Thermonuclear Experimental Reactor (ITER)," Revue général nucléaire, no. 1, January/February 1991, p. 95.

35. Louis Pracht, ed., European Figures 1989/90, 2nd ed., foreword by the Rt Hon Sir Leon Brittan QC and Ray Mac Sharry, Luxembourg, Office for Official Publications of the European Communities, 1989, p. 22.

36. Electricité de France International, Annual Report, Paris, 1990, p. 13.

37. Ibid., p. 13.

38. Wolf-J. Schmidt-Küster, "German Nuclear Energy Development and International Cooperation," in Joseph F. Pilat, Robert E. Pendley and Charles K. Ebinger, eds., Atoms for Peace: An Analysis After Thirty Years, Boulder, Westview Press, 1985, p. 103.

39. Pracht, ed., European Figures, p. 22. In the United Kingdom, this figure is about 17 per cent (Ibid., p. 22).

40. Hunt, Fission, Fusion and the Energy Crisis, pp. 127-28.

41. Rolf Linkohr (Rapporteur), Communautés européennes, Parlement européen, documents de séance, "Rapport de la commission de l'énergie, de la recherche et de la technologie," November 8, 1991, pp. 30-31. For a detailed account of nuclear fusion, in relation to fission, and the disadvantages regarding fusion, please refer to Ibid., pp. 30-32.

42. For example, the International Energy Agency (IEA) in Paris spent 900 million U.S. dollars on fusion R&D, as opposed to 157.6 million U.S. dollars on photovoltaic systems (1990). If one considers the EC R&D programme, its budget contributes more than 200 million ecus to fusion, as opposed to 4 to 6 million ecus to photovoltaic systems. Europe has spent approximately 4.7 billion

U.S. dollars on fusion R&D. This figure will be in the order of 40 billion U.S. before a reactor will come on line, i.e. ca. 2050. Some 100 billion dollars will have been spent on nuclear fusion (Ibid., pp. 30-31).

43. See H. Frewer, "Future Challenge of Nuclear Power in the European Community," Nuclear Europe Worldscan (Journal of the European Nuclear Society), no. 1/2, January/February 1990, pp. 63-75

44. Ibid., p. 74.

CHAPTER TWO

THE FRENCH CASE STUDY

As indicated in Chapter One, the thesis undertakes a comparative case study across time, examining the evolution of the nuclear industry in France and Germany, in order to explain why governments in leading industrial democracies may opt to reinvest public funds and policy support for nuclear power, a highly contested industry. Although the two countries have very different histories with respect to the nuclear industry and relatively divergent state systems, especially as of the 1970s, both countries attach high priority to international R&D in terms of making nuclear energy and, in particular, nuclear fusion, a viable, long-term energy alternative.

Chapter Two provides background information to the French nuclear industry and describes the French state system, in terms of its policy traditions, institutions and rules and norms. In particular, it examines the first hypothesis, i.e. nuclear fusion represents a long-term alternative strategy of an industry forced to innovate, primarily in response to political and technical obstacles relating to nuclear fission. It does so by tracing the evolution of the nuclear industry as of the 1970s, highlighting public opposition and technical problems associated with commercial nuclear fission, which in turn leads the French government and industry to refine existing nuclear systems, while reinvigorating the nuclear fusion option.

The final section of this chapter then explains the second hypothesis, which postulates that primarily due to the high capital costs and financial risk associated with long-term research, undertaking nuclear fusion R&D favours international cooperation and integration, which correspond to new industry-government strategies in the area of high technology. Chapter Two examines French government policy preferences for international collaboration and strategic partnering.

2.1 The French Nuclear Industry

French nuclear policy in the late 1950s/1960s was primarily military-based and built around the concept of "force de frappe" (later known as "force de dissuasion"), which ensured France a nuclear military capability in the event of aggression. Interest in nuclear fusion R&D in France predated serious nuclear fission R&D by approximately a decade. In 1959, the state-owned agency, the CEA, entered into a joint agreement with Euratom in order to pursue research in the area of the tokamak design (see note 23 in Chapter 1).[1] During the 1960s/70s, parallel to de Gaulle's "force de frappe" policy, a series of civilian projects were launched[2], in areas which were deemed to represent future growth sectors, including nuclear energy, civilian aircraft, computers, semi-conductors, telecommunications equipment, machine tools and biotechnology.[3]

The promotion of these high technology areas was motivated, in part, by France's will to distance itself from the United States in terms of its military capability, develop its own advanced weapons system, as well as its desire for national prestige.[4] The government advocated the creation of "national champion" companies through mergers amongst the strongest domestic firms, otherwise, it was believed that the French industries would be unable to compete with their rivals, the United States and Japan.[5] The French government has promoted its "national champions" and emerging industries by direct subsidization from government ministries and loans from government-owned banks and financial institutions[6], for example, as well as control through state-owned companies.

The oil crisis of 1973 had a major impact on French energy policy. In view of the crisis, political and military independence were perceived to be threatened. Given its dependence on Middle Eastern oil resources, France decided to pursue a policy whereby its energy self-sufficiency would be assured. The French nuclear programme, begun under the Pompidou government, was continued and reached a peak during the presidency of Giscard d'Estaing, who was actively involved in energy policy, especially in the area of nuclear power.[7] During the presidency of Giscard d'Estaing (1974-1981), the official rhetoric was the liberalization of the economy through the elimination [or restructuring] of uneconomical and inefficient programmes.[8] What actually happened, however, was a redistribution of the relative importance of programmes managed by government.[9] The conservative government of Giscard and his Prime Minister, Pierre Messmer, promoted the Messmer Plan (1974), the objective of which was to increase the share of nuclear energy in France's energy supply, as well as achieve the technical mastery of the fuel cycle on a national level.[10]

Nuclear energy was an area in which France intended to strengthen its world position over the United States and Japan. "When forced to choose between a variety of broader economic considerations which policy-makers in other nations often took very seriously, the French authorities opted consistently for industrial growth."[11] In this endeavour, France saw three main advantages to developing its nuclear industry: (1) the prospects of cheaper electricity for France, (2) nuclear technology development was expected to bring important technological breakthroughs for industrial programmes, and (3) the prospects of exporting electricity, which was expected to contribute positively to the trade balance.[12] Transition phase - sectoral policy thus fits into the broader objective of French economic policy at the service of global competition.

If nuclear energy remained a priority area for government in the 1970s, President Mitterrand's 1981 election campaign based on the Socialist Manifesto, "though not advocating the abandonment of the nuclear option, appeared to place less emphasis on nuclear power in the total energy mix"[13]. The advent of the Socialists to power, however, did not alter the nuclear programme significantly. Their policies (similar to those of Helmut Schmidt's government in Germany) highlighted modernization along with the internationalization of capital and the restructuring of production, especially in potential growth sectors of the economy.[14]

Throughout the evolution of the French nuclear industry, as in other areas of national policy, France has demonstrated a desire to maintain a significant degree of sovereignty in its pursuits. With respect to the quest for national independence, it may be assumed that all sovereign states exercise the prerogative, albeit to differing degrees, but this is an explicit norm of policy-making in France. It is acknowledged that one of the main official reasons for France's involvement in the nuclear industry is its quest for national independence, whether for military security or in terms of its energy supply.

2.2 The French State System

In the comparative politics literature dealing with the advanced industrialized countries, France is typically seen as being a centralized system, in terms of its institutions and policy-making process.[15]

Unlike Germany, the French government has a long tradition of direct intervention in the economy, especially with respect to the promotion of new industries.[16] In the post-war era, the state played a key role in developing strategies for specific industrial sectors and, further, applied considerable pressure on firms to comply with these strategies.[17] Such was the case with the creation of "national champions" in key sectors of the economy in the 1970s.[18]

The French state system is a highly integrated one which demonstrates a significant degree of collaboration among its institutions. John Zysman attributes the continuity in French industrial policy to the financial sector, due to its allegiance with government and business and its capacity for intervention. In particular, he underscores "the character of the bureaucracy, its relations to various groups in society, and the political balance"[19]. In his discussion about the financial system in relation to other institutions in France, he highlights the role of the elite civil service, a relatively independent political executive beyond the scrutiny and control of the legislative and the ministerial cabinet system. This exclusive group includes elite bureaucrats, political advisers and outside experts, thus allowing a high degree of central control.[20] As Peter Hall notes,

> ...[A]s part of a deliberate strategy formulated by the ruling elites immediately after the war and designed to turn the state into an agency fostering socioeconomic change, a set of institutions was imbedded within the French state for the purpose of inculcating its personnel with the notion that they were to be the grand strategies for the French economy and industry.[21]

Most of the engineers at the CEA, for example, are graduates of the Corps des Mines and, at the EdF, graduates of the Corps des Ponts et Chaussées.[22] In this way, "the French state gave its personnel a capacity to influence the activities of industry and a willingness to do so"[23]. This is in contrast to Germany, where state intervention has traditionally been limited and where, given the close relationship between finance and capital, the big German banks (i.e. Deutsche, Dresdner and Commerz) have a predominant influence on industrial policy.[24] The French state system allows for political cohesiveness unlike in Germany, where the policy process is much more decentralized.

In France, the main actors responsible for policy directives are the President, the Prime Minister and the Industry and Finance Ministries.[25] The National Assembly, by contrast, has traditionally had little influence on policy.[26]

The Ministry of Finance (MOF) plays a leading role in economic policy-making involving the allocation of public funds.[27] The French financial system is credit-based and characterized by a high degree of intervention by the central government. The MOF and the

Trésor, within the MOF, are responsible for most long-term loans to industry, in conjunction with para-public and long-term credit agencies, such as the Crédit National and the publically-owned banks, like the Banque Nationale de Paris.[28] Funds for the expansion of the electricity system "can come from new capital given by the state to the EDF, from authorization to borrow domestically or abroad, or from letting EDF increase its cash flow through higher rates"[29]. In Europe, French industry has traditionally had one of the highest debt-equity ratios.[30]

Organizations which carry out policy include the government agencies, CEA and EdF, and the industrial groups Framatome and Novatome.[31] The CEA, established in 1945, is "a government-owned body of a scientific, technical, and industrial character", mandated to promote the use of nuclear energy for civilian or military purposes[32] and carries out nuclear R&D and industrial development in these areas.[33] Most of its activities are in basic research and R&D in the area of new reactor lines and military applications of nuclear technology.[34] The CEA originally had a single, unified structure, however, in the 1970s began to form subsidiaries which became part of a new entity, CEA Industrie, established in December 1983.[35] One of the most important of the CEA's subsidiaries is the "Compagnie générale des matières nucléaires" (Cogéma), owned 100 per cent by the CEA and responsible for the commercialization of the nuclear fuel cycle.[36]

Technicatome, responsible for the engineering of advanced projects, is 90 per cent owned by the CEA and 10 per cent by the EdF.[37]

The EdF, created by a nationalization law in 1946, "is the national electricity authority, a public establishment of an industrial and commercial character"[38], and has a monopoly on nuclear electricity supply in France.[39] It designs, owns and manages plants and produces most of France's electricity supply (90 per cent in 1986).[40] It also transports and distributes a significant amount of energy to neighbouring countries.

Framatome is owned to the extent of 52 per cent by Compagnie Générale d'Électricité (CGE)[41], which was privatized in 1987 by the Chirac administration, 35 per cent by the CEA, 10 per cent by the EdF, and 3 per cent by the employees of Framatome.[42] It has a monopoly on PWR technology and, in 1982, bought the Westinghouse reactor licence and now builds its own PWRs.[43] Framatome designs, constructs and supplies nuclear islands.[44] In particular, it undertakes activities in the areas of nuclear [technology], mechanics and computers.[45] Novatome, owned 100 per cent by Framatome, designs and constructs FBRs.[46]

2.3 Political and Technical Difficulties

France underwent a period of crisis from the mid-1970s to the 1980s, during which time political and technical difficulties in relation to commercial nuclear fission led the French government to pursue alternative strategies in order to ensure the viability of the nuclear industry.

According to many observers, the world economic crisis represents the end of a particular model of capitalist development - the Fordist era. The economic crisis beginning in the 1970s affected all advanced, industrialized countries including France and Germany. The 1970s and 1980s brought about the crisis of the international monetary system and Keynesianism. The low rate of economic growth, mass unemployment and double digit inflation by the 1970s brought about stagflation. High capital costs and climbing interest rates made it increasingly difficult for the nuclear industry to remain competitive.[47]

Mytelka describes the crisis of Fordism by explaining,

> [i]n the 1950s and 1960s, through the set of social conventions and economic mechanisms put in place to ensure the mutual adjustment of mass consumption and production, a quasi constancy in profit sharing with respect to value added was maintained.

She notes, however, that a crisis in productivity emerged in the 1970s. With respect to production, the problems included imbalances in capacity utilization between highly specialized mass-production machinery, rigidities in supplier-client relationships and management structures, as well as labour problems. Regarding consumption, slower growth in domestic purchasing power occurred in the early 1970s, along with market saturation of many consumer durables, coupled with rising imports of "standardized, mass-produced products from low-wage countries"[48]. As a result, most industrialized nations were faced with rising inflation and unemployment, as well as increasing investment costs in the late 1960s and 1970s.

> Under these conditions, price-cutting strategies became more difficult to sustain and vanishing margins increasingly eroded investment capacity and opportunity thus putting into question earlier growth strategies based exclusively on mass-produced standardized products and exacerbating the pressures for market access.[49]

As well, energy forecasts in the early 1970s, which suggested an increasing energy consumption and demand by the 1970s and 1980s, proved to be exceedingly optimistic.[50] Consequently, the Messmer Plan and the advocacy of a French state "tout nucléaire" led to a surplus in electricity production in the 1980s, as demands for electricity and reactor orders actually fell in the late 1970s.

Public opinion in France, as in other western European countries, became increasingly sensitized to the potential health hazards of radiation, ineffective methods of long-term nuclear waste disposal and other problems associated with nuclear fission. In terms of public opposition, militant protest was a frequent feature of the antinuclear movement in France in the 1970s. It occurred, however, on a smaller scale and was politically less effective than what we will find the case to be in Germany, mainly as a result of the self-contained, French state system.

In 1975, however, some 5,000 people protested at La Hague, Flamanville, a site chosen by the EdF for a 5,200 MWe nuclear power complex.

> A regional committee, the Comité Régional d'Information et de Lutte anti Nucléaire (CRILAN), was subsequently established, and close links were forged with workers and trade unions, particularly during the three months' strike at the La Hague plant. A series of festivals and marches, involving from 3,000-10,000 people, culminated in February 1977 in an attempted occupation of the site, which was eventually thwarted by the intervention of a paramilitary police force of several hundred men.[51]

In March of the same year, a second protest at the Fessenheim reactor in Alsace took place, which mobilized 4,500 demonstrators in Strasbourg and 3,000 in Colmar.

Public protest against the Super-Phenix FBR may be considered a milestone in terms of public opposition to the nuclear debate in France. More than one hundred Malville committees were formed across the country to protest against the project. On July 31, 1977, 60,000 protesters attempted to occupy the reactor site. Despite this impressive showing of public dissent, riot police arrived using tear gas and batons in order to control the demonstrators. Further, problems surrounding the FBR led to significant controversy regarding the advent of a "plutonium society", whereby the reprocessing of spent fuel could be used toward other, more dangerous ends.

Yet another milestone in terms of public protest was in Plogoff, which culminated in the largest demonstrations ever in France in March of 1980 near the proposed reactor site of four reactors. The Plogoff complex was an exception in that it was one of the few to be cancelled by the Socialist government soon after assuming office in May 1981.[52] As well, later in April 1986, the nuclear disaster in Chernobyl did not help to allay public concerns about the potential dangers associated with nuclear installations.[53]

In terms of organizational and technical problems, the nuclear programme in France met with difficulties, albeit to a lesser extent than was experienced in other countries.[54] Despite the fact that initial estimates of the time it would take to build PWR power stations were somewhat optimistic, the problems did not stem, as in the cases of Germany or the United States, primarily from legal or political impediments, since the French system supports the decisions of its bureaucrats.[55] Rather, it was "the unpreparedness and inexperience of French industry, the shortage of skilled labour and the introduction of new regulatory requirements" which created difficulties.[56]

The Super-Phenix FBR in Crey-Malville is one instance in which technical difficulties were not overcome. Briefly, the FBR is an advanced technology which has passed engineering feasibility.[57] FBRs are deemed to be more fuel efficient than LWRs because they can create more fuel than they consume, i.e. they convert nonfissile uranium into fissile plutonium and can extract approximately 100 times more energy from the same amount of fuel as do LWRs.[58] The Super-Phenix was designed for commercial purposes and was a joint venture between France and Italy (1974), and later Germany (1976). The reactor went critical, i.e. began operation, in 1986. As opposed to the German SNR (Schneller Natriumgekühlter Reactor)-300 (a liquid metal-cooled fast breeder reactor or LMFBR) at Kalkar, the Super-Phenix was confronted with relatively few problems, owing to effective project management, the specificity of the regulatory process and the immunity of the central actors to outside criticism.[59] The EdF has a large engineering capacity, which placed it in a good negotiating position with respect to other contractors, kept costs down and ensured a high level of technical standardization.[60] Due to the high degree of standardization in French nuclear technology, the nuclear industry in France boasts some of the lowest construction costs in the world.[61]

As a result of the efficient regulatory process, the reactor was easily granted authorization and benefitted from the centralization of national security organizations and direct lines of communication with government, including the Ministry of Industry and the CEA. This arrangement, which tended toward maximum efficiency, is diametrically opposed to the decentralized system in Germany, where cumbersome federal and regional regulatory procedures plagued the SNR-300 at every stage of development. However, despite the favourable state system which supported its construction, certain drawbacks were also associated with the Super-Phenix. Its inner confinement wall was 1.7 to 1.8 times less resistant than that of the German FBR and relatively few studies on the environmental and health effects, as well as potential types of accidents associated with FBRs, had been conducted in France. In spite of its functioning to approximately June of 1992, after a series of technical difficulties, the Super-Phenix was decommissioned and plans to restart it remain uncertain.

