



The Sun on Earth

**How the Netherlands dealt with the Promise
of Nuclear Fusion, 1951-1979**

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Picture on frontpage: C.M. Braams (right) and D. Palumbo (middle) discussing the foundations of JET. Shaw, *Europe's Experiment in Fusion*, 8.

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1. Introduction

1.1. Promises of Nuclear Fusion

1.1.1. Hitting the Sixty-eighth Post

“Nuclear Fusion: A new era in the history of a centuries-old mansion,” headed the Dutch newspaper *Het Parool* on February 1959, announcing the new research institute for plasma physics in the Netherlands, FOM-Rijnhuizen, that would be opened later that year.¹ On the Rijnhuizen estate, located in Jutphaas, new constructions were built outside the manor, with the old stables making



Figure 1: Official opening of FOM-Rijnhuizen. Minister Jo Cals hits the sixty-eighth pile. Photo archive DIFFER.

way for large laboratory halls and workshops. The country house itself accommodated the theorists, management and the library of the institute. On 17 November 1959, the Minister of Education, Arts and Sciences, Jo Cals, knocked the sixty-eighth pile into the ground and opened the research institute festively.² In the next decades the scientists in these buildings would try to bring the sun to earth.



Figure 2: Minister of Education, Arts and Sciences Jo Cals during a debate in the House of Representatives on 12 July 1961. Wikimedia.

The sun, which derives its energy from a process of nuclear fusion, provided the inspiration for countless physicists all over the world to try to imitate this fusion process on earth to control this source of energy. The opening of FOM-Rijnhuizen marks the definitive establishment of the promise of controlled nuclear fusion in the Netherlands. This thesis

¹ ‘Kernfusie: een nieuw tijdperk in geschiedenis van eeuwenoud herenhuis’, *Het Parool* (14 February 1959).

² There is some debate as to exactly which pile Jo Cals hit into the ground. In the later memo from his own ministry it was claimed that it was the first pile on the construction site. However, the scientists of the old FOM-Rijnhuizen claim to know for sure that it was the sixty-eighth pile and the builders had already started earlier. ‘Kernfusie, thermonucleaire reacties, plasmafysica en FOM-activiteiten op dit gebied’ (2 January 1967), 2. NA 2.14.5168, Inventory number 8608.

examines the first three decades of the Dutch promise of nuclear fusion. From the first experiments in 1951 to a joint European collaboration on British soil in 1979.

During this period, the promise of nuclear fusion was characterized by a tension between the economic potential of an inexhaustible source of clean energy and the actual status of the research as a fundamental science. Nuclear fusion theoretically offered the possibility of extracting an almost inexhaustible amount of energy from relatively infinite resources, without producing radioactive waste. Clean, sustainable, energy which could provide an answer to predicted shortages of fossil fuels in the future. However, there were many technological and scientific problems that prevented a commercially deployable fusion reactor for ever being realised. The fusion reactor was always a few years into the future.

Nevertheless, there have been several moments in the history of nuclear fusion when a fusion reactor seemed closer than ever. By investigating how different Dutch stakeholders, such as scientists, investors, media and popular culture, related to the promise of nuclear fusion between 1951 and 1979, much can be learned about the context in which fusion research took place. Responses to the economic potential of nuclear fusion show that the will for European cooperation linked fusion research to the dynamics of the Cold War, that arguments for alternative sources of sustainable energy were already present in the 1950s, and that the believe in the promise of nuclear fusion was an important factor in the failure of the Dutch nuclear energy project.

1.1.2. Inexhaustible Clean Energy from Nuclear Fusion

The concept of nuclear fusion was discovered in 1920 by the chemist Francis Aston. Aston demonstrated that hydrogen atoms are relatively heavy compared to other elements.

Astrophysicist Sir Edmund Eddington subsequently argued that this meant that the sun fuses hydrogen into helium, converting the residual mass into energy via Einstein's $E=mc^2$. This was an important step in the debates about the origin of solar energy. For the first time serious theories were devised about mimicking this process on earth to gain

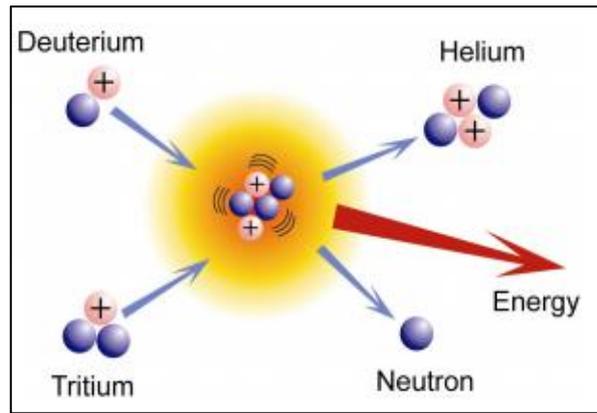


Figure 3: Two atoms, here deuterium and tritium, fuse. This fusion results in helium, a free neutron and energy. Westra, M.T., *Kernfusie: een zon op aarde* (Nieuwegein: FOM-Rijnhuizen, 2006), 2.

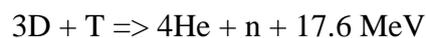
energy. The first international experiments were carried out before the 1940s, such as the discovery of plasma as a gas mixture of ions and electrons in 1927, the experiments in which tritium was made in Ernest Rutherford's laboratory in 1934, and the first experiments in the United States with trapping plasma in magnetic fields. International nuclear fusion research, however, really got off the ground after the Second World War.³

The fusion of two light atomic nuclei releases a lot of energy. Because a fusion reaction releases about four million times more energy than a chemical reaction such as carbon combustion, a nuclear fusion reaction requires only a minimal amount of fuel compared to a coal-fired power plant. In comparison, an average coal-fired power plant of 1,000 MW requires 2.7 million tonnes of coal to run for a year. For the same amount of energy, a fusion reaction uses only 250 kilograms of resources.

Many kinds of fusion reactions are possible: in stars, such as our sun, the light element hydrogen is converted into the heavier element iron by fusing light isotopes into heavier ones in different takes. Not every kind of fusion is suitable for replicating on Earth. For example, the fusion process that supplies the sun with energy cannot be used on Earth. The fusion process on the sun is slow because the sun burns relatively on a low heat. The energy that the sun

³ Vrouwe, A., *Hittebarrière: 50 jaar plasmafysica bij FOM-Rijnhuizen 1959-2009* (Houten: Drukkerij Badoux, 2009), 9-10.

produces in spite of the low temperature is due to the enormous size of the sun. This mass causes so much pressure in the centre that a fusion reaction starts. Only fusion reactions that have a reasonable reaction probability at a relatively low temperature and pressure are suitable for use on earth. The fusion reaction between the hydrogen isotopes deuterium and tritium (figure 3) is the easiest.⁴ This reaction runs according to this formula:



In this formula, D stands for the stable isotope of hydrogen, deuterium, with one proton and one neutron in the nucleus. T stands for the radioactive isotope of hydrogen, tritium, with one proton and two neutrons in the nucleus. $4He$ stands for helium, and n for neutron. The energy released is expressed in mega-electron Volt.⁵ A fusion reaction between two deuterium atoms (D+D) is theoretically possible on earth, making the use of radioactive tritium unnecessary.⁶ This reaction, however, requires a higher temperature, which in turn raises its own technical difficulties.⁷

Fusion does not happen by itself. Before a fusing reaction starts, atomic nuclei must be close enough to each other so that the strong nuclear force, which can only be felt at a short distance, can pull the nuclei towards each other. At greater distances, the electrical force predominates, and since the nuclei are charged positive, they repel each other. For the cores to come sufficiently close together, the temperature must be made sufficiently high.⁸

This temperature of one hundred and fifty million degrees Celsius brings matter into a special state: plasma, the fourth state of matter next to solid, liquid and gas. In the plasma state,

⁴ Westra, M.T., *Kernfusie: een zon op aarde* (Nieuwengien: FOM-Rijnhuizen, 2006), 3.

⁵ 1 MeV = $1.602 \cdot 10^{-13}$ Joule.

⁶ Tritium has a half-life of only 12.5 years in contrast to the half-life of 704 million years of the uranium used in nuclear fission

⁷ Westra, *Kernfusie: een zon op aarde*, 12.

⁸ *Ibidem*, 3-4.

electrons and nuclei move independently of each other. Plasma behaves like a turbulent liquid, which makes plasma a complex medium that can exhibit very complex behaviour. The behaviour of plasma together with the required temperature create the greatest obstacles in the search for commercially deployable energy from nuclear fusion.⁹

In recent decades, nuclear fusion research has focused on questions about plasma behaviour, plasma confinement and achieving a sufficiently high temperature. If these conditions are met and the price of the equipment can be reduced sufficiently, nuclear fusion offers an inexhaustible source of clean energy. This is the promise of nuclear fusion.

1.2. Balancing Between Interests: Historiographical Notions

1.2.1. Not Just Big Science

So far, Dutch fusion research has mainly been described by physicists involved in fusion research, or in commemorative books. The former director of FOM-Rijnhuizen, Kees Braams, did write an overview of the developments in international fusion research in which the Dutch contribution to this research is mentioned regularly. However, only the purely scientific development of the research is considered.¹⁰ A similar approach is used in the overview of the developments in Dutch physics after 1945 by the Dutch physicists Cees Le Pair and J. Volger. They thoroughly summarise the most important contributions to physics, including thermonuclear reactions, which includes nuclear fusion research and plasma physics.¹¹

A historiographical contribution on the organisation of Dutch nuclear fusion research is, however, often limited to a few entries in the historical descriptions of affiliated institutions.¹²

⁹ Ibidem, 2.

¹⁰ Braams, C.M., & P.M. Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research* (Bristol: IOP Publishing, 2002).

¹¹ Le Pair, C. & J. Volger (eds), *Physics in the Netherlands: a selection of Dutch contributions to physics in the first 30 years after the Second World War, Volume II* (Utrecht, 1982), 493 & 512.

¹² See for example Kersten, A.E., *Een organisatie van en voor onderzoekers: de Nederlandse Organisatie voor Zuiver-Wetenschappelijk Onderzoek (Z.W.O.) 1947-1988* (Assen, 1996), 143-147.

More detailed information on the organisation and science at Rijnhuizen is provided in a commemorative book published in celebration of the special anniversary of fifty years FOM-Rijnhuizen. The description of the history of the plasma physics in the institute in *Hittebarrière: Vijftig jaar plasmafysica bij FOM-Rijnhuizen* (2009) by science journalist Anouck Vrouwe is extensive, but lacks a focus on the historiographic debates and limits to the developments within the institute.¹³

Developments in international fusion research are more extensively documented. Especially by the fusion scientists themselves. The aforementioned book by Kees Braams is the most authoritative. Braams provides an overview of the major scientific fusion experiments in the world from the 1950s until the year 2000. Other examples report on the international collaboration projects, and on individual research in the fusion laboratories.¹⁴

In addition, several science journalists dealt with the international history of fusion based on interviews with fusion scientists.¹⁵ Individual episodes in the history of fusion research also received attention. This attention was not only limited to fusion scientists and science journalists, but some science historians also focused on the history of fusion research.¹⁶

In many of these descriptions, both by science journalists and science historians, nuclear fusion is described in the context of the rise of Big Science. Big Science is a concept used by science historians to interpret the developments in Western science after the Second World

¹³ Vrouwe, *Hittebarrière*.

¹⁴ Stacey, W.M., *The Quest for a Fusion Energy Reactor : An Insider's Account of the INTOR Workshop* (London: University Press, Incorporated, 2010); and Bruce Tarter, C., *The American Lab: An Insider's History of the Lawrence Livermore National Laboratory* (Baltimore: John Hopkins University Press, 2018). From the Russian side, Roald Sagdeev, who emigrated to the United States, described his experiences in Soviet Union fusion laboratories. Sagdeev, R.Z. & S. Eisenhower, *The making of a Soviet Scientist: my adventures in nuclear fusion and space from Stalin to Star Wars* (New York: Wiley, 1994).

¹⁵ Clary, D., *The Quest for Fusion Energy: A Piece of the Sun* (New York: Abrams, 2014); Herman, R., *Fusion: the Quest for Endless Energy* (Cambridge University Press, 1990); and Kenneth Fowler, T., *The Fusion Quest* (Baltimore: John Hopkins University Press, 1997).

¹⁶ See for example Shaw, E.N., *Europe's Experiment in Fusion: The JET Joint Undertaking* (Amsterdam: Elsevier Science Publications, 1990).

War. Increasingly larger projects emerged with funds from governments, or cooperation between different countries.¹⁷ Fusion research is often referred to as a striking example of Big Science, due to its large experiments, huge amounts of money and complex technology. Increasingly large funds were needed to pay for the ever larger experimental set-ups. As a result of



Figure 4: Photograph of the exterior of the Joint European Torus (JET) in 1991. JET is a great example of fusion as Big Science. EFDA-JET public relations page.

this development, fusion research began to focus on a different way of working in terms of producing the necessary materials and raising funds than was usual with smaller projects in which individual scientists and laboratories carried out research on a smaller scale, according to this historiography.¹⁸

Describing the development of fusion research in the context of the rise of Big Science means, however, that some decisive developments are overlooked, or underlying motives are only addressed to a limited extent. This is partly due to the focus on the scientists and their search for investments, whereby additional investments from industry or government are often attributed to a successful lobby from the scientists. This ignores possible other underlying motives that just as well determined investments. This thesis shows, by investigating the promise of nuclear fusion in the context of the Cold War, the search for alternative energy sources, and the failure of the Dutch nuclear energy project, that many more interests and opinions were involved in the development of Dutch nuclear fusion.

¹⁷ Price, D.S., *Little Science, Big Science* (New York: Columbia UP, 1986). A classic historiographical overview of the literature on the rise of Big Science is: Capshew, J.H., & K.A. Rader, 'Big Science: Price to the Present', *Osiris* 7 (1992), 2-25.

¹⁸ Kinsella, W.J., 'A "Fusion" of Interests: Big Science, Government, and Rhetorical Practice in Nuclear Fusion Research', *Rhetoric Society Quarterly* 26, 4 (1996), 66-68.

1.2.2. *Manoeuvring Between Super States: Dutch Cold War Science Policy*

Investments in fusion research are sometimes explained by pointing out the successful scientific lobby to portray nuclear fusion as a peace project. In 1952 the United States tested Ivy Mike, the first hydrogen bomb. With the help of a discharge by nuclear fission, an uncontrolled nuclear fusion reaction was initiated with devastating results. The successful test with Ivy Mike proved the power of fusion. To



Figure 5: An atmospheric nuclear test conducted by the U.S. at Enewetak Atoll on 1 November 1952. Ivy Mike was the world's first successful hydrogen bomb. The Official CTBTO Photo stream.

To tame this uncontrolled reaction, research programmes were started in the United States, Great Britain and the Soviet Union. However, these programmes did not succeed in solving the technical problems within a few years and did not create a fusion reactor.¹⁹

Because these attempts did not succeed, and because a fusion reactor for controlled nuclear fusion was not needed to produce weapons, the fusion research was declassified worldwide in 1958. In the succeeding years, collaboration and exchange between scientists from different countries, both East and West, was conducted which resulted in several major collaborative projects. This enabled fusion science to transcend the dynamics of the Cold War, according to the literature.²⁰

This thesis shows that the main reason to invest in Dutch fusion research was the possibility of European cooperation. Regardless of the belief in the promise of nuclear fusion, the Dutch government continued to invest in the research. Fusion research offered the possibility of European cooperation, because the European cooperation in the field of nuclear energy, which was established after the Second World War, focused increasingly on fusion research from the outset. Several countries saw added value in European cooperation, but were

¹⁹ Herman, *Fusion: the Quest for Endless Energy*, 10-12.

²⁰ *Ibidem*, 12.

not prepared to share the classified nuclear fission research. The added value of European cooperation consisted to a large extent in being able to jointly form a power block between the new superpowers of the Cold War, the United States and the Soviet Union. The development of Dutch fusion research was thus closely linked to the dynamics of the Cold War.

This offers an addition to the historiographical debate on post-war scientific research policy in the Netherlands. Two important phenomena, which were essential elements in the early Cold War, dominated the second half of the twentieth century: the rapid and powerful rise of science and technology as influential factors in society and the establishment of the global hegemony of the United States.²¹ According to the literature, the Dutch orientation in the years after the Second World War increasingly shifted towards the United States.²²

Historian Friso Hoeneveld states that Dutch natural science became so connected to the developments and investments in American science that it became inextricably linked to the greater conflict of the Cold War because investments in American science were supported by the dynamics of the Cold War and thereby the fear of the Soviet Union.²³ Historian David Baneke complements this statement by concluding that Dutch natural science focused primarily on the relationship with America and that the Soviet-Union was not used as a point of reference: “Western Europe took the West, not the East, as point of orientation”.²⁴ Cold War tensions, motivated by competition with the Soviet Union, played only a limited role in the Dutch science policy according to Baneke.²⁵

²¹ Hoeneveld, F., *Een vinger in de Amerikaanse pap - Fundamenteel fysisch en defensieonderzoek in Nederland tijdens de vroege Koude Oorlog* (Utrecht: Freudenthal Instituut, Universiteit Utrecht, 2018), 35; and Romero, F., ‘Cold War historiography at the crossroads’, *Cold War History* 14 (2014), 685-703.

²² See for example Von der Dunk, H.W., ‘Tussen welvaart en onrust. Nederland van 1955 tot 1973’, *BMGN* 101 (1986), 2-20.

²³ Hoeneveld, *Een vinger in de Amerikaanse pap*, 46-47.

²⁴ Baneke, D.M., ‘The Absence of the East: International Influences on Science Policy in Western Europe during the Cold War’, in J. Van Dongen (ed.), *Cold War Science and the Transatlantic Circulation of Knowledge* (Leiden, 2015), 166.

²⁵ Baneke, D.M., ‘De vette jaren: de Commissie-Casimir en het Nederlandse wetenschapsbeleid’, *Studium* 5 (2012), 110.

This thesis shows that, in addition to a focus on American science, Dutch science policy also focused strongly on European developments in fusion research. Dutch investments in fusion research were mainly set up to achieve further European cooperation. The aim of this European cooperation was to form a power block between the threatening superpowers of the United States and the Soviet Union during the Cold War, and to strengthen the position of the Dutch research by focusing on specialized niches. As a result, Dutch nuclear fusion research is a good example of the policy that Hoeneveld has called “getting in lane”.²⁶ In doing so, the Dutch government focused both on developments within the United States and developments within the Soviet Union.

These political motives behind the investments in nuclear fusion nuance the image of international fusion research as a peace project, which completely escaped the dynamics of the Cold War. The commitment of the Dutch government was indeed a peaceful cooperation between the European countries, but the desire for this peaceful cooperation was dictated by the dynamics of the geopolitical conflict of the Cold War.

1.2.3. A More Complicated History: Alternative Sources of Clean Energy

What does it say about the promise of nuclear fusion in the Netherlands when nuclear fusion was used to invest in European cooperation? In the decades between 1951 and 1979, the demand for fuel supply arose all over the world. Already in the 1950s concerns were expressed worldwide about the anticipated depletion of fossil fuels, which was accelerated by increasing prosperity. These questions were exacerbated by a restriction on oil supplies from the Middle

²⁶ “Getting in lane” is the English translation of the Dutch word “voorsorteren”. I borrow this translation from David Baneke. Baneke, D.M., ‘Let’s Not Talk About Science: The Normalization of Big Science and the Moral Economy of Modern Astronomy’, *Science, Technology and Human Values* (2019), 6. Hoeneveld, *Een vinger in de Amerikaanse pap*, 491.

East following the conflicts around the Suez Canal in 1956.²⁷ This pressure was also felt in the Netherlands, but a solution was soon to be found with the discovery of gas under the fields in Groningen in the early 1960s.²⁸

Yet it was precisely in the Netherlands that the same discussion flared up most strongly in the 1970s. In the early 1970s, an international group of scientists, captains of industry and philanthropists, who named themselves the Club of Rome, wrote a trendsetting report. The report from the Club of

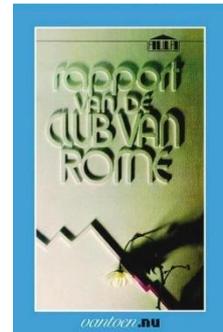


Figure 6: The Dutch translation of the report of the Club of Rome. Aulapocket 500.

Rome calculated that fossil fuels would be exhausted by the year 2000. A reduction in energy consumption was needed. At the same time the oil supply declined in a number of Western countries, including the Netherlands, with two oil crises in 1973 and 1979.²⁹

During these discussions, nuclear energy was seen as one of the main solutions. During the Second World War a different form of energy production from atoms than nuclear fusion blossomed, nuclear fission. In this process, a heavy atomic nucleus breaks into smaller pieces, which together are somewhat lighter than the nucleus used to be. The remaining mass is converted into energy. The world experienced the enormous, and destructive, power of this energy during the Second World War with the atomic bombs on Hiroshima and Nagasaki. Within a few years, scientists learned to curb this destructive force and use it for peaceful purposes: in 1951, four 15-watt incandescent lamps burned at the University of Chicago on the power of the first test power station. In 1954, the first nuclear power station in Obninsk in the Soviet Union was connected to the electricity grid.³⁰

²⁷ Verbong, G.P.J., and J.A.C. Lagaaij, 'Belofte van Kernenergie', W. Uriccho ed., *Techniek in de twintigste eeuw deel 2: defstoffen, energie, chemie* (Nijmegen: Vereniging voor de Geschiedenis van de Twintigste Eeuw, 1997), 239-242.

²⁸ Maas, A., 'De bietenakker van boer Boon: schop in eigen bodem 2,' in A. Maas & T. Cocquet (ed), *Verborgene krachten: Nederlanders op zoek naar energie* (Hilversum: Verloren, 2011), 103.

²⁹ Verbong, G.P.J., a.o., *Een kwestie van lange adem: de geschiedenis van duurzame energie in Nederland* (Den Bosch: Uitgeverij Aeneas BV, 2001), 56-60.

³⁰ Vrouwe, *Hittebarrière*, 10.

The Netherlands, too, invested a great deal of money in various periods for applied research into energy production from nuclear fission. However, energy extraction from nuclear fission had major drawbacks with the danger of radiation, radioactive waste and the expensive, limited raw materials such as uranium.³¹ The demand arose for alternative variants of clean energy. An alternative to fossil fuels, without the disadvantages of nuclear fission.

Energy historian Frank Liard shows that investments in alternative forms of energy, other than fossil fuels and nuclear fission, have a longer history than is often assumed in today's public debate. Liard places the origins of these investments in the 1970s and 1980s. Partly prompted by the Club of Rome Report, the two oil crises, and social objections to energy from nuclear fission in the 1970s, governments began to invest in alternative forms of energy, such as solar energy, wind energy and hydropower. Liard's main focus is on investments in the United States.³² His later articles also deal more specifically with the differences between the United States and other countries, including Germany, explaining the differences between the two countries' current energy policies based on different investments made in the 1970s.³³

Investments in alternative forms of renewable energy also began in the Netherlands in the 1970s. Energy historians Aat van Selm and Geert Verbong argue that based on the discussions about the Club of Rome Report, more policy attention was paid to these forms of energy and more was invested in research into these energy sources, including research into nuclear fusion.³⁴

This thesis nuances this perception. On the one hand, this research into nuclear fusion in the Netherlands shows that the arguments for alternative energy sources, besides energy from

³¹ Verbong, a.o., *Een kwestie van een lange adem*, 30-32.

³² Liard, F.N., *Solar Energy, Technology Policy, and Institutional Values* (Cambridge: University Press, 2001), 19-33.

³³ Laird, F.N., & C.H. Stefes, 'The Diverging Paths of German and U.S. Policies for Renewable Energy: Sources of Difference', *Energy Policy* 37, 7 (2009), 2619-2629.

³⁴ Verbong, a.o., *Een kwestie van lange adem*, 24-25 and 58

nuclear fission, were already being used by scientists in the 1950s and were also reflected in the media and popular culture. This mainly concerned the idea that with nuclear fusion an inexhaustible source of energy would be found that provided an answer to the depletion of fossil fuels and to the limited and expensive raw material uranium that was used for energy from nuclear fission. The lack of radioactive waste in nuclear fusion was also already recognized as an advantage by the scientists in the 1950s, but was not yet reflected in the public debate.

On the other hand, this thesis shows that this argumentation was not the main reason to invest in Dutch fusion research, despite the lobbying scientists. Increases in investments by the Dutch government in the 1970s were more in line with earlier investments in the 1950s and 1960s, rather than new policy. The main reason to invest in fundamental fusion research was consistently to promote the international position of the Netherlands, both scientifically and politically. Also in the 1970s, this remained the main reason and the resurgence of interest in alternative energy sources did not result in any significant additional investment in Dutch fusion research. So, the Dutch investors did not believe in the economic promise of nuclear fusion.

1.2.4. Failure of the Dutch Nuclear Energy Project

Despite the fact that nuclear fusion was not funded as an alternative form of sustainable energy, the promise of nuclear fusion played an important role in the failure of the Dutch nuclear energy project, which was based on nuclear fission. The promise of nuclear fusion was presented by activists as a serious alternative for nuclear fission. This argumentation managed to convince many social institutions, including a number of churches. The call from some of these churches to the Dutch government in 1977 to postpone the plans for new nuclear power plants and to enter into a broad public debate was honoured, which ultimately meant the abandonment of the Dutch nuclear energy project.

Several authors conclude that energy from nuclear fission did not really get off the ground in the Netherlands in the end. “Companies such as Mallinkckrodt in Petten, which supplies radiopharmaceuticals, and UCN in Almelo, which enriches uranium, may have made a profit, but the Rotterdam ‘Droogdok’ no longer builds reactor vessels, the nuclear power station in Dodewaard is waiting to be demolished, the KEMA suspension test reactor has already been demolished, and the Kalkar nuclear power station, for which the Netherlands paid 500 million euros, has become a theme park,” concludes the Dutch physicist Cees Andriessse in his devastating historiography of Dutch research into energy from nuclear fission.³⁵

The tipping point at which the major plans for the development of nuclear energy in the Netherlands were scaled down to an ever-increasing phasing out is generally situated in the postponement of the construction of three new nuclear power stations by the Dutch government in 1977.³⁶ This postponement would be followed by an attempt to engage in a broad public debate on the status of nuclear energy in the Netherlands. Under the leadership of the aristocrat De Brauw, many meetings were organised throughout the country in the early 1980s to gather opinions on nuclear energy. This meant many years of postponement and ultimately the cancelling of new investments in nuclear fission powered plants.³⁷

Several explanations are provided for the postponement of these nuclear power plants, including the rising costs and the reluctance of industry to actually start investing in energy sources other than fossil fuels. The main cause identified by historians, however, is the increasing social resistance to nuclear energy, which translated into strong social activism in

³⁵ Andriessse, C.D., *De Republiek der Kernegeleerden* (Bergen: BetaText, 2000).

³⁶ Verbong, a.o., *Een kwestie van lange adem*, 66.

³⁷ Van Hengel, G., ‘De wederopstanding van Jonkheer de Brauw: Schaduwspeel van het kernenergiedebat in de jaren zeventig en tachtig,’ A. Maas & T. Cocquet (ed), *Verborgene krachten: Nederlanders op zoek naar energie* (Hilversum: Verloren, 2011), 122-123.

the 1970s.³⁸ In the 1970s, various opponents of nuclear energy organised themselves into organisations such as the “Werkgroep Kernenergie” (WKE), and sought cooperation with other activist societies such as the Association for the Defence of the Environment (VMD). With these organisations, action was taken in various ways and social sentiment against nuclear energy was fuelled. These activists also managed to gain a foothold within various civil society organisations, including church communities. Church communities, which under the leadership of international umbrella organizations such as the World Council of Churches in the 1950s were still outspoken supporters of peaceful nuclear energy, became more critical of new nuclear energy in the 1970s, thanks to these activists. The main arguments against energy from nuclear fission were concerns about the environmental impact of radioactive waste and the effects of radiation on human health.³⁹

Recently, some Dutch historians have emphasized that the concerns about the effects of radiation and radioactive waste, had been around for a long time. According to historians Dick van Lente and Irene Cieraad, these doubts already existed widely in the Netherlands in the 1950s and 1960s. These doubts and fears were expressed in many anxious questions at exhibitions about the possibilities of nuclear energy, in popular scientific works about radioactivity, popular culture and opinions in the media.⁴⁰

The question that subsequently arises is what ultimately caused these fears to transform into an activist opposition to nuclear energy in the 1970s? And, what made the social resistance successful? This thesis shows that social belief in nuclear fusion as a viable alternative source

³⁸ Van Noort, W., *Bevlogen bewegingen: een vergelijking van de anti-kernenergie-, kraak- en milieubeweging* (Nijmegen: SUA, 1988); Hellema, D.C., *Nederland en de jaren zeventig* (Amsterdam: Boom, 2012); Verbong, a.o., *Een kwestie van lange adem*, 78-80.

³⁹ Verbong, a.o., *Een kwestie van lange adem*, 78-80.

⁴⁰ Van Lente, D., ‘Nuclear Power, World Politics, and a Small Nation: Narratives and Counternarratives in the Netherlands’, D. Van Lente (Ed.), *The nuclear age in popular media* (New York: Palgrave Macmillan, 2012), 149-174; Cieraad, I., ‘The Radiant American Kitchen: Domesticating Dutch Nuclear Energy’, R. Oldenziel (ed.), *Cold War Kitchen: Americanization, Technology and European Users* (Cambridge: University Press, 2009).



Figure 7: Demonstrators at the nuclear power plant, 7 April 1979. Anefo/National Archives

of clean energy was an important factor in the success of activism against energy from nuclear fission. Energy from nuclear fusion did not potentially produce radioactive waste and there were no accidents involving radiation. In the 1970s the policy of fusion scientists changed with more attempts to play a more active role in the public debate on energy. Fusion scientists focused on both nuclear fusion as an inexhaustible source of energy and the lack of radioactive waste.

At the same time, many nuclear physicists and administrators from the energy sector joined the social movement against nuclear energy. They translated the contribution of fusion scientists to the public debate by presenting energy from nuclear fusion as a realistic alternative to nuclear fission. By investing more in research into nuclear fusion, the new nuclear power plants would not be necessary, according to the activists. With nuclear fusion as an alternative, these scientists were able to influence social opinion, especially within church communities, in such a way that the Dutch government postponed the construction of the new nuclear power plants in 1977.

1.3. Investigating the Promises of Nuclear Fusion: Method and Sources

1.3.1. The Popularization of Science

To investigate how the promise of nuclear fusion as an inexhaustible source of clean energy developed in the Netherlands, this thesis uses a method based on historical research into the popularization of science.⁴¹ The research into the popularization of science argues that science presents promises to which different stakeholders in society relate based on their own interests. Scientists use these promises to obtain money or social support for their research, potential investors base their policy choices on the extent to which they are convinced of a promise, and the promise is discussed in the media and in popular culture.⁴²

The model developed by sociologist and historian Peter Weingart is central to this thesis. Based on various studies of how science advised politics in Germany and of the scientific basis for German eugenics in Nazi Germany with an emphasis on the interaction between this science and racially oriented politics in this period, Weingart formulates a model to distinguish different actors within the popularization of science.⁴³ In addition to scientists and government, Weingart argues that since the Second World War the media have played an increasingly important role in selling scientific promises and increasing the public debate on scientific promises. As the media increasingly write about the scientific promises of science while the research itself is still

⁴¹ The literature is largely selected on the basis of the extensive overview provided by Dick van Lente in: Van Lente, D., (Ed.), *The nuclear age in popular media* (New York: Palgrave Macmillan, 2012), 1-18. This literature review contains: Withley, R., 'Introductory Essay: Knowledge Producers and Knowledge Acquirers. Popularization as a Relation between Scientific Fields and Their Publics,' in T. Shinn, R. Withley (ed.), *Expository Science: Forms and Functions of Popularization* (Dordrecht: Reidel, 1985), 3-28; Hilgartner, S., 'The Dominant View of Popularization: Conceptual Problems, Political Uses,' *Social Studies of Science* 20 (1990), 519-539; Nelkin, D., *Selling Science. How the Press Covers Science and Technology* (New York: Freeman, 1995 2nd rev. edn.); LaFollette, M.C., *Making Science Our Own: Public Images of Science, 1910-1955* (Chicago: The University of Chicago Press, 1990); Kohring, M., *Wissenschaftsjournalismus. Forschungsüberblick und Theorieentwurf* (Konstanz: UVK Verlagsgesellschaft, 2005).

⁴² See for example McCray, W.P., *The Visioneers: How a Group of Elite Scientists Pursued Space Colonies, Nanotechnologies, and a Limitless Future* (Princeton University Press, 2012); and Lewenstein, B.V., 'From Fax to Facts: Communication in the Cold Fusion Saga', *Social Studies of Science*, vol. 35 (1995), 403-436.

⁴³ Weingart, P., & J. Lentsch, *Wissen Beraten Entscheiden. Form und Funktion wissenschaftlicher Politikberatung in Deutschland* (Weilerwist, 2008); and Weingart, P., 'Eugenics – Medical or Social Science?', *Science in Context* 8 (1995), 197-207.

in the stage of production, the social celebrity status of the scientist increases, making it easier to lobby for money, while social criticism of unfulfilled promises also increases.⁴⁴

In the research into the representation of the ‘Nuclear Age’ in popular media, historian Dick van Lente adds an important actor to this model: the representation in stories and images commonly known in a culture, on which representations of science and technology could draw, plays an important role in the way people think about promises of science. With this addition, Van Lente ultimately distinguishes four factors that influenced the development of scientific promises: the search for funding by scientists, the interests and policies of investors, the dynamics of the media, and the interaction between cultural images and the public debate.⁴⁵ This thesis uses this distinction to investigate how the promise of nuclear fusion developed in the Netherlands, and to what extent the use of the promise changed as a result of developments within international fusion research, Cold War tensions, energy issues or social resistance to nuclear energy.

The promise of nuclear fusion in the Netherlands offers a good case for this approach. Between 1951 and 1979 the Dutch fusion scientists made several attempts to obtain investments from the business community and government budgets. These attempts to attract new research budgets were strongly dominated by an emphasis on the promise of nuclear fusion as an inexhaustible source of clean energy. The lack of radioactive waste was also used several times by scientists as an argument to stress the need to invest in fusion research. On the other hand, both government and industry made various considerations as to whether or not to invest in fusion research based on this promise. These considerations and fluctuations in belief in the success of nuclear fusion can also be recognised in the way Dutch media reported on nuclear fusion and the way in which nuclear fusion was portrayed in popular culture. As a result of

⁴⁴ Weingart, P., *Die Stunde der Wahrheit? Zum Verhältnis der Wissenschaft zu Politik, Wirtschaft und Medien in der Wissensgesellschaft* (Weilerwist, 2001).

⁴⁵ Van Lente, *The nuclear age in popular media*, 7.

international developments in fusion research and lively discussions about the Dutch energy supply, different Fusion Hypes arose in de media.

1.3.2. *Dutch Fusion Scientists*

The Dutch fusion scientists used the promise of nuclear fusion as an inexhaustible source of renewable energy to raise money from the Dutch government and industry. The scientific lobby focused mainly on the question whether Dutch fusion research should be seen as a fundamental or applied science. In the history of science, ‘fundamental science’ means the part of science that focuses on basic principles and basic mechanisms. This science is about knowledge, without the need for a application in the direct future. Applied sciences include the scientific directions that aim to solve a specific problem, or to develop a product. Research is inspired, or sometimes even guided, by social questions that require a solution in the foreseeable future.⁴⁶ Many science historians have written about this distinction, demonstrating that it is often untenable. Despite a fundamental question, different scientific research often has different specific applications or applied research also deals with basic mechanisms.⁴⁷ In this thesis, the distinction between fundamental and applied science is used to indicate the difference in funding and organising scientific institution during the examined decennia.

The term fundamental science is used if the fusion research had been assigned to the Fundamental Matter Research Foundation (FOM). The aim of the foundation, which was founded in 1946, was to promote and undertake fundamental research in physics in the Netherlands by funding physics research through research programmes and projects, through

⁴⁶ Chorofast, D.N., *Science and Technology* (Geneve: Springer, 2015), 7.

⁴⁷ For example, research into solar panels was able to develop from fundamental science to applied science because this type of energy production could be used to supply satellites in space with energy. Geels, F.W. ‘The Multi-Level Perspective on Sustainability Transitions: Responses to Seven Criticisms’, *Environmental Innovation and Societal Transitions* 1.1 (2011), 24-40.

cooperation with industry, and by organising research themselves.⁴⁸ In the Netherlands fusion research was transferred to FOM in 1957 in a separate working community “research into thermonuclear reactions”. This working community initially consisted of five different working groups, each carrying out research into a separate area of research relating to nuclear fusion. These working groups were overseen by a coordinating committee comprising various professors, the chairmen of the working groups, the secretary of FOM and a scientific leader. The first chairman of this committee, Hendrik Brinkman, was the formal initiator of the research, while the

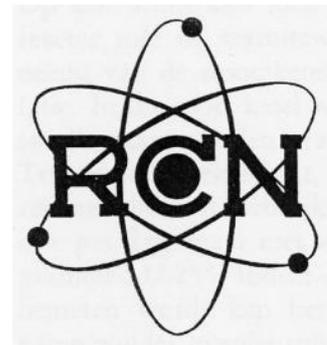
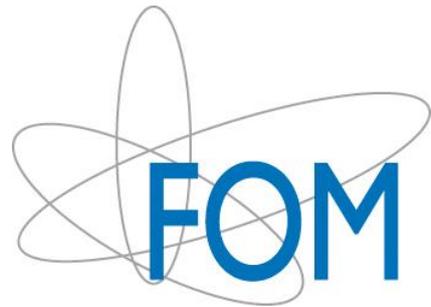


Figure 8: The logos of FOM and RCN.

scientific leader, Kees Braams, coordinated the working groups and maintained contacts with FOM and external organisations. From 1959 onwards three working groups settled in the newly acquired institute for plasma physics, FOM-Rijnhuizen, of which Braams became director. After Brinkman’s death in 1959, Braams would also assume the chairmanship of the coordinating committee.

The applied research in the field of nuclear energy in the Netherlands took place at Reactor Centre of the Netherlands (RCN). RCN was founded in 1956 by the Dutch government with the aim of stimulating and coordinating research into energy production from nuclear energy. Therefore, RCN was an answer to the increasing questions in the 1950s about the sustainability of the energy supply by fossil fuels in the longer term.⁴⁹ RCN employed various

⁴⁸ For a detailed overview of the establishment and objectives of the FOM, see: Hoeneveld, *Een vinger in de Amerikaanse pap*.

⁴⁹ Three commemorative books have been published about successive periods in the history of RCN/ECN. First the uncritical overview by former RCN director Jan Goedkoop: Goedkoop, J.A., *Een kernreactor bouwen. Geschiedenis van de Stichting Energieonderzoek Centrum Nederland. Deel 1: periode 1945-1962* (Bergen NH, 1995); then followed by the vile settlement of Dutch nuclear physics by Cees Andriess in Andriess, *De Republiek der Kernegeleerden*. The most recent, and most historically embedded, contribution has been made by energy and

nuclear physicists and was managed by a delegation from the government, industry and FOM. As a result of this cooperation and the social added value, RCN's nuclear energy projects generally had more to spend than the more fundamental projects at FOM, certainly those directly related to setting up Dutch nuclear power stations based on nuclear fission or enriching uranium.⁵⁰ Because of these larger budgets, the fusion scientists tried to transfer their fusion research to RCN from the start. In doing so, the promise of nuclear fusion was presented as an answer to the same social questions that the research at RCN was concerned with.



Figure 9: Kees Braams as extraordinary professor at Utrecht University.

