The Petro-atom

A century of ubiquitous oil involvement in nuclear energy, 1895-1993

PhD dissertation presented by Michiel Bron

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Michiel Bron

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Abbreviations

Please find below an overview of the abbreviations used in this dissertation (including company names). Both the oil and nuclear industries and the academic subfield of Science, Technology, and Society Studies (STS) have a strong tradition in developing abbreviations and jargon. In this thesis, I have tried to limit the use of these abbreviations, and only apply them to improve readability or when the public use of the abbreviation is more common than the full technical term.

AEC	Atomic Energy Commission (US)
AEI	American Enterprise Institute
Amoco	American Oil Company
ANT	Actor Network Theory
API	American Petroleum Institute
Aramco	Arabian American Oil Company
ASI	Adam Smith Institute
B-10	Boron-10
BP	British Petroleum
BPM	*Betaafsche Petroleum Maatschappij*
CEA	*Commissariat à l'énergie atomique*
CEO	Chief executive officer
CFP	*Compagnie Française Petroleum*
CIA	Central Intelligence Agency
CO2	Carbon dioxide
CPS	Centre for Policy Studies
CTA	Constructive Technology Assesment
ENA	*École Nationale d'Administration*
ENI	*Ente Nazionale Idrobarburi*
ERDA	Energy Research and Development Agency
FAECT	Federation of Architects, Engineers, Chemists, and Technicians
FEE	Foundation of Economic Education
GE	General Electric
HTGR	High Temperature Gas Cooled Reactor
IAEA	International Atomic Energy Agency

IEA	Institute of Economic Affairs (UK)
ISL	In Situ Leaching
ITER	International Thermonuclear Experimental Reactor
JCAE	Joint Committee of Atomic Energy
JET	Joint European Torus
JNAI	Jersey Nuclear-Avco Isotopes
LNG	Liquified Natural Gas
MLP	Multi-Level Perspective
NASA	National Aeronautics and Space Administration
NMR	Nuclear Magnetic Resonance
NRC	Nuclear Regulatory Commission
OCAW	Oil, Chemical and Atomic Workers International Union
OHTE	Ohmically heated Toroidal Experiment
OPEC	Organization of the Petroleum Exporting Countries
OWIU	Oil Workers International Union
Ph.D.	Doctor of Philosophy
RCN	*Reactor Centrum Nederland*
SCOT	Social Construction of Technology
Socony	Standard Oil of New York
STS	Science and Technology Studies
Texaco	The Texas Company
TFTR	Tokamak Fusion Test Reactor
TNO	*Nederlandse Organisatie voor toegepast natuurwetenschappelijk onderzoek*
TRIGA	Training, Isotopes, General Atomic
U-235, U-238	Uranium-235, Uranium-238
UF6	Uranium Hexafluoride
UGCCWA	United Gas, Coke and Chemical Workers of America
UK	United Kingdom
Urenco	Uranium Enrichment Company
US	United States of America
WOCA	World Outside Communist Areas

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CHAPTER 1

1

1. Introduction

The oil actors that shaped nuclear energy

1

Introduction

Seated in a room filled with journalists, shareholders, and cigarette smoke, the chairman of US oil giant Gulf Oil, the geoscientist Ed Brockett Jr., presented the company's 1967 annual report. The year 1967 had been busy for the oil major, and its developments would prove to be turning points in the company's history. For the eighth consecutive year, Gulf established new record highs in net income, cash dividends paid, and in volumes produced, processed, and sold in most categories of the company's business. Gulf accomplished these records despite many difficulties. An oversupply of products in the chemical industry resulted in depressed prices, a conflict in the Middle East closed shipping through the Suez Canal, and a civil war in Nigeria halted further production development in that country.[2]

Regardless of the pride in achieving these results in difficult circumstances, however, Gulf's board also expressed worries about sustaining this streak of success for the long-term. Although Brockett expected a worldwide adequacy of petroleum reserves for the coming decades, he noted that oil production in the United States had not kept pace with growing consumption. Also, increasing political and public pressure in the US forced the oil industry to reduce air and water pollution from petrochemical products. More importantly, however, governments in the Global South had already attempted to nationalize Gulf's assets, and Gulf's board expected this development to continue. The company needed alternative investments to preserve its growth.[3]