The case of the Super-Phenix illustrates how the French system may work to the immediate advantage of the bureaucrats and project implementers, yet does not diminish the technical problems associated with advanced nuclear reactor systems. Other problems of a technical nature in relation to FBRs have occurred in France: the reactor Rapsodie was permanently decommissioned in 1982 after 15 years of service, due to the deterioration of its inner confinement wall; in 1979, fissures appeared after a ten-year experiment in a test reactor at the Renardières research centre; sodium leakages in the vapour generators of the Phenix (precursor to the Super-Phenix) were reported in 1976 and 1982. As well, other problems common to the Phenix were suspected in the Super-Phenix, which necessitated investigation and caused construction delays.[62]

2.4 Changes in Policy

One could say that the centralized state system in France eased the impact of the "nuclear recession" of the mid-late 1970s and 1980s. "The steady progress of the French nuclear programme during these years owes a good deal to the success of EdF in limiting licensing and construction delays."[63] The standardization in the French industry led to cost advantages, maximized the reproduction of power plants of the same standard type, streamlined licensing procedures and limited delays due to public protests and legal proceedings.[64] As well, through the EdF, France was in a position to create an industrial structure that was able to compete internationally.[65] Also, due to the centralization of information and decision-making in France, the implementation of nuclear energy programme has been easier in France than in Germany. As a result, public opposition and activism against nuclear energy has been less widespread than in Germany.

Our research shows, however, that France did not entirely escape the political opposition and technical difficulties associated elsewhere with the nuclear industry. In view of the political and technical problems described above, the French government has been required to pursue a two-pronged strategy in order to maintain "a measure of public consensus in support of state policies" and reassert the primacy of its technical capabilities to compete effectively.[66]

In part, in response to public concerns with respect to nuclear safety, as well as to back up its increased emphasis on high technology, the French government created a series of new agencies beginning in the 1970s. These represent an innovative adaptation by the quasi-state nuclear industry in France which supports our first hypothesis.

On November 29, 1974, a national administrative public agency, the "Agence pour les économies d'énergie" (AEE), focused on French policy with respect to energy economics, was created. In 1977, it was put under the supervision of the Ministry of Industry and became more of an industrial and commercial body, with means of intervention. It was also targeted on new types of energy and sought to promote those resources which were insufficiently exploited.[67] In 1982, the AEE was replaced by the "Agence française pour la maîtrise de l'énergie" (AFME), with similar functions to the AEE but wider responsibilities. However, "it is true that new and not unimportant institutional and financial means were found to support the development of alternative energy technologies"[68]. The AFME offered the possibility for the diversification of knowledge and expertise, something which antinuclear proponents had been demanding for a long time.[69]

In 1979, a special agency within the CEA was created, namely the "Agence nationale pour la gestion des déchets radioactifs" (Andra), in order to deal with the problem of radioactive wastes[70], while another security-related agency, the "Direction de la sûreté des installations nucléaires" (DSIN), became more important.[71] As well, in 1989, the "Office parlementaire d'évaluation des choix scientifiques et technologiques" was established, a parliamentary commission responsible for evaluating the consequences and ramifications of technology.[72]

2.5 The Evolution of Nuclear Technology

These reassuring institutional changes, intended to calm public concerns, were not sufficient to support the nuclear industry over time. In terms of industrial strategies to promote alternative technologies, Frewer suggests that a common goal of the nuclear industry should entail overcoming the prevailing problems of public acceptance by developing successive, environmentally safer generations of nuclear power plants.[73] He states,

> [t]o regain public confidence in the environmentally safe operation of nuclear reactors, we have to demonstrate their ecological advantage over fossil plants and that future NPPs [nuclear power plants] will have even better safety features, which can

further reduce the potential risk of nuclear accidents.[74]

As well, in response to considerations regarding economies of scale, long-term financial and technological risk, as well as international competitiveness, nationally-based nuclear industries have been forced to adopt new industrial structures, which include European joint ventures. French industrial behaviour conforms to this pattern and, thus, partially supports our second hypothesis. Examples of industrial support for alternatives, which entail restructuring and strategic partnering in the nuclear industry, are detailed below.

2.5.1. *Advanced Nuclear Fission Systems*

A study sponsored by the French government initiated the construction of a new, advanced series of PWRs, the "N4" type, in 1990. The new series represents a progressive step in PWR development, as it incorporates various technological innovations based on technical progress and experience. An innovative feature of the new PWRs, for example, is the computerized control room, which incorporates new developments in electronic information processing relating to the control and command process of the nuclear facility.[75]

Nuclear Power International (NPI) was created in April of 1989 and represents an international consortium between Framatome and

Siemens/KWU, with its headquarters in Paris. Among NPI's objectives is the marketing of existing reactor technology and the development and commercialization of a common reactor type for industrial countries.[76] The commitment by French and German utilities to NPI was strengthened by their expressed desire to collaborate more closely in the context of the NPI and by their interest in the possibility of future orders for nuclear power stations, which would incorporate the basic features of the NPI concept.

> At a time when the nuclear industry is fighting for more standardization and harmonization in the safety field, these developments provide a good opportunity to pool the advanced reactor efforts of France and Germany to produce a unified line of development through NPI.[77]

The NPI arrangement is illustrative of a new marketing strategy for PWRs and Mytelka's notion of strategic partnering, whereby an important exchange of knowledge and information is occurring between European firms.

Despite the problems, as explained earlier, in the context of the Super-Phenix, as Frewer would argue, the knowledge gleaned from the experience of the Super-Phenix may be used in the context of future projects, such as the European Fast Reactor (EFR), currently being pursued at the international level. European research centres and the manufacturing industry have agreed to collaborate in the context of one reactor type, the EFR, decided upon in 1984 with the signing of a five-nation government memorandum of understanding[78], including France. According to the intergovernmental memorandum of understanding, the participating R&D organizations agreed to harmonize their programmes and achieve an efficient pooling of their resources and experience.[79] The project was implemented in March 1988.[80] The contracts under this project entail R&D agreements between the CEA, the Karlsruhe Nuclear Research Centre (KfK) and Interatom (Internationale Atomreaktorbau GmbH), a German manufacturer of FBRs, and the United Kingdom Atomic Energy Agency (UKAEA), which regulate the type and extent of research.[81] The aim of the EFR is to achieve economic efficiency and passive safety characteristics, based on past experience, by the participating countries.[82] An additional agreement attesting to the governments' support of this programme and its fuel cycle is expected to back the cooperation.[83]

Mr. Jean-Pierre Capron, General Administrator of the CEA, indicated that the CEA "[has] already been working for several years towards reducing the cost of the FBR generated electricity and will pursue an active R&D program to support the design of the next machine that will pave the way for a commercially competitive reactor"[84]. It is important to note, however, that the EFR association was "born out of necessity, rather than a partnership driven by market dynamics"[85]. Due to the long-term nature of the enterprise, it is expected that the EFR will not come into commercial use during this century, however, "the prime task of all parties is to prevent an irreparable break in the thread of fast breeder technology; only European cooperation is able to prevent this"[86].

Other examples of how French industry has opted for international collaboration in order to maintain a viable and competitive nuclear industry include the SERENA (Société europeéenne pour la promotion des systèmes de réacteurs rapides au sodium) initiative. In July 1977, agreements were concluded between France and Germany, which established the marketing firm SERENA, in which the French and Germans hold 65 per cent and 35 per cent of the shares, respectively. Under this agreement, France and Germany would share information and know-how on LMFBRs in France, Germany, Italy, Belgium and the Netherlands and grant licences for their industrial and commercial uses.

> ...The 1977 Franco-German agreements also provided for the exchange of detailed technical information and increased coordination on fast breeder and development between the CEA (representing France and Italy) and Interatom and the Karlsruhe Nuclear Research Centre (representing the Federal Republic, Belgium and the Netherlands).[87]

The SERENA initiative is another example of the extent to which governments have committed themselves to nuclear R&D, which supports Mytelka's notion of strategic partnering, given the detailed exchange of technological information and increased coordination between partners, in this case, regarding FBRs.

The REP 2000 Programme, begun in 1989 and conducted by the EdF, represents "a common front for European utilities to articulate their requirements for an advanced light water reactor" prototype for the year 2000.[88] The EdF has concluded a number of agreements on advanced LWR studies with European power utilities, including the VDEW (Consortium of German electricity utilities)[89]. One of the main aims of such agreements is to provide a forum for the exchange of knowledge and information in the area of FBRs between parties, in an effort to establish technical standards for future units and, eventually, to formulate joint specifications in the area of reactor safety.[90] The REP 2000 Programme is thus another example of the increasing frequency of information exchanges between firms, in this case, toward the harmonization and integration process taking place at the European level in the area of nuclear technology and safety standards.

Other developments at the European level, such as the decision by German utilities to cancel construction of a German-based reprocessing plant [Wackersdorf] in favour of such services already offered by France (and the United Kingdom) "underlines the reshifting of nuclear activities between the European countries"[91]. As Frewer suggests, one may expect that national nuclear policy will be increasingly replaced by a more integrated approach by the European Community.[92]

Government support of the above industry trends is attested to by statements by Mr. André Giraud, Minister of Industry from 1978 to 1981, who highlighted the privileged place of science and research in French society and their interdependence vis-à-vis industrial development and progress.[93] Such themes were continued by the Socialist government in the 1980s and correspond to new challenges of the 1980s and 1990s in terms of competitiveness.

With the Socialists ascent to power in 1981, the state objective was again focused on the economy.[94] Given increasing international competition, the global restructuring of production, France's industrial base and independence were considered to be threatened once more.[95] In order to maintain its technological lead, the French government decided to emphasize its technological capability and make R&D a central pillar of policy. Jean-Pierre Chèvenement, formerly Minister of State of Research and Technology (1981-82), highlighted the nuclear and oil sectors as key targets of R&D funding. In both sectors, France had attained a high level of expertise, which he argued, represented thriving high technology industries which had to be maintained.[96]

2.5.2. *Nuclear Fusion*

Among alternative technologies, nuclear fusion is considered an attractive, long-term energy option, which, as our hypothesis elaborated, is particularly well suited to revitalize the nuclear industry. The section below explains the parameters of the big international projects in nuclear fusion and their role in the dynamic international economy, in order to highlight France's commitment to nuclear fusion.

Nuclear fusion, readers will recall, produces less radioactive waste and represents a potentially limitless source of energy, if a sustained nuclear fusion reaction can be achieved. As well, in an article in the Quotidien de Paris (1991), the political and strategic significance of nuclear fusion is highlighted. For example, had nuclear fusion [as a commercial source of energy] been in place, it is suggested that nuclear accidents similar to Three Mile Island and Chernobyl might not have occurred, as a nuclear fusion reaction is easier to control and can be stopped within seconds. Also, the conflict in the Gulf might not have occurred, as there would not have been an incentive for Iraq to usurp Kuwait's oil reserves.[97]

Despite France's early interest in nuclear fusion R&D, due to the complexity of the technologies involved, nuclear fusion could only be contemplated on a long-term scale. Only after the oil crisis, when France's concern for energy self-sufficiency increased its emphasis on R&D for acknowledged growth sectors with spillovers into other high technology fields, was interest in nuclear fusion, in effect, revived with the European Fusion Programme.

The objective of the programme conforms to trends in the international economy described earlier, namely production based on knowledge-intensive activities, the harmonization, integration and standardization of technology and safety norms with a view to economic efficiency, industrial viability and especially, in the case of the nuclear industry, public acceptability. The objective of international cooperation in nuclear fusion R&D is the establishment of a science and technology base for fusion. In this endeavour, strong domestic programmes focused on basic elements and international collaboration, as the most expeditious way of achieving the goal, are key to the programme's success.[98] As well, EC representatives have made it clear that the objective of the European Fusion Programme is the commercialization of magnetic fusion.[99] The Programme entails JET, NET and DEMO phases, representing the joint construction of a nuclear fusion prototype. Europe's pursuit of JET is a key factor in international competitiveness, as JET is one of three main international experimental prototypes in the area of nuclear fusion, the other two being the TFTR in the United States and the JT-60 in Japan.

Briefly, the JET Joint Undertaking was set up in 1978 by the member states of the European Community[100] under the provisions of the 1957 Treaty of Rome and was preceded by the JET Working Group in 1971 and the JET Design Team in 1973.[101] In May of 1973, representatives of the CEA (France), Culham (England) and IPP (Germany) met in Saclay, France, to discuss the JET proposal, which, in turn, would be submitted to the EC Commission and then to the Council of Ministers.[102] Hans-Otto Wüster, a German with a high energy physics background and an in-depth knowledge of large international science and big project control, was invited by the German Government to apply as the Head of the project (which was subsequently confirmed).[103] Rebut, of the CEA, is currently the director of JET.[104]

NET, agreed to in 1983, has various objectives, including establishing nuclear fusion as scientifically and technologically feasible, as well as a safe, environmentally acceptable and practically inexhaustible source of energy.[105] NET is under conceptual design within ITER, a collaborative effort in nuclear fusion between Europe, the United States, Japan and the USSR. The Next Step phase is expected to come on line some time toward the end of this decade.

The ITER programme is based upon scientific knowledge and extrapolations derived from the operation of many tokamaks around the world and upon extensive R&D projects of the contributing parties.[106] Regarding R&D activities, design work is conducted at each party's home site, representing about 80 to 100 person years during the course of design activities.[107] Each country performs R&D in its laboratories and contributes approximately 10 million U.S. dollars per year to R&D activities.[108]

France's renewed commitment to nuclear fusion at the European level reinforces state support for this technology, initiated in 1958/59, when France and Euratom collaborated in R&D relating to the tokamak design. France's continued commitment to nuclear fusion has taken the form of various collaborative projects with Euratom. Since 1973 there have been three major experiments by the CEA, namely the first tokamak, TFR, at the Centre d'études de Fontenay-aux-Roses, PETULA AND WEGA experimental reactors at the Centre d'études de Grenoble and TORE SUPRA (1986) at the Centre d'études in Cadarache, an experimental reactor jointly owned by the CEA and Euratom.[109] The general financing of the TORE SUPRA (personnel, running costs, etc.) are assumed, for the most part, by the CEA (75 per cent) and Euratom (25 per cent).[110] TORE SUPRA focuses primarily on superconduction and is considered a decisive step toward a nuclear fusion reactor in the context of NET.

France's role in JET includes approximately 430 researchers, engineers and technicians based principally at the research centre in Cadarache, as well as in Culham at the JET site (1991).[111] The CEA's financial contribution to nuclear fusion research includes approximately 330 to 340 millions de francs (MF) per annum (1991).[112]

Further, in the context of developments in the area of nuclear fusion, in 1989, the CEA and Framatome, in conjunction with the Commission of the EC, developed a high flux thermal station, FE

200, located in Creusot (Saône-et-Loire).[113] Installation costs were as high as 10 MF, 7 to 8 MF of which was financed by the CEA, with Euratom absorbing 45 per cent of these costs.[114] FE 200 is a significant move toward an experimental nuclear fusion reactor. The FE 200 machine will be made available to laboratories working in the area of fusion, as it is focused on testing the resistance of materials at very high thermal fluxes in order to understand the interaction of substances with plasma in future thermonuclear reactors.[115] The project also has multifarious applications and may be used in several high technology areas, including space, aeronautics and defense.[116]

In an interview with La Recherche (1985), Hubert Curien, Minister of Research and Technology, acknowledged that European collaboration is, to a large extent, a result of financial necessity, however, he also alluded to the "European spirit" of cooperation, which rather than being predominantly financially motivated, now involves policy.[117] He also indicated that the Community's role in terms of science and technology is beneficial and should continue (he cites the ESPRIT programme as being a representative example of successful collaboration).[118]

The French case study has suggested that, despite the efficacy of the French state system, France has not escaped the public criticism and technical difficulties related to commercial nuclear power, as has been the case generally, on an international level.