This thesis examines the attempts of the fusion scientists to join RCN by investigating the minutes, correspondences and annual reports of the coordinating committee of the working community “research thermonuclear reactions” and the preceding research committee into the

Kees Braams:

The Dutch physicist Cornelis Marius (Kees) Braams was born in 's Hertogenbosch in July 1925. After the Second World War Braams studied mathematics and physics at the Utrecht University. He took his doctoral degree in 1952 and immediately published his first publication in the journal *Nature* on the “tippe top”, the phenomenon of self-stablising spinning tops.¹ In 1956 Braams obtained his doctorate cum laude on a nuclear physics study, which was partly carried out at the Massachusetts Institute of Technology (MIT). In 1957 Braams became the scientific leader of the working community “research thermonuclear reactions” and in 1962 extraordinary professor of Plasma Physics at Utrecht University.² In 1959, he also became director of the FOM Institute for Plasma Physics in Rijnhuizen, which he would remain until 1987. On the occasion of his retirement in 1987 he was awarded the royal decoration Knight of the Order of the Dutch Lion.³ After his retirement, Braams wrote a book on the development of nuclear fusion research together with Peter Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research* (2002).⁴ Braams died in July 2003 at the age of 78.

¹ Braams, C.M., ‘On the influence of friction on the motion of a top’, *Physica*, 18 (1952), 503-514.

² ‘Prof. Dr. C.M. Braams: buitengewoon hoogleraar Plasmafysica’, *Catalogus Professorum Academiae Rheno-Traiectinae*. <https://profs.library.uu.nl/index.php/profrec/getprofdata/282/23/209/0> (Last seen: 17 February 2020).

³ Vrouwe, *Hittebarrière*, 23.

⁴ Braams, C.M., & P.M. Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research* (Bristol: IOP Publishing, 2002).

technology historian Geert Verbong in Verbong, G.P.J., *Op weg naar de markt: de geschiedenis van ECN 1976-2001* (Petten: ECN, 2005).

⁵⁰ Verbong, a.o., *Een kwestie van lange adem*, 30-32.

feasibility of nuclear fusion research in the Netherlands. Subsequently, the travel reports of the various fusion scientists are examined to investigate how the scientists related to the international cooperation within fusion research. The lobbies of the fusion scientists at RCN and the government are also investigated based on the entries of the fusion scientists in the RCN bulletin *Atoom: maandblad gewijd aan atoomenergie en haar gevolgen voor mens en samenleving* (*Atom: Monthly Devoted to Nuclear Energy and its Consequences for People and Society*), later *Atoomenergie en haar toepassingen* (*Nuclear Energy and its Applications*). In these entries, which were also sent to responsible government officials and ministers, the lobby of the fusion scientists based on the promise of nuclear fusion was often clearly presented.

1.3.3. Government and Business Community

The fusion scientists' lobby to join RCN was largely determined by the money investors made available for nuclear research. Dick van Lente defines investors as governments, companies and philanthropists who each invested in scientific research based on their own interests or ideals.⁵¹ In contrast to the American fusion research, especially in the 1980s, where large amounts of money were invested by private investors, the Dutch fusion research did not know significant philanthropic contributions.⁵² Although industry was also involved in Dutch research, especially in the early stages, the Dutch government was the main investor together with the European Euratom.⁵³

Euratom, or the European Atomic Energy Community, is an international organisation set up in 1957 with the aim of making Europe's energy supply independent of the United States,

⁵¹ Van Lente, *The nuclear age in popular media*, 7.

⁵² In the 1980s, several large donations from philanthropists were collected for American nuclear fusion research in the United States. Herman, *Fusion: the Quest for Endless Energy*, 188-212.

⁵³ This is different from countries such as Japan where the industry carried the fusion research. Herman, *Fusion: the Quest for Endless Energy*, 110-115.

the Soviet Union and the Middle East by establishing its own nuclear energy programme through European cooperation, funded by the governments of the participating countries.⁵⁴ However, under pressure from some of the participating countries Euratom's focus increasingly shifted to fundamental research, with European fusion research playing a leading role.

In the Netherlands, governmental funding for fundamental research was mainly channelled through the Foundation for Pure Scientific Research (Zuiver Wetenschappelijk Onderzoek, ZWO). ZWO distributed the scientific budgets of the science department of the Ministry of Education, the Arts and Sciences (OKW), from 1967 onwards the Ministry of Education and Sciences (OW).⁵⁵ ZWO, founded in 1950, provided the main budgets for Dutch fusion research, while the ministry also made individual investments, for example in the purchase of FOM-Rijnhuizen.

Budgets for applied nuclear energy research at RCN were, for the main part, provided by the budgets of the Ministry of Economic Affairs (EZ). This ministry's policy was to invest primarily in research that was expected to be commercially independent within ten years.⁵⁶ This money was partly distributed via the Netherlands Organisation for Applied Scientific Research (TNO). TNO, already established in 1932, had the mission to connect knowledge and people to sustainably strengthen the competitiveness of Dutch industry and the welfare of society.⁵⁷ The fusion scientists' lobby therefore focused mainly on the ministries of Education, Arts and Sciences, and Economic Affairs, and the organisations of RCN, TNO and ZWO.

In addition to investments from Euratom and the Dutch government, the business community invested in Dutch fusion research. A distinction can be made between companies

⁵⁴ Dedman, M., *The Origins and Development of the European Union, 1945-2008: A History of European Integration* (Routledge, 2009), 63-81.

⁵⁵ See for a history of ZWO: Kersten, *Een organisatie van en voor onderzoekers*.

⁵⁶ Verbong, a.o., *Een kwestie van lange adem*, 30.

⁵⁷ Lintsen, H., a.o., *Tachtig jaar TNO* (Den Haag: Barlock, 2012).

that were involved in the research to earn a direct income, such as the metalworking company Vernooy, which specialised in vacuum chambers to supply the fusion scientists directly, and companies that conducted research themselves to earn money in the longer term. The latter category includes the large Dutch energy company KEMA, Philips, and later the oil firm Shell. KEMA and Philips, in particular, showed a great deal of involvement in the early years of Dutch fusion research, with KEMA even running its own working group within the working community.

While investigating the role of the various investors and their interests, this thesis mainly examines the discussions at the various ministries within the Dutch government and what role Euratom's investments played in these discussions. In these discussions a constant trade-off was made between the possibility that the promise of nuclear fusion could be realised quickly and the international interests of fusion as a fundamental science, in which the Ministry of Foreign Affairs (BuZa) also played an important role as advocate of the international position of the Netherlands.

Dutch post-war politics were strongly modelled on a consultancy economy in which the government regularly asked for advices from social partners and experts. These advices often form the basis for political decision-making and budget proposals.⁵⁸ Therefore, this thesis explicitly examines advices and reports on nuclear energy and fusion research by the Social and Economic Council (SER), the Scientific Council for Nuclear Energy (WRK), the Industrial Council for Nuclear Energy (IRK) and separate research committees. These organisations represent scientists, companies and societal partners, and provided regular advice on future investments and developments in energy demand, nuclear energy and fusion research during the examined period.

⁵⁸ Touwen, J., *Coordination in Transition: The Netherlands and the World Economy, 1950-2010* (Leiden: Brill, 2014), 1-9.

1.3.4. *The Dutch Media*

The dynamics of the Dutch media are the third factor in this research into the promise of nuclear fusion in the Netherlands. With ‘dynamics’ is meant the need for the media to attract readers or subscribers to sustain themselves by earning advertising revenues. These dynamics would make media more inclined to exaggerate presenting speculative promises of science because these promises would produce more appealing stories. To a large extent, these media would still report ideas objectively, but they would make more extreme statements in the headlines and pay explicit attention to the consequences of a scientific promise as if it was already almost reality.⁵⁹

Several historians, however, argue that this dynamic in the Netherlands in the post-war period was inhibited by a strong preference for objective reporting by leading editorial boards, and the phenomenon of pillarization.⁶⁰ Pillarization is the division of society on a philosophical or socio-economic basis. The model of pillarization is often used to describe Dutch post-war society between the 1950s and the breakthrough of the pillarization in the late 1960s, and 1970s.⁶¹ The division between the pillars in the Netherlands was expressed in separate political parties, trade unions, sports clubs, student organizations, and newspapers for the Protestants, Roman Catholics, socialists, and liberals. Because everyone who belonged to a pillar also made use of the facilities of this pillar, competition between the various media was limited. This would mean that there was also less reason to hype the scientific promises.⁶²

Nevertheless, at various times there was a strong increase in attention for nuclear fusion in the Dutch media with a strong emphasis on the promises of nuclear fusion as an inexhaustible

⁵⁹ Van Lente, *The nuclear age in popular media*, 7-8.

⁶⁰ Lijphart, A., *Verzuiling, pacificatie en kentering in de Nederlandse politiek* (Haarlem: Becht, 2008), 12.

⁶¹ Stuurman, S., *Verzuiling, Kapitalisme en Patriarchaat* (Nijmegen: Radboud University, 1983); and Lijphart, *Verzuiling, pacificatie en kentering in de Nederlandse politiek*.

⁶² Lijphart, *Verzuiling, pacificatie en kentering in de Nederlandse politiek*.

source of clean energy. This thesis defines this combination between increasing attention and the strong emphasis on the promise of nuclear fusion a ‘Fusion Hype’. These Fusion Hypes generally coincided with breakthroughs in international fusion research, and with an increasing demand for alternative sustainable energy sources reinforced by oil supply problems.

This thesis shows that the lobby for more money from Dutch fusion scientists played an important role in the way Dutch media presented nuclear fusion. In the attempts to convince RCN and the Dutch government to transfer fusion research to RCN, the fusion scientists wrote many articles in the media and the RCN bulletin about the successes and potential of fusion research. These articles often became sources for new articles in the Dutch media. This meant that the Dutch media generally adopted the focus of the Dutch scientists on American and European fusion scientists, and described the fusion research as an applied science.

To interpret these developments, this thesis examines media from the Protestant, Roman Catholic, Socialist and Liberal pillars. This thesis looks at national, regional as well some local newspapers. The papers investigated are *De Volkskrant*, *Algemeen Handelsblad* (later *NRC Handelsblad*), *Trouw*, *Telegraaf*, *Het Parool*, *Het Vrije Volk*, *De Tijd: Godsdienstigstaatskundig dagblad* (later *De Tijd/De Maasbode* and *De Tijd: Nederlands Dagblad*), *Nieuwsblad van het Noorden*, *De Friese Koerier*, *de Leeuwarder Courant*, *Limburgsch Dagblad*, *De Waarheid*, and *Het Gereformeerd Gezinsblad* (later *Nederlands Dagblad*). The media articles investigated include articles on nuclear fusion and articles on broader social issues, such as energy needs or the tensions in the Cold War, which also were about nuclear fusion. The number of mentions per year vary considerably. The graph in Figure 10 shows the

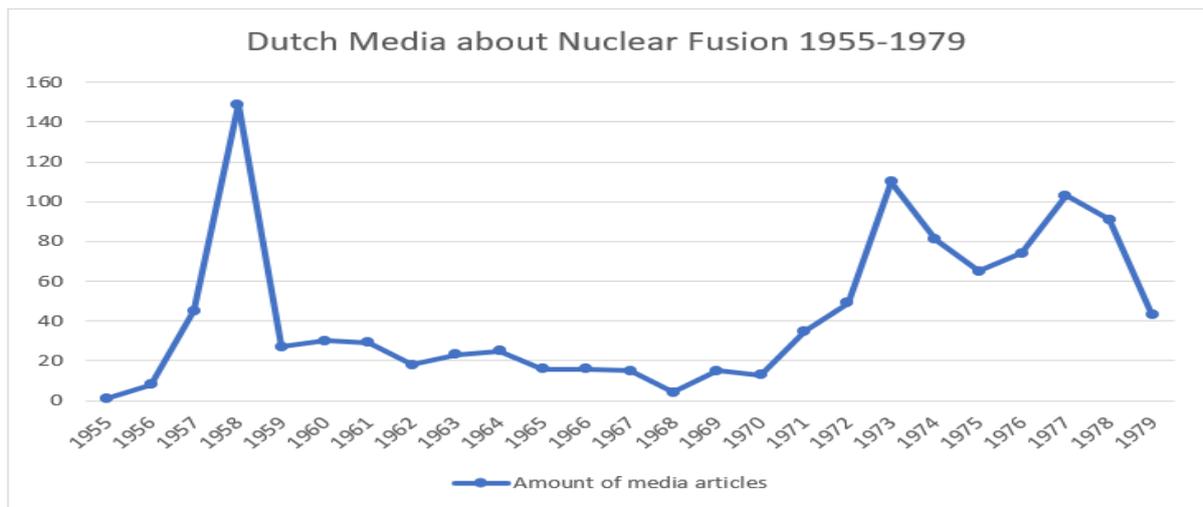


Figure 10: The graph provides an indication of the moments when the fusion hype appeared in Dutch media (between 1956 and 1958, around 1973, and 1977).

increase and decrease in the number of articles mentioning nuclear fusion. The Fusion Hypes investigated were around 1958, 1973 and 1977.⁶³

1.3.5. Public Perception of Nuclear Fusion

The images of the promise of nuclear fusion in popular culture and the way these images are reflected in the public debate are the last factor investigated in this thesis. In his research Dick van Lente shows how old and well-known images and narratives were used to portray nuclear energy and weapons. Van Lente focuses strongly on images, popular scientific articles and popular culture, such as comics and theatre performances.⁶⁴ However, to investigate how the images are used in the social debate, the expressions in the public debate in which these images

⁶³ To see to what extent the attention for nuclear fusion spread in the Dutch media, a wide range of different newspapers was investigated. The research took place by using different Dutch search terms such as ‘kernfusie’ (nuclear fusion) and ‘thermonucleair onderzoek’ (thermonuclear research) using the online search engine Delpher and then checking with each article whether it was actually an article about nuclear fusion, and not about a fusion between village centres or other kind of confusion of speech. It should be noted that this examination can never be completely accurate. It is conceivable that certain newspapers or volumes of newspapers have not been fully scanned or that the search engine is unable to recognise certain words. However, because the results are not entirely unexpected given the (inter)national developments in the field of nuclear fusion, the graph probably provides a fairly representative picture of the development of attention for this theme in the Dutch media.

⁶⁴ Van Lente, *The nuclear age in popular media*, 7-8.

are used, such as opinion pieces, pamphlets and public statements need to be taken into account too.

This extensive focus threatens to turn this factor into a repository of all expressions about the promises of nuclear fusion beyond scientists, investors and the media. To bring focus, this thesis uses the sources used by cultural historian Paul Boyer in his research into the representation of the atomic bomb in the American public debate in the second half of the 1940s. In doing so, Boyer considers popular scientific literature, comics, television programs, exhibitions, science fiction, comics, pamphlets, art, protest signs and pop songs. With this comprehensive approach, Boyer provides a complete picture of the development of sentiments about nuclear weapons that does justice to the different views in society.⁶⁵

Although this thesis uses these categories in research into the representation of the promises of nuclear fusion, this promise does not recur in all periods in all these categories in the Netherlands. In the coming chapters the focus will be on the different expressions in which nuclear fusion is dealt with. These include Marten Toonder's comics, various popular scientific books, science exhibitions such as *Het Atoom* in 1957 and the travelling exhibition *Energie Anders* in 1976, and pamphlets from anti-nuclear organisations such as the Association for Environmental Defence (VMD) and the "Werkgroep Kernenergie" (WKE).

1.4. Thirty Years of Nuclear Fusion in the Netherlands, 1951-1979

This thesis consists of six chapters. Chapter two covers the period from 1951 to 1959. This is the run-up period between the first fusion experiments in the Netherlands and the official opening of FOM-Rijnhuizen in 1959. This chapter introduces the most important parties and

⁶⁵ Boyer, P., *By the Bomb's Early Light. American Thought and Culture at the Dawn of the Atomic Age* (New York: Pantheon, 1985).

considerations concerning the Dutch promise of fusion. During this period, after some years of mutual competition, international fusion research was declassified. At the same time, in the 1950s, questions arose about the energy supply in the increasingly prosperous Western countries.

The third chapter describes the period between 1959 and 1968 when international fusion research ran into major problems and it seemed increasingly unlikely that a commercial fusion reactor would ever be realised. At the same time, energy issues in the Netherlands became less relevant with the gas discoveries at Groningen. However, the fundamental status of the research opened opportunities for maintaining contacts between American, European and Soviet scientists with regard to fusion research. Even during the fiercest periods of the Cold War.

The fourth chapter deals with the period between 1969 and 1979, when fusion research experienced a breakthrough after breakthrough and energy issues reappeared with the Club of Rome Report in 1972 and the Oil Crisis in 1973. During this period, the European plans for the JET were conducted and, after many discussions, the construction of the European reactor in Culham, England, finally started. These developments led to a renewed debate on the promise of nuclear fusion among scientists and investors, in the media, and in society's protests against nuclear power.

The last two chapters discuss the meaning of the thirty years promise of nuclear fusion in the Netherlands. They discuss the significance for the historiographical debates on the Cold War, the Dutch search for alternative energy and the failure of the Dutch nuclear energy project. Chapter five discusses what the conclusions mean for the way developments in fusion research in other countries, such as Italy, France, Great Britain, Japan and the United States, are described. Finally, chapter six investigates, as an epilogue, the developments of the promise of nuclear fusion in the Netherlands from the 1970s to the present day to see whether the themes from the first thirty years remain important.

2. “Taming the H-Bomb”: The Emerge of Dutch Nuclear Fusion Research, 1951-1959

2.1. Introduction

2.1.1. From Competition to Declassification

“Among the more important problems of modern engineering science, utilization of the energy of thermonuclear reactions stands out as one of the foremost significance.”⁶⁶ With these words Igor Kurchatov, head of the Soviet Union’s nuclear weapons program, started his lecture on the possibilities of producing thermonuclear reactions at

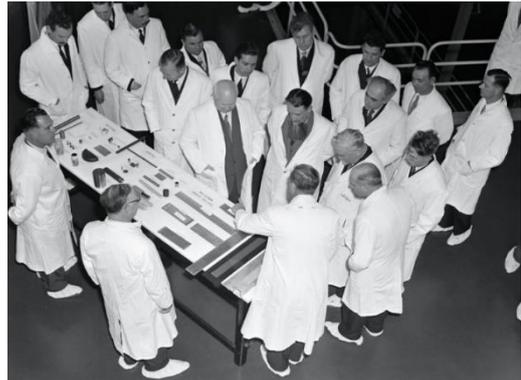


Figure 11: Nikita S. Khrushchev, physicist Igor V. Kurchatov (in the middle, with beard) and Nikolai A. Bulganin on 26 April 1956 in Harwell. *Iter* magazine 9.

the Harwell Atomic Energy Research Establishment, the heart of the very citadel of Britain’s secret nuclear research.⁶⁷ This speech in the spring of 1956, in which Kurchatov surprisingly called for nuclear fusion research to be declassified internationally, would change the future of the international fusion research drastically.

From the Second World War onwards, research into nuclear fusion really got off the ground. Especially in the United States, Great Britain and the Soviet Union, several research institutes were established where research into controlling nuclear fusion was conducted. It was expected that this research would soon bring energy production. The first nuclear power plants based on nuclear fission were already connected to the electricity grid a few years after the atomic bomb. It was expected that nuclear fusion would follow the same path after the

⁶⁶ Kurchatov, I.V., ‘On the Possibilities of Producing Thermonuclear Reactions in a Gas Discharge,’ *Nuclear Energy II*, vol. 4 (1957), 193-202.

⁶⁷ Herman, *Fusion: the Quest for Endless Energy*, 49.

successful test with the uncontrolled fusion reaction in the hydrogen bomb on the first of November, 1952.⁶⁸

This expectation led to a veritable race between the various superpowers. Successes were regularly claimed during press conferences and in media reports. In retrospect, however, these results and claims often turned out to be incorrect or did not yet directly lead to a working fusion reactor. The most prominent example was the British fusion project ZETA. ZETA, short for Zero Energy Thermonuclear Assembly, was a British fusion project based on a pinch plasma confinement technique, in which the fusion scientists tried to capture the plasmas with magnetic fields in a circular reactor. ZETA went in operation in August 1957. In September, first measurements suggested that the fuel was reaching a high enough temperature to produce nuclear fusion reactions. In January 1958 these results were shared with the international press. In May 1958, however, the results had to be repealed because they were based on incorrect measurements. The actual temperature was much lower than the measurements had suggested.⁶⁹

During the 1950s, it became increasingly clear to some scientists that fusion research still knew many problems. Reaching a fusion reactor was more difficult than had been thought. This led to the remarkable event in which the Russian nuclear scientist Kurchatov indicated to declassify Russian research in 1956. According to Kurchatov, it was not yet possible to realize a fusion reactor. The problems were so big that only international cooperation could solve them.⁷⁰ This call for international cooperation was honoured during a large-scale international congress in Geneva, Switzerland, in 1958. During this congress all countries formally declassified fusion research.⁷¹

In the meantime, the Russian call for declassification of fusion research from 1956 had led to several attempts by different countries, such as Germany, France and the Netherlands, to

⁶⁸ Vrouwe, *Hittebarrière*, 10.

⁶⁹ Herman, *Fusion: the Quest for Endless Energy*, 49-53.

⁷⁰ Kurchatov, 'On the Possibilities of Producing Thermonuclear Reactions in a Gas Discharge,' 201-202.

⁷¹ Herman, *Fusion: the Quest for Endless Energy*, 33.

set up their own fusion research. This often led to discussions about the status of fusion research. How realistic was a commercially deployable fusion reactor in the short term? Two important international developments played a major role in this discussion: the discussions about the sustainability of fossil fuels as an energy supply, and the rising tensions of the Cold War.

2.1.2. Atoms for Peace and the Rising Tensions of the Cold War

Kurchatov's appeal was surprising at a time when tensions between East and West increased. After the Second World War and the division of Germany, the Cold War between the Soviet Union and the United States started. Although the tensions never led to a large-scale escalation, partly because of the destructive power of the nuclear weapons developed in both superpowers, the geopolitical dynamic was dominated by the likelihood of war. Several smaller conflicts, such as the Korean War between 1950 and 1953 and the Soviet Union's repression of several protests in Eastern Europe, raised these tensions.⁷²

In response to these rising tensions, cooperation was developed in Europe. An important goal was to remain a significant factor in the new power balance after the Second World War. Jointly, Europe could become a power bloc in the face of rising tensions between the United States and the Soviet Union. Typical for this reasoning was the idea of creating the European Defence Community. In 1952, a treaty was concluded between the six participating countries about the creation of a European army. These countries were (West-)Germany, France, Italy, Belgium, Luxemburg, and the Netherlands. The treaty was a plan of the French president René

⁷² Especially under Stalin's regime tensions increased steadily. Under his successor Krushchev a more changeable policy was pursued. On the one hand, the tension increased with the invasion of Hungary by the Soviet Union, such as described in Borhi, L., *Hungary in the Cold War, 1945-1956: Between the United States and the Soviet Union* (Central European University Press, 2004). On the other hand, several attempts at rapprochement took place. For example, the Russian Orthodox Church was given permission to respond to the rapprochement of the, then still relatively Western, World Council of Churches. See Zeilstra, J.A., *Visser 't Hoof: Een leven voor de Oecumene, 1900-1985* (Skandalon: Middelburg, 2018), 359-400.

Coty, but was never ratified or implemented. Partly due to the death of Joseph Stalin in March 1953 the Russian threat seemed to decrease. At the end of August 1954, the French parliament voted the treaty away with 319 votes against and 264 votes in favour. However, the idea that Europe should form a power block between the United States and Russia persisted.⁷³



Figure 12: Chairman Homi Bhabha (pointing) at the first Atoms for Peace conference in 1955. IAEA.

While tensions were rising, American president Dwight Eisenhower initiated “Atoms for Peace” in 1953, calling for international cooperation on the peaceful use of nuclear energy. Nuclear energy should not be used for the production of weapons, which would lead to increasing tensions, but should be used to a new future with peaceful applications of nuclear energy. This appeal led to two congresses in Geneva in 1955 and 1958 at which scientists from different countries presented their results and learned from each other’s research. However, a lot of research into nuclear energy still appeared to be classified because of economic and military interests. During the first congress, energy from nuclear fusion did not yet gain much attention. Only in the closing words, the chairman of the conference, Homi Bhabha, hinted at the enormous potential of energy extraction from nuclear fusion. After Kurchatov’s call in 1956 to completely declassify fusion research, nuclear fusion became the main topic of the congress in 1958. Fusion research was definitively declassified by all countries in Geneva in 1958.⁷⁴ International fusion research was born.

A similar trend was apparent in Europe with regard to nuclear energy as an attempt at international cooperation. In 1957 Euratom was established with the aim of coordinating the peaceful applications of nuclear energy in Europe. Although nuclear energy from nuclear fission was initially mentioned as primary focus in *A Target for Euratom* (1957), it soon became apparent that the various countries were not willing to reveal all their secrets. This was foremost

⁷³ Dedman, *The Origins and Development of the European Union, 1945-2008*, 63-81.

⁷⁴ Herman, *Fusion: the Quest for Endless Energy*, 47.

apparent in France. Under President Charles de Gaulle, France had the ambition to become a nuclear power of its own with own nuclear weapons and nuclear energy. Research into nuclear fission was extremely important in this respect, so France preferred not to share this research with other countries.⁷⁵ Both within Euratom and through the European Parliament, France therefore increased the pressure for Euratom to stop focusing on nuclear fission. From 1958 onwards, Euratom increasingly focused on nuclear fusion research.⁷⁶

2.1.3. Peaceful Nuclear Energy as a Solution to Increasing Energy Demands

The second international development underlying the international search for the peaceful use of nuclear energy and nuclear fusion research was the growing awareness that fossil fuels would be depleted in the foreseeable future. A rapidly growing population in combination with an enormous increase in prosperity, especially in Western countries, raised concerns that fossil fuels would be already in short supply in the year 2000. The effects of a possible shortage were underlined by the Suez crisis in 1956. The war between Egypt, and Israel, France and Great Britain blocked the Suez Canal, and put pressure on oil supplies to the West from the Middle East.⁷⁷

Nuclear energy offered a potential solution. By generating their own energy through nuclear fission or fusion, Western countries would become independent of oil in the Middle East and would respond to the increasing energy needs. With a successful nuclear energy programme, fossil fuels could be replaced to a large extent. The disadvantage of nuclear energy, however, was that much research was still needed and the costs were high.⁷⁸ International cooperation could reduce some of these costs. In Europe, Euratom was in first instance not only

⁷⁵ Jackson, J., *A Certain Idea of France: The Life of Charles de Gaulle* (Penguin Books Ltd, 2019), 100.

⁷⁶ Shaw, *Europe's Experiment in Fusion*, 6-8.

⁷⁷ Verbong and Lagaaij, 'Belofte van Kernenergie', 239-242.

⁷⁸ *Ibidem*, 240.

an attempt to increase cooperation to form a renewed European bloc, but also an attempt to set up a peaceful nuclear energy project to meet energy needs.⁷⁹

The Netherlands, in which the revenues from the state mines in Limburg also fell, felt the consequences of the Suez Crisis too and held debates about the energy

supply of the future. An answer was also sought in the development of nuclear energy. In doing so, the Netherlands had the major advantage of possessing ten tons of raw uranium, or “yellow cake”, which the Dutch government had acquired shortly before the Second World War broke out in 1939, and which had been hidden successfully from the German occupiers and American liberators at the University of Delft.⁸⁰

Based on this advantage and the agreements made in *A Target for Euratom*, various memoranda were written by the Ministries of Economic Affairs (EZ) and of Education, the Arts and Sciences (OKW). A memorandum on nuclear energy from 1955 decided to set up a coordination centre for the development of nuclear energy, RCN, in which companies, scientists and the government worked together. In 1957 a new memorandum by the Minister of Economic Affairs, Jelle Zijlstra, invested more money in research to nuclear energy projects.⁸¹ The Dutch fusion scientists, who had started their research officially in 1956, tried to become part of these investments.

To promote the peaceful use of nuclear energy in society, the Dutch government, in cooperation with the business community and scientists, organised a major exhibition on the



Figure 13: Minister of Economic Affairs Jelle Zijlstra during a debate in the House of Representatives in 1959. Wikimedia.

⁷⁹ Dedman, *The Origins and Development of the European Union, 1945-2008*, 75-81.

⁸⁰ Streefland A.H., *Jaap Kistemaker en uraniumverrijking in Nederland 1945-1962* (Amsterdam: Prometheus, 2017), 36-39.

⁸¹ Verbong and Lagaaij, ‘Belofte van Kernenergie’, 242.

peaceful applications of nuclear energy, *Het Atoom* (The Atom), in the summer of 1957. The exhibition, which attracted tens of thousands of visitors, was a result of the Atoms-for-Peace programme that was embraced by the Netherlands as one of the first countries.⁸² The exhibition, organized by the Amsterdam Chamber of Commerce, scientists and Dutch government, wanted to provide



Figure 14: Opening exhibition *Het Atoom* by queen Juliana and prince Bernhard in 1957. The Netherlands Institute for Sound and Vision

visitors with insight into the depletion of raw materials, the basic principles of nuclear energy and the peaceful applications that research could produce. Local, Dutch and American entrepreneurs hoped to expand their market, scientists tried to gain more support and for the government. The aim was to show their scientific and technological potential. The biggest attractions were a test reactor and kitchen appliances running on nuclear energy, but attention was also paid to nuclear fusion.⁸³

However, Dick van Lente, based on interviews by local journalists with students who acted as tour guides at *Het Atoom*, shows that many visitors were afraid of radioactivity and the dangers of radiation. Some journalists noted that the detectors worn by staff around the reactor contradicted the message that there was no danger. Another journalist even speculated that visitors laughed belatedly at the optimistic stories of the scientists and organisers that there was no danger, and that the exhibition had in this way a counterproductive effect.⁸⁴ Also at other exhibitions, such as *Het Instrument*, questions were raised about radioactivity.⁸⁵ Other sources show that the fear of radioactivity was present in the 1950s too. The magazine

⁸² 'Three nations in U.N. support V.S. atoms-for-peace plan', *New York Times* (28 September 1954).

⁸³ Cieraad, 'The Radiant American Kitchen', 116.

⁸⁴ Van Lente, 'Nuclear Power, World Politics, and a Small Nation', 162.

⁸⁵ *The Instrument* was a two-yearly exhibition from Dutch companies and scientists at the Jaarbeurs, Utrecht, in which the latest innovations in scientific and industrial instruments were shown to an average of four thousand visitors. During the third edition in 1959, employees who had radioactive materials on stand were expressly informed in advance how to defuse questions about radiation. 'Tentoonstellingsbulletin No. 1' (23 September 1959). HUA, 4819, No. 544; '3e tentoonstelling 'Het Instrument voor wetenschap en bedrijf'', (1959). HUA, 4819, No. 544.

Panorama, which presupposed that it described themes that were close to public perception, devoted much attention to the dangers of radioactivity.⁸⁶ References to comics and stories that appeared in Dutch newspapers such as *L'énigme de l'Atlantide* (*The Riddle of Atlantis*, 1955) and Marten Toonder's *De splittererwt* (*The split pea*, 1957) also show the social debates on nuclear energy. These comics warned of the danger of nuclear energy and can therefore be interpreted as critical comments on the Peaceful Atom project.⁸⁷ The question answered in this chapter is therefore whether, the relatively clean, nuclear fusion was considered as a solution to the energy problem and offered an answer to the fear of nuclear energy.

2.1.4. Chapter Overview

The relatively short period in which Dutch fusion research was set up and a plasma physics institute was acquired on the Rijnhuizen estate shows how scientists, investors, media and public culture all dealt differently with the promise of nuclear fusion at a time when nuclear fusion research was moving from international competition to international cooperation and energy issues widely emerged. This chapter outlines how Dutch nuclear fusion research developed from the first experiments in 1951 to an organisational working community and an institute for plasma physics in 1959 (2.2.1.). The scientists tried to use the economic promise of nuclear fusion to obtain funding (2.2.2.). In addition, scientists invested in international cooperation, with a strong focus on European developments (2.2.3.).

This chapter then answers the question of why fusion research was set up in the Netherlands. Although the Dutch fusion scientists tried to present themselves as applied science and thus become part of the investments in nuclear energy made by the Ministry of Economic Affairs, the Dutch government and the business community did not believe in the direct economic application of nuclear fusion (2.3.1.). Nevertheless, a great deal of money was

⁸⁶ Lente, 'Nuclear Power, World Politics, and a Small Nation', 162-163.

⁸⁷ *Ibidem*, 164-165.

invested in setting up nuclear fusion as a fundamental science, prompted by the desire of the Dutch government to join the emerging European collaborations (2.3.2.).

In the last sections, this chapter examines the public impact of the considerations behind the establishment of nuclear fusion research in the Netherlands. The shift from international competition to subsequent international cooperation within the fusion research is well reflected in the portrayal of nuclear fusion in the Dutch media. The Dutch media reported mainly on the competition between different countries with regard to fusion research, rather than on the possibilities for cooperation until the world wide declassification in 1958 (2.4.1.). The enormous attention that fusion science received in the Dutch media until 1958 was linked to the lobby from the fusion scientists to present the research as applied science. This was mainly prompted by the economic possibilities of nuclear fusion (2.4.2.). Both the media attention for nuclear fusion and the considerations of the Dutch government paid little attention to the lack of radioactive waste that a potential nuclear fusion reactor would entail. This meant that nuclear fusion did not provide an answer to an increasing social fear of radioactive radiation (2.5.).

2.2. Positioning Dutch Fusion Research

2.2.1. The Quick Foundation of an Institution

In the summer of 1956 a committee was formed to study the possibilities for the Netherlands to make a contribution to international fusion research. Although the study committee was the first formally organised Dutch contribution to nuclear fusion



Figure 15: Jaap Kistemaker.
National Museum Boerhaave.

research, it was not the first scientific attention devoted to nuclear fusion in the Netherlands. In the decades preceding the study committee, theoretical physicists already thought about the

concept of nuclear fusion, imitating the sun on earth, and even about practical applications such as energy production.⁸⁸

This fusion research was limited to theory in the Netherlands until the Dutch nuclear physicist Jaap Kistemaker decided to carry out experiments with the creation of thermonuclear reactions in deuterium gas. It soon became clear to Kistemaker that only the fusion of hydrogen isotopes on earth was

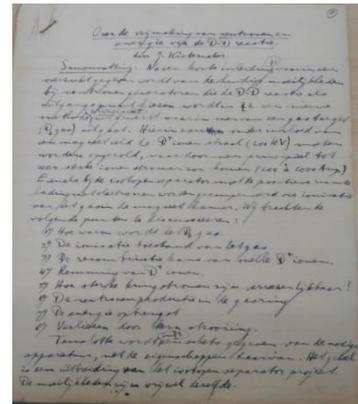


Figure 16: The first notes of Kistemaker's research. FOM Archives, NHA.

feasible. During the next six years, Kistemaker focused on the fusion of deuterium and deuterium and found that the main problem to initiate a prolonged thermonuclear reaction was to obtain and stabilize the correct temperature.⁸⁹ However, further research into these reactions and temperature required more money than was available. Therefore, Kistemaker strongly lobbied for more money for nuclear fusion research on several occasions.⁹⁰

In July 1956 Kistemaker saw his chance to plead within the institute for Fundamental Research into Matter (FOM) and industry for extra money to set up a major experiment with a high-voltage installation with which Kistemaker hoped to reach the right temperatures.⁹¹ Kistemaker argued for this experiment during a special meeting organised by FOM at the Royal Tropical Institute on 5 July 1956. Various natural scientists were present, as were delegations from FOM and RCN. The immediate reason for the meeting was the statement made by the Russian fusion scientist Kurchatov in Harwell in 1956, in which Kurchatov pleaded for the

⁸⁸ See for example Groot, H., 'Energieproductie bij kernreactie', *Atoom: Maandblad gewijd aan de atoomenergie en haar gevolgen voor mens en samenleving*, No. 10 (1947), 174-177.

⁸⁹ Kistemaker, J., 'Enkele opmerkingen gemaakt op de besloten vergadering d.d. 5 juli 1956 in het Koninklijk Instituut voor de Tropen' (5 July 1956). FOM archives, NHA.

⁹⁰ Already at the first plans for experiments in 1946 Kistemaker sighed in a letter to F. Simon, scientist at the Clarendon Laboratory in Oxford, that these experiments would cost a lot of money. Kistemaker, J., 'Dear Simon' (10 March 1946). AMOLF. Kistemaker kept lobbying for extra money for fusion experiments. This was also the case when accepting the chair from the Teylers Foundation: Kistemaker, J., *De veelvuldigheid der atoomkernen* (Amsterdam: Noord-Hollandse Uitgeverij, 1956), 10.

⁹¹ Kistemaker, 'Enkele opmerkingen'.

declassification of fusion research and where he shared research results showing that the Soviet Union had been engaged in creating a fusion reactor for several years.⁹²

Kistemaker used the results of his own experiments to convince the attendees that nuclear energy from fusion was possible by using gas discharges. Based on these findings and the articles shared by Kurchatov, it was concluded that Kistemaker's research should be supported. In addition, the participants of the meeting decided to set up a study group that, in six months' time, would make an inventory of the scientific problems and write an advice on whether or not to start with Dutch nuclear fusion research.⁹³

This study committee met for the first time on 18 October 1956 under chairman D.Th.J. Ter Horst, who worked at KEMA's energy department. The involvement of Ter Horst and KEMA was desirable, because KEMA was capable of investigating discharges in which very high powers are destroyed for a short period of time, with a large capacitor battery recently ordered for other purposes. This was an important line of research in Kurchatov's articles.⁹⁴ In addition to Ter Horst, the study committee consisted of a delegation from the FOM with Dr. W.J. Beekman and Drs. A.A. Bouman as secretary of the committee. Furthermore, the committee consisted of a number of physicists whose research touched on the research directions set out in Kurchatov's articles.⁹⁵

Within five meetings the study committee made an analysis of the limited information about fusion research in Great Britain and the United States, and started research at KEMA, at Amsterdam by Kistemaker and in Utrecht by the physicist Frans Boeschoten. As a result of this

⁹² 'Kort verslag van een gedachteswisseling over het vraagstuk van de thermonucleaire reacties tijdens en na een koffiemaaltijd in de bestuurskamer van het instituut voor de Tropen', (5 September 1956), 1-2. FOM archives, NHA.

⁹³ Beekman, W.J., 'Aan de leden van het uitvoerend bestuur van de Stichting voor het Fundamenteel Onderzoek der Materie' (2 October 1956), 2. FOM archives, NHA.

⁹⁴ 'Kort verslag van een gedachteswisseling over het vraagstuk van de thermonucleaire reacties', 3.

⁹⁵ The study committee consisted of Ir. A.J.H. Boerboom, Dr. F. Boeschoten, Prof. Dr. J. Kistemaker, Dr. H. Meyer, Dr. J.A. Smit, Dr. H.A. Tolhoek and Dr. N.F. Verster. Later, Drs. A.L. Boers, Prof. Dr. H.C. Van de Hulst and Dr. P.C. Veenstra joined the committee. 'Notulen eerste vergadering studiecmissie "thermonucleaire reacties"', (18 October 1956), 1. FOM archives, NHA; and 'Notulen tweede vergadering studiecmissie "thermonucleaire reacties"', (16 January 1957), 2. FOM archives, NHA.

inquiry the study committee produced a report. This report consisted of two parts: the scientific-technical appendices and the general considerations.⁹⁶ In addition, Frans Boeschoten suggested setting up a separate “small working group” on plasma physics.⁹⁷



Figure 15: Director Kees Braams on the foundations of FOM-Rijnhuizen. Photo archives DIFFER.

Less than four months later, the plasma physics working group was a reality. On 23 May 1957, the Board of Directors of FOM debated the report of the study committee and decided to set up a working community. This working community consisted of five working groups and an umbrella committee that oversaw the entire research into thermonuclear reactions. This working community as a whole was placed under the responsibility of FOM and had with Kees Braams its own scientific leader to coordinate the research.⁹⁸

As scientific leader, Braams was responsible for the composition of the coordination group, the start-up of the working groups and the international and political contacts. Braams began by presenting the various leaders of the working groups. Hendrik Brinkman, from his position on the executive board of FOM, became chairman of the committee coordinating the working community. The working community consisted of a theoretical working group (TN1), a plasma physics working group (TN2) under J.A. Smit and Boeschoten in Utrecht, a trochoidal discharge working group (TN3) under Ter Horst at KEMA in Arnhem, an arc discharge working group (TN4) under Kistemaker in Amsterdam, and a nuclear reactions working group (TN5) under Braams. In the following year, new, mainly young, scientists were rapidly recruited and research started.⁹⁹

⁹⁶ ‘Notulen vierde vergadering van de studietoelcommissie “thermonucleaire reacties”’, (26 March 1957), 2. FOM archives, NHA.