With their oil assets under pressure, one alternative for the major oil company to diversify had already emerged: nuclear energy. In 1967, Gulf launched an exploration program for uranium. Mainly focused in the western areas of the United States and Canada, the company aimed to use its geophysical expertise to search for the minerals needed as fuel in the rapidly growing nuclear industry. The company explicitly framed these investments as part of a wider strategy to get involved in the whole nuclear sector, and on this strategy the company delivered. On the nineteenth of October of the same year, Gulf announced that General Atomic had become a wholly owned subsidiary of the oil company. General Atomic, with a staff of more than two thousand people, was internationally recognized as a pioneer in the development of experimental nuclear research and the manufacturing of high-temperature gas-cooled reactors, known as HTGR, for electric nuclear power generation. With Gulf as its new owner, the subsidiary further developed the HTGR, and expanded its experimental nuclear research projects.[4]

Much of the historiography on the development of nuclear energy is state-centric, heavily focussing on state actors as the guiding forces of national nuclear strategies, instead of companies like Gulf.[5] As

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[2] E.D. Brockett and B.R. Dorsey, 'Letter to the Shareholders,' Gulf Oil Corporation, *1967 Annual Report Gulf Oil Corporation* (Pittsburgh: Gulf Oil Corporation, 1968), 3-5.
[3] Ibidem, 3-5.
[4] Gulf Oil Corporation, *1967 Annual Report Gulf Oil Corporation*, 18.
[5] Based on the foundations laid down by authors such as Loma Arnold and Margaret Gowing on British nuclear technological development, Gabrielle Hecht on France, Joachim Radkau on West Germany, and Robert Anderson on India, later nuclear histories have focused more and more on specific aspects in particular developments

this dissertation argues, nuclear developments were shaped not only by the autonomous goals of the state alone, but also by special interests of particular social groups, or "vested interests".[6] Industrial parties such as Westinghouse and General Electric, (petro)chemical companies such as DuPont, and various refinery construction and oilfield services companies, including Stone & Webster, dominated the US-based civil nuclear industry, often crossing the boundaries of the nation state. Also in other Western countries, companies like Siemens (Germany), Rio Tinto Zinc (Britain), and *Werkspoor* (Netherlands) played crucial roles in the development of national, and international, nuclear industries. Detailed studies of these industrial actors and their influence on nuclear developments, however, are still largely lacking.[7]

To address this gap, this dissertation specifically focusses on the development of nuclear energy through the lens of the oil industry. Gulf Oil was indeed not the only oil company getting involved in nuclear energy in the late 1960s. When Gulf announced its entrance into the nuclear industry, similar strategies were discussed in the board rooms of almost all of the major Western oil companies. Also in 1967, the Mobil Oil launched a large-scale project to use their old oil wells to search for uranium.[8] Not much later, Exxon established a subsidiary called Jersey Nuclear (later Exxon Nuclear) which would engage in various types of nuclear research, uranium mining and enrichment.[9] On the other side of the Atlantic, Shell acquired a stake in the Dutch uranium enrichment project in 1967, and in the early 1970s *Compagnie Française Petroleum* (CFP, later Total) embarked on new investments in uranium mining in former French colonies like Mauritania and Gabon.[10] Some mid-sized oil companies had already invested in the nuclear industry for a longer time; especially Phillips Petroleum and Kerr-McGee were involved in several uranium mining projects during the 1950s. Also, there were many small oil companies focusing on both oil and uranium exploration and extraction, and there were ubiquitous

within countries. Margaret Gowing, *Independence and Deterrence: Britain and Atomic Energy, 1945-1952* (Macmillan: London, 1974); Gabrielle Hecht, *The Radiance of France: Nuclear Power and National Identity after Second World War* (Paris: Editions La Decouverte, 2009); Joachim Radkau, *Aufstief und Krise der deutschen Atomwirtshaft 1945-1965: Verdrängte Alternativen und der Ursprung der nuclearen Kontroverse* (Rowohlt: Reinbek bei Hamburg, 1983); Robert Anderson, *Nucleus and Nation: Scientists, International Networks, and Power in India* (Chicago University Press: Chicago, 2010); Sercin Topçu, *La France Nucléaire: L'art de gouverner une technologie contestée* (Seuil: Paris, 2013); Karina Kalmbach, 'Revisiting the nuclear age: State of the art research in nuclear history', *Neue Politische Literatur* 1 (2017), 52.