In view of public opposition, technical difficulties and the new criteria of international competition, besides refining and enhancing existing reactor systems, France has turned to the pursuit of alternative technologies, namely nuclear fusion, which entails intensive international cooperation in this high technology field.

Chapter Two Notes

1. CEA, "Le CEA et la fusion en quelques données," in "Petit déjeuner de presse sur la fusion", November 14, 1991 (CEA Service Information-Presse).

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3. G. Carliner, "Industrial Policy for Emerging Industries," in Paul R. Krugman, ed., Strategic Trade Policy and the New International Economics, Cambridge (Mass.), MIT Press, second printing 1987 (1986), p. 162.

4. Ibid., p. 162.

5. Ibid., p. 163.

6. Ibid., p. 163.

7. Joseph A. Camilleri, The State and Nuclear Power: Conflict and Control in the Western World, Sussex, Harvester Press, 1984, p. 149.

8. Fach and Simonis, Die Stärke des Staates, p. 58.

9. Ibid., p. 58.

10. Ibid., p. 51.

11. Peter Hall, "Patterns of Economic Policy: An Organizational Approach," in Stephen Bornstein, David Held and Joel Krieger, eds., The State in Capitalist Europe, London, George Allen & Unwin, 1984, p. 31.

12. Fach and Simonis, Die Stärke des Staates, p. 53.

13. Camilleri, The State and Nuclear Power, p. 149.

14. Fach and Simonis, Die Stärke des Staates, pp. 58-59.

15. A useful analysis of the French state system in relation to nuclear policy is Lawrence Scheinman's Atomic Energy Policy in France Under the Fourth Republic. Scheinman underscores sources of French policy external to the mainstream institutions of policy-making and, more specifically, a relatively small, elite circle of government bureaucrats and scientific experts in the CEA, which directly influenced policy decisions in the nuclear field. As well, Scheinman highlights the policy tradition in France,

characterized by a quest for French leadership and "first-rank status". He suggests that the French state system promoted continuity with respect to such policy themes. The French Parliament was not represented in main policy areas, including those which were nuclear-related (Scheinman attributes this, in part, to "ministerial instability"). As well, the peripheral place of atomic policy in relation to general policy in France prevented it from becoming an object of public debate. As Scheinman notes, French atomic policy has been "conditioned by capacity and characterized by continuity...policy and capacity were in step and combined to produce substantial results - prototype electricity production reactors and the atomic bomb." (See Lawrence Scheinman, Atomic Energy Policy in France Under the Fourth Republic, Princeton (New Jersey), Princeton University Press, 1965). Walter Patterson, author of Nuclear Power, also offers comparative insights amongst industrialized nations regarding the evolution and issues surrounding nuclear technology, from the last century to the launching of the commercial nuclear industry in the 1970s. In particular, he highlights mounting public opposition to nuclear power in industrialized countries in the 1970s and the underlying problems of nuclear technology, such as radioactive wastes, maintaining economies of scale amid falling reactor sales and high capital costs associated with nuclear power stations (Walter C. Patterson, Nuclear Power, 2nd ed., Bungay (Suffolk, England), Chaucer Press, reprint ed. with postscript 1986 (2nd ed. 1983, reprint ed. with postscript 1981/1980, reprint ed. 1978, reprint ed. (twice) 1977, reprint ed. 1976, 1976).

16. Carliner, "Industrial Policy for Emerging Industries," p. 161.

17. Hall, "Patterns of Economic Policy," p. 32.

18. Ibid., p. 32.

19. See John Zysman, Governments, Markets, and Growth: Financial Systems and the Politics of Industrial Change, Ithaca (New York)/London (England), Cornell University Press, 1983, pp. 104-131.

20. Ibid., p. 131.

21. Hall, "Patterns of Economic Policy," p. 30.

22. Mary Davis, The Military-Civilian Nuclear Link: A Guide to the French Nuclear Industry, Boulder, Westview Press, 1987, p. 15.

23. Hall, "Patterns of Economic Policy", p. 30.

24. Ibid., p. 27.

25. Fach and Simonis, Die Stärke des Staates, p. 51.

26. John L. Campbell, Collapse of an Industry: Nuclear Power and the Contradiction of United States Policy, Ithaca (New York), Cornell University Press, 1988, p. 141.

27. Louis Puiseux, "The Ups and Downs of Electricity Forecasting in France: Technocratic Elitism," in Thomas Baumgartner and Atle Midttun, eds., The Politics of Energy Forecasting: A Comparative Study of Energy Forecasting in Western Europe and North America, Oxford, Claredon Press, 1987, p. 187.

28. See Zysman, Governments, Markets, and Growth, pp. 104-133.

29. Puiseux, "The Ups and Downs of Electricity Forecasting in France," pp. 186-87.

30. Hall, "Patterns of Economic Policy," p. 29.

31. Fach and Simonis, Die Stärke des Staates, p. 51.

32. Davis, The Military-Civilian Nuclear Link, p. 16.

33. Fach and Simonis, Die Stärke des Staates, p. 52.

34. Ibid., p. 52.

35. Davis, The Military-Civilian Nuclear Link, p. 16.

36. Ibid., p. 16.

37. Ibid., p. 16.

38. Ibid., p. 17.

39. Fach and Simonis, Die Stärke des Staates, p. 51.

40. Davis, The Military-Civilian Nuclear Link, p. 17.

41. Dominique et Michèle Frémy, Quid 1991, Paris, Éditions Robert Laffont, 1990, p. 1665.

42. Davis, The Military-Civilian Nuclear Link, p. 57.

43. Fach and Simonis, Die Stärke des Staates, p. 52.

44. "L'industrie nucléaire française: résultats et perspectives," communication présentée par M. Gérard Renon, Administrateur général du Commissariat à l'énergie atomique, le 8 avril 1986, à la XIXe conférence annuelle du Japon Atomic Industrial Forum, à Tokyo, in CEA, Notes d'information, no. 3, May/June 1986, p. 4.

45. Groupe Framatome, "Le groupe Framatome en bref," in CEA, "Petit déjeuner sur la presse de la fusion," November 14, 1991 (CEA Service Information-Presse).

46. Frémy, Quid, p. 1665.

47. Between 1970 and 1986, investments by the EdF were financed largely by loans and, to a lesser extent, by self-financing and capital endowments from the state. From 1970 to 1986, total borrowing figures for investment by the EdF increased from 27.9 per cent to 63.3 per cent respectively, after reaching a peak of 86.6 per cent in 1981 (Jacques Percebois, Économie de l'énergie, preface by Yves Mainguy, Paris, Economica, 1989, p. 659).

48. The above paragraph is adapted from Lynn Mytelka, "Crisis, Technological Change and the Strategic Alliance," in Lynn Krieger Mytelka, ed., Strategic Partnerships: States, Firms and International Cooperation, London, Pinter Publishers, 1991, pp. 22-23.

49. Ibid., p. 23.

50. Puiseux, "The Ups and Downs of Electricity Forecasting in France," pp. 180-202.

51. Camilleri, The State and Nuclear Power, p. 96.

52. The above two paragraphs describing antinuclear protests in France are adapted from Ibid., pp. 96-97.

53. Dorothy Nelkin and Michael Pollack provide a detailed examination of public opposition to nuclear power in France and Germany and how the state system in each respective case influences policy outcomes and the nuclear debate. Nelkin and Pollak note that, based on the official channels of communication to the policy level, available to opponents of nuclear power in Germany, the antinuclear movement there was stronger than in France and had more immediate repercussions, such as curtailing the construction of some nuclear reactors. They also highlight the increased collaboration between government and industry as of the mid-1970s, due to high capital costs and public controversy regarding nuclear power. In terms of major policy implications following from the nuclear debate and, of particular interest in the context of this thesis, the authors suggest that public opinion has a central role to play in the future of nuclear power. As well, the nuclear controversy has led to broader questions with respect to the long-term of science and technology in industrialized nations (See Dorothy Nelkin and Michael Pollack, The Atom Besieged: Antinuclear Movements in France and Germany, Cambridge (Mass.)/London (England), MIT Press, paperback ed. 1982 (1981).

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55. Ibid., p. 145

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61. Daniel Glorian, "France: EdF" in "What the Utilities Think," Nuclear Engineering International, October 1990, p. 38.

62. Unless otherwise indicated, information in the above two paragraphs is adapted from Finon, "SuperPhénix," pp. 79-81.

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64. H. Frewer, "Future Challenge of Nuclear Power in the European Community," Nuclear Europe Worldscan (Journal of the European Nuclear Society), no. 1/2, January/February 1990, p. 64.

65. Camilleri, The State and Nuclear Power, p. 280.

66. Ibid., p. 283.

67. Details regarding the AEE are adapted from François Dorget, Le choix nucléaire français, Paris, Economica, 1984, p. 289.

68. Puiseux, "The Ups and Downs of Electricity Forecasting in France," p. 186.

69. Ibid., p. 186.

70. Heinz-Peter Arndt, Mycle Schneider and Ludwig Siegele, "Atomkraft-non merci," Die Zeit, no. 31, July 31, 1992, p. 7.

71. Ibid., p. 6.

72. Ibid., p. 7.

73. Frewer, "Future Challenge of Nuclear Power," p. 66.

74. Ibid., p. 68.

75. The above paragraph is adapted from Glorian, "France: EdF," p. 38.

76. Dominique Vignon and Dieter Schneider, "NPI's New Reactor Takes a Further Step Along the Evolutionary Road," Nuclear Engineering International, April 1992, p. 48.

77. Ibid., p. 48.

78. H. Noel, M. Köhler and A. Green, "European Fast Reactor (EFR) Project - Present Stats and Perspectives," Nuclear Europe Worldscan, no. 11/12, 1990, p. 24.

79. Ibid., p. 25.

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82. Ibid., p. 67.

83. Ibid., p. 67.

84. "La Politique nucléaire française pour la XXIe siècle," communication présentée par M. Jean-Pierre Capron, Administrateur général du Commissariat à l'énergie atomique, le 14 avril 1987 à la XXe conférence annuelle du Japon Atomic Industrial Forum, à Tokyo, in CEA, Notes d'information, No. 4, July/August 1987, p. 15.

85. Frewer, "Future Challenge of Nuclear Power," p. 68.

86. Ibid., p. 68.

87. "FBR Agreement Signed," Nuclear Engineering International, August 1977, p. 93, in Camilleri, The State and Nuclear Power, p. 152. Information on SERENA is adapted from Ibid., p. 152.

88. P. Bacher, L. Reynes and G. Serviere, "Towards a European PWR: EdF Launches the REP 2000 Project," Nuclear Engineering International, October 1990, p. 58.

89. Electricité de France International, Annual Report, Paris, 1990, p. 17.

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91. Frewer, "Future Challenge of Nuclear Power," p. 65.

92. Ibid., p. 65.

93. "Discours de M. André Giraud, Ministre de l'Industrie à l'Académie des Sciences", in CEA, Notes d'information, No. 10, October 1979, pp. 12-14.

94. Fach and Simonis, Die Stärke des Staates, p. 59.

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97. Henri Tricot, "Fusion nucléaire: vers une seconde révolution industrielle?" Quotidien de Paris, December 17, 1991, p. 15.

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110. CEA, "Le Tokamak 'TORE SUPRA': une étape décisive vers un réacteur à fusion," in "Petit déjeuner de presse sur la fusion," November 14, 1991 (CEA Service Information-Presse).

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115. CEA/Groupe Framatome, "Communiqué de presse: mise en service de la station d'essais FE 200" in CEA, "Petit déjeuner de presse sur la fusion," November 14, 1991 (CEA Service Information-Presse).

116. "Demain le réacteur à fusion rapide," p. 20.

117. Martine Barrère (remarks collected by), "L'Europe de la science: les ministres nous répondent", La Recherche, vol. 16 (171), November 1985, p. 1422.

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CHAPTER THREE

THE GERMAN CASE STUDY

Although the German state system is significantly different from the French state system, trends similar to those explained in Chapter Two will emerge from our research findings in this chapter. The German case study first examines political opposition and technical difficulties in order to explore the first hypothesis and then identifies industry-government moves to a closer association, especially in the context of advanced technology and nuclear fusion. Chapter Three, in its final section, corroborates the second hypothesis by providing evidence of Germany's engagement in nuclear fusion R&D at the international level.

3.1 The German Nuclear Industry

Unlike France, after the Second World War, Germany was stripped of its military power and was eventually fully integrated into the Western Alliance, when it entered NATO in 1955. The restrictions imposed upon Germany after the War gave it bounded sovereignty, as constrained by its "special relationship" with the United States. Germany was, therefore, late in comparison to other Western countries (i.e. about fifteen years after the United States and ten years after the United Kingdom) to embark upon a commercial nuclear industry.[1] The development of nuclear technology in Germany was different from that of the United States, the Soviet

Union, Britain and France, in that it was not characterized by the construction of small tests reactors prior to the development of prototypes of several hundred megawatts.[2] As a result, Germany was forced to become highly efficient and competitive, in terms of its nuclear exports, especially in the 1970s, within a relatively short time period.[3]

Germany's first small reactor, the 15-MWe BWR at Karl in 1961, was a joint project between General Electric and the Allgemeine Elektrizitäts-Gesellschaft (AEG), one of the main German reactor manufacturers, before it was taken over by Siemens in 1977.

> The first phase of the commercial reactor programme, however, was dominated by light-water-moderated reactors beginning with a 250-MW(e) B.W.R. at Gundremmingen in 1966 and followed by a 280-MW(e) P.W.R. at Obrigheim in 1968, a 240-MW(e) B.W.R. at Lingen in 1968, a 630-MW(e) B.W.R. at Stade in 1971 and a 640-MW(e) B.W.R. at Wurgassen in 1972, and with the introduction of a larger B.W.R. station at Brunsbuttel and a large P.W.R. at Biblis this brought the total nuclear generating capacity in Western Germany to 3,500 MW(e) by 1975, with B.W.R. stations built by the A.E.G. and P.W.R.s built by Siemens under licence from Westinghouse playing approximately equal roles.[4]

3.2 The German State System

Industrial policy in Germany is distinguished by its liberal philosophies and reliance on the market, as opposed to the French interventionist tradition. These formal norms express policy traditions of private ownership, with indirect public financing of industry.

The German state system, with its liberal market bias, is reflected in the organization of nuclear research, even under the pre-World War II system. This philosophy may be attributed to the liberal theologian, Adolf van Harnack (1851-1930), whose main concern was to ensure that the executors of research were independent from state direction. The Kaiser-Wilhelm-Gesellschaft is such an example. Founded in 1911, it subsequently became the Max Planck Society for the Advancement of Science and now operates some fifty research institutes in different fields.[5]

Since the 1950s, thirteen major research institutes have been formed, among which some have been in the nuclear area, all of them in the private law form. The privatization of nuclear research was chosen for practical reasons, i.e. it removed research from the state budget and thus freed it from legal restrictions, allowed greater flexibility in terms of organizational structures and made it easier for the executors of research to control the results.

> It was, [however], the development of financial availability on the one hand and of research tasks on the other that from 1956 onwards compelled the Federation to intervene in the financing of research promotion, the consequence being joint decisions by Federation and Länder on the extent of promotion and the finding and distribution of financial resources.

An elaborate framework agreement between the federal government and the Länder regarding the promotion of research was, therefore, concluded on November 28, 1975.

An underlying reason for the change in this political structure shaping research activity was the "uncertainty as to policy" or in other terms, the contradiction between federal cultural sovereignty and modern requirements of research. Although this contradiction was not resolved politically, it was settled by pragmatic compromises and, under conditions of relative economic prosperity, the financing and organization proved adequate for modern requirements, leading to what Dian Schefold describes as a "cooperative federalism".[6]

Despite Germany's liberal market orientation, "this does not mean the role of the public sector has been negligible"[7]. Besides being more market-oriented, policy formation in Germany is less centralized than in France, as planning and coordination along the lines of the French state system are absent.[8] Yet, the lines of responsibility are relatively clear between the various actors[9], as fragmented authority, characteristic of a federal rather than a centralized state structure, requires some division of responsibilities.