⁹⁷ Boeschoten proposed to involve a number of astronomers from the Utrecht Observatory as well as a number of plasma physicists in the working group. They had been researching the phenomenon of plasma in space for several years. Boeschoten, F., ‘Voorstel tot oprichting van een werkgroep plasmafysica’, (15 March 1957). FOM archives, NHA.

⁹⁸ Beekman W.J., ‘Aan de leden van de studietoelcommissie “thermonucleaire reacties”’ (5 September 1957).

⁹⁹ ‘Concept-notulen van de eerste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermonucleaire reacties”’ (25 September 1957), 3. FOM archives, NHA.

Already at the second meeting of the coordination group on 31 October 1957, the lack of working space was discussed. FOM indicated that it was looking for more space in the vicinity of Utrecht. At the subsequent meetings it soon became clear that FOM's preference was a six-hectare estate in the area, where the stables could be turned into laboratories.¹⁰⁰ This was the Rijnhuizen country estate. Already in the spring of 1958 the scientists decided that Braams should become the director of the new institute to be established on this estate. On 11 March 1958 a meeting was held with the coordination group of the working community on the distribution of the costs and staff of Rijnhuizen.¹⁰¹



Figure 16:
Photo of Braams in his first public interview in the Dutch media. *Het Parool* (February 1959).

On 28 October 1958 FOM announced that Rijnhuizen had been definitively acquired and that the working groups TN1, TN2 and TN5 would move to the estate as soon as possible.¹⁰²

The scientists also decided that the focus of the institute would be on plasma physics, specifically plasma physics in a pinch reactor. This decision followed the American and British research which, together with further research in the Soviet Union, was declassified during the conference in Geneva in September 1958. When, in the summer of 1959, the first working groups settled in Rijnhuizen, with already 59 employees in 1960, plasma physics had grown from an idea for a small working group to a fully-fledged natural science discipline in the Netherlands in one and a half year.¹⁰³

¹⁰⁰ 'Notulen van de tweede zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermonucleaire reacties"' (31 October 1957), 4. FOM archives, NHA.

¹⁰¹ 'Notulen van de vierde zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermonucleaire reacties"' (11 March 1958), 3-7. FOM archives, NHA.

¹⁰² 'Notulen van de zevende zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermonucleaire reacties"' (28 October 1958), 2. FOM archives, NHA.

¹⁰³ 'Jaarverslag werkgemeenschap "onderzoek thermonucleaire reacties" 1960'. FOM archives, NHA.

2.2.2. *The Quest for Funding*

A lot of money was needed to set up research into nuclear fusion. Both the Dutch government, with the Ministry of Economic Affairs, and Dutch companies invested heavily in applied research into new forms of energy generation, such as nuclear energy, in the 1950s. To join this money flow, the Dutch fusion scientists tried to raise funds from these investors based on the economic potential of nuclear fusion research. In doing so, the scientists focused on both the inexhaustible resources and the lack of radioactive waste.

The report of the thermonuclear research committee in 1956 was the basis on which was decided to establish the working community and to start Dutch research on nuclear fusion. The report described the importance of setting up fusion research in the Netherlands. The future shortage of fossil fuels was the main motivation. The consumption of fossil fuels had risen to such an extent in the 1950s that “depletion seemed inevitable in the short term” according to the study committee. Energy extraction from nuclear fission offered an alternative, but faced the problem of radioactive waste. Clean and inexhaustible energy could be extracted by means of nuclear fusion.¹⁰⁴ The study committee still assumed that energy could be generated from fusion between the isotopes deuterium and deuterium (D + D). However, to make this clean energy commercially usable, “financial resources” were needed.¹⁰⁵

In the Netherlands, these financial resources would have to be raised by the government and the business community. The scientists in the study committee therefore tried to involve various companies in setting up the research at an early stage. Particularly interesting were companies involved in energy production, such as KEMA and Philips. Appointing Ter Horst as chairman of the study committee and later as leader of the working group on trochoidal discharges was an important step. Ter Horst worked as a researcher at the energy company

¹⁰⁴ ‘Notulen vijfde vergadering van de studiecmissie ‘thermonucleaire reacties’’, (3 April 1957), 2-4. FOM archives, NHA.

¹⁰⁵ The later variant in which the isotopes deuterium and radioactive tritium (D + T) merged was not yet the subject of the study.

KEMA. KEMA was a globally operating consultancy firm in the field of energy whose shareholders consisted mainly of Dutch utility companies. Within the department of KEMA in Arnhem, there was also plenty of room for research into energy generation.¹⁰⁶ From 1957 onwards, KEMA was also intensively involved in research into energy production from nuclear fission.¹⁰⁷ The potential added value of involving KEMA in nuclear fusion research, with financial and material resources and the available expertise, was recognized by the scientists at an early stage. Immediately after the meeting at the Institute for the Tropics, Ter Horst was recruited on behalf of KEMA as chairman of the study committee based on the potential economic possibilities of nuclear fusion.¹⁰⁸

Philips was also contacted at an early stage. On 2 October 1956 Beekman informed the executive board of FOM that they wanted to have the study committee supported by “two younger physicists from the physics laboratory of N.V. Philips’ Incandescent Light Bulb Factories, who would be appointed by the director of Philips, Hendrik Casimir”.¹⁰⁹ Although this support for the study committee ultimately did not get off the ground, Philips remained involved during the first years of the Dutch fusion research. The coordinating committee of the working community decided to ask Dr. Bruining to join the coordinating committee as a delegate from Philips.¹¹⁰ Bruining accepted this invitation and informed the committee that Philips was considering seconding an employee to the plasma physics working group.¹¹¹ Philips

¹⁰⁶ Ter Horst carried out research on behalf of KEMA into the storage of energy, by researching magnetic energy in coal: Ter Horst, D.Th.J., ‘Some Remarks on Energy Storage’, *Nuclear Instruments and Methods*, 4 (1959), 382-385.

¹⁰⁷ Van Loon, A.J., *50 Years of Nuclear Fission* (KEMA, 1989), 12.

¹⁰⁸ ‘Kort verslag van een gedachteswisseling over het vraagstuk van de thermonucleaire reacties’, 3.

¹⁰⁹ Beekman, ‘Aan de leden van het uitvoerend bestuur van de stichting van het FOM’.

¹¹⁰ ‘Concept-notulen van de eerste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’, 2.

¹¹¹ ‘Notulen van de tweede zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’, 3.

was also able to provide a number of devices to advance the research by the various working groups.¹¹²

Another important part of the investments in the new fusion research should be provided by the government. With the promise of inexhaustible clean energy through nuclear fusion the scientists tried to obtain money from the Ministry of Economic Affairs. This ministry had a large amount of money available and was already investing heavily in research into nuclear fission at RCN.¹¹³ Also, the scientists tried to convince the directors of RCN that fusion research should be part of RCN. In 1956 and 1957, articles by fusion scientists appeared regularly in the journal of RCN concerning the economic promises of fusion research.¹¹⁴ So from the beginning, the fusion scientists tried to obtain money based on the economic promise of nuclear fusion. From the outset, they had an eye for alternative energy sources other than nuclear fission in which radioactive waste was presented as a disadvantage of nuclear fission.

2.2.3. Opportunities for International Corporation

In addition to trying to get the money for the development of nuclear energy, the Dutch fusion scientists tried to join international, foremost European, research. In the first years, their strategy was to gather knowledge for their own experiments as quickly as possible. The results of their own research could then be used to gain a negotiating position to obtain more information by collaborating with other countries. However, this strategy changed with the international declassification of the research at the Geneva congress in 1958. During this congress it became clear to the scientists that it was also no longer necessary to build up a negotiating position for knowledge about fusion research. Although the official fusion research

¹¹² 'Notulen zevende vergadering van de studiecmissie 'thermonucleaire reacties'', (28 October 1958), 4. FOM archives, NHA.

¹¹³ Verbong and Lagaaij, 'Belofte van Kernenergie', 239-242.

¹¹⁴ Boeschoten, F., 'Energieproductie door reacties met lichte kernen', *RCN Bulletin* 1, 6 (1957), 69-74.

in the Netherlands was initiated following Russian calls for declassification, the focus from the scientists was mainly on American and especially European developments.

Dutch fusion scientists always considered the possibility of international cooperation an interesting option. The scientific leader, Kees Braams, had specifically been tasked with establishing and maintaining contact with foreign scientific institutions. This focus on international development descended from the study committee in which newspaper clippings about possible international breakthroughs and published scientific articles were regularly shared.¹¹⁵ Also, during the meeting at the Institute for the Tropics, Kistemaker already argued that he had met a number of Americans who stated they did not understand why the Netherlands did not work in the area of fusion science.¹¹⁶ During the first period of the working community between 1957 and 1958, many international working visits followed under the pretext that “international cooperation is important, but first something has to be done to improve the negotiating position”.¹¹⁷

This pretext changed after the Atoms for Peace congress in 1958. After attending the congress, it became clear that both the British, American and Russian scientists failed to control nuclear fusion. Brinkman concluded in front of the Dutch media that some experiments should be tackled differently than they had planned beforehand, but that the Netherlands could make an “A-contribution”.¹¹⁸ Because nuclear fusion research had been declassified internationally at the congress, Dutch scientists no longer had to try to gain a negotiating position to obtain knowledge. Several working visits to laboratories in Milan and the Pinch reactors in Harwell, used for the ZETA project, therefore followed each other in quick succession.¹¹⁹

¹¹⁵ The secretary of the study group on 3 January 1957, circulated, for example, the following article to the members of the study group: ‘Nieuwe atoomreactie ontdekt in Californië: uitzicht op energiewinning uit waterstof?’ *Algemeen Handelsblad* (2 January 1957).

¹¹⁶ ‘Kort verslag van een gedachtewisseling over het vraagstuk van de thermonucleaire reacties’, 1-2.

¹¹⁷ ‘Notulen van de derde zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’, 5.

¹¹⁸ ‘Nederland trekt profijt van “Geneve”’, *Het Parool* (3 September 1958).

¹¹⁹ ‘Notulen van de derde zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’, 3.

Dutch fusion scientists focused mainly on European cooperation since 1956. There had been further institutionalisation of European fusion research. After an unsuccessful attempt to accommodate a fusion research institute at CERN, the European fusion research soon switched over to Euratom.¹²⁰ As early as 1957, FOM was approached by Euratom to draw up an association agreement, but it was only from the congress in 1958 that the cooperation really started because secrecy was no longer needed.¹²¹ The cooperation of several European research institutes within Euratom and Euratom's budgets made it easy to exchange information on fusion research and to send European scientists to each other on an exchange basis.¹²² The Dutch fusion scientists made eager use of these opportunities.

2.3. Economic Applicability or International Politics: Who Invests in Fusion?

2.3.1. Investors' Responses to the Economic Promises of Fusion

Why was fusion research set up in the Netherlands? The Dutch fusion scientists tried to link their research to the large investments available for research into peaceful applications of nuclear energy. However, many investors did not believe in the success of nuclear fusion in the short term. The Ministry of Economic Affairs stated that it did not want to invest in fusion research, and some other investors changed their mind after the death of Hendrik Brinkman, the face of the Dutch fusion research.

The 1957 Memorandum on Nuclear Energy by Minister Zijlstra, announced that “nuclear legislation” was in progress and extra money was made available for the production of nuclear energy, but did not suggest that the Ministry of Economic Affairs should invest in

¹²⁰ The Dutch director of CERN, C.J. Bakker, saw potential in 1956 in a European research institute for fundamental research into nuclear fusion at CERN. These plans were subject of various discussions, but were ultimately rejected because of the CERN board's focus on particle research. Braams, C.M., *Kernfusie in historisch perspectief* (Eindhoven University of Technology, 1990), 10.

¹²¹ ‘Notulen van de derde zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’, 5.

¹²² Shaw, *Europe's Experiment in Fusion*, 9.

nuclear fusion. “For the sake of completeness”, Zijlstra described that “there are also nuclear reactions that release large amounts of energy precisely through the fusion of small atomic nuclei into one large core” and that “this form of energy production does not need to be discussed in more detail as no reliable data are yet available on its development”.¹²³

Several leading economists, such as Jan Tinbergen, had publicly agitated against the direct economic potential of nuclear fusion. Tinbergen, prominent Dutch economist and crown member of the Social and Economic Council (SER), stated that nuclear energy should not be overestimated and that very intensive research was needed before nuclear fusion would become profitable.¹²⁴ During the same period, SER issued a number of decisive opinions and reports, including on the work of the Committee on European Economic Integration. These reports discussed in detail the economic added value of nuclear energy, which referred exclusively to energy from nuclear fission, in relation to the Euratom. Nuclear fusion was not mentioned, although attention was paid to a European community in which there were possibilities for international research on nuclear energy.¹²⁵

In addition, RCN’s scientific advisory board and the board of TNO also indicated that they did not see any direct economic potential in nuclear fusion research.¹²⁶ TNO even stated to the lobbying scientists that only in the distant future they would, possibly, invest in fusion, pointing to already ongoing projects for alternative energy production such as solar energy.¹²⁷ RCN only wanted to remain involved in Dutch fusion research to a limited extent. By seconding Boeschoten, who had previously been a member of the study committee on behalf of RCN, to

¹²³ Zijlstra, J., ‘Geleidende brief Nota inzake kernenergie’ (1957), 4. Tweede Kamer document number 4727 under number 4. SGD.

¹²⁴ “‘Atoomenergie niet overschatten’” *Het Parool* (6 June 1957).

¹²⁵ ‘Verslag van de werkzaamheden van de commissie Europese Economische Integratie’, *Sociaal Economische Raad* (1956). Digital Publications SER.

¹²⁶ Beekman, ‘Aan de leden van het uitvoerend bestuur van de Stichting voor Fundamenteel Onderzoek der Materie’, (2 October 1957).

¹²⁷ Fetter, ‘Aan de directeur van de stichting voor Fundamenteel Onderzoek der Materie’ (26 July 1957).

FOM, RCN was able to remain involved in the developments in the working community without investing much money in the research.¹²⁸

In the same way, some companies wanted to stay involved in the Dutch fusion research or even wanted to participate in the research. The Provincial and Municipal Utrecht Power Supply Company (PEGUS) invested in Dutch fusion research by facilitating laboratory rooms of the plasma physics working group.¹²⁹ Philips was also involved in fusion research during the first years. However, the death of Hendrik Brinkman as the face of the Dutch fusion research in 1959 and the fundamental status of the research made Philips doubt the economic potential of the fusion research. These doubts led to a partly withdrawal of Philips from the research. Only Dr. Bruining remained on the coordinating committee of the working community.¹³⁰

An exception to these companies was the Dutch energy company KEMA. This company even set up its own working group within the working community under the leadership of Ter Horst. However, their research into toroidal discharges had more applications than nuclear fusion research alone. It was also potentially possible to make better batteries with this research.¹³¹ In view of these considerations, the partly withdrawal of Philips and the rejection from the Ministry of Economic Affairs, it is clear that the Dutch investors did not believe in the direct economic potential of Dutch fusion research, despite the lobbying of the scientists.

2.3.2. Investing in International Fundamental Science

Despite that many investors did not believe in the direct economic potential of nuclear fusion research, other parts of the government and related institutions invested in fusion research as

¹²⁸ ‘Concept notulen van de eerste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’, 3.

¹²⁹ Between 1957 and the final transition to FOM-Rijnhuizen in 1960, the plasma physics working group divided the research between the rooms in the PEGUS power station and the Physical Laboratory of Utrecht University. Vrouwe, *Hittebarrière*, 17 and ‘Notulen van de derde zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’, 6.

¹³⁰ Kersten, *Een organisatie van en voor onderzoekers*, 146-147.

¹³¹ ‘Kort verslag van een gedachtewisseling over het vraagstuk van de thermonucleaire reacties’, 3.

fundamental science. Because the fusion research was accommodated at FOM, the largest flow of money went via ZWO. Also the Ministry of Education, Arts and Sciences (OKW) did invest money to buy the Rijnhuizen estate. The possibilities for European cooperation were the main reason for investing in fusion as fundamental science.



Figure 19: The castle Rijnhuizen in Nieuwegein, former Jutphaas. The castle housed the theorists and directors of FOM-Rijnhuizen. Wikimedia.

In 1957, Dutch fusion research was transferred to FOM definitively. FOM published a five-year plan in 1957 for three new projects, including fusion research. Six million guilders were earmarked for the five-year plan, an important part of which was earmarked for nuclear fusion research.¹³² A few months later, this amount was increased with grants totalling over 2.5 million via ZWO to FOM. The majority of this money was intended for nuclear fusion research.¹³³ In an update of the memorandum on nuclear energy, Minister Jo Cals also noted that five hundred and forty-four thousand would be spent as a government contribution to fusion research within the budgets of Education, Arts and Sciences. In addition, a one-off sum of four hundred and twenty-five thousand was earmarked for the establishment of the FOM's own plasma research institute.¹³⁴

These investments were not always certain. In 1958 a committee of inquiry into the spending of the ZWO, the Verwey committee, recommended that the ZWO limited thermonuclear research to monitoring developments. This advice was initially endorsed by FOM, but the ZWO board was of the opinion that the determination with which FOM proceeded did not correspond with this endorsement. Doubts were mainly expressed about the possible acquisition of the Rijnhuizen estate. The Verwey committee, prompted by the loss of the face of nuclear fusion research with Brinkman's death, continued to have doubts. The president of

¹³² 'Vijfjarenplan voor kernfusie', *Telegraaf* (29-08-1957).

¹³³ 'Ruim vijf miljoen voor Z.W.O.', *Het Parool* (14 January 1958).

¹³⁴ Cals, J., J. Zijlstra, J. Luns and J.G. Suurhof, *Nota inzake de kernenergie* (11 November 1957), 13. Tweede Kamer document number 4727 under number 4. SGD.

ZWO, Jan Bannier, shared this scepticism and decided to reject a new expansion plan for Rijnhuizen.¹³⁵

Despite these reserves, FOM was able to realise the construction of a laboratory through the extraordinary service of the Ministry of Education, Arts and Sciences. The ministry made 400 thousand guilders available outside the ZWO for the purchase of Rijnhuizen and the setting up of the first research project.¹³⁶ When the Ministry asked ZWO for advice on the purchase of the estate in March 1958, the reaction was prudent: yes for the purchase, but a reservation for the construction of laboratories and other facilities.¹³⁷ In March 1959 the ZWO finally agreed to a furnishing loan for Rijnhuizen, which enabled Minister Cals to officially open FOM Rijnhuizen by hitting the sixty-eighth pile on 16 November 1959.¹³⁸

The main reason for the government to invest this money in fusion research, while there was no direct economic interest, was the possibility of European cooperation. The Ministry of Education, Arts and Sciences brought fusion research at FOM into contact with the increasing focus on the development of more fusion projects within Euratom.¹³⁹ At the expense of the Ministry of Education, Arts and Sciences, Braams was sent on various international trips and to make important contacts within Euratom.¹⁴⁰

FOM was able to conclude a cooperation agreement with Euratom under which European subsidies would flow to Dutch nuclear fusion research with help of the Ministry of Education, Arts and Sciences, and the Ministry of Foreign Affairs.¹⁴¹ The Minister of Foreign Affairs, Joseph Luns, even defended the Dutch accession to Euratom, arguing that funds for

¹³⁵ Kersten, *Een organisatie van en voor onderzoekers*, 146-147.

¹³⁶ *Ibidem*, 146.

¹³⁷ 'Notulen Z.W.O.-bestuur', (27 January 1958 and 17 March 1958) represented in Kersten, *Een organisatie van en voor onderzoekers*, 146.

¹³⁸ Vrouwe, *Hittebarrière*, 18.

¹³⁹ 'Concept-notulen van de eerste vergadering van de commissie onderzoek-programma Euratom' (1957), 2. FOM Archives, NHA.

¹⁴⁰ 'Notulen van de derde zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermo-nucleaire reacties"', 3.

¹⁴¹ Braams, *Kernfusie in historisch perspectief*, 10.

fusion research could come to the Netherlands in this way.¹⁴² It is clear that Dutch investments in fusion research were based on opportunities for European cooperation from the beginning.

2.4. Dutch Media about the Developments in Fusion Research

2.4.1. “Wrestling for the Fire of Heaven”

The development of the reports in the Dutch media illustrate the development of international fusion research from a competition between different countries to international cooperation between 1956 to 1958. Central to the reports of various newspapers before 1958 was the competition between the world superpowers within fusion research. Not until the conference in Geneva in 1958, when the international fusion research was declassified, the Dutch media paid attention to the possibilities for international cooperation.¹⁴³

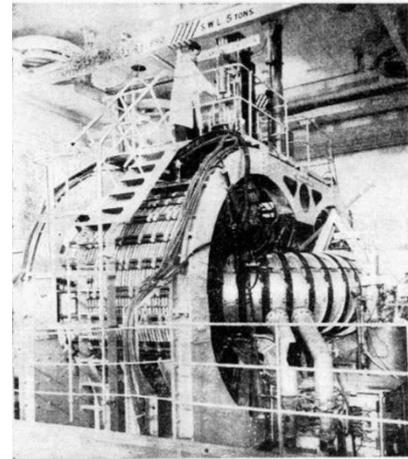


Figure 20: “This, then, is the gigantic Zeta machine enveloped in so much secrecy for months.” *De Telegraaf* (25 January 1958).

The image of competition was fed by potential breakthroughs in the different world powers. The competition between the United States and the Soviet Union in the field of nuclear fusion research for peaceful purposes received extensive attention in the Dutch media for the first time in December 1956. Different national and regional newspapers, such as *De Volkskrant*, *De Friese Koerier* and *De Tijd: Godsdienstig-Staatskundig Staatsblad*, wrote articles in response to a press release from the American Navy that temperatures over a million degrees Celsius had been reached during laboratory tests. These temperatures could be used for the peaceful use of energy from nuclear fusion. The news items also mentioned that the Russians had also reached these temperatures previous spring.¹⁴⁴

¹⁴² ‘Handelingen Eerste Kamer 1957-1958’ (3 December 1957), 76-77. SGD.

¹⁴³ See for example ‘Nederland trekt profijt van “Geneve”’, *Het Parool*.

¹⁴⁴ ‘Temperatuur van twee miljoen graden bereikt in V.S.’, *De Tijd: Godsdienstig-Staatskundig Dagblad* (5 December 1956).

This narrative of competition continued in the following years with a focus on announcements of developments in fusion research in Western countries, such as the establishment of fusion research in Germany, the construction of a new reactor at Princeton, and the British success with ZETA.¹⁴⁵ The articles compared the success of the country in question with success in the other countries. *De Tijd* even headed: “Wrestling for the fire of heaven: Hydrogen bomb is being tamed, after America and Russia also success in Germany”.¹⁴⁶

The launch of the Sputnik by the Russians intensified the image of this competition, as the United States and Great Britain took advantage of this launch to collaborate more in fusion research.¹⁴⁷ This American-British collaboration led to the highest peak in attention for fusion research in the Netherlands until the presentation of the ZETA success and the Geneva conference. Although the British media and the Dutch *Vrije Volk* had been reporting for some time that there were initial successes with plasma generation and stability with the ZETA pinch reactor in Harwell, the news was not officially made public until December 1957.¹⁴⁸

This timing had everything to do with the race between the Soviet Union, the United States and Great Britain in the run-up to Congress in Geneva. At the congress, each superpower wanted to show the best results.¹⁴⁹ On 9 January 1958, the chairman of the American Atomic Energy Commission, Lewis Strauss, added to this race by stating in a special press conference that the British and Americans had made “significant progress” in achieving high temperatures for nuclear fusion. At the end of January, the British and Americans presented a joint success:

¹⁴⁵ The succes of ZETA was first described in ‘Aan het begin van de Waterstofeeuw’, *Het Vrije Volk: democratisch-socialistisch dagblad* (9 September 1957).

¹⁴⁶ ‘Een worsteling om het hemelvuur: Waterstofbom is getemd, na Amerika en Rusland ook succes in Duitsland’, *De Tijd; Godsdienstig-Staatskundig Dagblad* (9 March 1957).

¹⁴⁷ This was the rationale presented in ‘Dank aan Spoetnik’, *Het Vrije Volk: democratisch-socialistisch dagblad* (29 October 1957).

¹⁴⁸ ‘Brits Procedé: Industriële energie door waterstofbomreactie’, *Algemeen Handelsblad* (18 December 1957); and ‘Britten winnen “energierace”’, *De Telegraaf* (18 December 1957). *Het Vrije Volk* mentioned the British project already in ‘Aan het begin van de waterstofeeuw?’, *Het Vrije Volk*.

¹⁴⁹ Herman, *Fusion: the Quest for Endless Energy*, 54-55.

controlled nuclear fusion was a fact and could be put into commercial use within twenty years.¹⁵⁰

The Dutch media published extensively about this news and *Het Vrije Volk* even stated that nuclear fusion is the most sensational scientific development so far in history, including Sputnik.¹⁵¹ The disappointment and subsequent attention in the Dutch newspapers was therefore great when the British and Americans had to withdraw their claims in May 1958 when it turned out that the plasmas were not stable enough after all and much more energy was lost than extracted.¹⁵²

2.4.2. The First Fusion Hype

The great attention paid to competition between the various powers that conducted research into nuclear fusion in the Dutch media was often linked to the economic promise of fusion research. Nuclear fusion research was portrayed as an applied science whose spectacular breakthrough was to come in the foreseeable future. Between 1956 and 1958, *Het Vrije Volk*

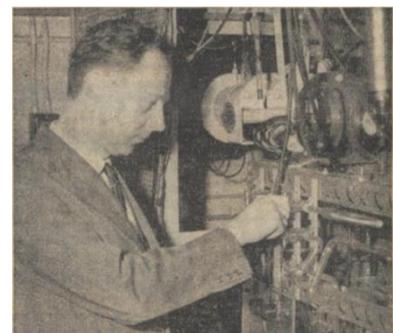


Figure 21: Jaap Kistemaker with one of his fusion experiments. *Het Parool* (16 January 1958).

wrote several articles extensively describing why nuclear fusion was the energy of the future.¹⁵³

In addition to *De Vrije Volk*, *Gereformeerd Gezinsblad* also described nuclear fusion as the greatest scientific promise in 1957.¹⁵⁴

In 1958, this positive view of nuclear fusion further increased in the Dutch media and even resulted in what could be called a real “Fusion Hype”. With the presented breakthroughs

¹⁵⁰ ‘Brits-Amerikaanse successen op het gebied der kernfusie’, *De Tijd: Godsdienstig-Staatskundig Dagblad* (9 January 1958).

¹⁵¹ ‘Britse primeur van kernfusie door VS opgehouden’, *Het Vrije Volk: democratisch-socialistisch dagblad* (14 January 1958).

¹⁵² See for example ‘Brits ZETA-apparaat bracht teleurstelling’ *Algemeen Handelsblad* (14 June 1958).

¹⁵³ ‘‘t Zal mijn tijd wel duren....’ Dat zit nog!’ *Het Vrije Volk: democratisch-socialistisch dagblad* (30 April 1958).

¹⁵⁴ ‘Een jaar wereldgebeuren in vogelvlucht’, *Gereformeerd gezinsblad* (31 December 1957).

in Great Britain and the United States, such as with ZETA, extensive attention was paid to the upcoming economic applications of nuclear fusion. Even the national *NTS-Journaal* devoted an extensive item on 25 January 1958 to the breakthroughs at ZETA and the potential for extracting electricity from water.¹⁵⁵

This way of reporting on international breakthroughs, in which the economic promises of nuclear fusion were constantly being challenged, was extended by the Dutch media to cover the launch of Dutch research into nuclear fusion. When FOM announced that a research committee had investigated the peaceful use of nuclear fusion, *De Volkskrant* headed: “Tamed hydrogen bomb for peaceful purposes; Energy from nuclear fusion also in study here”.¹⁵⁶

Even when at the end of 1957 it became clear that the fusion research was regarded as fundamental science and would take place at FOM, several newspapers wrote that the Netherlands was also trying to “tame” the H-bomb, and extensively wrote about fusion energy’s economic applications.¹⁵⁷ This economic connotation in the Dutch research remained in the media, even after the conference in Geneva where classification was breached and where it became clear that no country had yet been successful. In 1959, for example, a number of articles appeared in *Nieuwsblad van het Noorden* and *Leeuwarder Courant* on industrial potential and the future of energy through nuclear fusion.¹⁵⁸

It is striking that in the hype in the Dutch media about the economic potential of nuclear fusion research, only limited attention was paid to the advantage of the lack of radioactive waste over energy production. A few exceptions were an article by *Het Vrije Volk* in October 1957 in which nuclear fusion was mentioned as an alternative to radioactive nuclear energy, and a report on parliamentary questions about radiological danger from the Dutch Labour Party (PvdA) in

¹⁵⁵ *NTS-Journaal* (25 January 1958). The Netherlands Institute for Sound and Vision.

¹⁵⁶ ‘Getemde waterstofbom voor vreedzame doeleinde: Kernfusie ook hier in studie’, *De Volkskrant* (12 April 1957).

¹⁵⁷ See for example ‘Ook in Nederland: Onderzoek naar probleem kernfusie’, *De Waarheid* (21 November 1957).

¹⁵⁸ ‘Nederland werkt om energie uit zeewater te winnen’, *Nieuwsblad van het Noorden* (15 January 1959); and ‘Een gedane zaak’, *Leeuwarder Courant: hoofdblad van Friesland* (20 January 1959).

November 1957 in which *De Volkskrant* wrote that nuclear fusion could be an alternative in the future.¹⁵⁹

2.5. Promises of Inexhaustible and Clean Energy in the Public

In August 1957 *De Tijd* reviewed a popular science book by their editor H.C.M. Edelman. *Leven met Atomen: de Atoomkracht in dienst van welvaart en vrede* (*Living with Atoms: Atomic Power at the Service of Prosperity and Peace*, 1957) explained how nuclear reactors worked and offered different perspectives on the future in which the possibilities of nuclear energy would be endless. From an airborne locomotive to an atomic car, everything was described in detail and in a positive way.¹⁶⁰ The



Figure 22: H.C.M. Edelman. *De Tijd* (14 August 1957).

review, which “warmly recommended” the book, wrote that “radioactivity, nuclear fission and nuclear fusion” all were discussed.¹⁶¹

Although this review seems to suggest that nuclear fusion in the book was on an equal footing with energy extraction from nuclear fission, this is not apparent from the book itself. Nuclear fusion, announced under the heading hydrogen energy, only got one page in the 250-page work after the conclusion. Edelman started his remark on fusion with “there is a second dream of the future for nuclear physicists” and closes sceptical with: “will this ever work? Mankind is not given to foresee the future.”¹⁶²

This lack of attention contrasts sharply with the focus on radioactivity and the possible dangers of radiation in the book. In these parts Edelman tried to provide an answer to the social

¹⁵⁹ ‘Prof. Muntendam waarschuwt: Elke radioactiviteit is gevaarlijk’, *Het Vrije Volk: democratisch-socialistisch dagblad* (12 October 1957); and ‘Beknopt verslag Tweede Kamer donderdagavond’, *De Volkskrant* (30 November 1957).

¹⁶⁰ Edelman, H.C.M., *Leven met atomen: de atoomkracht in dienst van welvaart en vrede* (Amsterdam: Meulenhoff 1957), 229-241.

¹⁶¹ “‘Leven met Atomen’ Heldere en prettige beschrijvingen van ingewikkelde materie’, *De Tijd: Godsdienstig-staatskundig dagblad* (14 August 1957).

¹⁶² Edelman, *Leven met atomen*, 240-241.

concerns surrounding these subjects. Although the scientific study committee did state in their final report that nuclear fusion had the advantage of the lack of radioactive waste over nuclear fission, Edelman did not mention nuclear fusion in his chapter on radioactive waste. The reader was only told that “a warned man counts for two” and that every industry generates waste.¹⁶³ Possible future solutions were seen in an “economic miracle” whereby a way would be found to use waste for something new, turning it into a by-product rather than a residual product. Furthermore, options such as building new elements and converting existing elements were discussed by Edelman as possible future solutions. However, fusion was not noted as a possible solution.¹⁶⁴ The page on nuclear fusion did not mention the lack of radioactive waste either.¹⁶⁵

In the same summer that Edelman published his book, the exhibition *Het Atoom* took place at Schiphol Airport. Although the study committee noted six months before the exhibition that nuclear fusion offered a solution to the depletion of raw materials and several newspapers described nuclear fusion as being represented in their reports on the exhibitions, the actual attention turned out to be limited.¹⁶⁶ It was only mentioned in the exhibition room about “a view on energy sources of the future”. The description elaborated that nuclear fusion was a source of inexhaustible energy. No attention was paid to the lack of radioactive waste, which would make it preferable to nuclear fission.¹⁶⁷ It is clear that during the 1950s nuclear fusion was not presented as an answer to the fear of radioactive waste and radiation in the public debate.

2.6. Emerged Dutch Fusion Science

Between 1951 and 1959 nuclear fusion research emerged in the Netherlands. Kistemaker’s experiments in 1951, Russian calls for declassification and American and British research,

¹⁶³ Ibidem, 130-131.

¹⁶⁴ Ibidem, 135-142.

¹⁶⁵ Ibidem, 240-241.

¹⁶⁶ “‘Het Atoom’ wordt zeer attractief”, *De Telegraaf* (8 May 1957).

¹⁶⁷ Stichting Internationale Tentoonstelling Het Atoom, *Catalogus Het Atoom* (Amsterdam 1957), 9-25. SAA.

formed the basis of the report of the study committee “thermonuclear reactions” in 1957. It was concluded that the Netherlands should join the international fusion research. Nuclear fusion was presented as a clean and inexhaustible source of energy and thus as an alternative to the polluting and expensive extraction of energy from nuclear fission by the Dutch fusion scientists. Based on this economic promise, scientists tried to raise money from companies and the government. At the same time, the scientists made several international contacts, including Euratom. Especially after the congress in Geneva in 1958 at which nuclear fusion research was declassified worldwide, it became clear that the Netherlands could make an “A contribution” to the research. At a rapid pace a working community with five working groups was set up in the Netherlands under the supervision of scientific leader Kees Braams, and an independent institute for plasma physics was set up with the purchase and equipping of FOM-Rijnhuizen.

Economically oriented investors in the 1950s did not believe in the direct economic potential of nuclear fusion research most of the time. Several economists were critical of this economic potential. As a result, nuclear fusion research did not benefit from the budget increases proposed by the Ministry of Economic Affairs for nuclear energy. Although some companies wanted to stay involved in the research in some way by supplying instruments, seconding scientists or providing rooms for laboratories, the main investments were made by the Ministry of Education, Arts and Sciences. These investments were mainly due to the possibility of international, especially European, cooperation in fusion research.

Meanwhile, the narrative in the Dutch media was mainly determined by a strong emphasis on the economic promise of nuclear fusion. When media wrote about nuclear fusion and international relations, the narrative of competition between the major powers such as the United States, Great Britain and the Soviet Union dominated until 1958. The limited attention to international cooperation and emphasis on international competition related to the attention paid to the economic potential of energy production from nuclear fusion. Many media were

enthusiastic about the possibility of an inexhaustible source of energy and created a Fusion Hype in the 1950s. However, only limited attention was paid by the media to the lack of radioactive waste. Nuclear fusion was not presented as a response to increasing fears about radiation. Nuclear fusion also played only a limited role in the public debate on radioactivity during the 1950s.

3. Cold War Fusion: Establishing International Contacts During the Cold War, 1959-1968

3.1. Introduction

3.1.1. A Congress on Russian Soil

At the end of the spring in 1968, nine Dutch fusion scientists arrived in Novosibirsk, Soviet Union, for an international fusion congress. In the same months that the fusion scientists exchanged experiences in Siberia about fusion research with their colleagues from all over the world, the Prague Spring ignited in Czechoslovakia. Protests against the Soviet regime were harshly repressed by the Soviet authorities, leading to critical responses in Western countries. The tensions of the Cold War flared up again in the 1960s. This decade has been described as the fiercest in the Cold War. Tensions between East and West almost escalated worldwide on several occasions, with the construction of the Berlin Wall in 1961 and the Cuban Crisis 1962 as the most prominent examples.¹⁶⁸

The idea that European cooperation should form a power block between the United States and the Soviet Union persisted in the 1960s. Science was counted for as a good basis for cooperation. Euratom's ambition was to invest in research into peaceful uses of nuclear energy, while increasingly focussing on nuclear fusion. This focus was mainly due to increasing pressure from France. Under President De Gaulle, the French still had the ambition to become a nuclear power of their own.¹⁶⁹ Both within Euratom and through the European Parliament, France increased the pressure for Euratom to stop focusing on nuclear fission. According to France, Euratom had to focus on projects in fundamental science with nuclear fusion research

¹⁶⁸ Cieraad describes the first years of the 1960s as the fiercest of the entire Cold War. Cieraad, 'The Radiant American Kitchen', 126-129.

¹⁶⁹ Jackson, *A Certain Idea of France: The Life of Charles de Gaulle*, 100.

as one the most prominent examples.¹⁷⁰ This pressure resulted in several blocked Euratom budgets and eventually cuts in nuclear fission research through Euratom. In this way, it was possible to invest considerably more in nuclear fusion research. Euratom started to invest the money, originally intended for nuclear fission projects in more fundamental scientific projects such as fusion science.¹⁷¹

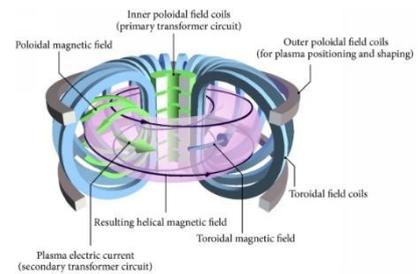


Figure 23: Schematics of a Tokamak.
Wikimedia.

Fusion research was regarded a fundamental science all over the world because of the big problems that were encountered during the different experiments. The main problem was reaching the right temperatures long enough to trigger a nuclear fusion reaction without the plasma escaping and the temperature evaporating. This was proving so problematic that the American physicist David Bohm concluded, based on the experiments conducted up to that point, that it was impossible to simulate the situation for controlled nuclear fusion on earth. His thesis came to be known as the Bohm-diffusion, a collective term for not fully understood heat losses to which a rule of thumb seemed to apply that indicated a connection between density, temperature, dimensions and the field strength of the magnets. Although the Bohm-diffusion was not theoretically derivable, it was made plausible by the disappointing results. More and more, especially American and European, scientists started to believe this thesis.¹⁷²

However, Soviet scientists claimed to have a model reactor which could reach higher temperatures and could keep plasmas stable for a longer time than was prescribed by the Bohm thesis. The model of the tokamak reactor had already been conceived in 1950 by Alexander Sakharov, but due to the earlier success of the screw pinch in America and at ZETA, it had received little attention in Russia for a long time. The Tokamak captured the plasma in a kind

¹⁷⁰ The other two projects were the ORGEL project at Ispra and research into fast reactors. Shaw, *Europe's Experiment in Fusion*, 12.

¹⁷¹ 'Euratom, a year of activity April 1965 – April 1966' (1966), 2. AEI.

¹⁷² Braams, *Kernfusie in historisch perspectief*, 15.

of donut form, surrounded by magnetic coils. The underlying principle was the same as the pinch concept of ZETA. When an electric current passed through a plasma cloud, a magnetic field was created around the plasma. This field “pinched” the plasma into its own invisible, magnetic bottle. The tokamak had the added



Figure 24: Lev Artsimovich (left) and Igor Kurchatov (right). *Iter* magazine 9.

feature of magnetic coils belted vertically around the outside of the chamber to add a second, stabilizing field. Although this system had not been used by Soviet scientists for some time, it was picked up again in Kurchatov’s laboratory in the 1960s. Especially the Russian scientist Lev Artsimovich became an fierce advocate of the Tokamak.¹⁷³

During the congress in Novosibirsk in 1968 the Russian fusion scientists would provide definitive proof with their tokamak that the Bohm-diffusion was false. However, this breakthrough only got a limited response from the fusion scientists of the Western countries. After the many failures within the fusion research, with ZETA as the greatest example, the main reaction was scepticism and disbelief. The findings of the Artismovich were not believed.¹⁷⁴

3.1.2. *Less Necessity for Alternative Energy Sources*

While the problems in fusion science seemed increasingly insolvable, the need to invest in alternative forms of energy declined. In 1959, natural gas was found in the Netherlands at Slochteren. This discovery would drastically change the energy supply in the Netherlands. The Dutch government, together with the oil companies Shell and Esso and the State Mines, converted the energy supply in the Netherlands to a system that largely ran on natural gas. In 1962, the Minister of Economic Affairs, Jan de Pous, presented a memorandum on natural gas. The state gained a greater grip on gas production and distribution and received a large part of

¹⁷³ Herman, *Fusion: the Quest for Endless Energy*, 80-82.