Unlike France, where nuclear policy is controlled primarily by the ruling party or influenced directly by politics, Germany's policy-making on nuclear questions is, to a large extent, outlined in the Atomic Law, which was ratified in 1959 and presents guidelines with respect to nuclear safety and compensation in the case of nuclear accidents.[10]

In contrast to the French system, the policy implementation process (such as regulatory procedure) in Germany is decentralized and accessible to the public.[11] German economic and industrial policy-making is built, to a large extent, upon broadly based consensus-building, where Labour and public opinion play major roles.[12] This is in contrast to France where labour has not been internalized in the policy-making process.[13] Consider the role of the courts, for example, in the nuclear debate. Unlike France, one of the main objectives of the German courts has traditionally been to uphold the interests and rights of individuals, rather than supporting government policy.[14]

The German financial system is also credit-based, however, in contrast to France, it is more decentralized and characterized by significantly less intervention by the central government. German private-commercial banks are key actors in the allocation of long-term loans to potential growth sectors of the economy.[15] In general, the MOF approves the rationalization for directed funds, prior to the banks taking the lead role in administering the loans.[16] A distinctive feature of the German state system is the collaboration and coordination amongst the banks, industry and government. Bank officers, for example, are members of the board in industry and often hold shares in large companies.[17] As Hall indicates,

> ...the German banks have a direct and extensive interest in the long-term performance of the major firms within German industry...[T]he banks, and in particular the big three [Deutsche, Dresdner and Commerz], are in a position to exercise immense influence over the activities of these firms. In keeping with this, the banks have developed considerable expertise in industrial matters and the capacity to provide detailed direction to the firms whose shares they hold.[18]

The state's involvement in the nuclear industry in Germany has been significantly less than in France. It is important to note, however, that the federal government subsidizes, for the most part, the construction and operation of a network of R&D laboratories, among others, in Jülich, Karlsruhe and Garching.[19] As well, it has provided incentives such as subsidies, tax breaks, loan guarantees and guarantees against operating losses to private firms, especially in the industry's earlier years.[20]

In Germany, the main actors responsible for executing government policy include the following: At the government level, the main actors include the Ministry for Research and Technology (Bundesministerium für Forschung und Technologie or the BMFT), responsible for public funding which includes the participation of the Länder government in certain cases; the Economics Ministry (Bundesministerium für Wirtschaft or BMWi), responsible for energy policy and planning; the Ministry of the Interior (Bundesministerium des Innern or BMI), responsible for licensing and nuclear safety; and the Ministry of Finance. Generally, the federal government is responsible for lawmaking and regulations under which licensing occurs, while the Länder, after final approval is given by the BMI, approve the sites, grant construction permits and issue operating licences[21], as well assist in formulating economic and regional development policies.[22]

The utilities in Germany are privately controlled, notwithstanding the fact that a substantial portion of their shares are owned by communities and municipalities. The utilities are responsible for placing reactor orders and for the financial burden and risk of a given project. Some exceptions to this rule apply, however, such as the SNR-300 and the gas cooled high temperature reactor (i.e. Thorium-Hochtemperaturreaktor (THTR)-300), whereby the financial contribution of the utilities was somewhat limited. The larger utilities in Germany include the Rheinische-Westphälische Elektrizitätswerke (RWE), Vereinigte Elektrizitätswerke Westfalen AG (VEW) and Preussenelektra.[23]

The main reactor vendor in Germany is the Kraftwerk Union (KWU), created in 1969, which originally had a 50/50 per cent shareholding of Siemens and AEG until Siemens took over 100 per cent of the shares in 1976/77, due to construction delays and technical problems in the industry which put AEG on the brink of bankruptcy.[24] Like the EdF in France, KWU represents Germany's chief architect-engineer of nuclear reactors.[25] Among its subsidiaries is Interatom, specializing in FBRs.[26] Table I indicates the main institutions of the nuclear industry in Germany.

One of the main drawbacks of the German state system, with respect to economic policy-making and the nuclear industry, is its lack of political cohesiveness and coordination. Unlike France, it has virtually no standardization mechanism with which to implement policy. This has created many difficulties in terms of the public acceptability and implementation of nuclear power in Germany, as the next section demonstrates.

3.3 Political and Technical Difficulties

In order to reexamine the first hypothesis in the German case, this section describes the political and technical difficulties, as they relate to commercial nuclear fission, which have hindered the progress of the nuclear industry and contributed to the pursuit of alternative technologies, such as nuclear fusion.

As suggested earlier, Germany did not escape the effects of the global economic recession in the 1970s and 1980s, which entailed a crisis in productivity, slower growth in domestic purchasing power, rising inflation and unemployment and increasing investment costs. Although Germany sought to be competitive on

TABLE I

Main Institutions in the Nuclear Industry of the Federal Republic of Germany

Utilities	Manufacturers	Fuel cycle	R and D	Government
Rheinische Westfalisches Elektrizitatswerke AG (RWE)	PWR, BWR, HWR: Kraftwerk Union AG (KWU) (100 per cent Siemens)	*Supply:* Uranerzbergbau GmbH Urangesellschaft mbH	Kernforschungszentrum Karlsruhe (KfK)	Bundesministerium für Forschung und Technologie BMFT (R & D)
Vereinigte Elektrizitätswerke Westfalen AG (VEW)	PWR: Babcock-Brown Boveri Reactor GmbH (BBR) (since 1981: 100 per cent BBC)	*Enrichment:* Urenco, Uranit	Kernforschungsanlage Jülich (KFA)	Bundesministerium für Wirtschaft BMWi (energy policy)
Preußenelektra	LMFBR: Internationale Atomreaktorbau GmbH (Interatom) (100 per cent KWU)	*Fuel elements:* Nukem, Alkem, Hobes, RBU	Gesellschaft für und Umweltforschung (GSF)	Bundesministerium des Innern BMI (licensing)
Nordwestdeutsche Kraftwerke AG (NWK)	HTGR: Gesellschaft für Hochtemperaturreaktor-Technik mbH (100 per cent Interatom)	*Reprocessing:* Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen (DWK)	Hahn-Meitner Institut für Kernforschung Berlin (HMI)	Governments of the Länder for licensing procedure, assisted by Gesellschaft für Reaktorsicherheit GRS
Badenwerk	Hochtemperatur-Reaktorbau GmbH (HRB) (55 per cent BBC, 45 per cent GAC)	Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen (GWK)		Technischer Über wachungsverein TÜV
Bayernwerke		*Waste disposal:* Government		
Energieversorgung Schwaben AG (EVS)				
Hamburgische Elektrizitätswerke AG (HEW)				
*Of the 680 utilities these eight supply approx. 80 per cent of the electricity and amongst them RWE has a share of approx. 50 per cent.				

Source: Ulrich Daünert, "Understanding the Structure of the Nuclear Industry," Nuclear Engineering International, May 1981, p. 28.

international markets in the 1970s by promoting nuclear exports, by the late 1970s, it was faced with falling reactor sales and decreased capital with which to expand.

Political opposition has been more organized in Germany than in France. Although there was relatively limited public opposition to nuclear power before 1974[27], a working-class militancy, which began in the 1950s and 1960s, gained momentum in the 1970s. The Green Party, which initially defended issues relating primarily to workers rights (1950s), took on a new purpose in the 1970s and became an active proponent of the environmental movement. A main target of its opposition was the nuclear industry. A series of public protests in Germany signalled the difficulties which confronted the industry.

The crisis over nuclear power was initiated in Germany by the occupation of the Whyl reactor site in 1975.[28] Among the main concerns of the protesters, besides reactor safety and the potential health hazards associated with nuclear power plants, was the environmental impact of the cooling towers and their effect on local agriculture.[29] In October and November of 1976, two major public rallies occurred at the Brokdorf reactor in its early stages of construction, on the Elbe River, eighty miles from Hamburg.[30] In March of 1977, more than 5,000 demonstrators protested against the reactor at Grohnde, 2,000 protesters rallied against the Ohu site at Easter and, in September of the same year, more than 50,000 demonstrators protested against the Kalkar FBR prototype.[31]

The incapacity of the nuclear industry to expand was not only a function of depressed market conditions, but the result of considerable delays in licensing and construction, resulting from political intervention, legal disputes and new regulation legislation.[32] Such was the case of the reactor at Obrigheim and the Mülheim-Kärlich, the latter being a nuclear reactor which has been out of commission, bound up in legal disputes since 1988.[33]

The Mülheim-Kärlich took more than eleven years to construct. Initially, it was feared that the site shared some of the same features as the Three Mile Island reactor plant, which suffered a loss of coolant and a subsequent partial core meltdown. The damaged nuclear steam system, designed and built by Babcock & Wilcox (United States), was very similar to the Mülheim-Kärlich model. Local opponents protested that the plant's cooling tower lacked a construction permit under the Environmental Protection Act (Bundesimmissionsschutzgesetz). Approximately one year later, in September 1988, the federal administration court in Berlin (Germany's highest authority in controlling public administration) declared the original construction permit, issued some thirteen years earlier, illegal and void, in which case a new construction permit had to be applied for and granted. In short, it took the licensing authority until July 1990 to issue another construction permit which was, in turn, challenged by the protesters, who called into question its state-of-the-art safety. The protestors' plea was again recognized by the courts (Coblentz) and a ban on the reactor's functioning continues to apply (1992).[34]

Opposition to nuclear power also came from within government. There were diverging views about nuclear energy within Chancellor Helmut Schmidt's government.[35] Given the oil crisis and mounting pressure from the environmental movement, the government was obliged to revise its 1973 energy programme in 1974, as well as in 1977.[36] The main thrust of the new policy was energy conservation and diversification, i.e. a reduced reliance on oil, and "the expansion of nuclear power at the rate necessary to secure electricity supply"[37]. By the end of 1979, although, Germany was looking to reduce its reliance on foreign oil, Social Democratic policy favoured the reduction of the contribution of nuclear power to Germany's energy supply and this put added strain on an industry already in difficulty.[38]

In terms of technical difficulties, Germany had a major problem with radioactive waste management. The difficulty stems from the nature of nuclear fission itself, which necessitates that radioactive wastes of spent or used fuel be treated and stored, in some cases, for very long periods of time, before the radioactivity is reduced to acceptable health levels. The problem of radioactive waste has not been so acute in France for several reasons. In

France, the utilities responsible for radioactive waste disposal are government-owned, unlike in Germany, where according to federal law, the responsibility is delegated by government to private utilities. In view of the preceding, "short-term profitability considerations [which] tended to outweigh the long-range sectoral interest in resolving the waste problem" is not an issue, as the French government absorbs much of the costs.[39] In Germany, however, efforts by Schmidt's government to coerce industry into overcoming "its short-sighted view" were relatively unsuccessful.[40]

Another major obstacle in Germany with respect to the reprocessing problem was public opposition, which was made possible given the many "institutional opportunities" nuclear critics had to obstruct policy implementation. Such was the case of the Gorleben site (Lower Saxony) for a reprocessing and waste management complex, whereby the licence for its construction was eventually refused by the Länder, due to intense political pressure.[41]

The thorium high-temperature reactor, THTR-300, in Hamm-Uentrop (late 1980s) is another example of technical difficulties which have stymied nuclear progress.[42] The THTR, upon opening, was almost immediately shut down due to 35 boltheads (Bolzenköpfe) which exploded in the hot gas canals (Heissgaskänalen). The estimated daily cost of the shutdown was in the order of 0.5 million Deutsche Mark (DM). Due to the extent of the problems associated with the reactor, few are willing to put more money into the venture. As of 1989/90, the reactor still was not operational.

The case of the German SNR-300 FBR at Kalkar parallels the study of the Super-Phenix in France in Chapter Two and demonstrates the influence of the German state system on the nuclear industry. Planning for the fast sodium-cooled reactor began in the 1960s and was subsequently implemented in the 1970s. Siemens/Interatom bid for government funds to pursue the project. The German Ministry of Science and Technology was central to the project, in conjunction with the Dutch and Belgian governments, which also agreed to collaborate in the joint venture. It is acknowledged, however, that this association was politically motivated, as opposed to being inspired by genuine interest in international cooperation. Given the experience of the Second World War, Germany sought to distance itself from any activity involving the potential suspicious use of plutonium, a by-product of FBRs, and as well, German actors saw the FBR enterprise as an opportunity to demonstrate Germany's commitment to European integration. A joint sodium-cooled prototype had also been contemplated with France, principally to reduce costs to the West German government. As well, Euratom had tentative plans for a European-built FBR. Despite the fact that the Karlsruhe nuclear research laboratory would have been in favour of Euratom financing part of the project, it also recognized that project leadership would have been removed from Karlsruhe. Karlsruhe scientists favoured a nationally controlled nuclear programme and German leadership and, therefore, opted for the control of the programme. Further, it was deemed that a single FBR prototype in Europe would not effectively meet the challenge of American competition.[43]

Despite the fact that the SNR-300 was one quarter the size of the Super-Phenix in France, its construction costs tripled between 1973 and 1982, to reach approximately the cost of the Super-Phenix.[44] These cost overruns are, in part, due to the decentralization of German decision-making. Major conflicts emerged between the federal and Länder governments during the construction of the SNR-300. The Minister of the Interior of Nordrhein-Westfalen, for example, refused to authorize the construction of the reactor, deeming that it represented an irreversible step toward a "plutonium society", whereby the plutonium by-products of the FBR could be used for potentially dangerous activities.[45] The matter was finally referred to the constitutional court. In view of the long-term implications of the project, however, a vote in the Bundestag in 1979 finally gave the project the necessary authorization to continue.[46] The SNR-300 joint venture, however, ended in failure, with the reactor finally being shut down.

In summary, the SNR-300 was intended to put Germany ahead in fast breeder technology in comparison to other countries, however, led to a loss of credibility for both the government administration and the industry. It highlighted the increasing strength of the judiciary on issues of technology policy and, as suggested by the first hypothesis, and called into question the social use and application of FBR technology.[47] The failure of the sodium-cooled FBR at Kalkar had a significant impact on public opinion and seemed to galvanize the public against nuclear energy in Germany, once and for all.

One of the main criticisms of the project was that government "checks and balances" were lacking in the policy-making process. Few, if any, decisions made by the Science Ministry were challenged by other political institutions, like the Finance Ministry, the cabinet or parliament.[48]

> Parliamentary control was practically absent. The Bundestag committee in charge of government R&D policy drew its information mainly from the ministry [Science], occasionally also from leading individuals from the organizations performing the program or from foreign institutions involved in fast breeder development.[49]

The electricity-cost estimates, for example, presented to the Science Ministry, were formulated by a study group comprised of young scientists, most of whom had come directly from university. As well, there was no economist in the group.[50] Further, the decision to build the SNR-300 at Kalkar was, in part, based on inaccurate energy predictions, which suggested "that high-grade uranium reserves would be exhausted by the 1990s and rising uranium prices would then help the LMFBR to economic competitiveness"[51].

3.4 Changes in Policy

Having now established that there were both political opposition and technical difficulties associated with commercial nuclear fission, we now look to see whether the German nuclear industry has been increasingly obliged to pursue alternative strategies in order to allay public concerns and ensure the viability of the industry. General shifts in policy on the part of industry and government toward international cooperation are then examined to assess the validity of our second hypothesis.

The federal government was little involved in energy policy-making before the mid-1970s.[52] As nuclear issues became more politicized, however, the government was forced to take a more active role in the decision-making process. Increasing state intervention may be explained by the influence of growing public discontent with nuclear power, especially in the case of Germany. In response to the public protest at Whyl, for example, the government launched an extensive information campaign in order to appease public concerns and discontent.[53] However, the fact that the nuclear enterprise is associated with large corporations which are closely connected with the state, and given that nuclear technology, by its very nature, is vulnerable (i.e. it requires strict supervision and security in order to protect the public from potential dangers, such as sabotage or the theft of fissionable material), necessitates at least some degree of government regulation.[54]

Since the mid-1970s, the German federal government has provided considerable support to the nuclear industry, specifically in the area of R&D.[55] The increasing involvement of government in nuclear R&D can be explained by the fact that the development of new technologies involved significant costs, high risks and long lead times, beyond the capabilities of business enterprise. As well, in view of the increased emphasis on technology and competitiveness in the international economy, large-scale intervention has become necessary.[56] Between 1953 and 1977, for example, public expenditure in Germany grew from 0.8 billion DM to 12.8 billion DM in the area of civilian, as opposed to military, R&D.[57] In 1988, Germany contributed approximately 2.7 per cent of GNP to R&D, as opposed to approximately 2.4 per cent in France and the United Kingdom.[58]

In the late 1970s, the Commission of Inquiry (Enquête Commission) was initiated by the federal government. This parliamentary inquiry, which was mandated to examine the nuclear debate mainly from a social perspective, represents a milestone in energy forecasting in Germany. Specifically, the Commission's mandate was to investigate "the possibilities and consequences of using 'and' abandoning nuclear energy", despite the fact that all parties in parliament at the time officially supported nuclear energy.[59] As well, its mission was to judge the merits of FBRs, while assessing the technical risks and social consequences of nuclear energy. Never before in German policy-making had an official parliamentary commission expressed doubts about the future use of nuclear energy. Further, it was the first time in parliamentary history that critics of nuclear energy were represented in a commission of inquiry.[60]

Briefly, at the conclusion of the inquiry, the Commission's recommendations included support for energy conservation, the development of renewable energy resources and support for R&D in the area. Nuclear energy still remained an option, as well as the construction of more nuclear power plants, if required.[61] The German government remained committed to fostering public support for nuclear power,

> and to this end took steps to ensure stability of uranium supplies, to encourage public confidence in the safety and operation reliability of German nuclear power plants, and to initiate studies and proposals for the long-term disposal of nuclear wastes.[62]

These actions though, in conjunction with the continuing high level of government funding for nuclear R&D, did not solve the licensing problem.[63] Delays plagued the nuclear industry throughout the 1970s, obliging renewed intervention the 1980s. In October 1982, the Cabinet Committee for the Peaceful Uses of Nuclear Power approved changes that would facilitate the decision-making process.