¹⁷⁴ *Ibidem*, 82.

the revenues in its own budget. In 1963 it began the transition to a gas network and five years later almost the whole of the Netherlands was connected to natural gas.¹⁷⁵

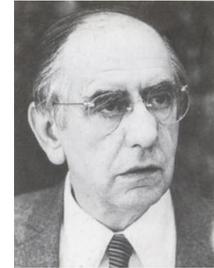


Figure 25: Jan de Pous as Dutch Minister of Economic Affairs, 1959-1963. LAKA.

The huge increase in natural gas made investments in alternative forms of energy less urgent. Investments in nuclear energy no longer seemed to be equally necessary. In addition, the commercial development of nuclear energy was much slower than had been expected in the 1950s and the costs appeared to be rising. Because these costs were no longer financially and politically affordable, the government had to make choices. Several projects at RCN were discontinued, but investments were continued, in those projects that seemed to yield the highest returns, such as the research initiated by Jaap Kistemaker into the application of ultracentrifuges and the research into suspensions reactors project at KEMA.¹⁷⁶

To better coordinate research into nuclear energy and the various commercial projects, the Nuclear Energy Act was enacted in 1963. With this law, licences could be granted to organisations that were professionally engaged in nuclear energy or materials needed for the research into nuclear energy. This law also established five advisory councils who would provide advice on the development of nuclear energy, including the Scientific Council for Nuclear Energy (WRK) and the Industrial Council for Nuclear Energy (IRK).¹⁷⁷ These councils, consisting of nuclear physicists or industrial businesses like KEMA and Philips, advised the government on a wide range of issues relating to nuclear energy during the 1960s and 1970s, including the status of international and Dutch fusion research.

¹⁷⁵ Verbong, a.o., *Een kwestie van lange adem*, 32-35.

¹⁷⁶ Ibidem, 35-37.

¹⁷⁷ The other three advisory councils were the Central Council for Nuclear Energy (CRK) and the Interdepartmental Committee for Nuclear Energy (ICK). The Health Council of the Netherlands, which has existed since 1919, was given an additional task. Van Vugt, F., *De hardheid van de nucleaire optie: een onderzoek naar de doorgang van een verguisde technologie* (Den Haag: ECN, 2004), 35.

In the meantime, the fear of radioactive radiation remained present in society and was even reinforced at times during the 1960s. Based on articles in *Panorama*, Dick van Lente shows that the message of the peaceful atom disappeared from the social debate during the early 1960s. In *Panorama* a new tendency emerged in which the dangers of radiation were linked to broader problems of Western societies. Together with other pollutants, radioactive radiation threatened especially children in society according to the articles. According to *Panorama*, there was no fundamental difference between military and peaceful uses of nuclear energy. With the rejection of the difference between military and peaceful applications of nuclear energy, combined with an increasing fear of nuclear destruction during a potential escalation of the Cold War, the support for nuclear energy disappeared from Dutch society during the 1960s, according to Van Lente.¹⁷⁸ This chapter examines how the promise of nuclear fusion was considered with the major scientific problems and the decreasing need for alternative energy sources. Could nuclear fusion in the 1960s offer an answer to the growing fear of radioactivity?

3.1.3. Chapter Overview

In a period when the promise of nuclear fusion in the Netherlands seemed further away than ever, research was still carried out by the working community “research thermonuclear reactions” and even experienced some major expansions during the 1960s (3.2.1.). The declining belief in the promise of fusion, however, forced the fusion scientists to shift their plans to transfer fusion research to RCN in the long term and to focus on the international status of the research in the lobby for new funding (3.2.2.). The fundamental status of fusion research made it possible to establish international contacts. Scientists focused mainly on American and European developments. The Russian claims about breaking the Bohm-diffusion were approached with scepticism, in line with the American scientists. This focus on American

¹⁷⁸ Lente, ‘Nuclear Power, World Politics, and a Small Nation’, 166-167.

science fits the historiographical narrative that Dutch post-war natural science focused mainly on American developments with the nuance that European science could also count on the attention of fusion scientists (3.2.3.).

With the increasing focus on a few projects within the nuclear energy project, it became increasingly clear that the Ministry of Economic Affairs would not invest in nuclear fusion research. Even companies that initially invested in fusion research, such as KEMA, withdrew from the research after the disappointing results. Various advisory bodies, such as the WRK, also expressed negative opinions about the economic potential of the fusion research (3.3.1.). Nevertheless, the WRK stated that investments should continue to be made in fusion research. The Ministry of Education, Arts and Sciences, from 1967 onwards the Ministry of Education and Sciences, even invested some large sums, outside the standard budgets, in the expansion of the laboratory spaces and the setting up of large projects. These investments were mainly prompted by the international status of research and the possibility of European cooperation as a power bloc between the United States and the Soviet Union. In this sense, investments in fusion research were motivated by the dynamics of the Cold War. (3.3.2.).

These developments are reflected in the reporting on nuclear fusion in the Dutch media. Due to the disappointing results in international and Dutch fusion research, and the decreasing urgency of alternative sources of sustainable energy, the attention for nuclear fusion decreased. At the same time, new themes arose in the descriptions of fusion research. The media paid more attention to the possibilities for international cooperation, with an emphasis on European research (3.4.). At the same time, nuclear fusion was unable to respond to the growing public fear of radioactivity. Nuclear fusion research was presented as an abstract scientific aspiration that did not provide answers to social questions (3.5.).

3.2. *The Ghost of Bohm: Dutch Thermonuclear Research in the 1960s*

3.2.1. *Expansion of the Research: Proceedings of the Working Community*

After the rapid build-up of Dutch fusion research in the 1950s, the 1960s were dominated by theoretical and experimental research for fusion researchers, training new scientists, stabilising revenues and establishing international contacts. The scientific problems that were encountered during the research were the most important motivation from the scientists. After the congress in Geneva in 1958, it became clear that heating plasma sufficiently and keeping it stable for long enough offered various challenges.



Figure 26: Injection experiment. Vrouwe, *Hittebarrière*, 29.

To tackle these problems, various fields of research were deployed in the Netherlands. In Rijnhuizen a pinch group, a high-frequency group and an injection group were installed. The injection group specialised in making magnetic bottles in which a quadrupole field, a magnetic field that becomes stronger on the outskirts, is created with two opposite coils.¹⁷⁹ The results, however, were disappointing because too many particles escaped the open system, despite the expensive research with large equipment.¹⁸⁰

In addition, the high-frequency group, the old working group TNII, focused on heating plasmas with electron and ion cyclotron heating, and the pinch group investigated various variants of pinch reactors. This pinch technique, copied from the British ZETA project, briefly compressed the plasma with a strong magnetic field, which allowed the plasma to be heated and neutrons to be released. In the end, the screw pinch proved to be surprisingly stable and Rijnhuizen became a specialist in this technique.¹⁸¹

¹⁷⁹ Vrouwe, *Hittebarrière*, 28-30.

¹⁸⁰ 'Notulen van de eenentwintigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermo-nucleaire reacties"' (19 November 1963), 3. FOM archives, NHA.

¹⁸¹ Braams & Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research*, 103-105.

However, the screw pinch did not lead to a major breakthrough in the Netherlands either. In 1963 a break-up time of six microseconds and a temperature of five hundred thousand degrees Celsius were achieved. These results did not come close to fusion conditions in which temperatures of hundreds of millions of degrees had to be reached over a longer period of time. At the end of 1961 FOM therefore concluded that “the backlog of research to thermonuclear reactions in the Netherlands compared to a few other countries could largely be made up”, but that the research also progressed more slowly than hoped for. “Although many new peculiarities about the behaviour of pinch discharges and Stellarator plasmas became known, this did not lead to significant improvements in temperature, density and storage time. Even rotating plasmas did not meet many expectations, while large injection experiments clearly disappointed”.¹⁸²

Nevertheless, the remaining fusion research, in Rijnhuizen and in Amsterdam, was expanded. Several new laboratory halls were built in Rijnhuizen. The Minister of Education and Sciences, Minister Isaac Diepenhorst, opened a brand new laboratory for larger experiments in 1967, and Kistemaker’s wishes for fusion science were explicitly taken into account in the search for a new laboratory in Amsterdam.¹⁸³ More and more staff and researchers were recruited to the various working groups, especially in Rijnhuizen, and more and higher salaries were paid.¹⁸⁴ As a result of the investments, during the 1960s it was possible to buy larger, and more expensive, equipment for bigger experiments.

¹⁸² ‘Jaarverslag 1961 Stichting Fundamenteel Onderzoek der Materie’. FOM archives, NHA.

¹⁸³ ‘Minister opent laboratorium plasmafysica’, *De Tijd: Dagblad van Nederland* (25-01-1967). See for wish Kistemaker about his laboratory: Streefland, *Jaap Kistemaker en uraniumverrijking in Nederland 1945-1962*, 27.

¹⁸⁴ In 1964, the coordinating commission of the working community debated on the question whether the salary costs might be getting out of hand. ‘Notulen van de drieëntwintigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’ (6 November 1964), 4. FOM archives, NHA.

3.2.2. *Short term and Long Term Positioning: Getting Funded Without Results*

FOM obtained the money for this expansion and intensification of fusion research in the 1960s mainly through Euratom, ZWO and occasional donations from the Ministry of Education, Arts and Sciences. Nevertheless, FOM's longer-term policy remained to transfer the nuclear fusion research to RCN and to have nuclear fusion research paid for by the Ministry of Economic Affairs with the budgets for nuclear energy based on the economic potential of nuclear fusion. To take this step in the longer term, the ties with the Ministry of Economic Affairs and RCN were maintained.

Large sums of money were made available to nuclear fusion research from Euratom in the 1960s. Between 1963 and 1967, Euratom had 425 million dollars to spend on nuclear research, of which 31 million dollars were spent on fusion research.¹⁸⁵ In the budget for 1967-1972, the funds for nuclear fusion research from Euratom were raised with three million.¹⁸⁶ Scientists could apply for individual grants, and research projects could be partly funded by the Euratom budgets. FOM benefited from these budgets through successive association agreements with Euratom. These treaties were individual contracts between Euratom and the research institutes in the various participating countries. In the 1960s, the Dutch research became increasingly part of the European exchange of information between scientists from the various countries.¹⁸⁷ The scientists at FOM used this contract to make many grant applications for research, the purchase of equipment and international conference visits.¹⁸⁸

In addition, Braams was able to raise a money with ZWO and the Ministry of Education Arts and Sciences by pointing out the advantages and obligations of the association agreements

¹⁸⁵ 'Euratom, a year of activity April 1962 – April 1963', 2. AEI.

¹⁸⁶ 'Euratom, a year of activity April 1965 – April 1966' (1966), 2.

¹⁸⁷ Shaw, *Europe's Experiment in Fusion*, 9.

¹⁸⁸ 'Notulen achttiende zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermo-nucleaire reacties"' (8 October 1962), 8. FOM archives, NHA.

with Euratom. Whereas the ZWO budget for 1959 still consisted of six million guilders, of which about a third was invested in FOM which in order invested half of this budget in nuclear fusion research, this amount was already increased to 9.25 million in 1960. This increase consisted almost entirely of additional investments in fusion research.¹⁸⁹

The funds provided by ZWO to FOM's nuclear fusion research fell into two parts: separate grant applications for short-term projects or international trips or conference visits, and accepted budget proposals from the working community to contain and expand the research.¹⁹⁰ These budget proposals were explained by Braams and assessed at the ZWO. In these explanatory notes Braams described the developments in Dutch fusion research, strongly emphasising the important function that the research performed internationally and the fact that certain expectations and obligations had been entered into through agreements with Euratom, as a result of which continuation and even expansion of the research was necessary.¹⁹¹ An extensive memorandum from FOM on the state of thermonuclear research in the Netherlands also emphasised that the international position of the research was very good.¹⁹² The economic potential of energy from nuclear fusion was also touched upon, although during the 1960s this was increasingly relegated to the background.¹⁹³

Financial applications from the fusion research at the Ministry of Education, Arts and Sciences were also justified by the international contribution of Dutch research and the

¹⁸⁹ Kersten, *Een organisatie van en voor onderzoekers*, 130-147.

¹⁹⁰ Each year a budget was submitted to ZWO. In addition, proposals were made, for example for the purchase of new calculation equipment for 389,000 guilders: 'Notulen zeventiende zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermo-nucleaire reacties"' (7 March 1962), 8. FOM archives, NHA.

¹⁹¹ See for example 'Notulen derstigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermo-nucleaire reacties"' (1 April 1968), 6. FOM archives, NHA.

¹⁹² Van Buuren, H.G., *Memorandum over het thermonucleaire onderzoek in Nederland* (1967), 3. NA 2.14.5168, Inventory number 8608.

¹⁹³ The memorandum stated that the economic potential of the fusion research 'should not be taken lightly'. This is a weakening of the conclusions of the study committee which stated in 1956 that nuclear fusion was the main solution to the impending fuel shortages in the near future. Buuren, *Memorandum over het thermonucleaire onderzoek in Nederland*, 3.

possibilities within Euratom. Contact with the Dutch government was well maintained by the scientists at FOM. For example, there was regular letter contact between the secretary of FOM and officials at the ministry about fusion science.¹⁹⁴ Delegations from the Dutch government were also regularly invited to Rijnhuizen. In 1965, FOM invited the Dutch government representative at Euratom in Brussels and public servants, Dr. Mani of Economic Affairs and Dr. Haas of Education, Arts and Sciences to Rijnhuizen for a working visit.¹⁹⁵

The Ministry of Economic Affairs was still involved by FOM to safeguard future investments, in the event that nuclear fusion research would experience a breakthrough in the search for a fusion reactor. It therefore appears that FOM tried to acquire investments at ZWO and the Ministry of Education, Arts and Sciences in the short term by pointing out the international potential of the research, but in the longer term the ambition of the scientists remained to transfer Dutch nuclear fusion research to RCN based on its economic potential.

This impression is reinforced by FOM's attitude towards RCN. In 1967, Kees Braams, as chairman of the coordinating committee of the working community "research on thermonuclear reactions" and director of FOM-Rijnhuizen, became part of RCN's executive board on behalf of FOM and the Dutch nuclear fusion research.¹⁹⁶ In addition, articles were regularly published by fusion scientists in the RCN-bulletin *Atoomenergie en haar toepassingen* (*Atomic Energy and its Applications*). Braams, for example, wrote an extensive article on developments in the field of energy extraction from fusion in 1964. In this article Braams stated that in the future, a few decades from now, nuclear fusion would indeed realise its economic potential.¹⁹⁷

¹⁹⁴ FOM archives contain an extensive correspondence between Dr. Haas as a civil servant of OKW (later OW) and Dr. A.A. Boumans as secretary of FOM about the state of affairs concerning the fusion research between 1957 and 1968. FOM archives, NHA 449, 766-767.

¹⁹⁵ 'Concept-notulen van de vierentwintigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermo-nucleaire reacties"', 3-4.

¹⁹⁶ Andriess, *Republiek der kerngeleerden*, 17 & 162.

¹⁹⁷ Braams, C.M., 'Fusie', *Atoomenergie en haar toepassingen* (October 1964), 208-210.

3.2.3. *Focus on the West: International Orientation of Dutch Fusion Scientists*

The money raised was used by the Dutch fusion scientists in two ways. Firstly, in maintaining and expanding fusion research, especially experimental research, in the Netherlands. More and more young scientists were needed to operate the ever larger and more expensive equipment. Secondly, investments were made to establish international contacts. There was a strong focus on research in Europe and the United States. Although the Russian contribution had led to international and Dutch nuclear fusion research, the Dutch attention among scientists for Russian progress was relatively limited. Even Soviet claims about breaking through the Bohm-thesis did gain a sceptical response.

When Artsimovich achieved results that the Bohm thesis considered impossible in 1965, the Russian fusion scientists presented their results at various international meetings and congresses.¹⁹⁸ The Soviet scientists were a welcome guest at these meetings after fusion research was declassified in 1958. For example, thirty-six scientists from the Soviet Union were present at a congress in Salzburg in 1961, the year the Berlin Wall was build.¹⁹⁹ The Russian scientists also maintained contacts with the Netherlands. In March 1967 five plasma physicists from the Soviet Union visited Dutch and Belgian thermonuclear research institutes, including FOM-Rijnhuizen. This visit was within the framework of a Netherlands-Belgium agreement with Russia on the exchange of physicists “within the framework of peaceful applications of nuclear energy”.²⁰⁰

Despite these contacts, the focus of the Dutch fusion scientists was mainly on the United States and Western European countries. The delegation of Dutch scientists to the Soviet Union

¹⁹⁸ Herman, *Fusion: A Quest for Endless Energy*, 80-82.

¹⁹⁹ See for a report of the conference: ‘Plasmafysica en kernfusie: conferentie geopend in Salzburg’, *De Tijd De Maasbode* (5 September 1961).

²⁰⁰ ‘Notulen achtentwintigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’ (7 March 1967), 4. FOM archives, NHA.

in 1965, as part of the same exchange with which the Soviet scientists visited FOM-Rijnhuizen, did not include a fusion scientist. For the exchange to the Soviet Union, FOM delegated Prof. Dr. C.C. Jonker, who had no connection with fusion research.²⁰¹ Although some laboratories in which plasma physics research was carried out were visited, such as Artsimovich's research centre, the focus of the



Figure 27: Signing of the exchange agreement by sitting from left to right: M. D'hont (Belgium), A.M. Petrosyants (USSR), J.A. Goedkoop (Netherlands). Standing in the background from left to right: J. Goossenaerts (Belgian Embassy in Moscow), S.T. Loginov (Ministry of Foreign Affairs USSR), I.D. Morokhov (Deputy Chairman of the State Commission for the Application of Atomic Energy), I.V. Tichonov (member of the State Commission), N.A. Nikolaev (member of the State Commission), A.P.R. Jacobovits de Szeged (Dutch Embassy in Moscow). *Atoomenergie en haar toepassingen*, 5 (May 1965), 100.

journey to the Soviet Union was mainly on different nuclear energy projects.²⁰² Also, Russian articles about fusion were generally not shared within the working community until they were translated into English. It was only until the congress in 1968 that two researchers, Adri Nijssen-Vis and H.W. Piekaar, were sent to Russian lessons.²⁰³

The main focus of the Dutch fusion scientists was on the American, British and European science. The money raised by FOM was mainly invested in various foreign visits to European and American laboratories. Various meetings of the European Study Group on Fusion Problems were attended and trips were made to research centres in the United States. Kees Braams went to the United States in 1961 for three months to learn from the research in Princeton and Boston, and in 1963, on behalf of Kistemaker's fusion research, Dr. Insinger spent four months in Berkeley based on a ZWO grant.²⁰⁴

²⁰¹ Goedkoop, J.A., 'Indrukken uit laboratoria in de Sovjet Unie', *Atoomenergie en haar toepassingen* 5 (May 1965), 87-101. There are no indications that Jonker was in any way involved in the nuclear fusion research. His areas of research do not touch on thermonuclear research or plasma physics anywhere: Blok, J., 'In memoriam C.C. Jonker', *Jaarboek VU 1980-1981*, 148-151.

²⁰² Goedkoop, 'Indrukken uit laboratoria in de Sovjet Unie', 87-101.

²⁰³ It was not until 1967 that two scientists of FOM-Rijnhuizen were taught Russian. 'Notulen negentwintigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermo-nucleaire reacties"' (27 October 1967), 6. FOM archives, NHA.

²⁰⁴ Journey of Braams: 'verslag van de reis naar Amerika door dr. C.M. Braams' (30 January 1962). FOM Archives. NHA. Journey of Insinger: 'Notulen negentiende zakelijk-organisatorische vergadering van de

Through Euratom, various European researchers were also assigned to Dutch research for defined periods, and Dutch plasma physicists were able to participate in research in European institutions.²⁰⁵ The travel reports made by the fusion scientists of each trip show that most of the meetings attended took place in Western Europe. Research institutes in Munich, Stütgart, Rome, Fontenay-Aux-Roses, Saclay and Brussels often provided the organising location. Occasionally a congress was also organised in Jutphaas at FOM-Rijnhuizen, such as in 1966 with delegations from France, Belgium, Germany, Italy and the Netherlands.²⁰⁶



Figure 28: The Russians presented their sensational results of the tokamak during the congress in Novosibirsk. Photo P. van der Laan in Vrouwe, *Hittebarière*, 37.

The focus on Western fusion science instead of developments in the Soviet Union is best illustrated by the reaction of the Dutch scientists during the congress in Novosibirsk in 1968 at which Artisimovich presented the results of the Tokamak. A large Dutch delegation of nine fusion scientists travelled to the congress.²⁰⁷ During the congress, the Soviet scientists delivered striking numbers showing that the tokamak was capable of creating what real fusion required, a hotter and more stable plasma. The Dutch scientists present only reacted lukewarmly. In his report after the conference Braams wrote that “the general impression was that there was little tension and sensation at this conference and that no shocking revelations were made”.²⁰⁸ Braams did describe that it was established that the Bohm diffusion was not an inevitable obstacle and that with this he was convinced that in time it would be possible to

commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties” (9 November 1962), 6-9. FOM archives, NHA.

²⁰⁵ ‘Notulen achttiende zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’, 8.

²⁰⁶ Braams, C.M., ‘The Euratom Working Group on interactions between high frequencies and plasmas, met in Jutphaas, the Netherlands, on 28th and 29th April 1966’ (May 1966), 1-3. DIFFER.

²⁰⁷ Kees Braams, Boumans, L.Th.J. Ornstein, Brandt, Minardi, Hopman, Van der Laan, Bobeldijk and J.C. Terlouw would travel to Russia. ‘Notulen dertigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’ (11 November 1965), 7-8. FOM archives, NHA.

²⁰⁸ Braams, C.M., ‘Algemene indrukken van de conferentie’, *Verslag van de Third Conference on Plasma Physics and Controlled Fusion Research, gehouden van 1-7 augustus 1968, Novosibirsk, USSR* (October 1968), 3-4. DIFFER.

develop a thermonuclear reactor, but the further report went on to focus mainly on European and American results and research directions with pinch reactors and open systems.²⁰⁹ It was clear that Dutch fusion science was focused on international contacts, but that the focus was not directly on Russian developments. Cooperation within Europe and focus on American research were central.

3.3. To European Corporation: Dutch Fusion Policy During the Cold War

3.3.1. A Declining Belief in the Economic Success of Nuclear Fusion

During the 1960s, the interference of the commercial companies in the fusion research decreased. From the 1950s onwards, three companies were partly involved in Dutch nuclear fusion research: KEMA, Philips and PEGUS. Of these, the involvement of the energy supplier PEGUS soon became particularly practical. Whereas between 1957 and 1959 the plasma physics workgroup made use of rooms made available by PEGUS, this workgroup moved to Rijnhuizen in 1959. From that moment on, PEGUS was only involved as a supplier of electricity for Rijnhuizen. Because Rijnhuizen simply paid for the power, the involvement of PEGUS became mainly an involvement between customer and supplier.²¹⁰

The same applied to the local metal company Vernooy from Juthpaas. Although the research institute on Rijnhuizen had its own workshop where instruments were made, not all equipment could be manufactured here. Initially, the welding and construction work was often outsourced to Vernooy. Over time, Vernooy also manufactured the vacuum chambers. In this way, the company developed from a family business that made fences for farmers and parts for

²⁰⁹ *Verslag van de Third Conference on Plasma Physics and Controlled Fusion Research, gehouden van 1-7 augustus 1968, Novosibirsk, USSR* (October 1968), 1-41. DIFFER.

²¹⁰ ‘Notulen twintigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap “onderzoek thermo-nucleaire reacties”’ (2 April 1963), 4. FOM archives, NHA.

the dredging industry to Vernooij Vacuum Engineering, which produced high-quality vacuum chambers internationally.²¹¹

In contrast to the suppliers, who could earn money from nuclear fusion research, KEMA and Philips pulled out the working community. After Brinkman's death, Casimir, as director of Philips, questioned the future success of Dutch nuclear fusion research, as described in the previous chapter. In spite of the research of the working community under Braams continuing to grow in the 1960s, Philips withdrew their involvement completely. In 1963, Dr. Bruining, delegated from Philips, withdrew as a member of the coordinating committee of the working community.²¹²

KEMA withdrew from the working community as well. Whereas at first KEMA seemed to want to invest a great deal in nuclear fusion research, even with its own workgroup, available space and equipment and a strong delegation in the coordinating committee with Ter Horst, this involvement was gradually phased out in the 1960s. Ter Horst took a step back and attended his last meeting of the working community on 24 April 1965.²¹³ In 1966, the working group at KEMA was definitively dismantled.²¹⁴

The Ministry of Economic Affairs also decided that there was no future in the promise of nuclear fusion during the 1960s. The 1962 Memorandum on Nuclear Energy, which was an adjustment of the memorandum of 1957, stated that the primary focus was no longer on new investments in nuclear energy. "The initial expectation that nuclear energy should provide a rapid and large-scale solution to the energy problem proved unfounded".²¹⁵ Investments were still being made in rendering a number of economically profitable nuclear power plants, but no

²¹¹ Vrouwe, *Hittebarrière*, 33-34.

²¹² 'Jaarverslag 1961 werkgemeenschap "onderzoek thermonucleaire reacties"' (1962), 2. FOM archives, NHA.

²¹³ 'Concept-notulen van de vierentwintigste zakelijk-organisatorische vergadering van de commissie van de werkgemeenschap "onderzoek thermo-nucleaire reacties"' (15 April 1965), 1. FOM archives, NHA.

²¹⁴ 'Kernfusie, Thermonucleaire reacties, plasmafysica en FOM-activiteiten op dit gebied', 2.

²¹⁵ Pous, J. De, 'Memorie van antwoord' (18 September 1968), 1. Tweede Kamer document number 4727 Nr. 7. SGD.

longer in new brands of research.²¹⁶ This meant that Dutch research into nuclear fusion during the 1960s would not become part of the budget of Economic Affairs. The minister of Economic Affairs, Jan de Pous, also stated that he saw no reason to belief in the direct economic potential in nuclear fusion.²¹⁷

This decision was supported by the WRK, the scientific council on nuclear energy. The WRK concluded in its recommendation that nuclear fusion research, partly thanks to the Bohm thesis, would not lead to an economically profitable reactor quickly or even at all.²¹⁸ The policy of Economic Affairs was also politically endorsed by an energy report of a committee of the Scientific Institute of the KVP, the Catholic political party that was part of the government since the early 1950s, and a report of the Wiardi Beckman Foundation, the scientific institute of the Dutch Labour Party (PvdA). Both reports concluded that although the Netherlands would be dependent on nuclear fusion and solar energy in the faraway future, nuclear fusion would not make an economic contribution for the time being.²¹⁹

3.3.2. *Investing in Science for European Integration*

Why were, increasing, investments still being made in Dutch research into nuclear fusion, while the investors clearly did not believe in the economic potential of the research? In their advice to the Ministry of Economic Affairs about the economic potential of the Dutch fusion research, the WRK also stated that the position of fusion research, from an international point of view,

²¹⁶ For example, Kistemaker's ultracentrifuge projects were also threatened by these cutbacks. Cieraad, 'The Radiant American Kitchen', 129.

²¹⁷ Pous, De, 'Memorie van antwoord', 26.

²¹⁸ The WRK advised not to invest from EZ because it was expected that there would not yet be a laboratory reactor in 10 years' time and that after that, an economically profitable reactor would have to be built afterwards. WRK, 'Advies aan zijne Excellentie, de minister van Onderwijs en Wetenschappen betreffende het thermonucleaire onderzoek in Nederland' (19 January 1967), 1. NA 2.14.5168, Inventory number 8608.

²¹⁹ Oele, A.P., A.A. de Boer, M. de Vreede, *Nederlandse en Europese energievoorziening in overgangperiode* (Amsterdam: De arbeiderspers, 1966). DNPP. And, *Rapport van de commissie energiebeleid* (1965). KDC, KVP-1708.

was very favourable. This led the WRK to recommend the Ministry of Education and Sciences to continue to pay for Dutch fusion research.²²⁰ This advice was subsequently taken up in a note to the minister by civil servant Dr. Haas. He stated that it was important to invest in fusion research because of the international position of the research, especially within the European countries.²²¹



Figure 29: The construction of a new laboratory hall at FOM-Rijnhuizen. Photo archives DIFFER.

This argumentation determined the Ministry of Education, Arts and Sciences' investments in Dutch fusion research. The focus on European corporation continued in the 1960s. In 1965 Haas wrote to the secretary of FOM, Dr. Bouman, that the ministry underlined that the fusion scientists were using the Euratom network to acquire knowledge and international contacts.²²² The ministry was also prepared to make additional investments at times when Euratom subsidies were temporarily at a standstill. For example around 1967, when there was some postponement of payments from Euratom because the European budgets were blocked in the European Parliament by France.²²³ So, the Netherlands invested in fusion research because of the possibilities of European corporation within Euratom.

An important reason for collaborating with other European countries through Euratom was to jointly form a power block between the major powers of the Soviet Union and the United States. Internal memos from the Ministry of Education, the Arts and Sciences show that the international position acquired with Dutch fusion research was seen as very favourable, partly because it strengthened cooperation with various European countries.²²⁴ This closer cooperation

²²⁰ WRK, 'Advies aan zijne Excellentie, de minister van Onderwijs en Wetenschappen betreffende het thermonucleaire onderzoek in Nederland', 1.

²²¹ Haas, E., 'Kernfusie: het thermonucleaire onderzoek in Nederland' (5 May 1967). NA 2.14.5168, Inventory number 8608.

²²² Haas, E., 'Aan de weledelzeergeleerde heer dr. A.A. Boumans' (15 January 1965). FOM Archives, NHA.

²²³ Shaw, *Europe's Experiment in Fusion*, 12.

²²⁴ 'Kernfusie: het thermonucleaire onderzoek in Nederland'.

was an important argument in the opinion of the WRK too. As a result of this closer cooperation, Dutch research was better able to keep pace with scientific developments in the Soviet Union and the United States.²²⁵ The latter was also stated by J.F.J. Hardeman, an official at the Ministry of Foreign Affairs and member of the Sub-Committee on Foreign Affairs of the Committee on Atomic Energy, in his memorandum for the Minister of Education, Arts and Sciences.²²⁶



Figure 30: Election program 1967 KVP. DNPP.

The Dutch government implemented Dutch science policy in line with the election programmes of the governing political parties. The Catholic People's Party (KVP) stated that, with regard to science, there should be a “coordinated science policy in the field of scientific education and research”.²²⁷ With regard to international cooperation, the KVP was very pro-European, because Europe could offer a stronger counterbalance within the dynamics between the United States and the Soviet Union during the Cold War. Especially the threat from communism, by which the Soviet Union was meant, was explicitly mentioned in the 1959 election programme.²²⁸ This cooperation in Europe had to take place, inter alia, by stepping up cooperation and contacts “where appropriate and necessary, in particular with regard to the harmonisation of legislation and diplomatic action and with regard to science and culture”.²²⁹

This line towards Europe was endorsed in the election programmes of the Anti-Revolutionary Party (ARP). Although science policy is often not explicitly mentioned, an investment by European cooperation was deemed necessary to be an equal player in a transatlantic pact with the United States, which would then have to resist the communist Soviet Union.²³⁰ This line from the ruling parties was interpreted by the responsible ministers. Dutch

²²⁵ WRK, ‘Advies aan zijne Excellentie, de minister van Onderwijs en Wetenschappen betreffende het thermonucleaire onderzoek in Nederland’, 3.

²²⁶ Hardeman, J.F.J., ‘IAEA en fusieonderzoek’ (16 June 1959). NA 2.06.101, Inventory number 499.

²²⁷ ‘Werkprogram 1967-1971. Dit wil de KVP: programma Tweede Kamer verkiezingen 1967’ (1967), 5. DNPP.

²²⁸ ‘Manifest KVP’ (1959), 2. DNPP.

²²⁹ ‘De wereld van morgen: Katholieke Volkspartij, werkprogram 1963’ (1963), 18. DNPP.

²³⁰ ‘Program van actie van de antirevolutionaire partij’ (1959), 11. DNPP.

science policy therefore focused on coordination from the government, and science was therefore used to promote European cooperation. The focus on this European cooperation was important to remain a strong, independent player during the increasing Cold War tension between East and West. This was an important reason to keep investing in Dutch fusion science during the 1960s.

3.4. Declining Interest and Different Themes: Dutch Media in the 1960s

The development of nuclear fusion research during the 1960s, in which failed experiments and the Bohm thesis raised more and more doubts about the economic potential of the research, is nicely illustrated by the attention for nuclear fusion in the Dutch media. Whereas the attention for nuclear fusion in the Dutch media still resulted in a Fusion Hype in the 1950s, this attention declined in the 1960s.

The decline in attention for nuclear fusion research in the Dutch media was accompanied by a change in the substantive approach to the theme. The economic promise of nuclear fusion research was still mentioned. *De Volkskrant* and *Het Algemeen Handelsblad* wrote in 1960 about the great economic potential after a success with short controlled nuclear fusion in Berkeley, United States.²³¹ *Algemeen Handelsblad* even wrote about the lack of radioactive waste in fusion energy.²³²

Despite this success, however, newspaper editors became more sceptical about the rapid success of fusion research. A month after the attention for the American success, *De Volkskrant*

²³¹ ‘Succes op weg naar getemde kernfusie’, *De Volkskrant* (5 November 1964).

²³² ‘Amerikaanse geleerden brachten korte beheerste fusie-reactie tot stand’, *Algemeen Handelsblad* (4 November 1960).

wrote a new article in which it was pointed out that more energy was needed than was produced.²³³ The most prominent change in writing about nuclear fusion can be seen in the four-volume series on fusion research by *Het Vrije Volk* in March 1962. Whereas at the end of the 1950s *Het Vrije Volk* was still very enthusiastic about the prospects of fusion research, the interviews with various scientists in this series became more sceptical.²³⁴ Headings such as “clap cigar” were used and the potential success of nuclear fusion research, explained by the Swiss

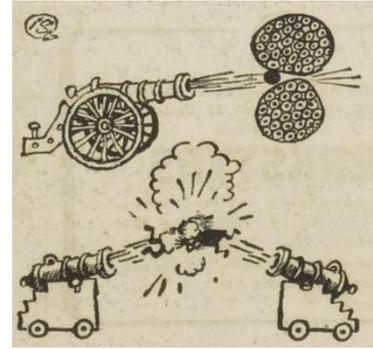


Figure 31: Simplified explanation of the difference between nuclear fusion and nuclear fission in the four-part series in which *Het Vrije Volk* was critical of the potential economic success of nuclear fusion research. ‘Beheerste kernfusie...het moet kunnen, maar hoe?’, *Het Vrije Volk* (4 July 1962).

scientist Fritz Houterman, was dismissed as a Nils Holgersson’s fairy tale.²³⁵ This scepticism about the rapid breakthrough of nuclear fusion continued in the following years with *De Telegraaf* writing in 1965 that although nuclear fusion was the key to future energy, it would not be achieved before 1985 anyway.²³⁶ In 1964 *Algemeen Handelsblad* even reflected on the media attention for nuclear fusion by stating that nuclear fusion between 1955 and 1958 was loudly applauded, but did not live up to expectations.²³⁷

Simultaneously with the growing scepticism about the direct economic potential of nuclear fusion, media attention for international cooperation in fusion research grew. The previous chapter described the emphasis on competition between countries within fusion research in the Dutch newspapers and this line was also continued in the first years after the 1958 conference in Geneva. In 1960, *De Volkskrant* analysed the increasing arms race between

²³³ ‘Los Alamos, proeffabriek voor atoomgeweld’, *De Volkskrant* (22 December 1960).

²³⁴ Series within *Het Vrije Volk*: ‘Beheerste kernfusie...het moet kunnen, maar hoe?’, *Het Vrije Volk* (four articles between 4 June 1962 and 9 June 1962).

²³⁵ ‘Beheerste kernfusie...het moet kunnen, maar hoe?’, *Het Vrije Volk* (4 July 1962).

²³⁶ ‘Rusteloos gaan we hoger, verder, dieper’, *De Telegraaf* (12 November 1965).

²³⁷ ‘Kernstopakkoord hindert vreedzaam gebruik atoomenergie’, *Algemeen Handelsblad* (3 September 1964).

the West and the Soviet Union and stated that the development of natural science, including nuclear fusion, played an important role in this competition.²³⁸

However, the narrative of competition, related to Cold War tensions, diminished as more international projects and conferences were set up at which countries all over the world freely shared results. *Algemeen Handelsblad* extensively described the new international journal *Nuclear Fusion*, including the Soviet Union on the editorial board and Russian, English, French and Spanish as languages of communication.²³⁹ Also, various media wrote about congresses such as the conference in Salzburg where five hundred scientists, including 36 from the Soviet Union, met.²⁴⁰ Successes achieved in various countries, although marked by the “realistic” notion that fusion energy was far from being close, were no longer described in the light of a race between countries. Even *De Volkskrant* wrote, a few years after the article about the race, that global cooperation was necessary to make the fusion research a success.²⁴¹

An important new theme in reporting on international cooperation in fusion research was European cooperation in Euratom. Central to the descriptions of Euratom’s focus on fusion was the French contribution. As described earlier, under French pressure, Euratom focused more and more on fundamental science such as fusion. Several newspapers reported extensively on the French development of nuclear energy and their position within Euratom.²⁴² As Euratom started to invest more in nuclear fusion, the Dutch newspapers also reported more about

²³⁸ ‘Wedloop tussen Oost en West met ontzaglijke hulpbronnen: wetenschap, de gouden sleutel van de toekomst’, *De Volkskrant* (21 May 1960).

²³⁹ The editorial board of *Nuclear Fusion* consisted of scientists from Australia, France, West Germany, Hungary, Italy, Japan, Poland, Sweden, the Soviet Union, the United Kingdom and the USA. ‘Nieuw tijdschrift over kernfusie’ *Algemeen Handelsblad* (24 October 1960).

²⁴⁰ See for one of the reports of the conference: ‘Plasmafysica en kernfusie: conferentie geopend in Salzburg’, *De Tijd De Maasbode*. Also *Het Parool*, *Friese Koerier*, *Nieuwsblad van het Noorden*, *Het Vrije Volk* and *De Waarheid* reported on this conference in September 1961.

²⁴¹ ‘Mens moet meewerken aan onstuitbare groei’, *De Volkskrant* (20 October 1964).

²⁴² From 1959 onwards Dutch media reported on the French ideas with Euratom and fusion. For example *Algemeen Handelsblad* wrote in 1959 on the opinion of the French H. Longchamber in the European Parliament who was critical on the Euratomproject and wanted to invest in fusion research: ‘Klein-Europees parlement: Agrarische integratie moet worden bevorderd’, *Algemeen Handelsblad* (24 June 1959). On the budgetchanges and the pressure of France see for example: ‘Frankrijk wil roer om in NAVO en Euratom’, *Trouw* (8 May 1964); and ‘Frankrijk wil snoeien in Euratom’, *Het Parool* (26 June 1964).