> These included the standardization of plant designs, timely and complete submission of licensing documents, uniform assessment of plants with respect to the provisions against damages required in accordance with current knowledge, limitation of public participation in the case of modifications to plants which did not entail negative consequences or dangers to third parties.[64]

Another shift in nuclear policy is reflected by the evolving role of the Fraunhofer Gesellschaft (FhG) which, as of the 1970s, was mandated to put greater emphasis on the promotion of R&D and new technologies. The FhG, an Association of Institutes of Applied Research, represents approximately twenty-five institutes which function as R&D laboratories. One of its main objectives is to disseminate technology to industry, in particular to small companies. Prior to 1965, it was relatively small. Thereafter, however, funding increased rapidly and it was made the chief vehicle for support of applied research. A noteworthy aspect of the FhG is its mandate from the BMFT to promote the commercialization of (new) technologies.[65]

3.5 The Evolution of Nuclear Technology

With respect to the second hypothesis, in response to increasing capital costs, long-term investment risks and increasing international competition in key sectors of high technology, German actors have been forced to pursue new industry-government relations, by way of international consortiums and joint ventures, involving the extensive exchange of information between firms, according to the concept of strategic partnering. A government role in industrial restructuring has become acceptable,

> [b]ecause of the outstanding importance of a reliable and sufficient energy supply on the socio-economic conditions in a country and as a basis for international competitiveness any government has a vital interest in energy politics and these can not be left solely to the forces of a free market economy. In the specific case of nuclear energy with all the implications of a worldwide political discussion it is inevitable that governments have to play an important role.[66]

3.5.1 *Advanced Nuclear Fission Systems*

As noted in Chapter Two, Germany has engaged in projects such as the NPI, as represented by the consortium between Siemens/KWU and Framatome, with the objective of developing and marketing a common PWR reactor on the international market, in response to the need for greater standardization and harmonization in the safety field. The German government and industry, through the KfK and Interatom, directly support initiatives toward a common fast breeder reactor type for Europe, in which collaborative R&D is highlighted. German-French agreements, including the SERENA initiative, in which the KfK and Interatom play a key role, is representative of detailed exchanges of technology and marketing information in support of European collaboration in FBR design. The REP 2000 Programme is also a key area of collaboration between European utilities, regarding the development of an advanced LWR, targeted for the next century. These examples of international cooperation reinforce the second hypothesis, as they represent moves toward integration and exemplify the notion of strategic partnering. As well, they represent the increasing need for innovative strategies at the international level in order to meet economic competition.

3.5.2. *Nuclear Fusion*

According to the two hypotheses, the pursuit of nuclear fusion is part of a long-term strategy in response to considerable public opposition to nuclear power and technical difficulties associated with commercial nuclear fission. The development of nuclear fusion technology conforms to new industry-government relations and priorities at the international level. Germany's commitment to nuclear fusion is supported by its own nationally-based fusion activities, most of which are directly related to JET and NET, and its participation in the European Fusion Programme.

The nuclear fusion breakthrough regarding the T3 reactor at the Kurchatov Institute in 1969 had a major impact on the German nuclear fusion programme, which was mainly concentrated on stellarators, an alternative line to the tokamak.[67] However, in the early 1970s, it launched its own tokamak project, namely PULSATOR at Garching, a refined design of the T3.[68]

Although the tokamak is considered to be one of most popular and promising prototypes, in terms of achieving a commercially viable fusion reactor, Germany also carries out projects regarding alternative lines to the tokamak, such as stellarators, as indicated above. Germany conducts a stellarator programme at Garching, the Wendelstein VII-A, one of the largest stellarators in the world.[69] Among its experimental stellarators is the Wendelstein VII-X, an advanced stellarator with superconducting coils, which has the objective of demonstrating reactor relevance of stellarators.[70]

In a publication by a team of leading research centres in Germany ("Arbeitsgemeinschaft der Grossforschungseinrichtungen (AGF)"), the significance of JET, in relation to the German fusion programme, is highlighted. The report indicates the key roles of the IPP, the Karlsruhe and Jülich research centres, as well as the Hahn-Meitner Institute for nuclear research in Berlin, in JET. In particular, IPP and Jülich played a direct role in building JET and continue their involvement through the research work of their participating scientists, as well as through the experimental R&D work they conduct. The R&D currently being undertaken also has multifarious applications in the context of NET.[71] As indicated earlier, NET, the next phase device, which is at the conceptual design stage within ITER CDA [Conceptual Design Activities], "aims at fully confirming the scientific feasibility and at addressing the technological feasibility of fusion as a potentially safe and environmentally acceptable, practically inexhaustible source of energy"[72], thus supporting the first hypothesis. Further, regarding ITER, Germany hosts the joint work of about forty to sixty professionals, sponsored by Euratom, at the IPP for a period of several months annually.[73]

Germany has made a significant commitment to the European Fusion Programme at the national level by undertaking ASDEX-UPGRADE, with the objective of plasma impurity control and the medium-sized tokamak, TEXTOR experimental fusion reactor at Jülich, begun in 1981 and concentrated on plasma/wall interaction studies.[74] The construction and operation of TEXTOR is based on an Agreement between Euratom, Canada, Japan, Turkey and the United States.[75]

The endorsement at the head-of-state level for international cooperation in nuclear fusion, as represented by the JET Joint Undertaking, is particularly important to Germany, given the substantial public opposition to nuclear fission. Germany has been involved in the JET programme from its inception and had a significant role in the project's organization. Readers will recall from Chapter Two, that representatives of the CEA, Culham and the IPP met in Saclay, France, to discuss the JET proposal. Germany's key role in the negotiations is attested to by the nomination of Hans-Otto Wüster as the first Project Director of JET.

The necessity of international collaboration in nuclear fusion was attested to in an interview with La Recherche (1985), whereby Heinz Riesenhuber (Christian Democratic Party (CDU)), Federal Minister of Research and Technology, saw a Europe of science and technology as a means of increasing the prestige and ability of European industry to penetrate international markets.[76] He states that he is in favour of putting Community funds toward R&D, especially in cases where a Community effort is more effective and economical or from a scientific or technical point of view. He cites the Community programmes in the area of nuclear fusion and ESPRIT as examples. Further, Riesenhuber indicates that the collaborative activities in the context of the two programmes avoid parallel research and create a new kind of scientific progress and competitiveness.[77]

Nuclear fusion continues to receive support from government in the 1990s. The Research Minister Riesenhuber (current) has suggested that nuclear fusion research could be carried out in centres in Karlsruhe or Garching. Such research could entail fusion R&D for international projects, which would include the United States, the Soviet Union and Japan.[78] As of 1990, Germany had invested DM3bn in nuclear fusion since 1974. The Bonn Research Ministry anticipates that the annual investment figure in this field will double to DM400m.[79] Some members of government, however, such as the chairman of the Bundestag Committee for Research, Technology and Technology Assessment, Wolf-Michael

Catenhusen (Social Democratic Party (SPD)), are less enthusiastic about putting more money into fusion and would like nuclear fusion to continue at the "lower-cost level of basic research". Nevertheless, alliance partners at a European Community level have not indicated their intent to either pull-out from or freeze fusion research.[80]

Nuclear fusion, as a preferred, long-term energy alternative, is particularly relevant in Germany, where opposition to nuclear power has been significant. As well, clearly, government and industry are committed to the pursuit of nuclear fusion and, an increased government role in nuclear R&D, with special emphasis on international collaboration in nuclear fusion, took place in Germany over the 1980s.

Chapter Three Notes

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2. Ibid., p. 236.

3. Wolf-J. Schmidt-Küster, "German Nuclear Energy Development and International Cooperation" in Joseph F. Pilat, Robert E. Pendley, and Charles K. Ebinger, eds., Atoms for Peace: An Analysis After Thirty Years, Boulder, Westview Press, 1985, p. 109.

4. The above data regarding Germany's early reactors is from Stanley Ernest Hunt, Fission, Fusion and the Energy Crisis, 2nd ed., Oxford/New York, Pergamon Press, 1980 (1973), p. 90.

5. Dian Schefold, "Shift of Research Policy to Independent Organizations (Especially Those Under Private Law) as Expression of Uncertainty in Science," in Bernard Crousse and Michael Th. Greven, ed., Political Science and Science Policy in an Age of Uncertainty, Frankfurt Campus Verlag, 1985, p. 150.

6. Discussion of the private law form and the evolution of the Federation's involvement in research is adapted from Ibid., pp. 150-179.

7. J. K. Paul, ed., High Technology, International Trade and Competition: Robotics, Computers, Telecommunications, Semiconductors, based on research by International Trade Administration, United States Department of Commerce, Washington DC and Office of Technology Assessment, Congress of the United States, Washington DC, Park Ridge (New Jersey), Noyes Publications, 1984, p. 374.

8. Ibid., p. 381.

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10. The Law was revised in 1976 with the addition "safety must take precedence over economic development and promotion of nuclear technology". In 1976, another amendment was added, stating that licensing would be dependent upon strict safety requirements of nuclear installations and the federal government would be responsible for the arrangements regarding the long-term storage and disposal of radioactive wastes (Joseph A. Camilleri, The State and Nuclear Power: Conflict and Control in the Western World, Sussex, Harvester Press, 1984, pp. 124 and 220).

11. John L. Campbell, Collapse of an Industry: Nuclear Power and the Contradiction of United States Policy, Ithaca (New York), Cornell University Press, 1988, p. 144.

12. Paul, ed., High Technology, p. 376.

13. Ibid., p. 376.

14. Campbell, Collapse of an Industry, pp. 144-45.

15. See John Zysman, Governments, Markets, and Growth: Financial Systems and the Politics of Industrial Change, Ithaca (New York)/London (England), Cornell University Press, 1983, pp. 251-266.

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17. Zysman, Governments, Markets, and Growth, p. 264.

18. Hall, "Patterns of Economic Policy," p. 25.

19. Keck, Policy-making in a Nuclear Programme, p. 25, and Robert Rycroft and Robert Brenner, Nuclear Energy Facility Sitting in the United States: Implications of International Experience, Research Monograph, No. 46, Princeton: Center for International Studies, Woodrow Wilson School of Public and International Affairs, 1981, p. 106, in Campbell, Collapse of an Industry, p. 148.

20. Ibid., p. 148.

21. Ibid., p. 144.

22. Paul, ed., High Technology, p. 375. Unless otherwise indicated, the above paragraph is adapted from Ulrich Däunert, "Understanding the Structure of the Nuclear Industry," Nuclear Engineering International, May 1981, pp. 28-32. See also Wolfgang Fach and Georg Simonis, Die Stärke des Staates im Atomkonflikt: Frankreich und die Bundesrepublik im Vergleich, Frankfurt, Campus Verlag, 1987, p. 85.

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25. Ibid., p. 139.

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28. Jim Falk, Global Fission: The Battle Over Nuclear Power, foreword by Robert Jungk, Melbourne, Oxford University Press, 1982, p. 125.

29. Dorothy Nelkin and Michael Pollack, The Atom Besieged: Antinuclear Movements in France and Germany, Cambridge (Mass.)/London (England), MIT Press, paperback ed. 1982 (1981), pp. 61-62. For a detailed account of the protest at Whyl see Ibid., pp. 61-64.

30. Falk, Global Fission, p. 126.

31. Ibid., p. 127.

32. Camilleri, The State and Nuclear Power, p. 137.

33. Thomas Roser, "Mulheim-Kärlich: Down By Law", Nuclear Engineering International, March 1992, pp. 22-23.

34. The summary of the Mulheim-Kärlich case is adapted from Ibid., pp. 22-23.

35. Camilleri, The State and Nuclear Power, p. 139.

36. Ibid., p. 139.

37. Otto Graf Lambsdorf, "Why the Government Strongly Supports Nuclear Power," Nuclear Engineering International, December 1978, p. 48, in Ibid., pp. 139-40.

38. Ibid., p. 140.

39. Campbell, Collapse of an Industry, pp. 174-175.

40. Ibid., p. 175.

41. Ibid., pp. 175-76.

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44. Dominique Finon., "SuperPhénix: la dictature de la nécessité," La Recherche, vol. 14 (140), January 1983, p. 78.

45. Michael Pollak, "Qui veut de Kalkar?", La Recherche, vol. 14 (140), January 1983, p. 77.

46. Ibid., p. 77.

47. Ibid., p. 76.

48. Keck, Policy-making in a Nuclear Programme, p. 223.

49. Ibid., p. 223.

50. Interviews with participants, November 1975, December 1975, October 1979, March 1980 in Ibid., pp. 108-9.

51. Ibid., pp. 230-31.

52. Hans Diefenbacher and Jeffrey Johnson, "Energy Forecasting in West Germany: Confrontation and Convergence," in Thomas Baumgartner and Atle Midttun, eds., The Politics of Energy Forecasting: A Comparative Study of Energy Forecasting in Western Europe and North America, Oxford, Clarendon Press, 1987, p. 73.

53. Falk, Global Fission, p. 125.

54. Ibid., p. 130.

55. Paul, ed., High Technology, p. 374.

56. Keck, Policy-making in a Nuclear Programme, p. 7.

57. Ibid., p. 1.

58. Martine Barrère, "Science et Europe: deux mots faits pour s'entendre", La Recherche (Dossier: La Science en Europe), vol. 19 (200), June 1988, p. 714.

59. The Social Democrats (SPD) (43 per cent of the seats in parliament) and the Liberal Democrats (FDP) (10 per cent of the seats) were forming a coalition government, while the Christian Democratic Union (CDU) and the Christian Social Union (CSU) (Bavaria) represented the opposition. By 1976, however, sizable

minorities in each of the parties began to doubt the future of nuclear energy (Diefenbacher and Johnson, "Energy Forecasting in West Germany," p. 76).

60. The above paragraph on the Commission of Inquiry is adapted from Ibid., pp. 75-77.

61. Ibid., p. 80.

62. Camilleri, The State and Nuclear Power, p. 140.

63. Ibid., p. 140.

64. ATW News, November 1981, p. 1, in Ibid., p. 140.

65. The above paragraph on the FhG is adapted from Paul, ed., High Technology, pp. 379-80.

66. Däunert, "Understanding the Structure," p. 31.

67. E. N. Shaw, Europe's Experiment in Fusion: The JET Join Undertaking, foreword by J. Teillac, Amsterdam, North-Holland, 1990, p. 17. The stellarator represents another method for the confinement of plasma in a nuclear fusion reactor (see note #23 in Chapter One).

68. Ibid., p. 17.

69. Ibid., p. 17.

70. IAEA, "General Overview", Nuclear Fusion (30 Years of "Nuclear Fusion" Anniversary Issue), vol. 30 (9). September 1990, p. 1659.

71. Eberhard Gockel, ed., Arbeitsgemeinschaft der Grossforschungseinrichtungen (AGF), Kommission Kernfusion, Deutsches Fusionsprogramm, Bonn, January 1985, pp. 1-8.

72. IAEA, "Executive Summary," Nuclear Fusion (30 Years of 'Nuclear Fusion' Anniversary Issue), vol. 30 (9), September 1990, p. 1645.

73. K. Tomabechi, "International Thermonuclear Experimental Reactor (ITER)," Revue général nucléaire, no. 1, January/February 1991, p. 96.

74. IAEA, "General Overview", p. 1659.

75. D. Palumbo, "The European Fusion Programme," in IAEA, Fusion Reactor Design Technology: Proceedings of the Third IAEA Technical Committee Meeting and Workshop on Fusion Reactor Design and Technology, Tokyo, October 5-16, 1981, Vienna, IAEA, 1983, p. 25.

76. Martine Barrère (remarks collected by), "L'Europe de la science: les ministres nous répondent," La Recherche, vol. 16 (171), November 1985, p. 1423.

77. The above comments by Riesenhuber are adapted from Ibid., p. 1424.

78. Karin Deckenbach, "International Partners Sought for Nuclear-Fusion Trials," German Tribune, no. 1437, September 30, 1990, p. 9.

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CHAPTER FOUR

DEVELOPMENTS IN THE NUCLEAR INDUSTRY AT THE EUROPEAN LEVEL

Chapter Two and Three represented micro studies of an essentially a global industry. Chapter Four focuses on developments at the European level, as Europe has been the forum for intensive cooperation in nuclear fusion and other high technology industries. In particular, Chapter Four extends the second hypothesis, i.e. that nuclear fusion favours international cooperation and integration, corresponding to new government strategies in the area of high technology, amid increasing international competition. It does so by explaining the shift from the "national champion" approach in the 1960s to international collaboration and new forms of cooperation between firms, such as strategic partnering. Chapter Four thus highlights the changes occurring in the international political economy, as well as the fundamental shift from a Fordist to a knowledge-intensive based paradigm, as they affect government strategy towards high technology and, in particulaı, the nuclear industry.

4.1 European Actors

The main actors of at the European level for the purposes of the thesis are Euratom and the European Coal and Steel Community (ECSC)/European Economic Community (EEC).

Euratom was created on April 17, 1957, with the main objective of achieving the creation and growth of a European atomic industry, in which EC members would agree to common R&D programmes.[1] Euratom's mandate was very ambitious, especially in view of the vital interests the nuclear sector represented to member states, such as defense and national independence.[2] Nevertheless, Euratom's efforts were concentrated in the following areas: (1) the development of common research, (2) the establishment of common security norms and standards, (3) the granting of loans for the construction of civilian nuclear installations, (4) supplying European utilities with minerals and nuclear fuel, and (5) the establishment of a control service to ensure that nuclear materials were not diverted to other ends.[3] For over thirty years, Euratom has established institutions, as well as research programmes, and continues to provide a forum for collaborative work in areas such as radiation protection, security of the fuel cycle, the management of radioactive wastes, thermonuclear fusion and basic R&D.[4]

The ECSC and EEC Treaties were established by the Treaties of Paris and Rome on April 18, 1951, and March 25, 1957, respectively. The Commission is a key institution in the EC system and reports to the European Parliament. At the time of writing (pre-Maastricht Treaty ratification), the Commission has a monopoly on legislative issues and exercises its decisional right over cases relating to the Treaties of Paris and Rome. As well, the Commission has financial autonomy and can exercise its rights and powers independently. Under the Commission are a series of Directorates General (DG), including a directorate for the internal market and industrial affairs (DG III), one for science, research and development (DG XII), which includes the Joint Research Centre (JRC), and, one for energy (DG XVII). The JRC is a research body of the Community, financed 100 per cent by the latter, which conducts research in specific areas, such as fusion technology.[5]

Another main institution of the EEC is the Council of Ministers, comprising representatives of member states who undertake a variety of topics, such as energy, the environment and agriculture.[6] The Council ensures the coordination of general economic policy of the member states and has judicial and quasi-legislative powers and shares certain powers with the European Parliament.[7]

4.2 Background to Developments in the Nuclear Industry in Europe

In keeping with the second hypothesis, we expect to find an increasing move toward international collaboration, especially as it relates to high technology industries, including nuclear fusion. A brief outline of the evolution regarding collaboration by EC members in nuclear fusion is as follows: In the 1950s, fusion programmes existed in each country as distinct national programmes subject to security classification. Only in the 1960s do we see the emergence of scientist-to-scientist exchanges. A major change with respect to collaboration in the area of nuclear fusion was the shift from associated laboratories to a common enterprise between the Commission and the Associations. The 1970s entailed joint projects between national programmes and, in the 1980s, a high-level government framework was established.[8] Most importantly, for the purposes of the thesis, it should be emphasized that the European Fusion Programme embodies all R&D work carried out in participating member states and represents itself as a unified body in its relations with other international fusion programmes.[9] A further explanation of this evolution is detailed below.

In the 1960s, Euratom's initiatives to coordinate European collaboration in the area of nuclear technology met with little success, mainly due to the strong national orientations of its member states. "[T]he real cause for the crisis" of Euratom in the late 1960s was "the absence of any genuine political will for joint action"[10]. "Given the adequacy of their own resources for immediate objectives, ...[France and Germany] wanted Euratom to specialize and remain remote from existing industrial activities in the nuclear sector."[11]

France already had a significant nuclear capability and Germany was well on its way to rebuilding its economic infrastructure to compete internationally. France, for example, rebuffed Euratom in favour of nationalist policies.[12]

> CEA officials saw their organization as the principal administrative anchor of European nuclear programs. Through early cooperation with the Commission, they hoped to 'nip in the bud' any nascent pretensions that Euratom might become the European equivalent of the CEA.[13]

France's desire was to have Euratom complement French resources and not become the pillar of independent Community programmes.[14]

German industry was unsupportive of Euratom because it considered itself strong enough in the chemical and electrical areas, for example, to compensate for lost time.[15] It also regarded Euratom, a supra-national organization, as a threat to free enterprise.[16] Further, there existed an internal rivalry between Germany and France.

> Cooperation with the United States and Great Britain in civilian nuclear programs was a natural complement to Germany's dependence on these countries in strategic nuclear areas. Cooperation internally, however, especially with France, risked a permanent institutionalization of Germany's backwardness.[17]

In Germany, the approach adopted was "whatever one did internationally, one must do at home on at least twice the scale"[18].

Why did the predominantly national approach not work? Purely nationally-based programmes led to considerable duplication of technology[19] and hampered effective competition, primarily vis-à-vis the United States. Sharp and Shearman highlight other reasons as to why European collaboration became a necessity. As they indicate, European technological collaboration has arisen as a result of rising costs and higher risks of investment, the convergence of technologies, the need for capabilities which span both scientific disciplines and business experience, and the increasing need to seek out global markets, as explained below.[20]

The co-financing of projects among countries, which has become commonplace, came about as a result of rising capital costs and the high risk of long-term investment. Cost-sharing has become a necessity to carry the burden of product development, manufacturing and marketing. As in the case of JET, companies involved in new technological areas are often required to pursue several research paths, before adopting one specific design.[21] As well, as with the areas of high energy physics and scientific space research, "if no programme is mounted at the European level, and, increasingly, at the fully international level, then progress, if it remains possible at all, becomes severely limited"[22].

Industry and government have become increasingly aware of the significance of competitiveness in the international economy. In the period 1983-84, it was acknowledged that Europe was lagging technologically behind the United States and suffering from "Eurosclerosis". Amid the "Euroscelerosis" debate, the United States and especially Japan were conquering new international markets, particularly in high technology fields. Europe was required to do the same.[23]

The requirement for collaboration also became apparent for capabilities which spanned both the scientific disciplines and business experience. Business and science often have common goals when it concerns international competition, which include strengthening the internal market, encouraging standardization and making full use of the division of labour within Europe.[24] As well, as indicated in Chapters Two and Three, expertise from different areas, such as the scientific and economic/public policy domains, in the context of energy forecasting, is necessary in order to achieve balanced results and publicly acceptable policies. As a result of the convergence of technologies, development teams are required to become increasingly cross-disciplinary.

4.3 Shifts in Policy

In response to the changing international priorities, new industry-government relations and strategies for international cooperation emerged. Briefly, some of the milestones in European policies supporting such change are as follows: In the late 1960s, especially in response to American competition, the Commission had already begun to emphasize the importance of cross-national mergers.[25] In 1974, the OECD International Energy Agency (IEA) was founded in response to the 1973 oil crisis in order to provide a framework for multilateral cooperation.[26]

In terms of nuclear fusion per se, the International Fusion Research Council (IFRC) was created in 1970 by the IAEA and meets annually.[27] In 1974, the EEC Commission considered the strategic development of the energy industry. Based on an interim report prepared by a subcommittee of CERD (European Committee on Research and Development), among the priority areas identified in response to issues such as energy conservation and utilization, the substitution of oil with other energy sources and the development of new technologies, figures the substitution of oil with nuclear energy for electricity generation and other uses.[28] As well, in terms of an energy strategy, the Commission of the EC acknowledges R&D as being central to achieving a common energy research policy, which could contribute to a new strategy for a common energy policy.[29] The salience of R&D, in fact, "emerged in the mid- and late 1960s as the linchpin of a whole set of economic and strategic processes central to the life of individual countries as well as European unity"[30]. In terms of strategic areas, the Report highlighted nuclear energy and projected the HTR and FBR for the 1980s and 1990s and nuclear fusion as a long-term goal.[31]

Throughout the 1970s and especially the 1980s, the topic of nuclear fusion became increasingly politicized. The Economic Summit's Fusion Working Group was initiated in 1982, when President

Mitterrand indicated in Versailles his intent to couple technology, growth and employment.[32] In terms of the priority assigned to developing nuclear fusion, in relation to Mitterrand's stated objective, it appeared as the second of eighteen topics in the technology listing. Since then, a Fusion Working Group was officially formed in 1983 and has set out goals for international fusion programmes.[33]

4.4 Changes in the Global Political Economy

From a theoretical perspective, the following section draws upon international relations literature, especially that of Krugman and Mytelka, to explain the changes in the international economy as of the late 1960s/1970s, which led to policy shifts and new criteria for competitiveness in the international economy. Despite their different state systems, as Chapters Two and Three demonstrated, both France and Germany conform to trends toward increasing international collaboration and strategic partnering, especially in high technology sectors.

Krugman and Mytelka highlight the dynamic and changing conditions of the international economy and the move by industry and government toward strategic partnerships, especially in the high technology sectors. As noted earlier, Krugman indicates that traditional theories of comparative advantage, the concept of profit and liberal trade are being challenged by new forms of competition, amongst others, in the form of monopolies and oligopolies, in specialized, knowledge-intensive sectors.

Krugman advances three main arguments in the context of the changing landscape of the international economy, namely (1) the changing role of the United States, (2) the changing character of international trade affecting many countries, and (3) the changing view of economics, especially as it pertains to industrial structure and competition. Briefly, Krugman highlights the increasing importance of international trade for the United States' economy. In the 1960s, he states that the United States was primarily selling products to American customers and competing with American rivals. However, especially as of the 1980s, international considerations have taken precedence and have led to increased competition.[34]

In terms of the changing view of the economy, innovation and technology exchange has become paramount, as has the role of basic R&D which, according to Krugman, yields spillovers to other parts of the economy. Clearly, given the increased emphasis on the internationalization of trade, where technology would appear to be a driving force behind international specialization, the traditional concept of comparative advantage no longer applies. The following attributes, according to Krugman, define the new international economics: international specialization, the heightened role of technology, which can generate important spillovers to other sectors, and major innovations in terms of industrial organization. This analysis leads Krugman to argue that government policies to support technology leaders have become a central element in creating comparative (i.e. competitive) advantage.[35]

Mytelka's analysis of the international economy builds upon that of Krugman's and underscores the shift from the Fordist paradigm to one characterized by primarily the knowledge intensity of production. The crisis of Keynesianism is characterized by a crisis in productivity and consumption, coupled with "rising imports of standardized, mass-produced products from low-wage countries"[36], and rising inflation and unemployment. Mytelka highlights that the growing trend of knowledge intensity of production pervades all sectors of the economy, "where knowledge is understood to include not only the classical components of research and development but also design, engineering, advertising, marketing and management"[37]. Mytelka emphasizes that in the current competitive reality, "non-material investment and changes in the organization and in the management of the innovation, production and marketing processes have become key elements in a firm's competitiveness"[38].

According to Mytelka, among the characteristics of the new international economy are (1) an increasing move toward liberalization, i.e. deregulation of domestic industry parallel to the opening of markets abroad in the 1980s, (2) the emergence of strategic trade policies, (3) the shift away from industrial to technology policies in Europe and other advanced industrial countries, and (4) promotion by states of strategic partnerships.[39] These trends correspond to a fundamental shift from the old Fordist paradigm to the new ICT model, characterized by changes from an energy (labour) intensive paradigm to an information-intensive one, hierarchical management structures to flat horizontal management structures, and single firm to networks, for example.[40]

With respect to the nuclear industry, examples of new industry-government relations and international collaboration abound. As indicated in Chapters Two and Three, the new criteria of the competitive economy is reflected in the nuclear industry in the form of extensive knowledge sharing between firms and new marketing strategies, such as the NPI and SERENA initiatives, which seek to streamline existing technologies and thereby win greater public acceptance in terms of advanced reactor systems. As well, the nuclear industry favours strategies which encourage the standardization of technology and security norms, as the NPI and EFR illustrate.

Based on the assumption that government and industry of industrialized nations favour the development of high growth sectors, primarily in order to remain competitive internationally, nuclear fusion may be considered a "core technology", i.e. one "with persuasive effects on the economy, whose mastery is decisive for growth, competition and strategic independence"[41]. Clearly, technology has become a major factor of competitiveness. For a listing of areas of technological advantage in Europe, see Table II.

4.5 The European Fusion Programme

The commitment by EC member states, to an international, collaborative effort in nuclear fusion, is attested to by the involvement of representatives of heads-of-state in the context of the European Fusion Programme. The European Council of Ministers, for example, articulated that the aim of the European initiative in fusion is "the joint construction of prototypes with a view to their industrial production and marketing"[42]. The structure of the Fusion Programme comprises three basic levels, i.e. a programme organization, government laboratories and industry, in which the role of the government laboratories predominates.[43]

Regarding the new type of programming at the European level which emerged in the 1980s, a watershed is the international cooperative programme ESPRIT, launched in 1984. The objectives of ESPRIT include (1) the promotion of intra-European industrial cooperation in R&D in five main Information Technology (IT) areas, including advanced microelectronics software technology, advanced information processing, office systems and computer-integrated

TABLE II

Patterns and Trends of Technological Advantage in Western Europe

Increasing	Stable	Decreasing
Advantage		
Agricultural chemicals	Drugs and medicines	Industrial organic chemistry
Soaps and detergents	Primary ferrous products	Industrial inorganic chemistry
Metal-working machinery	Special industrial machinery	Plastics and synthetic resins
Household appliances	General industrial machinery	Primary and secondary non-ferrous products
Miscellaneous electrical machinery	Miscellaneous non-electrical machinery	Engines and turbines
Nuclear reactors and systems	Electrical industrial apparatus	Motor vehicles
Aircraft and parts		
Disadvantage		
Food	Paints and varnishes	Office computing
Miscellaneous chemical products	Petroleum and gas	Radio and TV
Fabricated metal	Rubber and plastics	Electronic components; telecommunications equipment
Farm and garden machinery	Electrical transmission	Instruments
Construction and mining equipment	Guided missiles and space vehicles	
Refrigeration equipment		
Electric lighting and wiring		

Source: Pari Patel and Keith Pavitt, "Is Europe Losing the Technology Race?", Research Policy, no. 1, 1987, in Margaret Sharp and Claire Shearman, European Technological Collaboration, London/New York, Routledge and Kegan Paul, 1987, pp. 108-109.

manufacture, (2) the furnishing of European industry with the basic technologies in order to compete effectively through the 1990s, and (3) the development of European standards.[44]

JET and NET represent similar objectives to ESPRIT, insofar as they provide a common forum for collaboration and, specifically, the construction of prototypes, in the area of nuclear fusion at the European level, in order to enhance Europe's competitiveness on international markets. The organizational structure of JET and NET exemplify this new type of programming, as they are based on extensive international collaboration between partners.

Briefly, JET is headed by a Project Director, Paul-Henri Rebut of the CEA (1991). The JET Council, comprising representatives of Euratom and each member or associated country, is assisted by the Executive Committee and may seek the advice of the JET Scientific Council. The Council's main responsibility is the project's management[45], including approving the programme and budget estimates, as well as audited accounts.[46] The national research institutions provide the JET Council with information on technical issues.[47] The programme is steered by the Consultative Committee for the Fusion Programme (CCFP), made up of representatives of each member or associated country. The CCFP is an advisory body to the Commission on the technical, managerial, financial and political aspects of the project.[48] The executors of the programme are the Associations, JET, JRC and NET.[49] The management structure of

JET/NET (Figure 2) is a good example of the combining of political and technical elements of decision-making at the European level.[50]

The Commission, comprising fifteen delegations, including one from the Commission, one from each EC member state, as well as one from Sweden and Switzerland, fully associated with the programme[51], is responsible, to a large extent, in view of its extensive financial contribution (eighty per cent), for financial decisions regarding the project and its management.[52] The Council of Ministers, with the assistance of the Committee of Permanent Representatives, assumes responsibilities relative to political decisions of the project.[53]

In addition to its joint administrative structure, according to the Euratom Treaty, the EC Fusion Programme is approved at five-year intervals.[54] The Council of Ministers, however, opted for the sliding-programme principle, whereby after three years, a new five-year programme is established, overlapping the previous one by two years.[55] In order to avoid JET from becoming "a political football to be kicked around annually", it was believed that a system similar to the one at CERN (Conseil européen pour la recherche nucléaire)[56] should be proposed, whereby the budget for each year is settled one year in advance and provisionally two years in advance.[57]

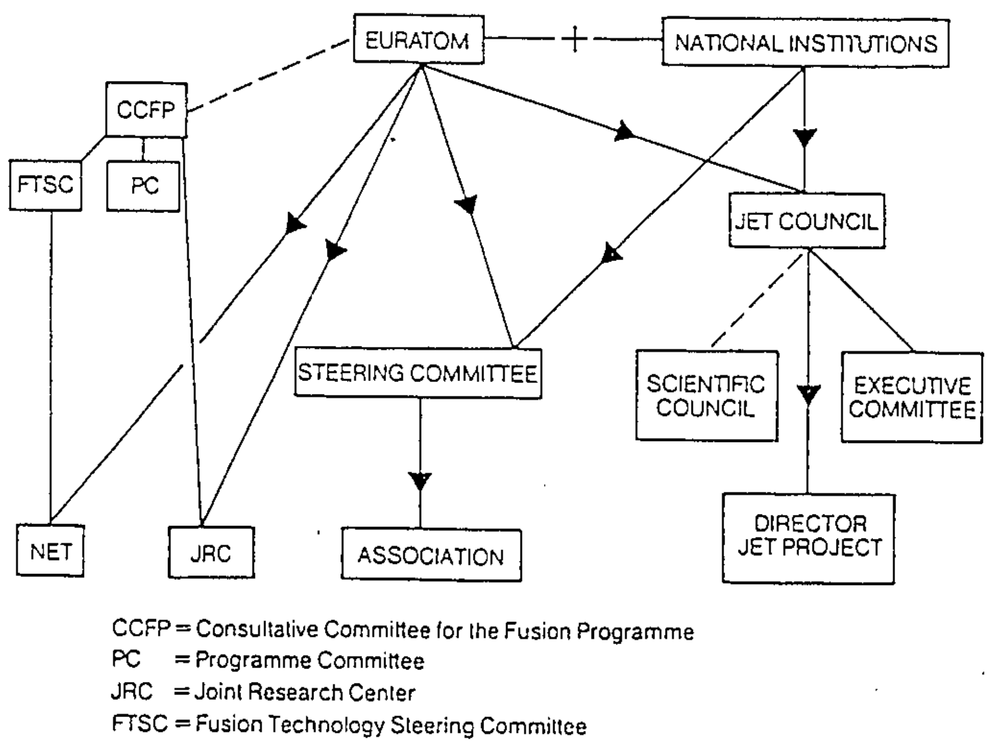

FIGURE 2

Management Structure for the European Fusion Programme

Source: D. Palumbo and D. R. Harries, "The European Fusion Programme," Journal of Fusion Energy, Vol. 6 (2), 1987, p. 106.