Euratom-funded research institutes. Investments in the German research centre at Jülich in 1964, for example, received a great deal of attention.²⁴³

3.5. A Scientific Wish Dream: Fusion Energy in the Public

The major problems within fusion science and the increasing improbability that the promise of nuclear fusion would be fulfilled also had an impact on the image of nuclear fusion in Dutch popular culture. Initially the attention for nuclear fusion was limited to a few pages in books such as *De mens tussen groot en klein* (*Between Stars and Atoms*, 1960) by Eibert H. Bunte and *Atomen regeren de toekomst* (*Atomic Energy: A Layman's Guide to the Nuclear Age* translated to Dutch in 1962) by Egon Larsen.²⁴⁴ This changed with a Dutch translation of *Kohle im Atomzeitalter* (*Coal in the atomic age*, in Dutch: *Automaten kontra Malthus*, 1965) in which the popular German writer Anton Zischka described the time as the third phase of the Industrial Revolution and that energy from nuclear fusion would be possible in the future.²⁴⁵

In addition to the books, attention was also paid to nuclear fusion in exhibitions such as *Het Instrument* in 1961, which showed the advance of science, and in comics such as Marten Toonder's *Tom Poes en de Bovenbazen* (*Tom Poes and the Upper Bosses*, 1963).²⁴⁶ Also on television attention was paid to nuclear fusion with programmes such as a VARA documentary on science and technology in Russia with attention to the nuclear fusion laboratory in the Soviet Union.²⁴⁷

²⁴³ See for example: 'Euratom steekt 10 miljoen in Jülich', *De Waarheid* (25 October 1962).

²⁴⁴ Bunte, E.H., *De mens tussen groot en klein: een hedendaagse tocht door wereld en ruimte* (The Hague: Ad. M.C. Stok, 1960); and Larsen, E., *Atomen regeren de toekomst: atoomwetenschap voor iedereen* (Bilthoven: H. Nelissen, 1962).

²⁴⁵ Zischka, A., *Automaten Kontra Malthus* (Tilburg: Nederlands Boekhuis, 1965).

²⁴⁶ Toonder, M., 'Tom Poes en de Bovenbazen', *Volkskrant* (28 August 1963); and 'Deelnemerslijst "het instrument 1963"' (17 June 1963). HUA, 4820, No. 621.

²⁴⁷ VARA, *Achter Hamer en Sikkell* (25 November 1965). The Netherlands Institute for Sound and Vision.

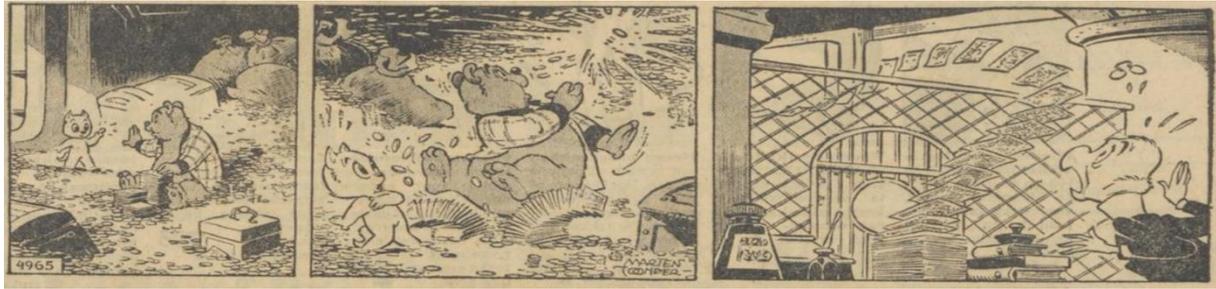


Figure 31: The scene in which Olivier B. Bommel started a nuclear fusion process by throwing a coin over his shoulder. Toonder, M., ‘Tom Poes en de Bovenbazen’, *Volkskrant* (28 August 1963).

However, nuclear fusion was increasingly presented as a scientific dream or as an abstract science in popular culture. In Marten Toonder’s story, the process of nuclear fusion was described as an “extraordinary phenomenon”. The main character Tom Poes offered his friend, the exorbitantly wealthy Olivier B. Bommel a coin as payment for a lost bet. Bommel, who at that moment was counting his enormous amount of money for tax, threw the coin almost carelessly over his shoulder on the pile of money. At that moment, a critical mass was reached that made the metal of the coins crackle. The cashier, who saw his nearby notes fluttering upwards towards the centre of the mass, understood: a nuclear fusion process had been initiated.²⁴⁸ Although in reality the process of nuclear fusion would not be initiated by an increase in mass this quickly, this image does refer back to the science behind nuclear fusion research. The fusion scientists were faced with the task of reaching a temperature with their plasmas that was higher than the temperature of the sun, while nuclear fusion processes were already taking place on the sun. This was because the sun could compensate for the relatively low temperature with a larger mass.²⁴⁹

In more popular scientific descriptions, nuclear fusion was mainly presented as something experimental in which learned nuclear scientists worked on a scientific wish dream. In the VARA documentary, Russian research on the machine “Ogra” was described as “experimental research” on a dream of energy in the distant future.²⁵⁰ In popular science books

²⁴⁸ Toonder, ‘Tom Poes en de Bovenbazen’.

²⁴⁹ Westra, M.T., *Kernfusie: een zon op aarde*, 16-17.

²⁵⁰ VARA, *Achter Hamer en Sikkell*.

and in the recurring exhibition *Het Instrument* nuclear fusion was presented as a scientific wish or as fundamental science.²⁵¹ During the 1961 and 1963 exhibitions, *Het Instrument* paid attention to nuclear fusion at the stands on scientific progress and nuclear physics. Nuclear fusion was depicted as a scientific dream that would not produce direct results for the next fifty years.²⁵² This meant that fusion was not been seen as something that would play a dominant role in everyday life anytime soon.

As a result, the development of energy through nuclear fusion could not provide an answer to society's fear of radioactive radiation. Although the promise of nuclear fusion from a clean energy without radioactive waste offered a potential answer to the increasing aversion to nuclear energy, the status of scientific wishful thinking and fundamental science of the fusion research stood in the way of this answer. The books of Bunte and Larsen did not discuss the clean aspect of nuclear fusion. The chapters on radioactivity and radiation did not mention nuclear fusion.²⁵³

A typical example of the inability of nuclear fusion research to provide an answer in public opinion to discussions about the peaceful use of nuclear energy was the *Parool-Life* book *De rusteloze materie* (*Restless Matter*, 1966). In extensive lemmas, science editor Gerton van Wageningen explained the difference between the process of nuclear fusion and nuclear fission. However, the difference in the lack of radioactive waste was not mentioned anywhere. Only the scientific problems that stood in the way of the success of this research were discussed and it was stated that decades of research were still needed to ever come to a deployable reactor.²⁵⁴

²⁵¹ Larsen, for example, describes nuclear fusion as scientific wishful thinking: Larsen, *Atomen regeren de toekomst*, 260.

²⁵² 'Deelnemerslijst "het instrument 1963"'.

²⁵³ Bunte. *De mens tussen groot en klein: een hedendaagse tocht door wereld en ruimte*; and Larsen, *Atomen regeren de toekomst: atoomwetenschap voor iedereen* .

²⁵⁴ Basford, L. (ed.), *De rusteloze materie* (Amsterdam: De Nationale Uitgeverij, 1966).

3.6. Dutch Fusion Research During the Cold War

While the Cold War tensions were at their height in the 1960s, fusion scientists worldwide managed to maintain contacts between East and West. Research was carried out by various countries to find a way to reject the Bohm-diffusion. In the Netherlands, FOM-Rijnhuizen was expanded considerably and research continued to be carried out in Amsterdam as well. FOM obtained the ever-increasing amounts of money from ZWO, Euratom, and the Ministry of Education, Arts and Sciences. The money was obtained by pointing out the international position of the research. At the same time, FOM still had the ambition to transfer part of the research to RCN in the long term. With the money raised, the research was expanded and international contacts were established. Although the greatest discoveries took place in the Soviet Union and there was contact between Dutch and Soviet scientists, the focus of Dutch researchers was mostly on science in Europe and the United States.

The Ministry of Economic Affairs and companies saw little economic potential in the research, partly due to the gas discoveries and the negative results of the fusion research. Still the Ministry of Education, Arts and Sciences, later the Ministry of Education and Sciences, kept investing in Dutch research, despite the limited results. By investing in nuclear fusion, the Dutch government hoped to enter into closer European cooperation. With this cooperation, European countries stood stronger in between the major powers such as the United States and the Soviet Union. Because of this European cooperation to obtain a stronger position vis-à-vis the United States and the Soviet Union, the development of Dutch fusion research cannot be separated from the Cold War dynamics.

The status of Dutch fusion research as a fundamental science meant that it was unable to provide an answer to the fear of radioactivity and radiation in the public debate on nuclear energy. In the Dutch media, attention for nuclear fusion declined as the success of the research, partly due to the Bohm thesis, seemed further away. At the same time, the narrative in the media

about international fusion research changed. Instead of emphasizing competition between the various world powers, international cooperation in the field of nuclear fusion was increasingly emphasized. The economic potential of research, especially as an inexhaustible source of energy, changed into a vision of the future. Also in popular scientific books comics, exhibitions, discussions and television programmes, fusion research was mainly presented as a scientific dream and nuclear fusion was depicted as an abstract process. Because of this image, the research into nuclear fusion could not offer a solution to the fear of radiation in the 1960s.

4. Rise of the Tokamak: New Debates on Fusion as Energy Source, 1969 – 1979

4.1. Introduction

4.1.1. European Cooperation Based on Russian Success

In August 1969, British scientists published an important breakthrough: the Russian claims about rejecting the Bohm diffusion with the tokamak were correct. The British scientists, led by Nic Peacock, were invited to the Soviet Union by the Russian fusion scientist Artsimovich, who was deeply offended by the Western rejection of his results in the 1960s, to do the research themselves. The British scientists did their temperature measurements using a method made possible by the invention of the laser. The scattering of laser light on the moving electrons in the plasma provided a measure of the temperature. After more than six months of measurements, it was clear that the tokamak was able to create a plasma of an average of 10 million centigrade and stabilise the plasma up to 20 thousandths of a second. The Russian claims had been correct. A fusion reactor could be possible after all.²⁵⁵

In the next five years, the tokamak would become the leading model reactor in American, Japanese and European research. International research gained a new impulse. Scientists once again dreamed big and wanted to build ever larger tokamak reactors, starting in Princeton. MIT would enter the competition with a small tokamak designed by the Italian Bruno Coppi. Following the British seal of approval for the tokamak, Soviet scientists openly discussed ambitious plans. They set out to design a series of increasingly larger tokamaks, culminating in a reactor that could be finished within a decade. If this reactor worked, the Soviet Union would be able to prove the scientific feasibility of fusion power. America and Japan, reacted to the Soviet ambition with new plans of their own. The “scaling laws” were immensely

²⁵⁵ Herman, *Fusion: the Quest for Endless Energy*, 88-89.

persuasive, but equally immense sums of money were needed to take the leap into fusion's future. The designers estimated that an American machine fit to outdo the Russians' immediate successor to their reactor from 1968 would cost several tens of millions of dollars, and required hundreds of people to build and operate.²⁵⁶



Figure 32: The first JET Council. Braams is the third from the left. Shaw, *Europe's Experiment in Fusion*, 103.

The breakthrough of the tokamak and the increase in scale in the United States, Japan and the Soviet Union caused an European reaction. To keep up with developments in the United States, Japan and the Soviet Union, European cooperation in Euratom was intensified. During the 1970s, plans for a joint European fusion reactor were increasingly devised. At an International Conference on Nuclear Fusion Reactors in Culham 1969, the British scientific leader of fusion research, Bas Pease, approached the scientific leader of Euratom research, Donato Palumbo, to establish closer co-operation between Euratom and Britain in fusion research. According to Pease, the research programme in England could no longer develop without a larger reactor, which was too expensive for the national research programme.²⁵⁷

In 1970, the first discussions were held on how this cooperation should take place. In August, Pease recommended that Western Europe should pursue the tokamak line by building a large machine as a joint effort in Brussels to delegates from Euratom and Kees Braams, the Chairman of the Groupe de Liaison, Euratom's scientific advisory commission.²⁵⁸ The Groupe de Liaison subsequently advised to redirect the European fusion programme towards the tokamak. The group stated that in addition to several small tokamaks in Europe, mostly in France and Italy, there was a need for a large tokamak. In a larger machine, a higher plasma

²⁵⁶ Ibidem, 96-100.

²⁵⁷ Shaw, *Europe's Experiment in Fusion*, 14-15.

²⁵⁸ Ibidem, 15.

temperature could be reached. Because this was too expensive for one laboratory or single nation, it was time for a joint project.²⁵⁹

In 1971, the construction of a large, shared tokamak was included in Euratom's objectives. There was also a name for the reactor: the Joint European Torus (JET).²⁶⁰ In the following year, a working group began an exploratory study. In 1975 the working group presented a design of a four metres high D-shaped torus.²⁶¹ Yet at first the construction of JET stranded. There was a fierce political discussion about where JET should be located, with each country standing up for its own interests. Not one single location received sufficient support. The candidates were Cadarache in France, Garching and Jülich in Germany, Culham in England, Ispra in Italy and Mol in Belgium. After ten meetings with the Council of Ministers, the project did not seem to go ahead. After two years, at the beginning of 1977, there were still two candidates with Culham and Garching, because France withdrew with the promise that the next big tokamak would be in Cadarache. In mid-October, after more than six months of deadlock, the final decision was made. The European science ministers announced that JET would be situated in Culham.²⁶² In 1979 the building of JET began: joint European research had been definitively accomplished.

4.1.2. Discussions on the Future of Energy

While fusion research experienced an international breakthrough and a commercially deployable reactor seemed close again, the provision of energy demands once again became urgent. New questions about the sustainability of fossil fuels combined with a growing population led to global concerns about the sustainability of existing energy sources in the early 1970s.

²⁵⁹ Rebut, P.H., a.o., *The JET Project* (Fusion Programme: Brussels, 1975), 43. AEI.

²⁶⁰ European Communities Information, 'The JET Project', *Research and Development* (1970). LAKA.

²⁶¹ Rebut, a.o., *The JET Project*.

²⁶² Shaw, *Europe's Experiment in Fusion*, 17-18.

In 1968, Aurelio Peccei, a senior manager of the Italian Fiat group, and Alexander King, Director-General for Science and Technology at the OECD, came up with the idea of an international and multidisciplinary meeting of scientists on global issues.²⁶³ With input from an MIT Report by Dennis



Figure 33: In 1972, the Club of Rome predicted that fossil fuels would run out soon. Wikimedia.

Meadows, in which the behaviour of the world system was analysed and predicted, the Club of Rome in 1972 published the report *Limits to Growth*. This report stated that after an initial exponential growth of population and industrial production, a dramatic decline would occur at these parameters. According to the report, a fundamental change in values and goals was needed at individual, national and global level.²⁶⁴

In the Netherlands, the conclusions of the report were reflected in the public debates on resource depletion, environmental pollution and a drastic review of the energy supply.²⁶⁵ The left-wing political parties in particular, with the PvdA, D66 and the PPR, responded to the call for rapid change. When these parties won the national elections in 1973, the most left-wing cabinet in the history of the Netherlands was formed under Prime Minister Joop den Uyl (PVDA) with the three left-wing parties and the KVP and ARP. Under this Cabinet, the need for a rapid energy review was underlined by a new oil crisis. By raising the price of oil by seventy percent and reducing oil production by five percent each month, the Arab countries raised the price per barrel enormously. A full oil boycott was also introduced against a number of countries that had directly supported Israel in the Yom-Kippur war, including the

²⁶³ At the first meeting in Rome, hence its later name the Club of Rome, Prof. F. Böttcher was present on behalf of the Netherlands as chairman of the Scientific Council for Government Policy (WRR). Verbong, a.o., *Een kwestie van lange adem*, 49.

²⁶⁴ Meadows, D., a.o., commented by the Club of Rome, *Rapport van de Club van Rome. De Grenzen aan de groei* (Utrecht, 1972). Aulapocket 500.

²⁶⁵ The Dutch Prime Minister, Barend Biesheuvel (ARP), stated that he was impressed by the forecasts: "I don't know what it is, but it sounds serious. I myself was brought up with the belief that creation is infinite. It had never occurred to me that this infinity might not be true. The report made clear the finiteness of supplies, and more importantly, the finiteness of human ingenuity. That biologized me". Quote as presented in Peters, P., 'De toekomst volgens de Club van Rome', *Kronieken van Duurzaam Nederland: Houdbare Economie* (NCDO 1997), 25.

Netherlands. In the Netherlands, car-free Sundays were introduced and petrol was rationed. On national television, the Minister of Economic Affairs, Ruud Lubbers (KVP) even discussed ways for households to use less energy, dressed in a warm sweater.²⁶⁶



Figure 34: Car-free Sunday in 1973, the Netherlands. National Archives.

These events led to a renewed discussion on nuclear energy. Nuclear energy offered an additional source of energy that did not rely on fossil fuels. However, energy production from nuclear fission was very expensive, and there were increasing public objections to this energy source because of the radiation and radioactive pollution. Still, the permit for the Borselle nuclear power plant, which had been ready for some time, was granted one month after the Den Uyl Cabinet took office. Cooperation between the Netherlands, Belgium and Germany was also continued with a joint nuclear reactor in Kalkar, Germany. To pay the rapidly rising costs of the Kalkar power station, a Kalkar levy of 3% of the energy bill was introduced in 1973.²⁶⁷ With the publication of the Energy Policy Memorandum in the autumn of 1974, Lubbers announced the construction of three new nuclear power plants, each with a capacity of 1,000 MW, which would come into operation around 1985.²⁶⁸



Figure 35: Ruud Lubbers as Minister of Economic Affairs in 1973. Wikimedia.

The Energy Policy Memorandum of 1974 also paid attention to alternative energy sources and research, and the potential significance of these energy sources for the Dutch energy supply. According to Lubbers, these sources included solar energy, biomass, wind energy, hydropower, geothermal energy and nuclear fusion. A national advice committee on

²⁶⁶ Kroeger, P.G. & J. Stam, *De rogge staat er dun bij: macht en verval van het CDA, 1974-1998* (Amsterdam: Balans, 1998), 47.

²⁶⁷ This measure had already been introduced by the previous cabinet. In 1969 the total cost of the project had been estimated at 800 million, but three years later the budget had already risen to over 1.7 billion. Despite the fact that this would never make the reactor competitive, it was decided for industrial policy and prestige reasons to continue the project. The German and Belgian governments decided to pay the rising costs directly from the public purse, but the Dutch government introduced a special levy. Verbong, a.o., *Een kwestie van lange adem*, 62.

²⁶⁸ Verbong, a.o., *Een kwestie van lange adem*, 61-63.

energy research, the “Landelijke Stuurgroep Energie Onderzoek” (LSEO), was set up for the elaboration of the new policy.²⁶⁹ Their first interim report was published in January 1975. Based on various energy scenarios, LSEO stated that, in addition to energy conservation, diversification of energy sources through sustainable forms of energy would be necessary.²⁷⁰ The Minister of Science Policy, Boy Trip, was recommended to promote this research.²⁷¹



Figure 36: Boy Trip as Minister of Science in 1974. Wikimedia.

The government adopted various recommendations, including the proposal to rename RCN to “Energie Centrale Nederland” (ECN), which would provide scope for new forms of energy production. This transition was to take place as early as 1975. The LSEO scenarios were the first of a long series of energy scenarios developed for the Netherlands. At least seventeen different energy scenarios appeared between 1976 and 1979 alone. These scenarios were provided by organisations such as the SER, LSEO and by major oil companies such as Shell and BP. They provide a forecast of the development of total primary energy consumption up to the year 2000.²⁷²

4.1.3. Escalating Fears: The Rise of the Anti-Nuclear Movement

Meanwhile, the 1970s were the stage for escalating fears of the effects of radiation and peaceful uses of nuclear energy. The underlying fear in the 1950s and 1960s turned into more activist opposition in the 1970s.²⁷³ Based on of the Dutch periodicals *Beta. Tijdschrift voor hoger en leidinggevende technische functionarissen*, *De Ingenieur*, *Elektrotechniek* and *Chemisch Weekblad*, energy historians Geert Verbong and Aat van Selm show that resistance to peaceful

²⁶⁹ Verbong, a.o., *Een kwestie van lange adem*, 69.

²⁷⁰ First interim report LSEO. Quoted in VDEN, *Toekomstige energiesituatie in Nederland* (1980), 204-205.

²⁷¹ During the Den Uijl cabinet, period 1973-1977, Boy Trip was a separate minister for science policy. Trip worked with civil servants and the budget of OW, but was only responsible for science policy within this budget. The Minister of OW in this period was Jos van Kemenade.

²⁷² See for an overview of the different predictions: Verbong, a.o., *Een kwestie van lange adem*, 72.

²⁷³ Together with the environmental movement, the peace movement and the grassroots’ movement, social protests increased in the 1970s. Hellema, *Nederland en de jaren zeventig*.

uses of nuclear energy increased. In *Beta*, which has been distributed free of charge since 1966, many articles and letters submitted by both supporters and opponents of nuclear energy were published.²⁷⁴ From 1970 onwards, the energy issue was discussed more often. Critical voices about nuclear energy also received more attention. In 1971 the “Werkgroep Kernenergie” (WKE) was set up, to which several frequent contributors in *Beta* joined.²⁷⁵

A striking feature of the growing opposition to nuclear energy was the active involvement of employees in energy companies and nuclear physicists among the opponents. Dick Nolson, an RCN employee, joined WKE early on. Kees Daey Ouwens, who worked on solar cells at Eindhoven University of Technology, G.A. Sanders, director of the municipal energy company in Dongen, Theo van Waas, a former employee of the Dodewaard nuclear power plant, and Wim Turkenburg, PhD student at Kistemaker in Amsterdam, also joined WKE.

In 1972, Erik-Jan Tuininga joined WKE. Tuininga, who was also active within the reformed church community, worked at TNO on energy issues and was one of the seven TNO translators of the Club of Rome Report. With these scientists, WKE had acquired the necessary expertise to thoroughly question the nuclear energy policy advocated by the government and the energy world. In September 1972 they wrote an (anti-) Nuclear Energy Memorandum which was presented to the House of Representatives. In addition, a more popular anti-nuclear brochure was published.²⁷⁶

These publications were the substantive basis for the opposition to nuclear energy in the Netherlands. Soon several other organisations were set up, in which members of WKE joined or collaborated, including the Association for the Protection of the Environment (Vereniging

²⁷⁴ Verbong, a.o., *Een kwestie van een lange adem*, 43.

²⁷⁵ Ibidem, 43-44.

²⁷⁶ Ibidem, 44-45.

Milieudefensie, VMD).²⁷⁷ In popular scientific literature too, much attention was paid to the dangers of radioactivity.²⁷⁸ In all the protests, there was attention to the danger of radioactive radiation and pollution from the discharge of nuclear waste.

Also, churches were increasingly resisting nuclear energy from nuclear fission under the influence of anti-nuclear activists in their own communities. Where many churches, including umbrella ecclesiastical organizations such as the Ecumenical World Council of Churches and the Roman Catholic Church, in the 1950s often expressed positive views on the peaceful use of nuclear energy, this enthusiasm declined rapidly in the 1970s.²⁷⁹ Several activists, such as Tuininga, spoke out in their own church communities against nuclear weapons and later also against peaceful applications of nuclear energy.²⁸⁰ Ultimately, the arguments of these activists would bring the Dutch Reformed Synod to a public call to postpone the construction of new nuclear power plants which the new Dutch government, led by the new Christian Democratic Party (CDA), endorsed in 1977.²⁸¹

In theory, nuclear fusion offered an answer to many of these objections. With the idea that a nuclear fusion reactor should be commercially deployable within the foreseeable future, the fusion scientists actively tried to influence the public opinion. In 1973 a lecture series on energy was organised by Studium Generale at Eindhoven University of Technology. In the series, which attracted a large audience of students and staff, Kees Braams did a guest lecture on nuclear fusion as an alternative source of energy.²⁸² From 1972 onwards open days were

²⁷⁷ For a detailed overview of all anti-nuclear energy movements in the Netherlands and their points of view see: Van Noort, *Bevlogen bewegingen*.

²⁷⁸ See for example Sanders, G.A., *Energie op leven en dood* (Amsterdam: Wetenschappelijke Uitgeverij, 1972).

²⁷⁹ The Secretary General of the World Council of Churches, the Dutch Willem Visser 't Hoofd, spoke out positively about nuclear energy in Berlin in the 1950s. In the 1960s the Council became more critical to peaceful nuclear energy after the Cuba Crisis. Zeilstra, *Visser 't Hoofd: Een leven voor de Oecumene, 1900-1985*, 325-327. The Catholic Church, too, became increasingly critical of nuclear applications. Dutch, R.S., *Let there be Light!: Nuclear Energy: a Christian Case* (Eugene: Wipf and Stock, 2017), 88.

²⁸⁰ Dutch, *Let there be Light!: Nuclear Energy: a Christian Case*, 88.

²⁸¹ Verbong, a.o., *Een kwestie van lange adem*, 70-72.

²⁸² Quotes of the lecture are presented in: Beurskens, H.J.M., C.C.H.T. Daey Ouwens, J.D. Fast, A.H.E. van Hengel, *Energie*, SG-dictate 9.004.

organised by FOM-Rijnhuizen to provide the general public more insight into research and to counteract the association with energy extraction from nuclear fission. Visitors to the open day learned about the fusion process on the sun, the problems facing fusion research in recent decades and the economic potential of an inexhaustible source of energy that would not release radioactive waste. Tritium and the wall of the fusion reactor, which are slightly radioactive due to the neutrons released during a fusion reaction, were explicitly not discussed.²⁸³

This chapter examines the extent to which the policies of scientists and investors changed as a result of the international breakthroughs in fusion research and the new energy issues. In addition, this chapter examines the role of the promise of nuclear fusion with these breakthroughs in the successful activism against nuclear energy.

4.1.4. Chapter Overview

Although historian Edwin Shaw argues that the Netherlands could not keep up with tokamak developments because of the desire for smaller projects, which would have been motivated by the fact that fusion research in the Netherlands was seen as fundamental, investments were made in large projects with international allure and tokamak experience was actively gained through an exchange project with MIT in the 1970s (4.2.1.). Also, Dutch research had a strong international focus, mainly on European developments (4.2.2.). Due to the international success with the tokamak, increasing European cooperation with JET and the expansion of RCN's research areas with the transition to ECN, Dutch fusion scientists saw the possibility of taking

²⁸³ Although in the 1970s scientists had already switched to research into a fusion reaction between deuterium and mildly radioactive tritium because of the lower temperatures required, the radioactive waste would be relatively limited and only have a half-life of 12.5 years. Also, these raw materials were much less expensive than the enriched uranium or thorium needed for nuclear fission-based power plants, according to the fusion scientists. The researchers' idea at the time was that with another material this problem with the wall would not exist. Still, despite a lot of research, no other material has been found. Vrouwe, *Hittebarrière*, 65-66. Prior to the first open day, Queen Juliana visited FOM-Rijnhuizen. The queen was so impressed that Kees Braams was invited to visit the queen afterwards to explain more about nuclear fusion. Vrouwe, *Hittebarrière*, 73.

a more active approach to FOM's longer-term policy of making fusion research part of RCN as applied science (4.2.3.).

However, the Ministry of Economic Affairs continued to have serious doubts about the direct economic potential of nuclear fusion. Based on various recommendations from advisory bodies, Lubbers decided not to invest in fusion research from the Ministry of Economic Affairs as long as more energy was not actually produced from nuclear fusion than was necessary to allow the fusion to take place in the reactor. He did not allow that the fusion research would be transferred to RCN/ECN (4.3.1.). The Ministry of Education and Sciences invested in research into alternative energy sources such as solar energy and also nuclear fusion, based on economic potential. In the literature, these investments are often regarded as the start of the Dutch search for alternative energy. This chapter shows, however, that the investments in nuclear fusion were more a continuation of the policy already initiated in the 1950s and 1960s (4.3.2.). Intensifying European cooperation was the main reason for investing in Dutch fusion research. Based on recommendations from the science department within the Ministry of Education and Sciences, the Ministry of Foreign Affairs (BuZa) made an effort to push ahead with JET and ensure the Dutch contribution (4.3.3.). New was the interest in fusion research from Dutch companies such as Shell (4.3.4.).

A new Fusion Hype emerged in the Dutch media in the 1970s. The increase in attention for nuclear fusion had two causes. Firstly, the media paid a great deal of attention to international cooperation within the research, focusing mainly on American breakthroughs and increasing European cooperation. Russian breakthroughs were discussed relatively little. The Dutch science editors mainly relied on Dutch scientific contributions and took over the focus of these scientists (4.4.1.). The second cause of the increasing attention for nuclear fusion was a revived belief in nuclear fusion as an alternative energy source. Although at the beginning of the 1970s the scepticism of the 1960s still had to be overcome, thanks to the scientific lobby

the media became increasingly enthusiastic about fusion research. More attention was also paid to the lack of radioactive waste in nuclear fusion compared to nuclear fission (4.4.2.). This increasing media attention translated into more attention for nuclear fusion in the public debate on nuclear energy. Opponents of nuclear energy believed that with additional investment in nuclear fusion the polluting power stations based on nuclear fission would not have to go ahead. This meant that nuclear fusion had an important role to play in postponing the Dutch nuclear energy project (4.5.).

4.2. A Renewed Scientific Belief in the Promise of Fusion

4.2.1. Dutch Response to International Developments

While the world switched to the model tokamak, FOM concluded in the 1970 annual report that a large tokamak was too expensive: “Within the thermonuclear field, the increase in scale is already in such a way that the Netherlands would find it extremely difficult to build a machine of the tokamak type, currently - rightly - very fashionable, itself”.²⁸⁴

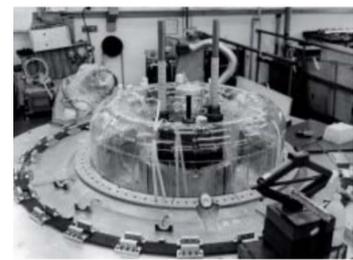


Figure 37: The SPICA experiment at Rijnhuizen. Photo archives DIFFER.

Edwin Shaw argues that the Dutch choice not to invest in the tokamak was due to Braams’ focus on small-scale plasma experiments instead of larger experiments, prompted by the fact that in the Netherlands fusion was not regarded as applied science.²⁸⁵

In the light of the previous development of Dutch research into nuclear fusion, this is a somewhat peculiar observation. From the beginning, the aim of the scientists was to transfer fusion research to RCN and to have it paid for by the Ministry of Economic Affairs. The scientists also regularly lobbied successfully for more money for larger projects. This lobby

²⁸⁴ FOM, *Jaarverslag 1970 Stichting Fundamenteel Onderzoek der Materie* (1971). FOM archives, NHA.

²⁸⁵ Shaw, *Europe’s Experiment in Fusion*, 15.

continued in the 1970s. An unprecedented four million guilders was invested in a new major project: the construction of the large screw pinch SPICA. In addition, in the 1970s the collaboration with RCN was intensified and both parties worked actively on bringing parts of the fusion research under RCN. The Dutch scientists also continued to connect with international research and to acquire a position within the increasing European cooperation.

FOM-Rijnhuizen decided to focus almost entirely on its own speciality with the screw pinch. In the 1960s, the first ideas to switch to large-scale research with the screw pinch had already emerged and the lobby for funding already started. Although the tokamak had been presented as the final rejection of the Bohm-diffusion in 1968 and 1969, at the beginning of the 1970s Dutch scientists still thought that the screw pinch, which had many similarities with the model of the tokamak, would in theory be more efficient in trapping high-pressure plasmas.²⁸⁶

In 1973, the 60 centimetre high torus was finally installed. SPICA set new records for plasma compression and produced many publications in leading international journals.²⁸⁷ However, it soon became clear that configurations with pinches would never develop into a fusion reactor. Because a pinch rapidly compresses the plasma, a wall of non-conductive material was required. These types of materials caused many contaminants when it came into contact with the plasma, which caused great instabilities.²⁸⁸

To gain experience with tokamak research at the same time, a collaboration agreement was signed in 1970 with MIT in Boston, United States. Based on new American budgets for economic research, MIT built a tokamak with a very strong magnetic field: the Alcator project. MIT, however, lacked the resources in manpower to do the research, because many fusion scientists had stopped research after the failures of the 1960s. FOM-Rijnhuizen had the money

²⁸⁶ Braams & Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research*, 103-105.

²⁸⁷ The research with SPICA would eventually run until 1987. See for example of research: Bobeldijk, C. a.o., *Novosibirsk* 1 (1968), 287.

²⁸⁸ Braams & Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research*, 104.

and resources to enlist many young scientists who wanted to study abroad. Between 1971 and 1975, fourteen Dutch scientists worked in the United States, most of them for a year. There the Dutch scientists measured the current, voltage, position and electron density.²⁸⁹

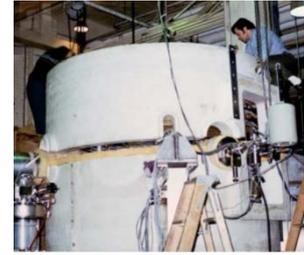


Figure 38: Dutch scientists with the Alcator project at MIT. Photo P. van der Laan in Vrouwe, *Hittebarrière*, 39.

Initially, Alcator had to contend with a lot of polluted plasma because the plasma discharges released hydrogen, hydrocarbons and oxygen from earlier experiments. As a result, the first version of Alcator caught fire in 1972. During the reconstruction, much attention was paid to experiments with cleaning the reactor vessel. By burning the vessel clean with hydrogen discharges, an improved vacuum technique and a pulsed fuel supply, the new tokamak broke all records in the following years with a retention time and plasma densities a factor of ten higher than in other tokamak experiments.²⁹⁰

Meanwhile, at the institute of FOM-Rijnhuizen and in Amsterdam at Kistemaker's laboratory, investments were made in other major experiments. At Rijnhuizen the gas blanket experiment, which had been started in 1966, was continued. In 1974 this led to a large Ring Arc set-up, in which the transport of helium was investigated. The gas blanket experiments tried to capture the pressure of the hot plasma in the vessel with a layer of cold gas.²⁹¹ In addition, with the torus Tortur, originally known as "torture" by the abbreviation "Toroidal Turbulence Experiment", research was carried out into heating methods by current-driven turbulence in which the plasma was heated in a fraction of a microsecond using strong currents.²⁹²

In Amsterdam too, fusion research continued. Although parts of the plasma physics research, including the laser research, were transferred to FOM-Rijnhuizen, the fusion research

²⁸⁹ In his farewell lecture at Eindhoven University of Technology, Prof. Dr. Daan Schram, one of the Dutch scientists on the Alcator project, stated that this was a "golden opportunity": "it was the only thing that worked and it gave the necessary basic information". Schram, D.C., *Plasma's, vuur, en wat nu?* (Eindhoven: Technische Universiteit Eindhoven, 2005), 9.

²⁹⁰ Schram, *Plasma's, vuur, en wat nu?*, 10.

²⁹¹ Braams & Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research*, 121-122.

²⁹² Vrouwe, *Hittebarrière*, 48-51.

continued to count on great commitment from Kistemaker.²⁹³ He thoroughly read through all of JET's draft plans and provided them with his own notes, which he sent to the working community "research thermonuclear reactions".²⁹⁴ In later plans by FOM in 1975, Amsterdam was also mentioned as a location for research into plasma heating and fundamental plasma physics.²⁹⁵ In the 1970s, Dutch fusion science certainly was engaged in large-scale experiments of international significance.

4.2.2. Dutch Fusion Science in European Context

The international focus of Dutch fusion research was not limited to the results of SPICA and Alcator's success. The fusion scientists remained strongly focused on international developments, focusing mainly on Western, American and European science. During the 1970s, the intensification of European cooperation in the run-up to JET was increasingly important. Dutch scientists saw opportunities in European projects and were even prepared to adapt their own research directions to developments within Euratom.

In the 1970s, Dutch scientists continued to visit international meetings. American and European congresses, lectures and seminars were the main destinations. The main reason for the visits to the American meetings was the work on the successful Alcator project in Boston. In the fusion world, Rijnhuizen's involvement in the project was widely known, and this reputation was further enhanced by the fact that the scientists seconded to MIT travelled through the United States after the year in which they worked on the project to give lectures at the large fusion laboratories.²⁹⁶ Several other visits to the United States were also planned, such as the

²⁹³ Streefland, *Jaap Kistemaker en uraniumverrijking in Nederland 1945-1962*, 258-260 and 265.

²⁹⁴ See for example Kistemaker, J., 'The FOM Plasma group in Amsterdam (TN III) in the period 1976-1981' (1981). AMOLF.

²⁹⁵ 'Beantwoording van ragen over FOM-RCN nota' (4 February 1975). NA 2.14.5168, Inventory number 8608.

²⁹⁶ Schram, *Plasma's, vuur, en wat nu?*, 9.

visit of E. Minardi, a fusion scientist at Rijnhuizen, to the APS Conference in Madison in 1971. Although no major breakthroughs were presented at this conference, Minardi was impressed by the tokamak results from Princeton and the research by Bruno Coppi.²⁹⁷ These lectures were referred to in subsequent travel reports by other Dutch fusion researchers.²⁹⁸

It is striking that these American results were regularly mentioned while Russian scientists had achieved the big breakthrough with the tokamak and also attended the congresses. The general tendency was that Soviet scientists had been successful with the model reactor, but did not understand the real science behind it. According to the Western scientists, the Russian fusion scientists could not explain why the tokamak was successful.²⁹⁹ The American tokamak results became the starting point and left an important mark on the scientific debates about fusion research in the Netherlands.

Nevertheless, the primary focus of Dutch fusion scientists was on European research. The vast majority of the conferences, lectures and study groups attended by scientists were European meetings attended mainly, or exclusively, by European scientists. For example, on 20 and 21 January 1972, the fourth High- β meeting was organised at which C. Bobeldijk, P.C.T. Van der Laan and R.J.J. Heijninge presented their research. These High- β meetings brought together various European fusion scientists to discuss the theory behind nuclear fusion. Many of the European research conferences were organised within the Euratom framework. These included the High- β conferences, but also several small meetings of European scientists working on the same research.³⁰⁰

²⁹⁷ Minardi, E., 'Report on the APS Conference at Madison, November 15-19, 1971' (November 1971), 1-2. DIFFER.

²⁹⁸ See for example: Weenink, M.P.H., 'Verslag deelname "Sherwood-Conference", Los Alamos' (March 1972), 2. DIFFER; and Bobeldijk, C., P.C.T. Van der Laan & R.J.J. Van Heijninge, 'Verslag van de 4^e Hoog- β bijeenkomst op 20 en 21 januari 1972 te Lausanne' (January 1972), 2. DIFFER.

²⁹⁹ 'Verslag van de Third Conference on Plasma Physics and Controlled Fusion Research, gehouden van 1-7 augustus 1968, Novosibirsk, USSR', 2.

³⁰⁰ See for example Van Ingen, A., 'Verslag over bijeenkomst van het Steering Committee for the 6th Symposium on Fusion technology', (January 1970). DIFFER.



Figure 39: The site committee for JET grouped around D. Palumbo (Chair). The Dutch scientist Ad van Ingen is the fourth from the left. Shaw, *Europe's Experiment in Fusion*, 54.

Of course, these meetings were easier to travel than meetings in other parts of the world, but from the time that British scientists began to work more actively within Euratom in preparation for JET, more meetings were also organised in England. British scientists also attended meetings in Italy, France, Germany and the Netherlands more often than in the 1960s. For example, the British D.C. Robinson and E.P. Butt presented their research results at the fourth High- β meeting in 1972.³⁰¹ The increasing cooperation brought the focus more to the British research. This shows that European cooperation was more important than distance.

The increasing cooperation in the run-up to JET dominated the attention paid by Dutch fusion scientists to international developments. Kees Braams was actively involved in the first plans for JET. As chairman of the Groupe de Liaison, Braams attended the presentation by the British scientists Bas Pease on the need for European cooperation between Great Britain and Euratom with regard to a joint fusion reactor, which would finally happen with the joining of the United Kingdom to Euratom in 1973.

Between 1971 and 1975, two major innovations were introduced within Euratom. In addition to paying more for the exchange of scientists within European research, Euratom would support up to forty-four per cent, instead of the usual twenty-four per cent, of the budget for research projects of European benefit. The Groupe de Liaison monitored this, which in practice meant additional funding for research projects that were useful to JET. With Braams,

³⁰¹ Bobeldijk, Van der Laan & Van Heijninge, 'Verslag van de 4^e Hoog- β bijeenkomst op 20 en 21 januari 1972 te Lausanne', 3-4.