As indicated above, JET is financed by Euratom to the extent of eighty per cent, ten per cent is assumed by the host country, the United Kingdom, and the remaining ten per cent is shared between the associated laboratories in member states (including Switzerland and Sweden), in proportion to their annual budgets.[58] At the project's outset, the general weighting of funding contributions in relation to GNP and a probable supply level to JET was as follows, for a representative selection of countries: United Kingdom 32.6 per cent, Germany 29.4 per cent, France 20.6 per cent, Italy 9.9 per cent, Belgium 4.5 per cent, Denmark 2.5 per cent, Ireland 0.5 per cent.[59] Including national institutions, funding for the EC fusion programme is approximately 400 to 450 million ECUs per year or 0.5 per cent of the annual overall budget of the EC (1990).[60] Figure 3 represents the percentage contribution of the different partners to the budgets of JET.

The relationship between industry and government in the nuclear sector is unique compared to other advanced technology sectors in the EC (for example, IT), insofar as the ECSC and Euratom Treaties conferred specific responsibilities for nuclear industries upon the EC, enabling Euratom to provide a forum for collaboration in the area of R&D. A formal provision for general industrial or technology policy in Europe, however, does not exist.[61]

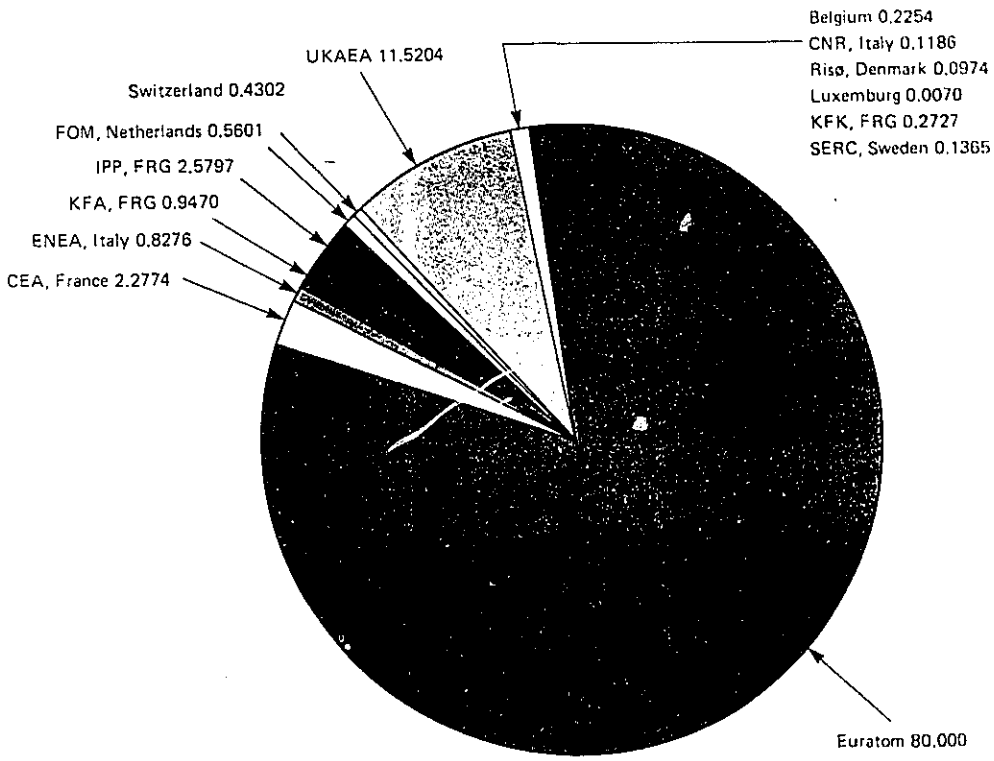

FIGURE 3

Percentage Contributions of the Different Partners to the Budgets of JET (1984)

Source: E. N. Shaw, Europe's Experiment in Fusion: The JET Joint Undertaking, foreword by J. Teillac, Amsterdam, North-Holland, 1990, p. 170.

With respect to the role of industry in the Fusion Programme, despite the effort to keep decision-making with respect to JET within the programme until essentially the manufacturing stage, industry was brought in early.[62] This avoided developing products that already existed on the market or reinventing already existing technologies.[63] In general, contracts with industry were considered more effective than those with the Associations, as there was a clear client-supplier role with industry, which was not the case with the Associations. However, the Associations also undertook many contracts relating to the design and the construction of JET.[64]

To date, there is no evidence to suggest a business-government (Community) partnership in the programme. Nevertheless, most R&D contracts are awarded to large companies and multinationals, such as Siemens, for example, which also conduct extensive, in-house R&D programmes. Yet, due to the non-commercial (pre-competitive) nature of nuclear fusion activities at present, industry's involvement is limited. It is estimated that, in the context of the European Fusion Programme, government laboratories of the participating nations are given approximately eighty per cent of fusion contracts, while industry receives twenty per cent.[65] Industry's role, however, especially that of the private sector, is expected to increase as the fusion programme progresses.[66] Spin-off technologies apply to the fields of vacuum technology and high precision mechanics, advanced processing and manufacturing techniques and the development of materials, and high power densities.[67]

In his analysis of the interconnection between the nuclear industry and the state, one of Joseph Camilleri's main observations is, in France as in Germany, the commercialisation of nuclear energy became, for the most part, dependent on the state's administrative and financial resources.[68]

> State intervention, whether through the intermediary of public electricity utilities or through direct government planning and expenditure aimed at maximising electricity consumption, was largely instrumental in generating the demand for nuclear electricity ... Where the domestic market could not, as in the case of most European countries, sustain competing reactor designs or more than one manufacturer of nuclear steam supply systems, governments took the initiative re-organising the industry, partially with view to achieving economies of scale, reducing capital costs and ensuring long-term viability.[69]

Consequently, R&D was put directly or indirectly under the control of governments, despite Germany's firm ideological commitment to market principles and its strong financial and industrial base of private capital. This trend is even more obvious in France, "where the required level of scientific and technical development exceeded the capability of domestic capital"[70]. The above reinforces our second hypothesis, as international collaboration and the formation of strategic alliances between firms and governments have become increasingly necessary in the new competitive reality.

It has been suggested that increased government support for international projects, such as nuclear fusion, increases the perceived public acceptability of such programmes. In the case of government-financed, as opposed to solely industry-financed R&D, there is a tendency for optimism, with respect to the technological and economic evaluation of new civilian technology.[71] As well, support for programmes at the national and international levels tend to reinforce support for the technologies in question.

> The existence of this international commitment to fusion provides an incentive for participating nations to develop and maintain adequate fusion capability to successfully compete for involvement in the Euratom fusion programme, whose principal experiment is the JET.[72]

The above gives credence to the Franco-German axis, as programmes which were supported by these two countries were the most likely to be successful.[73] Therefore, France and Germany, besides being motivated by their own self-interest and desire to enhance their respective competitive positions on world markets, may be considered key actors and integral to the overall success of the European Fusion Programme.

Developments in the nuclear industry parallel broader trends at the European level. Moves toward integration are reflected in the Single European Act (1987). The Act adds a Title to Part III of the EC Treaty and may be considered a first step toward a unified Europe, economically, socially and monetarily. As well, the Act represents the first time that Community policies in the area of advanced technologies were given a legal basis, an integral step in terms of the Community's efforts to remain competitive on international markets.[74] According to the Title (VI, Article 130F):

> The Community's aim shall be to strengthen the scientific and technological base of European industry and to encourage it to become more competitive at an international level. In order to achieve this it shall encourage undertakings, including small and medium-sized undertakings, research centres and universities in their research and technological development activities; it shall support their efforts to co-operation with one another, aiming, in particular, at enabling under-takings to exploit the Community's internal market to the full, in particular through the opening-up of national public contracts, the definition of common standards and the removal of legal and fiscal barriers to that co-operation.[75]

The Act also specifies a multiannual framework programme, which lays out the main scientific and technological objectives and defines priorities of the EC. Consider, for example, Tables III and IV with respect to the five-year Framework Programme budgets for 1987-91 and 1990-94, respectively.

As Chapter Four indicated, Euratom's mandate has taken on new importance, as the nation-state is no longer able to compete independently in high technology sectors, due to significant capital and investment costs and the risk of long-term technology. As of the 1970s, we noted an increase in collaborative projects,

TABLE III

1987-91 Framework Programme Budget

	Projected expenditures ECUm	% of total
I **Quality of life**		
Health	67	1.2
Radiation protection	60	1.1
Environment	292	5.1
II **Towards an information society**		
IT (ESPRIT)	1,534	27.3
Telecommunications (RACE)	462	8.2
Applications of IT	105	1.9
III **Modernisation of Industry**		
Manufacturing (BRITE)	396	7.0
Advanced materials (EURAM)	205	3.6
Raw materials	65	1.5
Standards	188	3.3
IV **Biological resources**		
Biotechnology	121	2.2
Agro-Industry	88	1.6
Agricultural competitiveness	56	1.0
V **Energy**		
Fission	472	8.4
Fusion	902	16.0
Non-nuclear	190	3.3
VI **S & T for development**	67	1.2
VII **Exploiting the sea-bed**	67	1.2
VIII **S & T Cooperation**		
Stimulation	176	3.1
Large Facilities	25	0.4
Forecasting	22	0.4
Dissemination	56	1.0
Total	5,617	100.0

Source: Department of Trade and Industry, <u>A Guide to European Community Industrial Research and Development Programmes</u>, London, July 1990 ed., in Margaret Sharp, "The Single Market and European Technology Policies," in Christopher Freeman, Margaret Sharp and William Walker, eds., <u>Technology and the Future of Europe: Global Competition and the Environment in the 1990s</u>, London, Pinter Publishers, 1991, p. 68.

TABLE IV

1990-94 Framework Programme Budget

	Projected expenditures ECUm	% of total
I **Enabling technologies**		
1 *Information and communications technologies*		
Information technologies	1,352	23.7
Communication technologies	489	8.6
Development of telematics	380	6.6
2 *Industrial and material technologies*		
Industrial and materials	748	13.1
Measurement and testing	140	2.5
II **Management of natural resources**		
3 *Environment*		
Environment	414	7.3
Marine Sciences	104	1.8
4 *Life sciences and technologies*		
Biotechnology	164	2.9
Agriculture and agro-industry	33	5.8
Biomedical and health	133	2.3
Life sciences for Third World	111	2.0
5 *Energy*		
Non-nuclear	157	2.9
Fission safety	199	3.5
Controlled fusion	458	8.0
III **Management of intellectual resources**		
6 *Human capital and mobility*	518	9.0
Total	5,700	100.0

Source: Department of Trade and Industry, A Guide to European Community Industrial Research and Development Programmes, London, July 1990 ed., in Margaret Sharp, "The Single Market and European Technology Policies," in Christopher Freeman, Margaret Sharp and William Walker, eds., Technology and the Future of Europe: Global Competition and the Environment in the 1990s, London, Pinter Publishers, 1991, p. 70.

such as JET/NET and ESPRIT, parallel to increased emphasis on technology policy and integration. These trends are also reinforced by the Single European Act. Our data thus supports a fundamental shift from a Fordist paradigm to one based on knowledge-sharing, where new industry-government relationships, in the form of strategic partnering, have become necessary in order to compete in the global market.

Chapter Four Notes

1. Margaret Sharp et Claire Shearman, European Technological Collaboration, London/New York, Routledge and Kegan Paul, 1987, p. 28.

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3. Ibid., pp. 63-64.

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6. Fontaine and Malosse, Les alphabetiques Retz, p. 44.

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9. D. Palumbo and D. R. Harries, "The European Fusion Programme," Journal of Fusion Energy, vol. 6 (2), 1987, pp. 105-109.

10. Quoted in the European Community, March 1969, p. 5 in Roger Williams, European Technology: The Politics of Collaboration, London, Croom Helm, 1973, p. 41.

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13. Nau, National Politics, p. 108.

14. Ibid., p. 108.

15. Daniel Pepy, "Euratom", Droit social, January 1957, in Olivier Pirotte et al., Trente ans d'expérience Euratom: la naissance d'une Europe nucléaire, Brussels, Bruylant, 1988, p. 17.

16. Pirotte et al., Trente ans d'expérience Euratom, p. 18.

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38. Ibid., p. 26.

39. Ibid., p. 25.

40. Based on the table by C. Perez. Technical Change, Competitive Restructuring and Institutional Reform in Developing Countries, World Bank Strategic Planning and Review discussion paper, No. 4, World Bank, Washington, DC, 1990, and R. Boyer, Paper given to OECD Conference on Technical Change in Helsinki, December 1989, in Christopher Freeman, Margaret Sharp and William Walker, eds., Technology and the Future of Europe: Global Competition and the Environment in the 1990s, London, Pinter Publishers, 1991, p. 11.

41. François Chesnais, "Science, Technology and Competitiveness," STI Review, no. 1, Paris, OECD, Autumn 1986, p. 98.

42. Palumbo and Harries, "The European Fusion Programme," p. 105.

43. Fiona H. Jarrett, "International Collaboration in Magnetic Fusion Energy: The Industrial Role," Journal of Fusion Energy, vol. 6 (2), 1987, p. 216.

44. J.-M. Cadiou, "Esprit, un premier bilan", Bulletin de Liaison de la Recherche en Informatique et Automatique", No. 105, 1986, p. 3, and Commission of the European Communities, ESPRIT The First Phase, Progress and Results, Brussels, 1987b, in Lynn Mytelka, "States, Strategic Alliances and International Oligopolies: The European ESPRIT Programme," in Lynn Krieger Mytelka, ed., Strategic Partnerships: States, Firms and International Cooperation, London, Pinter Publishers, 1991, p. 184.

45. United States National Research Council, Commission on Engineering and Technical Systems, Energy Engineering Board, Committee on International Cooperation in Magnetic Fusion, Cooperation and Competition on the Path to Fusion Energy, Report, Washington, National Academy Press, 1984, p. 83.

46. Shaw, Europe's Experiment, p. 142.

47. U. S. National Research Council, Cooperation and Competition, p. 83.

48. D. Palumbo, "The European Fusion Programme," in IAEA, Fusion Reactor Design Technology: Proceedings of the Third IAEA Technical Committee Meeting and Workshop on Fusion Reactor Design and Technology, Tokyo, October 5-16, 1981, Vienna, IAEA, 1983, p. 11-12.

49. Palumbo and Harries, "The European Fusion Programme," p. 105.

50. U.S. National Research Council, Cooperation and Competition, p. 83.

51. Maisonnier, "The European Community Fusion Programme," p. 73. The participating countries in JET are Belgium, Denmark, Germany, Greece, France, Ireland, Italy, Luxembourg, Netherlands, Switzerland, Sweden, Spain, Portugal and the United Kingdom.

52. U.S. National Research Council, "Cooperation and Competition," pp. 83-84.

53. Ibid., p. 84.

54. Palumbo and Harries, "The European Fusion Programme," p. 107.

55. Ibid., p. 107.

56. CERN, created on September 29, 1954, is focused on basic research in the area of high energy particles and has its headquarters in Geneva, Switzerland.

57. Shaw, Europe's Experiment, p. 28.

58. Palumbo, "The European Fusion Programme," p. 8.

59. Shaw, Europe's Experiment, p. 137.

60. IAEA, "General Overview," p. 1659.

61. Sharp and Shearman, European Collaboration, p. 26.

62. Shaw, Europe's Experiment, pp. 129-130.

63. Ibid., p. 130.

64. Ibid., p. 130.

65. The above paragraph is adapted from Jarrett, "International Collaboration," pp. 216-217.

66. Ibid., p. 216.

67. IAEA, "General Overview," p. 1666.

68. Joseph A. Camilleri, The State and Nuclear Power: Conflict and Control in the Western World, Sussex, Harvester Press, 1984, p. 276.

69. Ibid., pp. 276-77.

70. Ibid., p. 278.

71. Otto Keck, Policy-making in a Nuclear Programme: The Case of the West German Fast Breeder Reactor, foreword by Robert G. Gilpin, Jr., Lexington (Mass.)/Toronto, LexingtonBooks, 1981, p. 245.

72. Jarrett, "International Collaboration", pp. 215-16.

73. Margaret Sharp, "The Single Market and European Technology Policies," in Christopher Freeman, Margaret Sharp and William Walker, eds., Technology and the Future of Europe: Global Competition and the Environment in the 1990s, London/New York, Pinter Publishers, 1991, p. 62.

74. The above paragraph is adapted from Ibid., p. 59.

75. Ibid., p. 59.

CHAPTER FIVE

CONCLUSION

The thesis has attempted to validate the two hypotheses presented in Chapter One, namely (1) nuclear fusion, based on the assumption that it will provide a commercially viable source of energy, represents a long-term alternative strategy of an industry forced to innovate, in response to political and technical obstacles relating to nuclear fission, and (2) in an industry which has come to rely increasingly on government financing due to the high capital costs and financial risk associated with long-term research, nuclear fusion reinforces trends toward international cooperation and integration, corresponding to new industry-government strategies in the area of high technology.

Briefly, in order to achieve the above, the following methodology was used. The thesis undertook a core case study over time, from approximately 1970 to 1992, in order to analyze the evolution of the nuclear industry, from the time of the launching of the commercial fission-based industry in the early 1970s to a period of increasing public opposition and technical difficulties associated with nuclear fission, beginning in the mid-1970s.

The two comparative case studies, France and Germany, were central to the thesis due to their key roles in the nuclear industry and the European Fusion Programme. Each country has a different state system, and yet, despite their differences, the evolution of their respective nuclear industries as of the 1970s illustrated common public policy trends in the area of high technology, and specifically nuclear technology.

These trends, as we have shown, led to the pursuit of alternative strategies, including the promotion of nuclear fusion, which corresponds to new industry-government relations in the area of high technology. The time frame for our study occurs in a period of global industrial restructuring in terms of the internationalization of capital and finance, where international joint ventures, collaboration and strategic partnering, involving knowledge sharing between firms, have become central to policy-making, especially in the area of high technology. The thesis assessed the applicability of the above trends in the context of the nuclear industry in France and Germany, as well as at the European level.

Chapter One provided background information on the evolution of the nuclear industry. Broad trends in this regard were noted, beginning with the military applications of the industry. The 1950s/60s were characterized by restrictive cooperation in R&D between countries, principally due to the secret nature of nuclear technology. The energy crisis of the 1970s played a key role in launching the commercial nuclear industry, as we know it today. The 1970s also initiated the shift from a Fordist-based international economy to globalization, industrial restructuring, new business-government arrangements, as well as the preeminence of competitiveness in the 1980s and 1990s. The fundamental difference between the principles of nuclear fission and fusion were highlighted to explain how, due to the decreased amount of radioactive wastes associated with nuclear fusion and the potentially limitless source of energy it represents, nuclear fusion could represent a more publically acceptable form of commercial energy than the current fission-based industry.

An underlying theme of the thesis, as articulated by Frewer, is as follows: In terms of the relationship between the political and technical dimensions of the nuclear industry, assumptions with respect to the postulated course of the nuclear industry entail the belief that the long-term viability of the industry depends not only on improved economic efficiency and the maximization of capital costs, but also on increased reliability and safety, and enhanced public acceptability. Accordingly, each successive phase of technological development builds upon the experience and expertise, to some degree, of the former. In this regard, nuclear fusion can be viewed as an ultimate technology choice in the substitution process, notwithstanding the fact that nuclear fusion represents a fundamentally different type of energy, as compared to fission.

In order to evaluate the two hypotheses, with respect to the first hypothesis, evidence in the context of the two case studies regarding public opposition and technical difficulties vis-à-vis commercial nuclear fission was examined, as were the moves on the part of government, toward more transparent public policy. Policy shifts and the improvement of existing reactor systems and/or the introduction of more advanced ones were highlighted. To set the stage for the second hypothesis, we reviewed new priority areas of the international economy, such as the salience of R&D and new industry-government arrangements, including strategic partnering. Data supporting the fundamental shift, from the old Fordist paradigm to a knowledge-intensive one and how nuclear fusion corresponds to the above criteria, was used in this analysis.

Chapter Two developed the two hypotheses in the case of France. Here we saw that the centralized state system played a key role in the promotion and public acceptance of the nuclear industry in France, insofar as it protected government bureaucrats from public opposition, due to strong central management and policy-making, and facilitated the implementation of nuclear policies, through streamlined regulatory and licensing procedures. This was demonstrated by the sub-case study, the Super-Phenix, which was administratively less problematic and relatively successful, in contrast to the SNR-300 at Kalkar in Germany, which met with political wrangling at nearly every step of the regulatory and implementation process.

Despite the efficacy of a centralized state system, however, France did not escape the public pressures and technical difficulties associated with commercial nuclear fission. In terms of public opposition, the public protests at La Hague, in Alsace and Plogoff in the 1970s and 1980s, for example, indicated substantial public opposition to nuclear fission. In terms of technical difficulties, perhaps the relatively recent difficulties surrounding the Super-Phenix at Crey-Malville were among the most disappointing technical setbacks for the nuclear industry, especially in a country where nuclear energy is deemed to be a success.

We found that France was obliged to introduce policy shifts, which included more flexible forms of public policy, entailing the creation of new agencies, such as the AFME (1982), in an effort to allay public anxieties over nuclear power and open discussions based on alternative forms of energy. Issues such as nuclear safety were given heightened profile through the agency, Andra (1979), and an effort was made through the creation of the "Office parlementaire d'évaluation des choix scientifiques et technologiques" (1989), to open the debate about the social implications of technology.

Regarding the second hypothesis, due to increasing capital costs, risk factors and the complexity of nuclear technology, as of the late 1970s, France increasingly abandoned its predominantly national approach to nuclear policy and engaged in international projects in order to sustain economic competition. Examples of this included the following: NPI, as represented by the consortium between Framatome and Siemens/KWU, with the objective of developing and marketing a common PWR reactor on the international market, in response to the need for greater standardization and harmonization in the safety field; EFR, entailing collaborative R&D toward a common fast breeder reactor for Europe; the SERENA initiative, representative of detailed information exchanges between countries in support of FBR collaboration in Europe; as well as the REP 2000 Programme, aimed at establishing a common front for European utilities to articulate their requirements for an advanced light water reactor prototype in the next century. These examples correspond to new industry-government strategies at the international level, as they support collaboration in R&D and promote strategic partnering, in an effort to maximize economic efficiency and competitiveness.

The pursuit of commercial nuclear fusion, beginning in the 1970s, played an important role in this new industry-government approach to support the nuclear industry. Nuclear fusion is seen to represent a more publicly acceptable form of nuclear energy, as opposed to fission, and corresponds to new industry-government arrangements in the 1980s and 1990s.

Briefly, the European Fusion Programme, including JET, NET and DEMO, represent a long-term, cooperative project of EC member states, designed to lead to the joint construction of nuclear fusion prototypes. The programme corresponds to new industry-government relations at the international level, as it represents a cutting edge in nuclear technology and, nuclear fusion, by its very nature, requires extensive international cooperation and collaboration, as well as knowledge-sharing between firms and governments. ITER, also an international initiative in fusion, aimed at demonstrating the scientific and technological feasibility of fusion power, represents similar trends.

France's renewed commitment to nuclear fusion, which began in 1959 through a joint agreement in R&D between the CEA and Euratom, was represented by its involvement in the European Fusion Programme and ITER. In particular, France's contribution to the international effort in fusion R&D was demonstrated by TFR (1973) and TORE SUPRA (1986), two nationally-based, experimental tokamaks. As well, France's commitment to nuclear fusion was also represented by FE 200, a high flux thermal station located in France, jointly-owned by the CEA, Framatome and the EC, which will be made available to laboratories working in the area of fusion. The latter also conforms to new industry-government competitive strategies, as FE 200 represents an important forum for the pooling of technological know-how.

The German case study presented in Chapter Three also examined the two hypotheses. The lack of success of the fission-based industry in Germany was attributed, to a large extent, to the significant role of public opposition, as supported by the courts and the broadly consensus-based, decision-making process. As a result of Germany's decentralized policy-making structure, mobilizing a broad base of support at the federal and Länder levels was difficult, if not impossible, to obtain.

Examples of public opposition and technical difficulties were numerous in Germany and included the public uprisings at the Whyl (1975), Brokdorf (1976) and Kalkar (1977) reactor sites and opposition to the Mülheim-Kärlich, for example. The THTR-300 in Hamm-Uentrop (1980s) and problems associated with the reprocessing of radioactive wastes, for example, represented technical difficulties associated with nuclear fission, which were difficult to overcome.

Despite the differences in state systems, similarities in terms of public policy approaches to nuclear energy were found in the German and French cases. In order to redress the status of nuclear energy, German industry and government were obliged to address public concerns, hence the Enquête Commission, for example, in the 1970s, mandated to investigate the nuclear debate.

Given significant public opposition to nuclear fission, nuclear fusion was considered a preferred, long-term energy alternative by industry and government. Nuclear fusion, besides allaying public concerns, as suggested by the first hypothesis, corresponds to new industry-government arrangements in high technology sectors in Germany too. Germany's commitment to the international effort in nuclear fusion was attested to by German involvement in the European Fusion Programme, given the extensive industry-government participation in the programme through national laboratories and projects, such as ASDEX-UPGRADE, TEXTOR and stellarator research, and in ITER, by hosting R&D work at the IPP in Garching.

Chapter Four reinforced the second hypothesis in particular. It described the shift from the "national champion" approach in the 1960s to new forms of industry-government relations in the 1980s and 1990s. From collaboration between the Associations in the 1960s on an ad hoc basis, the European nuclear industry evolved to a high-level government framework of programme coordination. In the area of fusion, Euratom became a unified body, representative of European collaboration, in its international relations with other countries, such as the United States and Japan.

The chapter drew upon the analyses of Krugman, Mytelka and Sharp, in particular, to explain why the traditional concept of comparative advantage has changed, making R&D, especially in knowledge-intensive sectors, a central pillar of technology policy in the 1980s and 1990s. International collaboration emerged, among other reasons, in response to rising capital costs, the convergence of technologies, the need for capabilities which span both scientific disciplines and business experience and the increasing need to seek out global markets. Consonant with the above, changes in the nuclear industry at the European level were noted.

As Chapter Four explained, the EC Commission began to emphasize cross-national mergers in the late 1960s. In the 1960s, Euratom was ineffective in coordinating the activities of the European Associations in the area of the nuclear industry. However, given the new emphasis on competitiveness, especially vis-à-vis the United States and Japan in advanced technology, Euratom achieved greater cooperation from member states with respect to collaborative nuclear R&D. European collaboration in nuclear fusion corresponds to new industry-government strategies of strategic partnering and multiparty joint ventures, as described by Mytelka, insofar as it involves knowledge-sharing, and has fundamentally changed the competitiveness of European firms and governments. As well, from a primarily nuclear fission-based focus in the early 1970s, the Community turned its attention to nuclear fusion, regarding a long-term, commercial energy alternative, as reflected in the European Fusion Programme.

Our analysis of changing public policy in the European nuclear industry raises broader questions for political scientists relating to the role of the nation-state in an era of global competitiveness. Evidence has been provided in the case studies to suggest that, despite the fact that it would seem that national economic goals, as they relate to the nuclear industry, are now being promoted through European collaboration, the role of the nation-state has not been obscured.

Williams[1], Paul[2] and Nau[3] suggest that, despite significant changes in policy and industrial structures, national goals have remained significant. France demonstrated its intent to be energy self-sufficient, for example. As well, in terms of the SERENA initiative, over and above its obvious interest in international cooperation, an underlying motive for France's participation in the project was its will to assert its leadership in the commercialisation of fast breeder technology.[4]

In the area of fusion, the European Fusion Programme is based on strong national programmes, such as TORE SUPRA in France and ASDEX in Germany. As indicated in a report on the German nuclear fusion programme, the success of the European Fusion Programme in the past and in the future is based on independent, national laboratories, in conjunction with an effective coordination through the Associations with Euratom.[5] Further, as Sharp and Shearman note, "European collaboration in the 1980s continues to be directly and indirectly afflicted by intergovernmental rivalries among national states and with the European Community"[6].

There does, nonetheless, appear to be political will behind European integration, as attested to by the Single European Act (1987). The French scientific community, for example, pronounced itself in favour of the "yes" vote on European unity (1992) at the time of the debate of the Maastricht Treaty.[7] Research in Europe has been rooted in the large institutions, such as Euratom, however, it is obvious that a harmonization among the main research bodies responsible for the management of R&D in the different countries can be beneficial.[8] In terms of science and technology policy, the Maastricht Treaty confirms the central role of collaborative R&D and supports decisions which would improve the competitiveness of European industry and promote modern, up-to-date policies in the area of the environment, agriculture and education.[9]

Regarding the possibility of an internationally-based nuclear fusion industry, it is important to consider the specificity of the nuclear industry in relation to other high technology areas. Due to the complexity of nuclear fusion, the effort to achieve nuclear fusion for commercial purposes has been an international collaborative endeavour from the beginning.[10] No one country has the financial means by which to pursue such an elaborate R&D project. This would, therefore, suggest that, possibly, some new arrangement will eventually be put in place to manage a commercial, fusion-based industry at the international level.

The ultimate success of nuclear fusion will depend on its scientific, engineering and commercial feasibility.[11] At this stage, given that the work in the context of the European Fusion Programme is primarily pre-competitive, partners, including France and Germany, have their respective areas of expertise and little competition would appear to exist between them. Once partners, both government and industry, perceive sufficient benefit in the long-term, there should be an incentive to sustain cooperation and collaboration in the short-term and reconcile, generally speaking, any major differences of view.[12] The real debate, however, regarding the public acceptability of nuclear fusion, has not yet emerged.

Chapter Five Notes

1. Roger Williams, European Technology: The Politics of Collaboration, London, Croom Helm, 1973, pp. 152-171.

2. J. K. Paul, ed., High Technology, International Trade and Competition: Robotics, Computers, Telecommunications, Semiconductors, based on research by International Trade Administration, United States Department of Commerce, Washington DC and Office of Technology Assessment, Congress of the United States, Washington DC, Park Ridge (New Jersey), Noyes Publications, 1984, p. 382.

3. See Henry Nau, National Politics and International Technology: Nuclear Reactor Development in Western Europe, Baltimore, Johns Hopkins University Press, 1974.

4. Joseph A. Camilleri, The State and Nuclear Power: Conflict and Control in the Western World, Sussex, Harvester Press, 1984, p. 152.

5. Eberhard Gockel, ed., Arbeitsgemeinschaft der Grossforschungseinrichtungen (AGF), Kommission Kernfusion, Deutsches Fusionsprogramm, Bonn, January 1985, p. 6.

6. Margaret Sharp and Claire Shearman, European Technological Collaboration, London, Routledge and Kegan Paul, 1987, p. 82.

7. Hubert Curien, "L'Europe des chercheurs," Le Monde, September 18, 1992, p. 10.

8. Ibid., p. 10.

9. Ibid., p. 10.

10. Whereas, with respect to ESPRIT, for example, long-term cooperation in IT may not be guaranteed. In this instance, R&D partnerships with international actors and access to global markets will continue to exercise a counterweight to European collaboration in this area (Lynn Krieger Mytelka and Michel Delapierre, "The Alliance Strategies of European Firms in the Information Technology Industry and the Role of ESPRIT," Journal of Common Market Studies, vol. 26 (2), December 1987, in François Chesnais, "Technical Co-operation Agreements Between Firms," STI Review, no. 4, Paris, OECD, December 1988, p. 108).

11. W. Häfele, J. P. Holdren, G. Kessler and G. L. Kulcinski, Fusion and Fast Breeder Reactors, Laxenburg (Austria), International Institute for Applied Systems Analysis, revised edition July 1977 (November 1976), p. 6.

12. Margaret Sharp, "The Single Market and European Technology Policies," in Christopher Freeman, Margaret Sharp and William Walker, eds., Technology and the Future of Europe: Global Competition and the Environment in the 1990s, London/New York, Pinter Publishers, 1991, p. 62.

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