Dutch fusion science was thus closely involved in the European distribution of money. Dutch plasma physicist Ad van Ingen was also put in the committee that would assess the suitability of JET's locations on behalf of Rijnhuizen.³⁰²



Figure 40: The Tortur experiment at Rijnhuizen. Photo archives DIFFER.

Rijnhuizen itself did not have to be the research location. The location was actually too small and Braams estimated that the Netherlands would have no chance in the political game that would arise between Great Britain, Italy, France and Germany.³⁰³ However, Dutch fusion scientists did see opportunities for their own research to be part of the European project. For a nuclear fusion, a temperature of at least one hundred million degrees had to be reached. The Russian tokamak reached only ten million degrees in 1968. The tokamak extracted all its heat from the current flowing through the plasma, but there was a limit to how far the current could be increased. From twenty million degrees, so much heat leaked out that increased current did not raise the temperature. External heating therefore became an important theme in the 1970s and eighties.³⁰⁴

Dutch fusion scientists focused on this theme with a new experiment: Tortur. Tortur was an experiment with turbulent heating. It turned out that the temperature could be raised in a straight tube. Tortur was an experiment to reduce the heat losses in a toroidal form. Euratom recognised the importance of this experiment and invested up to forty-four percent of the budget. With this money Tortur could be expanded. By replacing the quartz glass wall of Tortur I with metal in Tortur II, with a large capacitor bank, and an expensive coil system, Tortur started to look more and more like the model tokamak.³⁰⁵ Because the turbulent heating eventually only partially worked and still could not be converted to JET, the focus shifted to

³⁰² Shaw, *Europe's Experiment in Fusion*, 17-18.

³⁰³ Ad van Ingen is quoted in Vrouwe, *Hittebarrière*, 78.

³⁰⁴ Herman, *Fusion: the Quest for Endless Energy*, 167.

³⁰⁵ Vrouwe, *Hittebarrière*, 48-51.

tokamak diagnostics on Tortur which would become the Dutch scientific contribution to JET.³⁰⁶

In this way, Dutch research gradually came more in line with the European programme.

4.2.3. Together with RCN

The success of the tokamak, resulted in a worldwide belief among fusion scientists that a commercially deployable fusion reactor was definitively possible. For FOM, this breakthrough was the reason to reinstate the long-term goal of transferring nuclear fusion research to RCN, paid for by the Ministry of Economic Affairs.

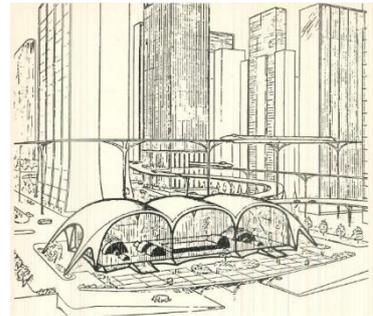


Figure 41: Artist impression of a future fusion reactor in a city. Represented in Brandt, B. 'Kernfusiereactoren', *Atoomenergie en haar toepassingen* (March 1972), 60.

At the beginning of the 1970s, the attention paid to nuclear fusion research in the RCN monthly bulletin increased exponentially. Several articles by Braams and his colleagues from Jutphaas appeared in the magazine between 1969 and 1975. Fusion scientist L.Th.M. Ornstein wrote in 1969 that the advantages of thermonuclear reactors would be considerable: “fuel is the unlimited availability and relatively inexpensive deuterium, the reaction produces no radioactive waste products, nuclear explosion hazard is absent - inherent in the system”.³⁰⁷

It is striking that economic potential, including the lack of radioactive waste, was again used by the scientists as an argument to indicate that fusion research should now be seen as applied research.³⁰⁸ Braams was interviewed extensively in May 1971 about the SPICA project in Jutphaas. He argued that an experimental reactor in which a break-even point, a point at

³⁰⁶ Ibidem, 51.

³⁰⁷ Ornstein, L.Th.M., 'Thermonucleaire reactoren', *Atoomenergie en haar toepassingen* 10 (1969), 247.

³⁰⁸ See for example: 'Thermonucleair onderzoek', *Atoomenergie en haar toepassingen* 10 (1971), 264-265; and Braams, C.M., A.M. Van Ingen, B. Brandt, 'The Joint European Torus', *Atoomenergie en haar toepassingen* 12 (1973), 285-289.

which the temperature reaches such a level that the combustion process can keep itself going, would be feasible in the 1970s.³⁰⁹ Cooperation between FOM and RCN was necessary to allow Dutch research to participate in this next phase.³¹⁰

The Ministry of Education and Sciences was approached with the same argumentation. Braams and, to an increasing extent, Jan Terlouw contacted the ministry.³¹¹ In 1968 Terlouw published an extensive article on the added value of nuclear fusion research for Dutch energy production. Terlouw wrote about the various advantages and stated that it seemed that the goal of the taming of the hydrogen bomb would be achieved. This was “in view of the rapidly increasing need for energy of the utmost importance”.³¹²

In 1973, Terlouw and Braams jointly wrote an extensive position report on plasma physics in the *Dutch Journal of Physics*. The articles were sent directly to the Ministry. In the 1973 article, the energy requirement in view of the oil crisis was touched upon more strongly. In addition, the article stated that a demonstration fusion reactor on a laboratory scale would be possible in the 1970s. To this end, closer collaboration with RCN was required.³¹³

This argument and the international successes with the tokamak seemed to convince RCN and officials of the Ministry of Education and Sciences. Various conversations between the ministries, RCN and FOM were held. On 8 February 1974 the first meeting was organised between the various representatives. Based on the international successes with the tokamak and the start-up of the large international projects, including the plans for JET in Europe, the

³⁰⁹ This did require European cooperation and Braams expressed the hope that England would soon fully join Euratom research on nuclear fusion. ‘Het SPICA project van FOM in Jutphaas: een interview met prof. dr. C.M. Braams’, *Atoomenergie en haar toepassingen* 5 (1971), 122.

³¹⁰ ‘Het SPICA project van FOM in Jutphaas: een interview met prof. dr. C.M. Braams’, 122-124.

³¹¹ Terlouw had joined Hans van Mierlo’s new political party, D66, in 1967. After returning from Novosibirsk in 1968, Terlouw became more active within the party, for which he became number two on the list of municipal election at Utrecht in 1970. A year later he even entered the Lower House as number ten on the list, where he soon obtained the portfolios of economy, energy and environment. Van Engen, J., *De onweerstandbare opkomst van Jan Terlouw* (Alphen aan den Rijn: Sijthoff, 1982).

³¹² Terlouw, J.C., ‘Thermonucleair onderzoek’, *Natuur en Techniek* 5 (1968), 1-10.

³¹³ Braams, C.M., & J.C. Terlouw, ‘Plasmafysica: een positiebepaling’, *Nederlands Tijdschrift voor de Natuurkunde* (1973), 82-87.

scientists stated that success was near. More expenditure was needed to participate properly in Euratom. This was important to meet energy needs, but also to keep up with the United States and the Soviet Union where large projects were launched. It was agreed that FOM and RCN would draw up a five-year plan for the period 1976-1980 in which fusion research would be transferred to RCN.³¹⁴

A follow-up meeting took place on 19 November 1974. In the months before, RCN and FOM had reached agreement on a division of the investigation. In Rijnhuizen the gas blanket research and the high beta research would remain as fundamental research. FOM-Rijnhuizen and Kistemaker in Amsterdam would also continue to focus on plasma heating and fundamental plasma physics. At the same time, RCN and FOM-Rijnhuizen would jointly conduct research into technical developments and system studies. Other research into radiation damage on wall materials and in superconducting materials, the use of lithium and the diffusion behaviour of tritium in structural materials would be transferred to RCN.³¹⁵

During the discussion the scientists once again emphasized that RCN should be involved in fusion research. An increase in the yearly budget from ten to twenty million was desired and an investment of seventy million guilders was required for a follow-up to SPICA. These investments were needed to continue to participate fully within Euratom, to keep up with the United States and the Soviet Union and to meet the increasing energy demand.³¹⁶ In conclusion, Shaw's claims can be nuanced. The scientists themselves did reinstate nuclear fusion as an

³¹⁴ On behalf of FOM L.H.Th. Rietjens conducted the meeting and on behalf of RCN the director J.A. Goedkoop was present. Braams fulfilled a double role as director of Rijnhuizen and board member of RCN. 'Verslag van het gesprek van het uitvoerend bestuur met prof. dr. C.M. Braams, prof. dr. J.A. Goedkoop en prof. dr. L.H.Th. Rietjens over de toekomstige organisatie van het thermonucleaire onderzoek in Nederland' (8 February 1974). NA 2.14.5168, Inventory number 8608.

³¹⁵ 'Beantwoording van vragen over FOM-RCN nota'.

³¹⁶ 'Verslag van een bespreking op het ministerie van Onderwijs en Wetenschappen over het kernfusieonderzoek' (19 November 1974). NA 2.14.5168, Inventory number 8608.

applied science in the 1970s. In doing so the FOM's longer-term policy in the 1950s and 1960s was reinstated.

4.3. Investors' Change of Minds?

4.3.1. No Part of the New Investments in Nuclear Energy

The Ministry of Economic Affairs did not respond enthusiastically to the plans of transferring nuclear fusion research to RCN. Public servants of the ministry had grave doubts about the future success of fusion research. The senior civil servant H.K. Mani regularly questioned the proposals from FOM and RCN. He wanted to know whether it was possible to keep pace with the results from the United States and the Soviet Union, and whether a successful commercially deployable fusion reaction could be initiated at all. In a memo on nuclear fusion research from December 1974 he stated that the fusion research was interesting, but the information was still too scarce.³¹⁷ After an extensive answer from RCN and FOM in which his questions were answered and the proposed division of research between RCN and FOM was listed, Mani remained critical.³¹⁸ During the follow-up meeting on 12 February 1975, Mani indicated that advice from the WRK was desirable.³¹⁹ During the subsequent meeting on 28 February, he again asked questions about the desirability and, in addition to the advice of the WRK, also wanted advice from the Industrial Advisory Council (IRK).³²⁰

The doubts of Mani were prompted by various advices and reports issued between 1969 and 1974. At the end of 1970 the Delft professor J.J. Went had published a report on the possibilities and problems of nuclear fusion reactors, commissioned by three ministries: the

³¹⁷ 'Nota beleid kernfusie onderzoek' (3 December 1974). NA 2.14.5168, Inventory number 8608.

³¹⁸ 'Beantwoording van vragen over FOM-RCN nota'.

³¹⁹ 'Verslag van een bespreking op het ministerie van Onderwijs en Wetenschappen over het kernfusieonderzoek' (12 February 1975). NA 2.14.5168, Inventory number 8608.

³²⁰ 'Verslag van een bespreking op het ministerie van Onderwijs en Wetenschappen over het kernfusieonderzoek' (28 February 1975). NA 2.14.5168, Inventory number 8608.

Ministries of Economic Affairs, Education and Sciences, and Foreign Affairs. Due to the depletion of fossil fuels and environmental control, nuclear energy was needed for the future, Went stated. The advantage of nuclear fusion reactors was that they did not produce radioactive waste. Only when tritium with an estimated half-life of thirty years was used there would be some waste. Also, so little fissile material was used that “the reactor would not get out of control with serious consequences”. According to Went, Russian research had virtually solved the problems within fusion research. However, the supplies of the lithium from which the tritium for deuterium and tritium fusion would have to be extracted were expensive and impractical to extract. Therefore, energy extraction from nuclear fusion was not feasible. This was a new argument that put even more pressure on the promise of an inexhaustible source of energy.³²¹

The WRK was more positive about the economic potential of fusion research in an earlier report in 1970. Developments in international research and collaboration with Euratom again made it necessary to look again at economic prospects of nuclear fusion. Nevertheless, the research was still described as purely scientific.³²² A later energy report, from 1974, of the SER, which elaborated on the energy perspectives for the Netherlands up to 2000, also stated that, in addition to fossil fuels, other energy reserves existed, such as energy from nuclear fission or fusion, solar energy, and geothermal energy. However, these energy reserves, with the exception of energy from nuclear fission and geothermal energy, were still entirely at the experimental stage, according to the SER.³²³

These reports led to the exclusion of energy production from nuclear fusion in the investments in nuclear energy in Ruud Lubbers’ Energy Memorandum in 1974, in which three

³²¹ Went, J.J., *Mogelijkheden en problemen van kernfusiereactoren* (4 November 1970). NA 2.06.101, Inventory number 499.

³²² WRK, *Advies aan Zijne Excellentie de minister van Onderwijs en Wetenschappen betreffende het thermonucleaire onderzoek en het aandeel dat ons land daarin moet nemen* (24 September 1970). NA 2.06.101, Inventory number 499.

³²³ SER, *Rapport inzake de energievoorziening en de sociaaleconomische aspecten daarvan* (1974), 6. SER.

new nuclear power plants were announced. An earlier Memorandum on Nuclear Energy Policy by Lubbers' predecessor as Minister of Economic Affairs, Harrie Langman, still described fusion research as a study in which important progress had been made in the past decade. The memorandum stated that, although the technological steps would be difficult, there would be a regular exchange about reactor technical problems between RCN and the FOM institute for plasma physics because of the upcoming fusion reactor.³²⁴

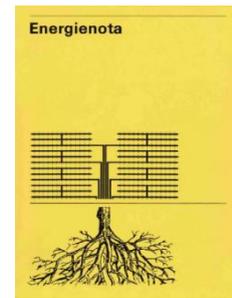


Figure 42: Lubbers' memorandum on Energy, 1974. SGD.

The Lubbers memorandum built on this memorandum, but changed some important notes regarding the distribution of money. The Energy Memorandum of 1974 stated that a nuclear fusion reactor would not be possible before 1985. The chapter on nuclear energy stated that an important future activity could lie in the field of the technological development of the fusion reactor, which phase fusion research was now approaching. However, the development of this future task of RCN should be further explored before investments should be made by the Ministry of Economic Affairs. So, fusion research did not profit from the new investments in nuclear energy.³²⁵

Nuclear fusion research continued to be regarded as fundamental research by the Ministry of Economic Affairs in the 1970s. This also ensured that fusion research did not become part of the new ECN, to which RCN would merge. The Ministry of Economic Affairs stuck to the policy that they only invested in new forms of energy generation if these would realize its economic potential within ten years. Lubbers confirmed this strategy in his answers to Parliamentary questions by Bart Verbrugh (GPV). In response to a public report from FOM in 1975, in which FOM stated to be disappointed with the lack of government policy on fusion research, Verbrugh asked Lubbers whether the Ministry of Economic Affairs should be

³²⁴ Langman, H., *Nota inzake het kernenergiebeleid* (1972), 4-6. SGD.

³²⁵ Lubbers, R.F.M., *Energienota* (1974), 140. SGD.

responsible for the research in view of the rapid international developments towards working fusion reactors. In his reply, Lubbers clearly stated that as long as the “proof-of-principle” was not met, meaning that until there was an actual fusion reactor, the research should still be accounted for as fundamental science and therefore as the responsibility of the Minister for Science Policy.³²⁶

4.3.2. Nuclear Fusion as a Serious Alternative Energy Source?

When Shaw states that fusion research in the Netherlands was regarded as fundamental, this was not true from the point of view of the scientists who actively tried to transfer the research to RCN/ECN. On the other hand, the government indeed saw the research as fundamental science. Investments in research into alternative energy sources, such as solar energy and nuclear fusion, fell under the responsibility of the Minister of Science Policy in the 1970s and were all referred to as fundamental research. However, investments in alternative forms of energy seem to be made in the 1970s based on their economic potential. Wouter van Dieren, journalist and party colleague of the Minister of Science Policy, Boy Trip, predicted in 1976 a competitive policy between the Minister of Science Policy and the Minister of Economic Affairs because Trip would invest based on economic potential in developing alternative forms of sustainable energy, including nuclear fusion.³²⁷ Several historians, including Aat van Selm and Geert Verbong, argue that the 1970s were the beginning of the Dutch development of alternative energy because of these investments.³²⁸

It is questionable, however, whether the investments in fusion in the 1970s really came from additional investments in alternative energy sources. Although the Ministry of Education

³²⁶ Lubbers, R.F.M., *Beantwoording Kamervragen Kernfusieonderzoek* (15 April 1975). SGD.

³²⁷ Van Dieren, W., ‘Bespreking Energierapport’, *Beta* (February 1975), 7.

³²⁸ Verbong, a.o., *Een kwestie van lange adem*, 24-25 and 58; but also on a more international level: Liard, *Solar Energy, Technology Policy, and Institutional Values*, 19-33.

and Sciences did indeed invest in science based on this economic potential from 1976 onwards, the investments from the ministry were more a lip service to recommendations in the energy reports of the National committee on Energy research, LSEO, than actual new investments. The investments in nuclear fusion at the end of the 1970s were not a real policy innovation. Above all, the existing policy of the late 1950s and 1960s was continued in the 1970s.

In 1976, in response to LSEO's second interim report, *Energie 1976 (Energy 1976)*, Minister Trip wrote to the Lower House of Parliament that in the long term, after 2000, a contribution to the Dutch energy supply would be possible from solar energy, wind energy, geothermal energy and nuclear fusion.³²⁹ With respect to nuclear fusion, LSEO recommended that a Dutch programme should be implemented as a contribution to the European structure with costs to be shared between the member states at a rate of 5%, that a Dutch activity in the field of plasma research adapted to European development should be maintained, that essential materials research should be expanded, and that studies should be carried out into the integration of nuclear fusion reactors into our society.³³⁰ As it was not yet possible at that time to identify which of the systems mentioned would offer the best technical, economic and social opportunities in the long term, research into renewable energies had to be continued on a broad front, according to Trip. However, the financial implications of the various proposals needed to be further assessed in the light of the financial scope available.³³¹

This assessment caused that for the period 1976-1981 a sum of one hundred and ten million guilders was set aside to finance national energy research. This was twenty million guilders more than before, but fifty-five million guilders less than recommended by the LSEO. Of this twenty million, six million went to sustainable energy in addition to the investments in

³²⁹ Trip, F.H.P., *Brief inzake kabinetsreacties tweede interim-rapport Landelijke Stuurgroep Energie Onderzoek* (August 1976). Tweede Kamer document number 13250 Nr. 4. SGD.

³³⁰ LSEO, *Energie 1976* (1976), 48. Tweede Kamer document number 13250 Nr. 4. SGD.

³³¹ Trip, *Brief inzake kabinetsreacties tweede interim-rapport Landelijke Stuurgroep Energie Onderzoek*.

renewable energy research already made prior to these decisions. Other important categories were research into the safety aspects of nuclear energy and radioactive waste storage, and research into energy conversion and transport.³³² Also, ZWO's budgets for nuclear fusion remained largely the same in the 1970s.³³³

This meant that the actual increase per field of science remained relatively limited. Especially when compared to investments in research into energy from nuclear fission. For 1977, for example, thirty-six million guilders had been earmarked for different fission projects, such as the fast breeder reactor in Kalkar.³³⁴ The investments made in nuclear fusion in the 1970s were thus mainly a continuation of the investments as they had been made since the 1950s and were not part of a major revival of interest in alternative forms of renewable energy.

4.3.3. Political Manoeuvring into European Corporation

Not only did the amount of money for fusion research remain in line with the amounts from previous decades. The policy behind the amounts also remained largely the same. In the 1970s, several new large projects were launched in the Netherlands. In the early 1970s, the Ministry of Education and Sciences made two and a half million guilders available for the new experiment SPICA.³³⁵ This was an unprecedented sum for a research project in fundamental science in the Netherlands. The main reason behind this investment was the international position of Dutch fusion research.

³³² Interdepartementale Werkgroep Energie (IWE), *Rapport inzake het nationaal programma energieonderzoek 1976* (Ministry of Economic Affairs, 1976), 19-25.

³³³ Kersten, *Een organisatie van en voor onderzoekers*, 264-267.

³³⁴ IWE, *Rapport inzake het nationaal programma energieonderzoek 1976*, 19-25.

³³⁵ FOM paid 1.5 million from its own budget, mainly obtained from Euratom. FOM, *Jaarverslag 1970 Stichting Fundamenteel Onderzoek der Materie*.

In its advisory report of 1970, the WRK stated that fusion research in the Netherlands was keeping pace with other countries, including the United States and the Soviet Union. To keep this up, investments had to be made in SPICA to focus on the Dutch quality with the screw pinch.³³⁶ Therefore, officials of the Ministry of Education and Sciences wrote different memos in favour of the Dutch fusion research. In an internal memo on thermonuclear research, officials wrote in 1975 that both the United States and Japan invested large amounts of money in fusion research. Germany and France also wanted to participate definitively in JET, with the Netherlands playing a key role in the realisation of the project.³³⁷ This was the reason for Minister Trip to visit Rijnhuizen in person to show that fusion research was important for the Netherlands.³³⁸

The international developments in fusion research, the increasing European cooperation within Euratom and the genesis of JET also led to closer coordination between the officials responsible for science policy and the Ministry of Foreign Affairs. Since the 1960s, officials from the Ministry of Foreign Affairs had been forwarding scientific articles from international fusion research to the Ministry of Education and Sciences. These mainly involved American and Russian articles, such as Artsimovich's ideas about a possible fusion reactor in Russia and the world's first plasma power station in action in Moscow.³³⁹ Although the Dutch fusion scientists were mainly focused on American and European developments, the Dutch government also kept an eye on Russian developments. According to the Ministry of Foreign Affairs, it was important to continue to look for ways to position Dutch fusion research

³³⁶ WRK, *Advies aan zijne excellentie, de minister van onderwijs en wetenschappen betreffende het thermonucleaire onderzoek en het aandeel dat ons land daarin moet nemen*, 9.

³³⁷ 'Het thermonucleaire onderzoek' (28 October 1974). NA 2.14.5168, Inventory number 8608.

³³⁸ See for visit minister: 'werkbezoek aan het FOM-instituut voor plasmafysica te Jutphaas' (13 January 1975). NA 2.14.5168, Inventory number 8608.

³³⁹ For example, this article was distributed: Artsimovich, L.A., 'Controlled Nuclear Fusion: Energy for the Distant Future', *Bulletin of the Atomic Scientists* (1970), 47-55. Immediately after its publication, a memo from Foreign Affairs was also sent to OW on the following article: 'World's first plasma power station in action in Moscow', *Morning Star* (14 December 1971).

internationally in such a way that it could continue to keep pace with developments in world powers such as the Soviet Union and the United States. European cooperation was the key to this.³⁴⁰



Figure 43: Laurens-Jan Brinkhorst (left) as junior minister for Foreign Affairs with Ruud Lubbers (right) in 1977. Wikimedia.

This policy was shared at the Ministry of Education and Sciences. Already in 1969, the minister, Gerard Veringa warmly recommended the Minister of Foreign Affairs to launch a multi-year programme on nuclear fusion in Euratom in 1970, based on the WRK's advice on keeping up with American and Russian research.³⁴¹

When the multi-annual Euratom fusion programme turned out to be far-reaching cooperation within JET, the Dutch government continued to be committed to European cooperation. In 1977, in response to various parliamentary questions, the Junior Minister for Foreign Affairs, Laurens-Jan Brinkhorst, replied that the Dutch government's commitment was to get the JET project up and running as quickly as possible. During the Dutch chairmanship of the European Commission, this was also actively pursued by bringing together different countries with opposing views.³⁴²

The Netherlands was able to play this key role in the European JET debate, which focused mainly on where the reactor should be located, because it did not have to be a location itself. For the Netherlands, it did not matter where the reactor would be located, as long as Dutch research could make a contribution. Brinkhorst therefore applied two criteria for the location: there had to be experience with fusion research at the site and the community character had to

³⁴⁰ 'Beleid met betrekking tot Europees vijfjarenplan 1976 t/m 1980 voor kernfusie' (29 October 1974). NA 2.14.5168, Inventory number 8608.

³⁴¹ Veringa, G.H., 'Thermonucleair onderzoek' (17 September 1970). NA 2.14.5168, Inventory number 8608.

³⁴² 'Handelingen eerste vergadering Vaste Commissie voor Buitenlandse Zaken' (22 August 1977), 7. Tweede Kamer document number 14119 SGD. Junior Minister is the translation of 'Staatssecretaris'. This translation is borrowed from: Schmidt, J.E.T, *Perspectives on cutback management in public organisations: what public managers do* (Leiden University: Leiden, 2020).

be central.³⁴³ The latter meant that a real community procedure was provided for and that countries that were not candidates for a location could nevertheless make a real contribution.

In addition, expansion of the European project was actively encouraged. When new countries such as Sweden and Switzerland wanted to participate, this accession was supported by the Netherlands.³⁴⁴ With more members, the European corporation could easier keep pace with the United States and the Soviet Union. It is in this light that the ultimate support of the Netherlands for the British site in Culham should be seen: with a European scientific project on English soil, Great Britain was definitively actively involved in European cooperation.³⁴⁵

4.3.4. New Involvement of Dutch Companies

The developments in international fusion research and the predictions in the Club of Rome report also led to new interest in fusion research among investors other than the government, including a number of large Dutch companies. Of course, companies that were involved as suppliers in Dutch research remained connected to fusion research in the 1970s. PEGUS continued to supply power to Rijnhuizen, and Vernooij developed further as an internationally highly regarded metalworking company specialised in vacuum chambers.³⁴⁶ In the 1970s, a number of new Dutch companies also became involved in fusion research as suppliers. For example, the Dutch electrical engineering company Holec, founded in 1963, supplied the conversion unit for the European JET reactor.³⁴⁷

³⁴³ 'Handelingen eerste vergadering Vaste Commissie voor Buitenlandse Zaken', 7.

³⁴⁴ 'Zweden vraagt om aansluiting bij werk van Euratom', *Trouw* (23 March 1974).

³⁴⁵ 'Verslag betreffende de uitwerking en toepassing van de Verdragen tot oprichting van de EEG en Euratom over het jaar 1977' (1977), 26-27. Tweede Kamer document number 15095, Nr. 2. SGD.

³⁴⁶ Vrouwe, *Hittebarrière*, 33-34.

³⁴⁷ Shaw, *Europe's Experiment in Fusion*, 184.

A number of Dutch companies also became substantively involved in the scientific enterprise of fusion research. As a result of the increasing debates about meeting the Dutch energy demand in the future, various agencies made predictions about the developments in energy consumption in the Netherlands. The most prominent were of course the LSEO reports, but companies



Figure 44: The Doublet III research reactor is still in use. A worker inside the DIII-D vacuum vessel during a maintenance period in 2017. Wikimedia.

including oil companies such as BP and Shell also made a number of public energy scenarios for the Netherlands. In these scenarios, Shell also examined alternative sources of renewable energy, such as solar energy and nuclear fusion.³⁴⁸ Although the expected contribution of these energy sources for 2000 was not estimated to be immensely significant, this attention led to some public calls from Shell to the Dutch government to invest more in these forms of energy.³⁴⁹

At the same time, Shell did commit itself via the General Atomic Company to a number of large fusion projects in the United States, such as the Doublet III project. Doublet III was an experimental plasma device in California that was used to carry out experiments with nuclear fusion. This project was also largely paid for by the Department of Energy of the United States and the Japanese Office of Science and Technology.³⁵⁰ Shell did not invest directly in the Dutch fusion research. In 1977, Shell director Ir. K. Swart even stated that it was unlikely that a company was willing to invest in the Dutch fusion research.³⁵¹

³⁴⁸ Shell Nederland B.V., *Zonne-energie* (The Hague: Shell Nederland B.V., 1978).

³⁴⁹ For example, the energy advisor to the Royal Dutch Shell Group, Dr. Ir. I. Hoog, and the advisor for oil and gas production at Shell, A. Hols, jointly called in 1976 for more investment in research into alternative energy sources such as nuclear fusion. 'Energietekort zonder kerncentrales en kolen', *De Telegraaf* (24 November 1976).

³⁵⁰ Sluyterman, K., *Concurreren in turbulente markten, 1973-2007: Geschiedenis van Koninklijke Shell, deel 3* (Amsterdam: Boom, 2007), 105.

³⁵¹ 'Shell geeft alternatieve energie 'n kans', *Het Vrije Volk: democratisch-socialistisch dagblad* (10 December 1977).

This was because the companies were indeed convinced of the possibility of the success of the fusion research, but did not want to bear the entire risk of taking the research from its fundamental status to a commercially deployable reactor. For this reason, investments were mainly made in projects in which governments removed a significant part of this risk by investing heavily themselves with budgets based on economic potential, such as the Doublet III project, rather than the lower science budgets. In the Netherlands, companies such as Shell were apparently not convinced that the announced extra investments in alternative forms of sustainable energy, such as nuclear fusion, by Minister Trip would quickly make the step towards a commercially deployable fusion reactor in the Netherlands possible.

4.4. New Fusion Hypes

4.4.1. Focus on Western Developments

After the media attention for nuclear fusion had declined sharply in the 1960s, more attention was paid again to fusion research in the 1970s. There were two peak moments in the media coverage of nuclear fusion during this period. The first peak was largely prompted by the increasing debates surrounding the energy issue, with the Report of the Club of Rome in 1972 and the Oil Crisis in 1973. The second peak around 1977 also paid attention to the debates on energy, but was dominated by reporting on the JET European collaborative project and the associated debates. The coverage of European cooperation built on the dominant new theme of the 1960s: the focus on international, European, cooperation in fusion research.

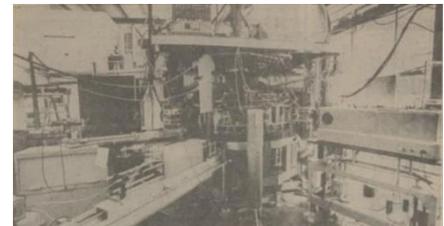


Figure 45: Photo of an experiment at FOM-Rijnhuizen. This photo was displayed above a article stating that the international uncertainty about the JET should not last any longer. ‘Onzekerheid kernfusie mag niet langer voortduren’, *NRC Handelsblad* (6 July 1976).

The Dutch media paid a lot of attention to developments in international fusion research. After the British confirmation of the breakthrough of the tokamak in 1969, the various scientific

institutes and research centres regularly experienced breakthroughs about which extensive reporting was done. *De Tijd*, for example, wrote an extensive article about the America's focus on nuclear fusion to solve the energy issues of the future.³⁵² Breakthroughs such as a breakthrough in Texas with laser heating were also described in various media.³⁵³

It is striking that the Dutch media paid relatively much attention to Western developments. There were extensive reports about breakthroughs in Princeton, Texas and the Alcatraz project at MIT. Very little was written about Russian developments and plans in the newspapers. Only *Algemeen Handelsblad* wrote an article about the Russian breakthrough of the tokamak in 1968.³⁵⁴ This lack of attention to Russian fusion research appears to have been caused by focus on discussions by Dutch scientists in journals such as the *RCN-Bulletin* who were more focused on American and European research instead of Russian developments. Many news items about nuclear fusion in Dutch media are based on articles in *Atoomenergie en haar toepassingen*.³⁵⁵

Dutch media extensively reported on the European developments. There was attention for the discussions about the distribution of money in the Euratom budgets, which led to political turmoil in Europe every five years and in which more and more money became available for fundamental fusion research.³⁵⁶ In addition, during the 1970s, more and more attention was paid to the development of JET. The media paid a lot of attention to the scientific status and the required cooperation. The British involvement in setting up JET was widely reported in the newspapers. The British nation, which in the 1950s and 1960s was still described as a world

³⁵² 'Amerika richt zich naar de zon: huiver voor kernenergie', *De Tijd: Dagblad voor Nederland* (17 February 1973).

³⁵³ 'Onderzoek universiteit van Texas: kernfusie mogelijk met zeer sterke laserstraal?', *Leeuwarder Courant* (21 February 1973); and 'Amerika zet vaart achter kernfusieonderzoek', *Nederlands Dagblad* (14 April 1975).

³⁵⁴ 'Beteugeling waterstofbom: Russisch succes vermoed', *Algemeen Handelsblad* (12 April 1969).

³⁵⁵ See for example: 'In de oceaan valt nog voor eeuwen te halen', *NRC Handelsblad* (14 April 1973). Lectures by Dutch scientists at Dutch symposia were also used as a source: 'Nieuwe energiebronnen', *Trouw* (21 March 1973).

³⁵⁶ See for example: 'Europees vijfjarenplan vergt 170 miljoen dollar: fusiereactor voor goedkopere energie', *De Volkskrant* (17 June 1970).

power in fusion research together with the United States and the Soviet Union, was now going to cooperate with the Euratom association.³⁵⁷

The various newspapers took position when the discussions about the location of JET flared up and the project seemed to get bogged down. Many Dutch media were particularly dissatisfied with the Italian attitude. In *De Volkskrant* and *De Waarheid*, the Italians were plainly accused of abusing the European presidency in 1975 to push their own location through while the location was clearly inadequate.³⁵⁸ In doing so, the Italians endangered European progress according to *De Volkskrant*.³⁵⁹

The Dutch fusion research and the developments in Rijnhuizen and Amsterdam were also described in the light of international research. When the SPICA project was launched, *NRC Handelsblad* wrote that Euratom was coordinating the project and that there were opportunities for the Netherlands in European research.³⁶⁰ Reports of the Rijnhuizen open day also placed a great deal of emphasis on the international position of Dutch research. The media stood aside Dutch scientists when they asked for more investments to participate fully in European cooperation. In 1974, *NRC Handelsblad* called on the Dutch government to intensify European cooperation on nuclear fusion, and *De Volkskrant* reported extensively on the proposals put forward by FOM in 1975.³⁶¹ It is clear that the Dutch media were on the hand of Dutch scientists and took part in the emphasis on European cooperation. The scientific focus on the United States and Europe was adopted.

³⁵⁷ See for example: 'Euro-project voor kernfusie naar Britten', *Trouw* (26 October 1977).

³⁵⁸ 'Voorsprong wordt bedreigd: Europees program kernfusie strandt', *De Volkskrant* (17 December 1975); and 'Het kabinet: alles op 'Europese kaart'', *De Waarheid* (16 December 1975).

³⁵⁹ 'Voorsprong wordt bedreigd: Europees program kernfusie strandt'.

³⁶⁰ 'Jutphaas op weg naar kernfusie', *NRC Handelsblad* (19 December 1970).

³⁶¹ 'De atoomrace der bomlozen', *NRC Handelsblad* (6 July 1974); and 'Voorstellen aan regering: opvoeren inspanningen kernfusie gevraagd', *De Volkskrant* (15 March 1975).

4.4.2. “The Sun Brought to Earth”: A Renewed Belief in Clean Energy

At the end of the 1960s, the international cooperation, which received a lot of attention in the Dutch media, was mainly described in relation to the fundamental status of fusion research. In particular, reports on Euratom’s budgetary treatment emphasised that Euratom was spending relatively more and more money on fundamental research, including nuclear fusion. Dutch research, for example in the description of the SPICA project by *NRC Handelsblad*, was also described as fundamental research into the behaviour of plasma and the reaction of materials.³⁶² It took a while in the early 1970s before the scepticism, heightened by the disappointing results with ZETA in the 1950s and the problems with the Bohm-diffusion in the 1960s, was dispelled among the journalists. After some of the international scientific breakthroughs and the Dutch scientific lobby for more money and transferring fusion science to RCN/ECN, the media again became hyped.

This changing attitude is reflected in the representation of the social energy debate in which nuclear fusion was put forward as an alternative source of sustainable energy. When, in the early 1970s, the debates on the future of energy supply in the Netherlands emerged with the report of the Club of Rome in 1972 and the oil crisis in 1973, journalists asked what the alternatives to fossil fuels would be. In addition to nuclear energy from nuclear fission, various alternatives were raised, including solar energy and nuclear fusion.³⁶³ At the beginning, it was stressed that the economic potential of a fusion reactor was far from being realised. *NRC Handelsblad* wrote in 1971 that a commercially deployable fusion reactor could take another thirty to fifty years.³⁶⁴

³⁶² ‘Jutphaas op weg naar kernfusie’.

³⁶³ See for example: ‘Goedkope energie uit oceaanwater’, *De Tijd: Dagblad voor Nederland* (4 April 1970).

³⁶⁴ ‘Fusioreactoren komen in zicht’, *NRC Handelsblad* (23 October 1971).

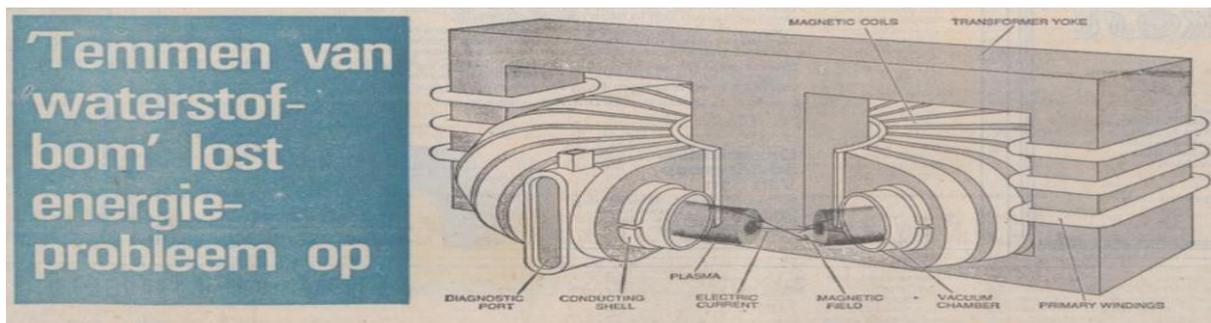


Figure 46: “Taming the H-Bomb solves energy issue” with schematics of tokamak reactor. ‘Optimisme over kernfusie keert terug’, *Het Parool* (27 March 1976).

However, as international, especially American, breakthroughs increased, plans for JET became more concrete and the energy issue became more urgent, these predictions changed. In 1972, *NRC Handelsblad* had already adjusted the forecast from thirty to forty years and less than a year later they already wrote that in about ten years all problems would be solved and a fusion reactor would be possible within twenty years.³⁶⁵

The media made an important distinction between energy from nuclear fusion and energy from nuclear fission. The different processes were clearly explained and the advantages of fusion energy over nuclear fission were mentioned. The main difference discussed was the advantage of an inexhaustible resource. With energy from water the world could be fully supplied with its energy needs. With the urgency of the energy issue with the 1973 Oil Crisis and the discussion of the Club of Rome report, this side of the economic potential of nuclear fusion became increasingly prominent in the media debate on alternative forms of renewable energy.³⁶⁶ With the development of JET and increasing cooperation between Britain and Euratom, attention to this promise increased. This eventually resulted in statements such as “Energy of nuclear fusion approaching: clean and plentiful” in *De Telegraaf* and “The sun will be brought to earth” in *Het Parool*.³⁶⁷

³⁶⁵ ‘Elektriciteit direct van de zon’, *NRC Handelsblad* (26 February 1972); and ‘Kernfusie in nabije toekomst oplossing energievraagstuk’, *NRC Handelsblad* (30 September 1972).

³⁶⁶ See for example: ‘Energie uit kernfusie haalbaar?’, *Nederlands Dagblad* (23 May 1972).

³⁶⁷ ‘Energie van kernfusie naderbij: schoon en overvloedig’, *De Telegraaf* (14 August 1978); and ‘Kernfusieproject naar Engeland’, *Het Parool* (26 October 1977).

In the discussions on the economic potential of nuclear fusion, the lack of radioactive waste was mentioned more extensively in the media than before as an advantage of energy from nuclear fusion.³⁶⁸ However, this growing optimism was not shared in all newspapers and articles. Critics remained sceptical about the time frame in which a fusion reactor would be commercially deployable or even doubted that the fusion research would ever be successful. Interestingly, a significant proportion of these sceptics were in the camp of supporters of nuclear energy.³⁶⁹ Both supporters and opponents of nuclear energy saw this as an argument to reinforce their own point of view. By investing more in alternative energy sources, including nuclear fusion, opponents wanted to make nuclear energy from nuclear fission redundant, while supporters pointed out the bridging function that energy from nuclear fission would have to fulfil until it was replaced by cleaner nuclear fusion. Nuclear fusion was still truly fundamental research and would not be able to contribute to solving the energy problems before 2000.³⁷⁰

4.5. Social Unrest: Nuclear Fusion and Anti-Nuclear Activism

The public debate knew a strong focus on the economic potential of nuclear fusion as an inexhaustible source of energy, but the lack of radioactive waste and radiation was also discussed more often during the 1970s. In this respect, the efforts of the scientists at Rijnhuizen to bring nuclear fusion into the limelight through open days and lectures succeeded.

Nuclear fusion was not only discussed at open days in Rijnhuizen and lectures by scientists. In television programmes, popular scientific books, opinion pieces and literature nuclear fusion was discussed as an alternative form of energy. Anton Zischka wrote in his book

³⁶⁸ See for example: 'Fusioreactor: krachtbron van de 21^{ste} eeuw', *Nederlands Dagblad* (14 August 1972).

³⁶⁹ For example, the director of Kalkar argued in 1976 that nuclear fusion was only a solution in the distant future: 'Kalkar-project duurt langer en kost meer dan verwacht was', *Nederlands Dagblad* (18 March 1976).

³⁷⁰ See for an example of nuclear fusion as argument against nuclear energy: 'Kernfusie te verkiezen boven kernsplijting', *Het Parool* (1 April 1972); and for example of reasoning in favour of nuclear energy: 'Kernfusie in nabije toekomst oplossing energievraagstuk'.

De wereld is nog steeds rijk: een optimistische inventarisatie (*The World is Still Rich: an Optimistic Inventarisation*, 1976) that the major energy shortages identified in the Club of Rome's report would not be a problem because of the imminent success of nuclear fusion.³⁷¹ Various leading opinion makers and organisations in the social debate also discussed the pros and cons of energy production from nuclear fusion and the status of research. Wouter van Dieren explicitly wrote about nuclear fusion in a reaction to the report of the Club of Rome as an answer to energy problems, Vereniging Milieudefensie (VMD) paid relatively much attention to the status of nuclear fusion research, and in 1977 energy consultant Erik Lysen was outspokenly positive about the economic potential of nuclear fusion in his popular scientific book *Eindeloze energie: alternatieven voor de samenleving* (*Endless Energy, Alternatives for Society*).³⁷²

This positive approach contrasts sharply with the social perception of nuclear fusion in the 1960s and 1950s. Nuclear fusion was embraced enthusiastically by the media in the 1950s, but this enthusiasm was not really part of the public debate on energy or the dangers of radiation. In the 1960s, both the media and popular culture dismissed nuclear fusion as abstract research and a scientific fantasy. In the 1970s however, fusion research was greeted with new enthusiasm. This development was prompted by two factors. Firstly, the energy debates raised by the report of the Club of Rome. In September 1972, VMD published an alternative nuclear energy memorandum in which a strong plea was made for nuclear fusion as an alternative energy source that could meet the entire energy requirement. Of course, the research was still fundamental, but with the new international developments and by investing more money the

³⁷¹ Zischka, A., *De wereld is nog steeds rijk: een optimistische inventarisatie* (Amsterdam: Keesing B.V., 1976).

³⁷² Van Dieren, W., 'Kritiek op de Club van Rome: hoe komen we van het tunneldenken af?', *NRC Handelsblad* (6 May 1972); 'Milieudefensie: kernenergie is geen lange-termijnoplossing', *NRC Handelsblad* (5 September 1972); and Lysen, E.H., *Eindeloze energie: alternatieven voor de samenleving* (Utrecht: Spectrum, 1977).

development of energy from nuclear fusion would go faster, according to the memorandum. In this way, nuclear fusion could provide an answer to the upcoming energy shortages.³⁷³

Secondly, during the 1970s, nuclear fusion, with its lack of, or limited, radioactive waste, was increasingly put forward as an alternative to nuclear energy from nuclear fission, thanks to the international successes of the research and the lobby of the Dutch fusion scientists. Together with the “Werkgroep Kernenergie” (WKE) and a number of other initiatives, VMD was part of the anti-nuclear energy movement in the Netherlands. In the alternative nuclear energy memorandum, VMD and the WKE stated that Langman’s memorandum on nuclear energy overlooked a number of critical aspects of the environment and safety. Also, the energy lobby was so convinced of the current state of nuclear energy that it did not consider a serious study of energy-saving and less environmentally damaging alternatives to be necessary. According to WKE and VMD, nuclear fusion was one of the most important alternatives to nuclear energy from nuclear fission due to the lack of radioactive waste.³⁷⁴ VMD and WKE were supported by some scientists with experience at energy companies or RCN and Kistemaker’s laboratory. One of the participants at WKE, director of the municipal energy company in Dongen G.A. Sanders, wrote his own book, *Energie op leven en dood* (*Energy between life and death*, 1972), in which he described nuclear fusion as a serious alternative to nuclear fission.³⁷⁵

These descriptions of nuclear fusion gradually became commonplace in society in the 1970s. Various initiatives adopted the image of nuclear fusion as a serious alternative to nuclear fission and used the development of nuclear fusion as an argument against investments in nuclear power plants based on nuclear fission. In 1978 and 1979, for example, the travelling

³⁷³ WKE, *Kernenergienota* (Vereniging Milieudefensie, 1972), 5.

³⁷⁴ WKE, *Kernenergienota*, 7.

³⁷⁵ Sanders, *Energie op leven en dood*.

energy exhibition *Energie Anders (Energy Different)*, organised by the Energy Different Foundation, dealt extensively with nuclear fusion as an alternative source of energy.³⁷⁶

In the 1970s, Dutch churches, too, became increasingly critical of the dangers of radioactive waste during nuclear fission. For example, in 1974 the Rotterdam professor Peter Odell, on behalf of technologically oriented theologians, stated within the World Council of Churches that nuclear fusion, and solar energy, were the clean alternatives for the future.³⁷⁷ In 1977 the Synod of the Dutch Reformed Church, partly on the initiative of E.J. Tuininga, who was an active member of WKE, and Odell, came up with a proposal for a broadly oriented social discussion on nuclear energy. The government, which was led by the Christian CDA party after the 1977 elections, adopted this advice and postponed the plans for the nuclear power plants described in the energy memorandum of 1974.³⁷⁸ In the end, this postponement would lead to the cancelling of the new nuclear power reactors. Social pressure against nuclear fission had won. The alternative that nuclear fusion seemed to offer, prompted by lobbying fusion scientists and enthusiastic scientific critics of nuclear fission, played an important role in this victory.

4.6. The Tokamak Decade

After the definitive breakthrough of the tokamak in 1969, many research institutes switched to this new model. FOM decided that a tokamak was too expensive for Dutch research, but this did not mean that only small-scale research was carried out in the Netherlands. Rijnhuizen started a new experiment with the screw pinch and several other large experiments in the early 1970s. Dutch researchers also gained experience with a tokamak reactor through an exchange

³⁷⁶ *Energie Anders, Een jaar voortvarend*, (Rotterdam: 1979).

³⁷⁷ 'Rijke landen klapten niet', *Trouw* (1 July 1974).

³⁷⁸ Verbong, a.o., *Een kwestie van lange adem*, 66.

project with MIT. This exchange characterised the international focus of Dutch fusion research. Fusion researchers from Rijnhuizen visited many international meetings, focusing mainly on American and European scientific developments. Especially the increasing European cooperation towards JET received a lot of support from the Dutch scientists. These international developments were reason for FOM to try to realise their long-term goals. To transfer fusion research as an applied science to RCN, FOM, together with RCN, lobbied the Ministry of Economic Affairs and agreed on a mutual division of research.

The Ministry of Economic Affairs, however, still had many doubts about the predicted breakthrough of fusion research. These doubts were prompted by reports from advisory bodies and ensured that in 1974 nuclear fusion research definitely did not become part of the new investments in nuclear energy. These investments were necessary because the Report of the Club of Rome in 1972 and the Oil Crisis in 1973 had shown that fossil fuels could not meet the energy needs of the Netherlands in the long term. To continue to produce energy in the longer term, the Ministry of Education and Sciences made additional investments in research into alternative forms of energy in addition to energy from nuclear fission. However, the investments in nuclear fusion show that this was mainly a continuation of the existing policy. This policy was to invest in nuclear fusion to promote European cooperation in order to counterbalance the United States and the Soviet Union and to keep pace with the developments in the international fusion research. For this reason, the initiative of European cooperation with JET was actively supported by the Dutch government.

The growing debates about the future energy supply and the developments in international fusion science created new Fusion Hypes in the Dutch media in the 1970s. The media paid a lot of attention to international developments, focusing on science in the United States and Europe. The science editorial staff mainly relied on input from Dutch fusion scientists. This also meant that during of the 1970s the media became increasingly positive

about nuclear fusion as an alternative source of sustainable energy. The various reports emphasised the difference between energy from nuclear fission and nuclear fusion by pointing to the lack of radioactive waste. Opponents of nuclear energy in particular used this as an argument against investing in new nuclear power stations. This attitude was also reflected in the public debate on energy supply and nuclear energy outside the media. The public profiling of fusion scientists and the support of critical nuclear scientists ensured that nuclear fusion was seen as a serious alternative to nuclear fission and increased social pressure against new investments in nuclear energy. Because of this increasing pressure, these investments were eventually postponed in 1977.

With these developments, nuclear fusion research in the Netherlands entered a new phase: even more focused on major international, European, projects such as JET, while the lobby to join investments in nuclear energy had to be reviewed now that investments in nuclear energy were decreasing. At the same time, it remained to be seen whether the promise of nuclear fusion, that had truly occupied the minds of scientists, investors, the media and public culture in the first thirty years, would be realized.

5. The Sun on Earth: Concluding Observations

5.1. The Dutch Promise of Nuclear Fusion, 1951-1979

5.1.1. European Cooperation During the Cold War

The developments regarding the promise of nuclear fusion in the Netherlands between 1951 and 1979 took place against the background of the Cold War. Friso Hoeneveld rightly states that the policy regarding Dutch post-war natural science was strongly influenced by this Cold War. Developments and investments in Dutch research were strongly inspired by developments in American research. David Baneke adds that the focus on American research largely lacks attention to Russian scientific developments. Although fusion research is generally presented in the literature as a peace project that managed to transcend the Cold War tensions, the considerations of scientists, investors and the media show that the development Dutch fusion research was determined by the developments of the Cold War, with the Dutch government also considering Soviet developments.

After the declassification of fusion research during the congress in Geneva in 1958, a worldwide exchange of research results took place during various meetings and congresses, and through various articles and journals. This exchange continued even during the fiercest periods of the Cold War. The Dutch fusion scientists made grateful use of this by visiting and organizing many international meetings. The scientists focused strongly on the American, but also British and European developments in fusion research. Although the first call for declassification came from the Soviet Union, and the most important breakthrough in international research turned out to be the Russian tokamak reactor, the Dutch fusion scientists paid little attention to Russian developments. The main focus was on European developments within Euratom, especially at the time that the European fusion reactor JET was set up in collaboration with Great Britain.

This focus on Europe was encouraged by the investments made by the Dutch government, which continued to invest in fusion research regardless of its lack of belief in a breakthrough to a commercially deployable reactor. These investments were mainly prompted by the possibility of further European cooperation through fusion research. This possibility was caused by the increasing focus of the European Euratom on fusion research. The Dutch government wanted to invest in increasing European cooperation to jointly form a power block between the United States and the Soviet Union, the major powers of the Cold War, and keep up with fusion developments in both countries. In doing so, the government focused on developments in both the United States and the Soviet Union and invested in specific projects with a great international impact. So, the Dutch fusion research is a great example of Hoeneveld's notion of "getting in lane". In this way, investments in Dutch fusion science were partly prompted by the developments of the Cold War.

Although the Dutch media did write about the international cooperation within fusion research, this story did not live up to society's expectations. Both the media and popular culture focused mainly on the economic promise of nuclear fusion. The media, which was strongly focused on Dutch fusion scientists, adopted the scientific focus on Western, since the 1960s specifically European, developments in fusion science. Even before the worldwide declassification, when the various countries were in competition with each other, the media focused mainly on American and British potential breakthroughs. In the case of nuclear fusion, the lack of attention for Russian developments within Dutch post-war natural science, as described by Baneke, existed mainly among the scientists and within the media, and not within the investing government.

5.1.2. The Dutch Search for Alternative Energy

That the potential for European cooperation was the main reason for investing in nuclear fusion nuances the historiography of the development of alternative energies. Both Frank Laird and Geert Verbong and Aat van Selm attribute the origins of the search for alternative, sustainable energy sources, which include nuclear fusion, to the 1970s. In this decade, in various countries, including the Netherlands, following the Club of Rome Report and the Oil Crises, more large-scale investments were made in research into these energy sources. However, the Dutch development of the promise of nuclear fusion shows that in the Netherlands the arguments for investing in alternative energy sources, other than nuclear energy, already existed among scientists, media and popular culture in the 1950s and 1960s. In addition, it is clear from the investors' considerations that the investments in nuclear fusion in the 1970s as an alternative energy source were not new, but a continuation of the policy of investing in the possibility of European cooperation.

Already in the 1950s, fusion scientists lobbied for additional investment in fusion research based on society's need for alternative sources of energy other than fossil fuels. The report of the study committee “thermonuclear reactions”, which investigated the possibility and desirability of setting up fusion research in the Netherlands, from 1956, already referred to nuclear fusion as an inexhaustible source of energy that provided an answer to the predicted shortages of fossil fuels. Nuclear fusion was also proposed as an alternative to nuclear energy from nuclear fission because energy production from nuclear fusion used cheaper raw materials and did not produce radioactive waste, showing that the arguments for alternative energy sources were already clearly present before the 1970s.

Although the Dutch government did not believe in this promise, investments were mainly made in fusion research because of the possibility of international, European cooperation. Based on international positioning, the government invested several large sums of

money in fusion research in the 1950s and 1960s with the purchase, and later expansion, of the Rijnhuizen estate, the setting up of major experiments such as SPICA, and the payment of international trips by fusion scientists. These investments did not change substantially in the 1970s. Although the Minister of Education and Sciences, Boy Trip, indicated to invest more money in research into alternative energy sources, the actual increase in the budget was limited. In the case of nuclear fusion, the investments were much more in line with earlier investments in the 1950s and 1960s than new policies.

Also the Dutch media and popular culture paid attention to nuclear fusion as an alternative source of energy earlier than the 1970s. The Fusion Hype in the 1950s was dominated by the presentation of nuclear fusion as an inexhaustible source of energy, in which cheaper raw materials compared to nuclear fission was mentioned as an advantage. In the 1960s these advantages were seen in the media and popular culture too, but then fusion was mainly seen as a scientific, abstract, wishful thinking. In the 1970s the narrative from the 1950s revived in the media. Attention to the lack of radioactive waste as an advantage of energy extraction from nuclear fusion was new in the media and in popular culture.

5.1.3. Fusion as an Important Factor in the Failure of the Dutch Nuclear Energy Project

The increasing attention for the lack of radioactive waste in energy production from nuclear fusion offers a new perspective on the failure of the Dutch nuclear energy project with the postponement and later cancelling of the construction of three new nuclear power plants at the end of the 1970s. Activism against nuclear energy flourished in the 1970s. Dick van Lente and Irene Cieraad show that this activism stemmed from a broader fear in society of radiation that was already present in the 1950s and 1960s. This thesis shows that the development international fusion research caused that the promise of nuclear fusion was considered an

alternative to nuclear fission among social activists in the 1970s. This was an important factor in the success of the social activism.

Although scientists in the 1950s already considered the lack of radioactive waste as an advantage of nuclear fusion over nuclear fission, this argument was mainly used in direct lobbying of investors. It was not until the 1970s that fusion scientists began to profile themselves more publicly by organising open days and giving more public lectures. Also in articles in more accessible journals, scientists more often mentioned this argument during the 1970s. They combined this advantage with recent international breakthroughs in fusion research that would soon make a fusion reactor possible. Nuclear fusion was presented as an alternative to energy production from nuclear fission.

The Dutch media used of these lectures and articles by the fusion scientists as a source for their own news articles and interpretations of the promise of nuclear fusion. In the 1970s, the media paid more attention to the lack of radioactive waste in nuclear fusion in the new Fusion Hypes, where the advent of a commercially deployable fusion reactor was considered imminent. Proponents of nuclear energy were more cautious about the speed at which a commercially deployable fusion reactor could be put into operation, while opponents of nuclear energy saw investments in nuclear fusion as an alternative to investments in energy production from nuclear fission.

These opponents of nuclear energy in the 1970s consisted in part of scientists who had a background in the energy world or nuclear physics, such as Tuininga. These scientists used the fusion scientists' lobby as a foundation for their campaign against nuclear energy. In various manifestos, popular scientific books and opinions, energy extraction from nuclear fusion was presented as a fully-fledged alternative to energy extraction from nuclear fission if only enough was invested in research into nuclear fusion. Through the activist scientists, this argumentation also reached various Dutch church communities at congresses and at lectures. Eventually,

during the Reformed Synod, a number of churches would speak out in favour of a public debate on nuclear energy. This call was endorsed by the Christian-oriented government. This meant postponing the plans for the new nuclear power plants and ultimately also postponing new investments in the Dutch nuclear energy programme, with the promise of nuclear fusion as an important factor in the failure of the Dutch nuclear fission project.

5.2. A Small Country in a Big World: Dutch Fusion in Relation to Other Countries?

5.2.1. Nuclear Fusion as Fundamental Science: Italy and the Netherlands

The conclusions on how the promise of nuclear fusion was considered in the Netherlands between 1951 and 1979 could provide new perspectives on the development of nuclear fusion in other countries. During the previous research, developments or decisions in France, Great Britain, the United States and the Soviet Union have been described in so far they influenced developments in the Netherlands. Developments in other countries such as Germany, Italy and Japan have also been hinted at.

In his book on the foundations of JET, Edwin Shaw presents a distinction between European countries regarding nuclear fusion as purely academic (Italy and the Netherlands), as economic promise (Great Britain), as scientific insurance (France) or as a sign of national identity (Germany).³⁷⁹ Based on the literature concerning the worldwide developments in fusion research, the United States, Soviet Union and Japan are added in this section. Japan is often cited as an example of a country that has invested in fusion research based on economic considerations.³⁸⁰ The United States and the Soviet Union were of course the two superpowers during the Cold War that other countries were trying to keep up with.

According to Shaw, fusion research in Italy and the Netherlands was mainly of a purely scientific nature. The emphasis was on fundamental research into the behaviour of plasma, there

³⁷⁹ Shaw, *Experiment in Fusion*, 10.

³⁸⁰ Herman, *Fusion: the Quest for Endless Energy*, 110.

were only limited investments in research, and the economic promise of nuclear fusion only played a role in the background.³⁸¹ The previous research shows that investors generally did not invest in Dutch research based on the economic promise of nuclear fusion. Nevertheless, fusion scientists made use of the promise to try to acquire funds and in

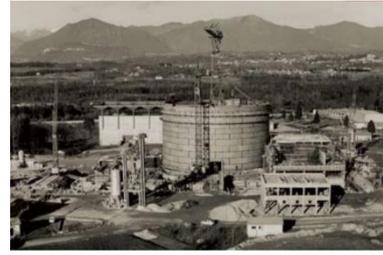


Figure 47: The ORGEL reactor at Ispra, 1962. European Commission, *JRC ISPRA: A 50 Years Pictorial History*, 17.

the Dutch public debate the economic potential was at times often elaborated on. Large sums of money were invested in fusion research by the Dutch government. These investments were mainly due to the possibility of more intensive European cooperation through joint fusion research.

The same reasoning seems to apply to Italy. Italy, together with the Netherlands, Germany, France, Luxembourg and Belgium, was one of the founders of the European association Euratom. The increasing focus of Euratom on fundamental scientific projects was also experienced in Italy. Euratom focused on three fundamental science projects: nuclear fusion, fast reactors and the ORGEL project at Ispra in Italy.³⁸² ORGEL, or ORGAnique-Eu Lourde, was an Italian research programme into an organic cooled, heavy water moderated fission reactor. This study was initiated by Euratom at the beginning of 1960 and was scheduled to last from 1963 to 1967. However, the research continued after 1967 with new investments in 1969. Therefore Italy had the opportunity to invest in European cooperation both through this fission project and through fusion research.³⁸³

The Italian government also continued to invest in both fundamental projects without believing in the direct economic potential of the research. Italy was strongly committed to the preservation of the ORGEL project.³⁸⁴ Investments also continued in nuclear fusion research.

³⁸¹ Shaw, *Europe's Experiment in Fusion*, 10.

³⁸² Ibidem, 12.

³⁸³ EC, *JRC ISPRA: A 50 Years Pictorial History* (Brussels: European Communities, 2009), 17.

³⁸⁴ Lenvy, J.C., a.o., *ORGEL: A European Power Reactor Design* (1962). AEI.

Even during the 1960s, when a fusion reactor seemed further away than ever, Italy continued to invest in fusion research. These investments came mainly from the Italian government's science budgets.³⁸⁵ Italy also wanted to become the site of JET. To do so, Italy even risked diplomatic tensions by using their chairmanship of the European Commission to have JET built on Italian soil, something the Dutch media were highly critical of. In doing so, Italy used as the main argument for the establishment of JET in Ispra that it could benefit from the facilities already present with the ORGEL project.³⁸⁶ In Italy too, therefore, investments in fusion research seem to stem mainly from the opportunities for joining prestigious international, foremost European, science projects without believing in the economic potential. It is plausible that Italy wanted to strengthen the international position too.

5.2.2. Scientific Insurance or National Identity: France and Germany

In other European countries, too, the economic potential of nuclear fusion was not the main reason for investing in fusion research. Shaw argues that in Germany, national identity was the main reason for investments, while France invested in fusion research as scientific insurance. By scientific insurance, Shaw means that France wanted to remain involved in fusion research to avoid missing the boat if there was ever a breakthrough in research.³⁸⁷ This strategy is very similar to the one described by Friso Hoeneveld as “a finger in the American pie” in his description of the post-war Dutch natural sciences. Scientists and governments tried to keep up with developments in the United States to not be left behind in the event of a breakthrough.³⁸⁸

In France, the investing government clearly had little faith in the economic potential of fusion research. The previous research showed that France tried to become a nuclear power itself. To this end, France developed its own nuclear weapons programme and also invested

³⁸⁵ European Commission, *JRC ISPRA: A 50 Years Pictorial History*, 17.

³⁸⁶ ‘Voorsprong wordt bedreigd: Europees program kernfusie strandt’, *De Volkskrant* (17 December 1975).

³⁸⁷ Shaw, *Europe’s Experiment in Fusion*, 10.

³⁸⁸ Hoeneveld, *Een vinger in de Amerikaanse pap*, 27-32.

heavily in nuclear energy from nuclear fission. France did not want to share fission research with other countries. Instead a strategy was pursued whereby Euratom had to focus more and more on fundamental research projects, such as nuclear fusion. That France's fusion research was not included in its own, classified, nuclear energy programme from the outset shows that France did not believe in an economically profitable fusion reactor in the short term. It is also questionable to what extent France invested in European nuclear fusion to form a power block between the Soviet Union and the United States when they thought they could be a considerable power themselves by investing in nuclear fission. However, France still invested in European collaborative projects by Euratom, and had an active involvement in JET. Presumably, France tried to strengthen European cooperation because there were other benefits to it, such as flourishing trade through the mutual treaties and European peace.

The wish for a peaceful Europe probably also partly applies to Germany. Germany, divided between East and West, struggled with the development of its own national identity. Investments in science, especially fundamental science without a military purpose, such as fusion research, helped with developing a new, peaceful, national identity.³⁸⁹ By actively investing and entering into European cooperation in the field of nuclear fusion, Germany was able to work towards European peace and create a new national identity, according to Shaw. Shaw interprets the unexpected German rapprochement in the debate about the location of JET in this way. In 1977, Germany supported the British claims with which the European debate was settled and the JET definitively settled on British soil.³⁹⁰ So, the big European countries, Germany and France, seem to have had their own reasons for investing in European science. Smaller European countries such as the Netherlands profited from this German and French

³⁸⁹ After the Second World War, there were many debates in Germany about the extent to which investments in science were “tainted” by the Nazi focus on science. In the end it was decided to invest mainly in “clean” fundamental science. Kapczynski, J.M., *The German Patient: Crisis and Recovery in Postwar Culture* (University of Michigan Press, 2008), 62.

³⁹⁰ Shaw, *Europe's Experiment in Fusion*, 61-68.

commitment to European cooperation. In this way these countries could connect with the scientific developments in the United States and the Soviet Union.

It would be interesting to examine to what extent German and French scientists tried to use the promise of nuclear fusion to obtain money from governments and companies, and how the public debate reacted to this lobby. Frank Laird's research into the origins of current American investments in alternative renewable energy sources compares policy in the United States and Germany. In doing so, Laird explains the origins of the differences between the two countries in the policy choices made in the 1970s and 1980s.³⁹¹ However, the previous research has shown that in the Netherlands arguments for these alternative renewable energy sources were already being used by fusion scientists in the 1950s and that the media also responded to this. Did this also play a role in Germany, or France, when the fusion research was set up in the 1950s?

5.2.3. Nuclear Fusion as Economic Promise: Great Britain and Japan

In view of the previous investigation, it is somewhat remarkable that certain countries, such as Great Britain and Japan, are attributed to investing in the fusion investigation based on economic potential. According to Robin Herman, Japan initially took a conservative approach to nuclear fusion. After the worldwide declassification of fusion research, in consultation with industry and scientists, the Japanese government decided to start studying basic plasma physics at universities and sending young fusion scientists to American universities to gain experience. In the 1970s, as a result of ever larger Western tokamaks and the oil crisis in 1973, Japan decided to deploy a large scale nuclear fusion reactor. The oil crisis in particular made clear how dependent Japan was on external energy sources. Own nuclear fusion energy offered an

³⁹¹ Laird & Stefes, 'The Diverging Paths of German and U.S. Policies for Renewable Energy: Sources of Difference', 2619-2629.

alternative. In close cooperation with large industrial companies, the Japanese government invested large sums of money in fusion research based on the economic promise.³⁹²

In Great Britain there was almost an opposite development. Prior to the declassification in 1958, both industry and the government invested in fusion research with the expectation that the research, following the example of energy from nuclear fission, would lead to a commercially deployable reactor in the short term. Shaw argues that, until the 1970s, British investments were mainly made on economic grounds. This reflects in the decline in investments in the 1960s, when after the failure of the British ZETA experiment and the formulation of the Bohm thesis, a fusion reactor seemed further away than ever. In the 1970s, British scientists were therefore forced to seek intensive contact with the European countries in Euratom to keep up with tokamak developments in the United States, the Soviet Union and Japan.³⁹³

It is striking that the British, but especially the Japanese, investments in fusion research were so linked to the economic potential of nuclear fusion, while the Netherlands and other European countries, such as France, did not believe in this short-term economic potential. Of course, investments in Great Britain decreased as the economic promise became more uncertain and the largest investments by the business community took place before the declassification. However, the Dutch Ministry of Economic Affairs decided not to invest in fusion research, even before the declassification in 1957. Substantial investments were made in Japan in the 1970s based on economic potential, while the Netherlands did not invest in fusion research at that time either. In the latter case, the research was even completely public and the European governments and Japanese companies took other decisions based on relatively the same information.

A possible explanation for these different outcomes could be a difference in the success of the lobbying of fusion scientists in the different countries. In the Netherlands, the fusion

³⁹² Herman, *Fusion: the Quest for Endless Energy*, 110-114.

³⁹³ Shaw, *Europe's Experiment in Fusion*, 1-3, 7, 10.

scientists, supported by the media, actively lobbied for fusion research to become part of the investments in nuclear energy based on the economic promise of nuclear fusion. It is possible that the Japanese fusion scientists were more successful in this because, on the one hand, the economic urgency was higher and, on the other hand, they had a more influential position vis-à-vis the government and the business community. In Japan, both in the 1950s and 1970s, the government actively engaged in a national debate on whether or not to invest in nuclear fusion research. As a result, scientists and the media may have been able to play a greater role in decision-making.³⁹⁴

For Great Britain, however, the question is rather why part of the investments remained in place in the 1960s, when it was clear that the economic potential based on which the investments had initially been made was uncertain, and that in the 1970s European cooperation was actively pursued by the British government, rather than investing again itself. It is possible that keeping up with developments in the United States and the Soviet Union and acquiring a better position within the dynamics of the Cold War, instead of pure economic goals, may also have been an important reason to invest in British fusion research from the beginning. This would also explain why the British government joined Euratom in 1973 and was actively deployed on JET on British soil while belief in its economic potential had declined sharply in the 1960s.

5.2.4. Cold War Powers: Soviet Union and United States

In the previous research, the increasing tensions between the United States and the Soviet Union during the Cold War were central. Keeping up with these superpowers was an important reason for many countries to invest in international cooperation projects based on fundamental science. Nuclear fusion research turned out to be extremely suitable for this because the fundamental

³⁹⁴ Herman, *Fusion: the Quest for Endless Energy*, 110-111.

scientific problems proved too difficult for one country to solve, the potential of a commercially deployable response seemed at times almost unattainable, and a fusion reactor is not a necessary step in manufacturing nuclear fusion weapons, such as the hydrogen bomb. The question that remains is why the United States and the Soviet Union invested in fusion research? After all, they were the superpowers that other countries wanted to keep up with, and they had to descend with the same economic considerations as other countries.

In the United States, research into nuclear fusion has been conducted on a large scale since the Second World War. Initially, a lot of research was carried out by the American Defence. In the years prior to declassification, it slowly became clear in the United States that the problems were more difficult than had been thought. To take the research further, in the mid-1950s a start was made on more intensive cooperation with Great Britain. This led to new claims for success, including the British-American collaboration with ZETA, in the run-up to the Geneva conference.³⁹⁵ By that time it was already clear that the problems within the research were probably too substantial. Fusion research was therefore considered a good commitment to international cooperation within the framework of the Atoms-for-peace strategy. In the 1960s, when the problems seemed insurmountable with the Bohm-diffusion, research in America became increasingly disconnected from investments by the Ministry of Defence and budgets were reduced.³⁹⁶ This changed completely after the British confirmation of the successes with the tokamak. The United States increased investment in fusion research once again, with ever larger experiments. They had a strong commitment to surpass the Russian results and to remain the leading international player in fusion research.

At the end of the 1940s, fusion research was also started in Russia. Initially, the focus was on manufacturing of a hydrogen bomb, following in the footsteps of the United States. In addition, Alexander Sakharov designed the model of the tokamak reactor as early as 1950.

³⁹⁵ Shaw, *Europe's Experiment in Fusion*, 2-3.

³⁹⁶ Herman, *Fusion: the Quest for Endless Energy*, 66-70.

Nevertheless, it soon became clear to the Russians that controlled fusion would not be turned into a reactor from which energy could be extracted by Soviet scientists. Russian fusion scientists actively called for worldwide declassification. In the years following the declassification, fusion research was actively pursued. The Russian fusion scientist Lev Artisimovich strongly believed in the tokamak model and actively tried to surpass the American, and British, results at international conferences. When the success of the tokamak was also internationally recognized, this was a reason for the Soviet Union to set up big plans and try to become a leader in fusion research.³⁹⁷

Despite international cooperation, the development of fusion research in both countries appears to be strongly influenced by the dynamics of the Cold War, in which both countries wanted to be the most prominent. The international conferences were characterised by the bidding of both superpowers on who had achieved the best results.³⁹⁸ This competition, which dominated Dutch media coverage of nuclear fusion before 1958, continued to lead the investments in both countries. Because other countries followed these investments, partly by cooperating with each other as in Europe, international fusion research was strongly dominated by the dynamics of the Cold War, despite the peaceful nature of the research.

³⁹⁷ Ibidem, 99.

³⁹⁸ Ibidem, 66-70.

6. Epilogue

6.1. Fusion: A Road into the Future

International, and Dutch, research into nuclear fusion did not stop with the construction of JET. Even today, in many different countries, including the Netherlands, scientists try to bring the sun to earth. The promise of nuclear fusion persisted, experiencing several low points and new revivals, in the decades between 1979 and the present.

Already during the construction and initial start-up phase of JET in the late 1970s and early 1980s, optimism about the tokamak waned. It turned out to be more difficult than expected to increase temperatures even further. Meanwhile, Europe, Japan, the United States and the Soviet Union were discussing a possible joint successor to JET. INTOR, or International Tokamak Reactor, should become a reactor on a global scale. However, this project ran aground on the disappointing first results with the tokamak at JET. The economy also picked up again after the oil crises in the 1970s, the price of oil fell sharply and other sources of renewable energy such as solar and wind energy developed strongly towards commercially usable energy sources. Investments in fusion research declined worldwide. According to the descriptions by Anouck Vrouwe and Herman Robin, this seemed to be the deathblow for fusion research in the first half of the 1980s.³⁹⁹

However, in 1982 a German invention offered salvation. During heating experiments, a method was found to improve the confinement of the plasma by a factor of two so that the heat could be retained longer. This proved essential in solving the problems that the tokamak reactors continued to face. JET was adapted in 1986 to mimic the German method. After this modification, the break-up times at JET proved to be so good that it was decided in 1991 to

³⁹⁹ Vrouwe, *Hittebarrière*, 10; Herman, *Fusion: the Quest for Endless Energy*, 126-131.

experiment for the first time with the fusion fuels deuterium and tritium. This had not yet happened because this reaction would make the walls slightly radioactive, which would make future experiments more difficult. For the first time, a real controlled fusion reaction was set in motion, with an efficiency of 33 percent in the first experiment. It absorbed three times more energy than was generated. After a few expansions, a power of 16 megawatts was generated in 1997 with an efficiency of 64 percent. This is still the largest fusion power that has ever been generated.⁴⁰⁰

American and Japanese tokamaks also achieved good results, and experimented with fusion between deuterium and tritium. Internationally, a possible follow-up of the various large tokamak projects was again considered. In 1985, the president of the Soviet Union, Mikhail Gorbachev, and the American president, Ronald Reagan, met in Geneva. Although the discussions, in which the dismantling of the nuclear arsenal was discussed, did not yield much, Gorbachev did propose the construction of an international fusion reactor. The United States agreed and together with Japan and Europe the design of the large fusion reactor ITER, Latin for “the road”, was started. This reactor, which was scheduled to start construction in 1998 and would celebrate its opening in 2005, was intended to initiate a fusion reaction that would generate more energy than it would cost to start it up. The aim was a power output of 1.5 gigawatts, the same as that of future coal-fired power stations. ITER also had to be able to burn for at least a quarter of an hour.⁴⁰¹

Expectations about the promise of a fusion were once again high, but at the end of the 1990s more and more doubts were raised about the feasibility of a fusion reactor. In the United States, fusion scientists feared that all the budget for their research would disappear to ITER, costing \$6.5 billion, while Japan struggled with economic problems that made new investments

⁴⁰⁰ Vrouwe, *Hittebarrière*, 83.

⁴⁰¹ McGray, W.P., ““Globalization with Hardware”: ITER’s Fusion of Technology, Policy, and Politics”, *History of Technology*, 26, 4 (2010), 312.

difficult. Initially, the objective of ITER was halved, and when the United States withdrew from ITER in 1998, the fusion dream seemed to have completely faded.⁴⁰²

Nevertheless, the Belgian European Commissioner for Research Philip Busquin and the British government science advisor Sir David King attempted to restart the project. In November 2001, King issued an advice for an accelerated trajectory towards commercial nuclear fusion. On this road to the future, ITER was described as an essential step. Europe should take the lead in the construction, according to King.⁴⁰³ Years followed in which the political discussions between Canada, France, Spain and Japan about the location of ITER ran high. In 2003 the United States joined ITER again. Also, China and South Korea joined. After mutual consultation, the European countries joined France's lobby with support from China and the Soviet Union. The United States and South Korea supported the Japanese site. In June 2005 it finally came to a breakthrough. ITER was to be placed in Cadarache, France.⁴⁰⁴

ITER is now under construction and various research institutes around the world are contributing to parts of the joint project. ITER will be definitively built in 2025 and will use the next 20 years to prove that a fusion reactor can generate more energy than that is needed to start the fusion process. Meanwhile, another lobby is taking place for a follow-up to ITER: a demonstration reactor, DEMO, which is to become the first commercially deployable reactor. Lessons learned from this demonstration reactor should make new reactors increasingly cheaper, enabling nuclear fusion energy to make a substantial contribution to the global energy supply at the end of the twenty-first century.⁴⁰⁵ So, the promise of nuclear fusion is still, very much, alive.

⁴⁰² Vrouwe, *Hittebarrière*, 71-72.

⁴⁰³ King, D., a.o., *Conclusions of the Fusion Fast Track Experts Meeting* (2001).

⁴⁰⁴ McGray, "Globalization with Hardware": ITER's Fusion of Technology, Policy, and Politics', 312.

⁴⁰⁵ Arnoux, R., 'ITER....and then what?', *ITER Magazine*, 3 (May 2014).

6.2. European Minded and More Realistic: Dutch Scientists in JET and ITER

In the Netherlands, too, research into nuclear fusion continued after 1979. Dutch fusion research made an active contribution to the research at JET. FOM-Rijnhuizen built three diagnostic devices for JET in the 1980s, and there were Dutch researchers in Culham for maintenance and research. Some of the scientists were seconded for a longer period of time, other scientists visited JET regularly. The institute's theory group was also involved in the work on JET. In 1989 they installed a computer program to interpret the measurement data. This program was based on magnetohydrodynamics, the theory that describes the plasma as a magnetic liquid. In terms of governance, Rijnhuizen's most important contribution was Braams' involvement in the scientific council of JET. The council, consisting of 15 scientists, advised the board of JET on the scientific program and changes to the tokamak. Braams was chairman from 1979 to 1985.⁴⁰⁶

In addition to the Dutch involvement in JET, the fusion scientists entered into various commitments with other European research institutions. In the 1980s, the Dutch fusion scientists focused more on tokamak diagnostics and external heating of the tokamak using gyrotrons. To carry out this research, in 1982 a partnership was engaged between Rijnhuizen and the French research institute in Fontenay-aux-Roses, where the Dutch gyrotrons were connected to the tokamak of the French institute.⁴⁰⁷ From 1996 onwards there was also more intensive collaboration with various research institutes in Belgium and Germany, TEC. With TEC, Trilateral Euregio Cluster, larger-scale research projects were set up together, scientists were exchanged and articles were published.⁴⁰⁸ When large-scale international collaboration with ITER became definitive, Dutch research continued to make a contribution. Negotiations for ITER were conducted from a European perspective, with the Netherlands trying to make a

⁴⁰⁶ Vrouwe, *Hittebarrière*, 79-80.

⁴⁰⁷ *Ibidem*, 51.

⁴⁰⁸ *Ibidem*, 46-47.

contribution by drawing on its own expertise in external heating.⁴⁰⁹ The focus on Europe thus remained strong in Dutch fusion research.

After the end of the Cold War in 1989, there was also more contact with the former Soviet Union. More attention was paid to technological developments in Russia. In 1992 Rijnhuizen even ordered some new Russian gyrotrons. This purchase of the 110 gigahertz gyrotrons ran counter to the agreements within Euratom that all investments in nuclear fusion research should be made by European industry, unless no European industry was available for this purpose. In the case of the gyrotrons, a debate arose because the French electronics group Thomson also manufactured gyrotrons. However, according to Dutch fusion scientists, these gyrotrons were of poorer quality and the Russian gyrotrons were much cheaper. With these arguments the Dutch scientists succeeded in convincing the European Commission of their purchase.⁴¹⁰

In addition to the European focus, the fusion scientists kept lobbying for more money based on the promise of nuclear fusion in periods when the climate debate or energy issues were raised. Especially during periods of major international breakthroughs, such as in the late 1980s, the records with JET in the 1990s and the construction of ITER, fusion scientists regularly referred to the potential of nuclear fusion to provide an answer to climate issues as a sustainable alternative to fossil fuels.⁴¹¹ However, there was also a shift towards more openness about the disadvantages of a nuclear fusion reactor with a radioactive wall. In later FOM-Rijnhuizen open days this disadvantage was openly discussed, and other public lobbying activities, such as the large-scale travelling Fusion Road Show, also paid attention to the problems of realising a nuclear fusion reactor and the problems of radioactivity.⁴¹²

⁴⁰⁹ Ibidem, 98-107.

⁴¹⁰ Ibidem, 77. This gyrotron is now at the National Museum Boerhaave in Leiden, the Netherlands.

⁴¹¹ Several meetings were organised with companies to try to obtain investments. Vrouwe, *Hittebarrière*, 62

⁴¹² The Fusion Road Show is a lecture/theatre performance about FOM-Rijnhuizen's research into nuclear fusion. The show premiered in 1999 and presents the energy problem of the 21st century with nuclear fusion as one of the solutions. 'Fusion Road Show', National Museum Boerhaave. Vrouwe, *Hittebarrière*, 66.

As a result, the Dutch fusion scientists seemed to become more realistic in their lobby about when the promise of nuclear fusion could be fulfilled and what the disadvantages of nuclear fusion were. This may have to do with the loss of investment in research into nuclear energy based on nuclear fission by the Dutch government. After the end of the 1970s no new major investments were made in the development of this form of energy. This also reduced the need for the fusion scientists to lobby for research to be transferred to RCN/ECN instead of the FOM.

6.3. Foremost European Cooperation: Dutch Investors After the 1970s

The debate on nuclear energy in the Netherlands slowly faded away. In June 1980, the Broad Social Discussion on Nuclear Energy in the Netherlands was launched with a starting document, in which the three new nuclear power plants were still considered an option.⁴¹³ In the following years, however, the government's attention to nuclear energy declined steadily. A report on the energy supply in 2050, commissioned by the Ministry of Economic Affairs, already concluded that nuclear energy would play a limited role.⁴¹⁴ On 13 March 1989, the Minister of Economic Affairs, Rudolf de Korte, stated that, in the light of environmental considerations, nuclear energy could not be completely ruled out, but at the same time the decision to build new nuclear power stations was again postponed.⁴¹⁵

Subsequently, in January 1994, a report of the General Energy Council was published stating that the construction of new nuclear power stations was not necessary in the short term. A new nuclear power plant in 2010 could even lead to overcapacity.⁴¹⁶ The government stated in 1996 that the construction of new nuclear power stations was not an issue.⁴¹⁷ In 1999, it was

⁴¹³ 'Deel 3: Brandstofinzet centrales', *Nota Energiebeleid* (17 July 1980), 233. LAKA.

⁴¹⁴ *Kernenergie een beperkte rol* (25 August 1987). NA 2.06.101, Inventory number 499.

⁴¹⁵ De Korte, R., *Het energiebeleid nader bezien* (13 March 1989), 11. LAKA.

⁴¹⁶ AER, *Advies naar aanleiding van het dossier kernenergie* (January 1994). LAKA.

⁴¹⁷ Wijers, G.J., *De Derde Energienota* (1996), 65. LAKA.

even confirmed that the existing nuclear power plant in Borssele would be closed. Although later Ministers of Economic Affairs continued to keep this nuclear power plant open for a longer period of time, no more investments were ever made in new nuclear power plants.⁴¹⁸

The research budget for nuclear energy was also decreasing. In April 1998, only 23 million guilders were invested in nuclear fission research. Research into nuclear fusion received 15 million in the same year. The budget for fusion research was increased several times in the preceding years. Whereas the Ministers of Education and Sciences and of Economic Affairs, Wim Deetman and Gijs van Aardenne, announced in 1982 that the research budgets for fusion research would be frozen because of the disappointing results with JET, investments were again raised in the second half of the 1980s. This money came from the budgets of the Ministry of Education and Sciences, from 1994 onwards Education, Culture and Science. Even today, this Ministry invests in Dutch fusion research.⁴¹⁹

The Ministry of Economic Affairs refrained from investing, and explicitly did not want to invest any natural gas revenues in fusion research in 2000. This policy changed with the definitive arrival of ITER. In 2001, FOM-Rijnhuizen still received part of the natural gas funds to establish ITER-NL, a collaboration of companies that would produce parts of the ITER reactor. These companies could directly supply material and technology to the new research reactor. In time, after ITER proves successful and a new demonstration reactor may be built, energy producers would have to take over part of the research and costs. However, no agreements have been made yet.⁴²⁰

The main reason for the Dutch government to invest in fusion research seems to remain to improve the international position of the research. Of course, the Cold War tensions dropped after the fall of the Berlin Wall, but the goal was still to keep up with developments within the

⁴¹⁸ *Energierapport 2008* (18 June 2008), 86-87. LAKA.

⁴¹⁹ Vrouwe, *Hittebarrière*, 101.

⁴²⁰ *Ibidem*, 101.

world's superpowers through European cooperation. Together with other European countries, active efforts were made to push ahead with ITER and international lobbying was carried out to bring ITER research to Europe. When the Netherlands took over the presidency of the European Union in 2004, the Minister of Education, Culture and Science, Maria van der Hoeven, together with the various scientific advisors from Dutch fusion science, set about relaunching the negotiations on the location of ITER that were deadlocked at the time. Together with the European Commissioner for Research, Janez Potočnik, they worked on a plan to make it more attractive for Japan to give up. In June 2005, the discussion was settled and the location of Cadarache became final.⁴²¹

6.4. Great Promises: Dutch Media and Popular Culture

After 1979, fusion research was still discussed in the public debate too. Dutch media wrote about fusion research, and documentaries, comics and popular scientific literature paid attention to the promise of nuclear fusion. In the decade of the eighties the phenomenon of the Fusion Hype reached its climax. Reporting on JET played an important role and the German solutions received a lot of attention after the initial disappointment in the media when the budgets for Dutch fusion research were frozen. However, more attention was also paid to extraordinary ideas of semi-scientists, or as they were called in fusion science: “quackers”.⁴²²

The promise of nuclear fusion and the problems within fusion research had always attracted dubious figures who presented their own ideas as a breakthrough. However, very little was written about these situations in the Dutch media, as the media was strongly focused on the Dutch fusion scientists themselves. A well-known example was the Austrian scientist, Ronal Richter, who, supported by the Argentine president Perón, claimed to have achieved controlled

⁴²¹ Ibidem, 103.

⁴²² Braams described the loose scientists who tried to sell their claims as "Quakers" in a letter to the Ministry of Education and Sciences. Braams, C.M. 'Reactie brief ing. Karl Novak inzake kernfusie' (29 January 1974). NA 2.14.5168, Inventory number 8608.

nuclear fusion, in the 1950s. After Perón was overthrown Richter was arrested for fraud and his claims were adjusted false. The Dutch media did not really pay attention to this situation.⁴²³

In the Netherlands, in the 1970s, an Austrian engineer, Karl Novak, tried to gain a foothold with his own solution to the problems within fusion research. After Novak had sent a letter to the Dutch Queen Juliana, his plans were discussed at both the Ministry of Economic Affairs and the Ministry of Education and Sciences. Eventually Kees Braams was consulted several times as director of FOM-Rijnhuizen and Novak's claims were investigated at the German research institute in Jülich. In the end these claims turned out to be untrue, and the Dutch media never wrote about them either.⁴²⁴

In the 1980s, however, two wrongful claims made the Dutch news. The internationally best known claim came after a press conference in 1989 in which two electrochemists, Martin Fleischmann and Stanley Pons, reported that a nuclear fusion reaction had taken place during the electrolysis of heavy water on the surface of a palladium electrode. Nuclear fusion could take place in a glass on the kitchen table, at room temperature. This claim caused a huge media hype all over the world.⁴²⁵ The claimed breakthrough was also widely reported in the Netherlands. Certainly when many, including Dutch, fusion scientists tried to imitate the research, much was written about it. However, when in the following years it became clear that the claims about Cold Fusion were not based on truth, the disappointment was once again great in the Dutch media.⁴²⁶

Earlier in the 1980s, the Netherlands had another hype regarding nuclear fusion that proved to be unjustified. In 1980 the Dutch physicist Geert Dijkhuis published an article in

⁴²³ While the international media often paid a lot of attention to these hypes. Herman, *Fusion: the Quest for Endless Energy*, 16-17.

⁴²⁴ The long correspondence between Karl Novak, the Dutch Royal House, the Ministries of Economic Affairs and Education and Science, Kees Braams and the Institute of Jülich can be found in the archives of the Ministry of Education and Sciences. NA 2.14.5168, Inventory number 8608.

⁴²⁵ Seife, C. *The Sun in a bottle: The Strange History of Fusion and the Science of Wishful Thinking* (Viking Publishers, 2008).

⁴²⁶ See for example: 'Weer negatief oordeel fusie', *Het Parool* (8 May 1989).

Nature about ball lightnings. These small, but very powerful fireballs sometimes occur during thunderstorms. In his article, Dijkhuis published a model for a lightning ball in which he stated that nuclear fusion could possibly take place in a lightning ball.⁴²⁷ Dijkhuis's plan was to tame a lightning ball and thus solve the global energy problem. In 1983, his company Convectron N.V. raised a few million guilders through share issues with which Dijkhuis set up experiments in Rotterdam and later also at KEMA in Arnhem. The Dutch media wrote enthusiastically about these ideas that would solve the energy problems and provide an alternative to nuclear fission.⁴²⁸ This research even received so much attention that Kees Braams published a brochure, *Het kronkelige pad van een bolbliksem (The Winding Path of Ball Lightning)*, in which he explained all his objections. "The idea that nuclear fusion occurs in ball lightning has no experimental or theoretical basis. (...) The models [of Dijkhuis] conflict internally, with each other and with large pieces of well-known physics".⁴²⁹

This brochure and the lack of results ultimately ensured that the hype for ball lightning was extinguished in the Dutch media. In combination with the once again disappointing results of Cold Fusion, public opinion became increasingly sceptical about the promise of nuclear fusion in the 1990s and early 2000s. When the plans for ITER were increasingly postponed and the United States even withdrew from ITER in 1998, attention for the promise reached its lowest point. As a result, the narrative of nuclear fusion as a real alternative to nuclear fission seems to have disappeared in the Dutch media.⁴³⁰

More recently, however, nuclear fusion seems to attract more and more attention with the ongoing build-up of ITER and new small-scale, partly private, initiatives in the United

⁴²⁷ Dijkhuis, G.C., 'A model for Ball Lightning', *Nature* 284 (1980), 150-151.

⁴²⁸ Van der Berg, R., 'Ingenieur Dijkhuis en de bolbliksems,' A. Maas & T. Cocquet (ed), *Verborgene krachten: Nederlanders op zoek naar energie* (Hilversum: Verloren, 2011), 126-127.

⁴²⁹ Braams, C.M., *Het kronkelige pad van een bolbliksem* (Jutphaas: FOM-Rijnhuizen, 1983).

⁴³⁰ Of course it was still mentioned, but the amount of attention given to nuclear fusion as an alternative to nuclear fission declined sharply. Presumably this was also prompted by the decrease in investments in nuclear fission by the Dutch government, as a result of which the promotion of an alternative became less necessary.

States. Coupled with attention for the economic promise of nuclear fusion and the lack of CO₂ emissions from nuclear energy, more attention has been paid to the subject in recent years. Various podcasts from news media devoted a broadcast to the status of nuclear fusion and also discussed the promise.⁴³¹ The subject is also again described in more detail in the written media, presenting nuclear fusion as a possible alternative to nuclear fission.⁴³² The promise of nuclear fusion remains relevant.

⁴³¹ In recent years, articles and podcasts on Dutch nuclear fusion research have been published regularly. See for example NRC, 'Waarom de wereld wacht op kernfusie', *NRC Onbehaarde Apen* (12 December 2018). Podcast, Spotify; and BNR, 'Waarom kernfusie ons deze eeuw niet zal helpen', *BNR de Technoloog* (31 January 2019). Podcast, Spotify.

⁴³² See for example: 'Is kernfusie de oplossing voor het energieprobleem', *Nu.nl* (2 February 2019); and 'Kernfusie: Energiebron van de toekomst of interessante illusie', *De Volkskrant* (25 May 2018).

7. Abstract

On 17 November 1959, the Minister of Education, Arts and Sciences, Jo Cals, knocked the sixty-eighth pile into the ground. The Dutch institute for plasma physics, FOM-Rijnhuizen, was festively opened. This opening marks the definitive establishment of the promise of nuclear fusion in the Netherlands. In previous years scientists had promised to be able to generate inexhaustible clean energy from controlled fusion in the near future, the energy of the sun on earth, and this promise had led to a real fusion hype in the media.

In the following decades, Dutch fusion research, which was part of an internationally declassified research area during the Cold War, experienced several setbacks and successes, although it never came to a commercially deployable fusion reactor. However, the Dutch government continued to invest considerable amounts of money in the research. Even at times when a fusion reactor seemed far from likely.

This thesis examines how Dutch scientists, investors, media and popular culture related to the promise of nuclear fusion between 1951 and 1979 and how this attitude may or may not have changed as a result of breakthroughs in international fusion research, rising tensions in the Cold War and social debates about energy supply.

This research shows that the possibility of European cooperation to keep up scientifically with developments in the United States and the Soviet Union was the main motivation for investing in Dutch fusion research, that arguments for alternative sustainable energy sources had been known longer than has been thought, and that the promise of nuclear fusion played an important role in the failure of the Dutch nuclear energy project.

8. List of Abbreviations

ARP	Dutch Anti Revolutionary Party
BuZa	The Dutch Ministry of Foreign Affairs
CDA	Dutch Christian Democratic Party (former KVP, ARP and CHU)
D66	Dutch Liberal Democratic Party
ECN	Energie Centrum Nederland (former RCN)
Euratom	European Atomic Energy Community
EZ	The Dutch Ministry of Economic Affairs
FOM	Fundamenteel Onderzoek der Materie
GPV	Dutch Reformed Political Convention
INTOR	International Tokamak Reactor
IRK	Industrial Council on Nuclear Energy
ITER	International Thermonuclear Energy Reactor
JET	Joint European Torus
KEMA	Keuring van Elektrotechnische Materialen te Arnhem
KVP	Dutch Catholic Party
LSEO	Landelijke Stuurgroep Energie Onderzoek
MIT	Massachusetts Institute of Technology
OECD	Organisation for Economic Cooperation and Development
OKW/OW	The Dutch Ministry of Education, Arts and Sciences (from 1967 onwards the Ministry of Education and Sciences)

ORGEL	ORGanique-Eu Lourde
PEGUS	The Provincial and Municipal Utrecht Power Supply Company
PPR	Dutch Political Party of Radicals
PvdA	Dutch Labour Party
RCN	Reactor Centrum Nederland
SER	Dutch Social Economic Council
SPICA	Screw Pinch Confinement Approach
TEC	Trilateral Euregio Cluster
TN I -V	The five working groups within the working community “research thermonuclear reactions”
TNO	Netherlands Organisation for Applied Scientific Research
Tortur	Toroidal Turbulence Experiment
VMD	Vereniging Milieudefensie
WKE	Werkgroep Kernenergie
WRK	Scientific Council on Nuclear Energy
ZETA	Zero Energy Thermonuclear Assembly
ZWO	Foundation for Pure Scientific Research

9. Overview of Archives Consulted

Online Archives

- Archive of European Integration (AEI): <http://aei.pitt.edu/>
- Delpher: www.delpher.nl
- Documentation Centre for Dutch Political Parties (DNPP). University of Groningen: <https://dnpp.nl/>
- Publications Social and Economic Council of the Netherlands (SER): <https://www.ser.nl/nl/Publicaties>
- Staten Generaal Digitaal (SGD): www.statengeneraaldigitaal.nl

Amsterdam

- Documentation and Research Centre Nuclear Energy (LAKA)
- NWO Institute AMOLF. Science Park
- Amsterdam City Archives (SAA)

Eindhoven

- Dutch Institute for Fundamental Energy Research (DIFFER). Science Park

Haarlem

- FOM Archives. Archives of Noord-Holland (NHA)

Hilversum

- The Netherlands Institute for Sound and Vision

Leiden

- National Museum Boerhaave

Nijmegen

- Catholic Documentation Centre (KDC). Radboud University Nijmegen

The Hague

- Archives of the Ministry of Economic Affairs. National Archives (NA)
- Archives of the Ministry of Education and Sciences. National Archives (NA)

Utrecht

- Utrecht City Archives (HUA)

10. Bibliography

- ‘Aan het begin van de Waterstofeeuw’, *Het Vrije Volk: democratisch-socialistisch dagblad* (9 September 1957).
- ‘Amerikaanse geleerden brachten korte beheerste fusie-reactie tot stand’, *Algemeen Handelsblad* (4 November 1960).
- ‘Amerika richt zich naar de zon: huiver voor kernenergie’, *De Tijd: Dagblad voor Nederland* (17 February 1973).
- ‘Amerika zet vaart achter kernfusieonderzoek’, *Nederlands Dagblad* (14 April 1975).
- ‘Beheerste kernfusie...het moet kunnen, maar hoe?’, *Het Vrije Volk* (four articles between 4 June 1962 and 9 June 1962).
- ‘Beknopt verslag Tweede Kamer donderdagavond’, *De Volkskrant* (30 November 1957).
- ‘Beteugeling waterstofbom: Russisch succes vermoed’, *Algemeen Handelsblad* (12 April 1969).
- ‘Brits-Amerikaanse successen op het gebied der kernfusie’, *De Tijd: Godsdienstig-Staatskundig Dagblad* (9 January 1958).
- ‘Britse primeur van kernfusie door VS opgehouden’, *Het Vrije Volk: democratisch-socialistisch dagblad* (14 January 1958).
- ‘Brits Procédé: Industriële energie door waterstofbomreactie’, *Algemeen Handelsblad* (18 December 1957).
- ‘Brits ZETA-apparaat bracht teleurstelling’ *Algemeen Handelsblad* (14 June 1958).
- ‘Britten winnen “energierace”’, *De Telegraaf* (18 December 1957).
- ‘Dank aan Spoetnik’, *Het Vrije Volk: democratisch-socialistisch dagblad* (29 October 1957).
- ‘De atoomrace der bomlozen’, *NRC Handelsblad* (6 July 1974).
- ‘Een gedane zaak’, *Leeuwarder Courant: hoofdblad van Friesland* (20 January 1959).
- ‘Een jaar wereldgebeuren in vogelvlucht’, *Gereformeerd gezinsblad* (31 December 1957).
- ‘Een worsteling om het hemelvuur: Waterstofbom is getemd, na Amerika en Rusland ook succes in Duitsland’, *De Tijd; Godsdienstig-Staatskundig Dagblad* (9 March 1957).
- ‘Elektriciteit direct van de zon’, *NRC Handelsblad* (26 February 1972).
- ‘Energie uit kernfusie haalbaar?’, *Nederlands Dagblad* (23 May 1972).
- ‘Energie van kernfusie naderbij: schoon en overvloedig’, *De Telegraaf* (14 August 1978).
- ‘Energietekort zonder kerncentrales en kolen’, *De Telegraaf* (24 November 1976).
- ‘Euratom steekt 10 miljoen in Jülich’, *De Waarheid* (25 October 1962).

‘Europees vijfjarenplan vergt 170 miljoen dollar: fusiereactor voor goedkopere energie’, *De Volkskrant* (17 June 1970).

‘Euro-project voor kernfusie naar Britten’, *Trouw* (26 October 1977).

‘Frankrijk wil roer om in NAVO en Euratom’, *Trouw* (8 May 1964).

‘Frankrijk wil snoeien in Euratom’, *Het Parool* (26 June 1964).

‘Fusiereactoren komen in zicht’, *NRC Handelsblad* (23 October 1971).

‘Fusiereactor: krachtbron van de 21^{ste} eeuw’, *Nederlands Dagblad* (14 August 1972).

‘Getemde waterstofbom voor vreedzame doeleinde: Kernfusie ook hier in studie’, *De Volkskrant* (12 April 1957).

‘Goedkope energie uit oceaanwater’, *De Tijd: Dagblad voor Nederland* (4 April 1970).

“‘Het Atoom’ wordt zeer attractief”, *De Telegraaf* (8 May 1957).

‘Het kabinet: alles op ‘Europese kaart’’, *De Waarheid* (16 December 1975).

‘Het SPICA project van FOM in Jutphaas: een interview met prof. dr. C.M. Braams’, *Atoomenergie en haar toepassingen* 5 (1971).

‘In de oceaan valt nog voor eeuwen te halen’, *NRC Handelsblad* (14 April 1973).

‘Jutphaas op weg naar kernfusie’, *NRC Handelsblad* (19 December 1970).

‘Kalkar-project duurt langer en kost meer dan verwacht was’, *Nederlands Dagblad* (18 March 1976).

‘Kernfusie: een nieuw tijdperk in geschiedenis van eeuwenoud herenhuis’, *Het Parool* (14 February 1959).

‘Kernfusie: Energiebron van de toekomst of interessante illusie’, *De Volkskrant* (25 May 2018).

‘Kernfusie in nabije toekomst oplossing energievraagstuk’, *NRC Handelsblad* (30 September 1972).

‘Kernfusieproject naar Engeland’, *Het Parool* (26 October 1977).

‘Kernfusie te verkiezen boven kernsplijting’, *Het Parool* (1 April 1972).

‘Kernstopakkoord hindert vreedzaam gebruik atoomenergie’, *Algemeen Handelsblad* (3 September 1964).

‘Klein-Europees parlement: Agrarische integratie moet worden bevorderd’, *Algemeen Handelsblad* (24 June 1959).

“‘Leven met Atomen’ Heldere en prettige beschrijvingen van ingewikkelde materie’, *De Tijd: Godsdienstig-staatskundig dagblad* (14 August 1957).

‘Los Alamos, proeffabriek voor atoomgeweld’, *De Volkskrant* (22 December 1960).

‘Mens moet meewerken aan onstuitbare groei’, *De Volkskrant* (20 October 1964).

‘Milieudefensie: kernenergie is geen lange-termijnoplossing’, *NRC Handelsblad* (5 September 1972).

‘Minister opent laboratorium plasmafysica’, *De Tijd: Dagblad van Nederland* (25-01-1967).

‘Nederland trekt profijt van “Geneve”’, *Het Parool* (3 September 1958).

‘Nederland werkt om energie uit zeewater te winnen’, *Nieuwsblad van het Noorden* (15 January 1959).

‘Nieuwe atoomreactie ontdekt in Californië: uitzicht op energiewinning uit waterstof?’ *Algemeen Handelsblad* (2 January 1957).

‘Nieuwe energiebronnen’, *Trouw* (21 March 1973).

‘Nieuw tijdschrift over kernfusie’ *Algemeen Handelsblad* (24 October 1960).

‘Onderzoek universiteit van Texas: kernfusie mogelijk met zeer sterke laserstraal?’, *Leeuwarder Courant* (21 February 1973).

‘Ook in Nederland: Onderzoek naar probleem kernfusie’, *De Waarheid* (21 November 1957).

‘Plasmafysica en kernfusie: conferentie geopend in Salzburg’, *De Tijd De Maasbode* (5 September 1961).

‘Prof. Muntendam waarschuwt: Elke radioactiviteit is gevaarlijk’, *Het Vrije Volk: democratisch-socialistisch dagblad* (12 October 1957).

‘Rijke landen klapt niet’, *Trouw* (1 July 1974).

‘Ruim vijf miljoen voor Z.W.O.’, *Het Parool* (14 January 1958).

‘Rusteloos gaan we hoger, verder, dieper’, *De Telegraaf* (12 November 1965).

‘Shell geeft alternatieve energie ‘n kans’, *Het Vrije Volk: democratisch-socialistisch dagblad* (10 December 1977).

‘Succes op weg naar getemde kernfusie’, *De Volkskrant* (5 November 1964).

‘Temperatuur van twee miljoen graden bereikt in V.S.’, *De Tijd: Godsdienstig-Staatkundig Dagblad* (5 December 1956).

‘Thermonucleair onderzoek’, *Atoomenergie en haar toepassingen* 10 (1971), 264-265.

‘Three nations in U.N. support V.S. atoms-for-peace plan’, *New York Times* (28 September 1954).

‘‘t Zal mijn tijd wel duren....’ Dat zit nog!’ *Het Vrije Volk: democratisch-socialistisch dagblad* (30 April 1958).

‘Verbluffende ontwikkeling in onderzoek kernfusie’, *Trouw* (4 September 1958).

‘Vijfjarenplan voor kernfusie’, *Telegraaf* (29-08-1957).

‘Voorlichting over fysica: laboratoria open voor publiek’, *De Volkskrant* (6 April 1972).

‘Voorsprong wordt bedreigd: Europees program kernfusie strandt’, *De Volkskrant* (17 December 1975).

‘Voorstellen aan regering: opvoeren inspanningen kernfusie gevraagd’, *De Volkskrant* (15 March 1975).

‘Weer negatief oordeel fusie’, *Het Parool* (8 May 1989).

‘Wedloop tussen Oost en West met ontzaglijke hulpbronnen: wetenschap, de gouden sleutel van de toekomst’, *De Volkskrant* (21 May 1960).

‘World’s first plasma power station in action in Moscow’, *Morning Star* (14 December 1971).

‘Zweden vraagt om aansluiting bij werk van Euratom’, *Trouw* (23 March 1974).

Andriess, C.D., *De Republiek der Kerneleerden* (Bergen: BetaText, 2000).

Arnoux, R., ‘ITER....and then what?’, *ITER Magazine*, 3 (May 2014).

Artsimovich, L.A., ‘Controlled Nuclear Fusion: Energy for the Distant Future’, *Bulletin of the Atomic Scientists* (1970), 47-55.

Baneke, D.M., ‘De vette jaren: de Commissie-Casimir en het Nederlandse wetenschapsbeleid’, *Studium* 5 (2012).

Baneke, D.M., ‘Let’s Not Talk About Science: The Normalization of Big Science and the Moral Economy of Modern Astronomy’, *Science, Technology and Human Values* (2019), 1-31.

Baneke, D.M., ‘The Absence of the East: International Influences on Science Policy in Western Europe during the Cold War’, in J. Van Dongen (ed.), *Cold War Science and the Transatlantic Circulation of Knowledge* (Leiden, 2015), 165-183.

Basford, L. (ed.), *De rusteloze materie* (Amsterdam: De Nationale Uitgeverij, 1966).

Van der Berg, R., ‘Ingenieur Dijkhuis en de bolbliksems,’ A. Maas & T. Cocquet (ed), *Verborgen krachten: Nederlanders op zoek naar energie* (Hilversum: Verloren, 2011), 125-130.

Beurskens, H.J.M., C.C.H.T. Daey Ouwens, J.D. Fast, A.H.E. van Hengel, *Energie*, SG-dictate 9.004.

Blok, J., ‘In memoriam C.C. Jonker’, *Jaarboek VU 1980-1981*, 148-151.

Boeschoten, F., ‘Energieproductie door reacties met lichte kernen’, *RCN Bulletin* 1, 6 (1957), 69-74.

Borhi, L., *Hungary in the Cold War, 1945-1956: Between the United States and the Soviet Union* (Central European University Press, 2004).

Boyer, P., *By the Bomb’s Early Light. American Thought and Culture at the Dawn of the Atomic Age* (New York: Pantheon, 1985).

Braams, C.M., ‘Fusie’, *Atoomenergie en haar toepassingen* (October 1964), 208-210.

Braams, C.M., *Het kronkelige pad van een bolbliksem* (Jutphaas: FOM-Rijnhuizen, 1983).

Braams, C.M., *Kernfusie in historisch perspectief* (Eindhoven University of Technology, 1990).

Braams, C.M., A.M. Van Ingen, B. Brandt, ‘The Joint European Torus’, *Atoomenergie en haar toepassingen* 12 (1973), 285-289.

- Braams, C.M., & J.C. Terlouw, 'Plasmafysica: een positiebepaling', *Nederlands Tijdschrift voor de Natuurkunde* (1973), 82-87.
- Braams, C.M., & P.M. Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research* (Bristol: IOP Publishing, 2002).
- Bruce Tarter, C., *The American Lab: An Insider's History of the Lawrence Livermore National Laboratory* (Baltimore: John Hopkins University Press, 2018).
- Bunte, E.H., *De mens tussen groot en klein: een hedendaagse tocht door wereld en ruimte* (The Hague: Ad. M.C. Stok, 1960).
- Capshew, J.H., & K.A. Rader, 'Big Science: Price to the Present', *Osiris* 7 (1992), 2-25.
- Chorofast, D.N., *Science and Technology* (Geneve: Springer, 2015).
- Cieraad, I., 'The Radiant American Kitchen: Domesticating Dutch Nuclear Energy', R. Oldenziel (ed.), *Cold War Kitchen: Americanization, Technology and European Users* (Cambridge: University Press, 2009).
- Clary, D., *The Quest for Fusion Energy: A Piece of the Sun* (New York: Abrams, 2014).
- Dedman, M., *The Origins and Development of the European Union, 1945-2008: A History of European Integration* (Routledge, 2009).
- Van Dieren, W., 'Bespreking Energierapport', *Beta* (February 1975).
- Van Dieren, W., 'Kritiek op de Club van Rome: hoe komen we van het tunneldenken af?', *NRC Handelsblad* (6 May 1972).
- Dijkhuis, G.C., 'A model for Ball Lightning', *Nature* 284 (1980), 150-151.
- Von der Dunk, H.W., 'Tussen welvaart en onrust. Nederland van 1955 tot 1973', *BMGN* 101 (1986).
- Dutch, R.S., *Let there be Light!: Nuclear Energy: a Christian Case* (Eugene: Wipf and Stock, 2017).
- Edelman, H.C.M., *Leven met atomen: de atoomkracht in dienst van welvaart en vrede* (Amsterdam: Meulenhoff 1957).
- Energie Anders, *Een jaar voortvarend*, (Rotterdam: 1979).
- Van Engen, J., *De onweerstaanbare opkomst van Jan Terlouw* (Alphen aan den Rijn: Sijthoff, 1982).
- European Commission, *JRC ISPRA: A 50 Years Pictorial History* (Brussels: European Communities, 2009).
- Geels, F.W. 'The Multi-Level Perspective on Sustainability Transitions: Responses to Seven Criticisms', *Environmental Innovation and Societal Transitions* 1.1 (2011), 24-40.
- Goedkoop, J.A., *Een kernreactor bouwen. Geschiedenis van de Stichting Energieonderzoek Centrum Nederland. Deel 1: periode 1945-1962* (Bergen NH, 1995).

- Goedkoop, J.A., 'Indrukken uit laboratoria in de Sovjet Unie', *Atoomenergie en haar toepassingen* 5 (May 1965), 87-101.
- Groot, H., 'Energieproductie bij kernreactie', *Atoom: Maandblad gewijd aan de atoomenergie en haar gevolgen voor mens en samenleving*, No. 10 (1947), 174-177.
- Hellema, D.C., *Nederland en de jaren zeventig* (Amsterdam: Boom, 2012).
- Van Hengel, G., 'De wederopstanding van Jonkheer de Brauw: Schaduwspeel van het kernenergie-debat in de jaren zeventig en tachtig,' A. Maas & T. Cocquet (ed), *Verborgene krachten: Nederlanders op zoek naar energie* (Hilversum: Verloren, 2011), 113-124.
- Herman, R., *Fusion: the Quest for Endless Energy* (Cambridge University Press, 1990).
- Hilgartner, S., 'The Dominant View of Popularization: Conceptual Problems, Political Uses,' *Social Studies of Science* 20 (1990), 519-539.
- Hoeneveld, F., *Een vinger in de Amerikaanse pap - Fundamenteel fysisch en defensieonderzoek in Nederland tijdens de vroege Koude Oorlog* (Utrecht: Freudenthal Instituut, Universiteit Utrecht, 2018).
- Ter Horst, D.Th.J., 'Some Remarks on Energy Storage', *Nuclear Instruments and Methods*, 4 (1959), 382-385.
- Jackson, J., *A Certain Idea of France: The Life of Charles de Gaulle* (Penguin Books Ltd, 2019).
- Kapczynski, J.M., *The German Patient: Crisis and Recovery in Postwar Culture* (University of Michigan Press, 2008).
- Kenneth Fowler, T., *The Fusion Quest* (Baltimore: John Hopkins University Press, 1997).
- Kersten, A.E., *Een organisatie van en voor onderzoekers: de Nederlandse Organisatie voor Zuiver-Wetenschappelijk Onderzoek (Z.W.O.) 1947-1988* (Assen, 1996).
- King, D., a.o., *Conclusions of the Fusion Fast Track Experts Meeting* (2001).
- Kinsella, W.J., 'A "Fusion" of Interests: Big Science, Government, and Rhetorical Practice in Nuclear Fusion Research', *Rhetoric Society Quarterly* 26, 4 (1996), 65-81.
- Kistemaker, J., *De veelvuldigheid der atoomkernen* (Amsterdam: Noord-Hollandse Uitgeverij, 1956).
- Kohring, M., *Wissenschaftsjournalismus. Forschungsüberblick und Theorieentwurf* (Konstanz: UVK Verlagsgesellschaft, 2005).
- Kroeger, P.G. & J. Stam, *De rogge staat er dun bij: macht en verval van het CDA, 1974-1998* (Amsterdam: Balans, 1998).
- Kurchatov, I.V., 'On the Possibilities of Producing Thermonuclear Reactions in a Gas Discharge,' *Nuclear Energy II*, vol. 4 (1957), 193-202.
- LaFollette, M.C., *Making Science Our Own: Public Images of Science, 1910-1955* (Chicago: The University of Chicago Press, 1990).

- Laird, F.N., *Solar Energy, Technology Policy, and Institutional Values* (Cambridge: University Press, 2001).
- Laird, F.N., & C.H. Stefes, 'The Diverging Paths of German and U.S. Policies for Renewable Energy: Sources of Difference', *Energy Policy* 37, 7 (2009), 2619-2629.
- Larsen, E., *Atomen regeren de toekomst: atoomwetenschap voor iedereen* (Bilthoven: H. Nelissen, 1962).
- Van Lente, D., 'Nuclear Power, World Politics, and a Small Nation: Narratives and Counternarratives in the Netherlands', D. Van Lente (Ed.), *The nuclear age in popular media* (New York: Palgrave Macmillan, 2012).
- Van Lente, D., (Ed.), *The nuclear age in popular media* (New York: Palgrave Macmillan, 2012).
- Le Pair, C. & J. Volger (eds), *Physics in the Netherlands: a selection of Dutch contributions to physics in the first 30 years after the Second World War, Volume II* (Utrecht, 1982).
- Lewenstein, B.V., 'From Fax to Facts: Communication in the Cold Fusion Saga', *Social Studies of Science*, vol. 35 (1995), 403-436.
- Lijphart, A., *Verzuiling, pacificatie en kentering in de Nederlandse politiek* (Haarlem: Becht, 2008).
- Lintsen, H., a.o., *Tachtig jaar TNO* (Den Haag: Barlock, 2012).
- Van Loon, A.J., *50 Years of Nuclear Fission* (Arnhem: KEMA, 1989).
- Lysen, E.H., *Eindeloze energie: alternatieven voor de samenleving* (Utrecht: Spectrum, 1977).
- Maas, A., 'De bietenakker van boer Boon: schop in eigen bodem 2,' in A. Maas & T. Cocquet (ed), *Verborgen krachten: Nederlanders op zoek naar energie* (Hilversum: Verloren, 2011), 103-112.
- McGray, W.P., "'Globalization with Hardware": ITER's Fusion of Technology, Policy, and Politics", *History of Technology* , 26, 4 (2010).
- McCray, W.P., *The Visioneers: How a Group of Elite Scientists Pursued Space Colonies, Nanotechnologies, and a Limitless Future* (Princeton University Press, 2012).
- Meadows, D., a.o., commented by the Club of Rome, *Rapport van de Club van Rome. De Grenzen aan de groei* (Utrecht, 1972). Aulapocket 500.
- Van Noort, W., *Bevlogen bewegingen: een vergelijking van de anti-kernenergie-, kraak- en milieubeweging* (Nijmegen: SUA, 1988).
- Ornstein, L.Th.J. 'Thermonucleaire reactoren', *Atoomenergie en haar toepassingen* 10 (1969).
- Peters, P., 'De toekomst volgens de Club van Rome', *Kronieken van Duurzaam Nederland: Houdbare Economie* (NCDO 1997).
- Price, D.S., *Little Science, Big Science* (New York: Columbia UP, 1986).

- Romero, F., 'Cold War historiography at the crossroads', *Cold War History* 14 (2014), 685-703.
- Sagdeev, R.Z. & S. Eisenhower, *The making of a Soviet Scientist: my adventures in nuclear fusion and space from Stalin to Star Wars* (New York: Wiley, 1994).
- Sanders, G.A., *Energie op leven en dood* (Amsterdam: Wetenschappelijke Uitgeverij, 1972).
- Schmidt, J.E.T., *Perspectives on cutback management in public organisations: what public managers do* (Leiden: Leiden University, 2020).
- Schram, D.C., *Plasma's, vuur, en wat nu?* (Eindhoven: Technische Universiteit Eindhoven, 2005).
- Seife, C. *The Sun in a bottle: The Strange History of Fusion and the Science of Wishful Thinking* (Viking Publishers, 2008).
- Shaw, E.N., *Europe's Experiment in Fusion: The JET Joint Undertaking* (Amsterdam: Elsevier Science Publications, 1990).
- Shell Nederland B.V., *Zonne-energie* (The Hague: Shell Nederland B.V., 1978).
- Sluyterman, K., *Concurreren in turbulente markten, 1973-2007: Geschiedenis van Koninklijke Shell, deel 3* (Amsterdam: Boom, 2007).
- Stacey, W.M., *The Quest for a Fusion Energy Reactor : An Insider's Account of the INTOR Workshop* (London: University Press, Incorporated, 2010).
- Streefland A.H., *Jaap Kistemaker en uraniumverrijking in Nederland 1945-1962* (Amsterdam: Prometheus, 2017).
- Stuurman, S., *Verzuiling, Kapitalisme en Patriarchaat* (Nijmegen: Radboud University, 1983).
- Terlouw, J.C., 'Thermonucleair onderzoek', *Natuur en Techniek* 5 (1968), 1-10.
- Toonder, M., 'Tom Poes en de Bovenbazen', *Volkskrant* (28 August 1963).
- Touwen, J., *Coordination in Transition: The Netherlands and the World Economy, 1950-2010* (Leiden: Brill, 2014).
- Verbong, G.P.J., and J.A.C. Lagaaij, 'Belofte van Kernenergie', W. Uriccho ed., *Techniek in de twintigste eeuw deel 2: defstoffen, energie, chemie* (Nijmegen: Vereniging voor de Geschiedenis van de Twintigste Eeuw, 1997).
- Verbong, G.P.J., a.o., *Een kwestie van lange adem: de geschiedenis van duurzame energie in Nederland* (Den Bosch: Uitgeverij Aeneas BV, 2001).
- Verbong, G.P.J., *Op weg naar de markt: de geschiedenis van ECN 1976-2001* (Petten: ECN, 2005).
- VDEN, *Toekomstige energiesituatie in Nederland* (1980).
- Vrouwe, A., *Hittebarrière: 50 jaar plasmafysica bij FOM-Rijnhuizen 1959-2009* (Houten: Drukkerij Badoux, 2009).

- Van Vugt, F., *De hardheid van de nucleaire optie: een onderzoek naar de doorgang van een verguisde technologie* (Petten: ECN, 2004).
- Weingart, P., *Die Stunde der Wahrheit? Zum Verhältnis der Wissenschaft zu Politik, Wirtschaft und Medien in der Wissensgesellschaft* (Weilerwist, 2001).
- Weingart, P., 'Eugenics – Medical or Social Science?', *Science in Context* 8 (1995), 197-207.
- Weingart, P., & J. Lentsch, *Wissen Beraten Entscheiden. Form und Funktion wissenschaftlicher Politikberatung in Deutschland* (Weilerwist, 2008).
- Westra, M.T., *Kernfusie: een zon op aarde* (Nieuwegein: FOM-Rijnhuizen, 2006).
- Withley, R., 'Introductory Essay: Knowledge Producers and Knowledge Acquirers. Popularization as a Relation between Scientific Fields and Their Publics,' in T. Shinn, R. Withley (ed.), *Expository Science: Forms and Functions of Popularization* (Dordrecht: Reidel, 1985), 3-28.
- WKE, *Kernenergiemora* (Vereniging Milieudefensie, 1972).
- Zeilstra, J.A., *Visser 't Hooft: Een leven voor de Oecumene, 1900-1985* (Skandalon: Middelburg, 2018).
- Zischka, A., *Automaten Kontra Malthus* (Tilburg: Nederlands Boekhuis, 1965).
- Zischka, A., *De wereld is nog steeds rijk: een optimistische inventarisatie* (Amsterdam: Keesing B.V., 1976).