[6] Peter A. Hall, 'Policy Paradigms, Social Learning, and the State: The Case of Economic Policy Making in Britain', *Comparative Politics* 25, 3 (1993), 275-296.

[7] With a few exceptions: Fabio Lavista, 'Political Uncertainty and Technological Development: The Controversial Case of AGIP Nucleare (1956-1962)', Elisabeth Bini and Igor Londero (eds), *Nuclear Italy: An International History of Italian Nuclear Policies during the Cold War* (Trieste: University Press Italiane, 2017), 41-56; Marcia Rorke, 'The Manhattan Project, the Du Pont Company, and the Management of new product development' (Ph.D. Diss., George Washington University, 2003); Pap Ndiaye, *Nylon and bombs: DuPont and the March of Modern America*, trans. Elborg Foster (Baltimore: Johns Hopkins University Press, 2007); David A. Hounshell and John Kenly Smith, jr., *Science and Corporate Strategy: Du Pont R&D, 1902-1980* (Cambridge, UK: Cambridge University Press, 1989).

[8] 'Double-Duty Prospectors' (1968), 19, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center of American History), box 2.207/F120.

[9] 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' (Philadelphia: The Chemical Heritage Foundation. Oral History Transcript #0144, 11 May 1995), 19.

[10] Jaap Kistemaker, *De geschiedenis van het Nederlandse Ultracentrifuge Project: hoe een nieuwe industrie ontstond* (Amsterdam: FOM-Instituut voor Atoom- en Molecuulfysica, 1993), 18-23; Abel Streefland, *Jaap Kistemaker en uraniumverrijking in Nederland, 1945-1962* (Amsterdam: Prometheus, 2017), 256; Accord de Transfert. Total S.A. Archives. Box. 50ZZ520. Folder 6. Paris.

individuals who had left careers in the oil industry to join the emerging nuclear industries in the United States, France, United Kingdom, and the Netherlands from the 1940s onward.[11]

As this dissertation argues, the ubiquitous intertwining of nuclear energy with the oil industry from 1967 onward was a product of already existing technological spillovers between the oil industry and the development of early quantum mechanics dating back to the beginning of the twentieth century. From the moment that Becquerel and the Curies sparked scientific interest in radioactivity and industrial parties in both Europe and the United States increasingly marketed products containing radium, oil actors were involved in the exploration, extraction, transport and selling of radioactive minerals, and research into atomic physics.[12] This link with the oil industry was reinforced when early geophysicists found ways to locate oil by measuring radioactive decay, and geochemists started analyzing gases and liquid fuels based on measurements of mass-to-charge ratio of ions. From that moment, the oil industry invested in the development of geoscientific technologies based on early quantum mechanics that would, together with the capital and large-scale project management experience present in the sector, put the industry in a leading position to get involved in the early development of nuclear energy during and after the Second World War.

These technological spillovers between the oil sector and early nuclear energy developments were shaped by many individual oil actors moving between both industries over the span of their careers. These actors shared a background in (geo)physics or chemical engineering, often with some training in atomic physics during their studies, before they entered the oil industry. The main part of this cohort of scientist-engineers graduated in the 1920s and 1930s and experienced the Second World War and early developments of nuclear energy while being employed within the oil industry. During the first decades after the war, they became involved in setting up nuclear industries in the United States and Western European countries such as France, the UK, and the Netherlands. Many of them retired during the late 1970s and 1980s. This overlapping network of actors, based on shared technologies and knowledge, created a basis for many oil companies to diversify into nuclear energy during the 1950s, 1960s and early 1970s.

The 1970s marked the heydays of oil involvement in nuclear energy. During this period, many oil firms invested in a variety of projects throughout the nuclear fuel cycle. In the United States, a 1976 Federal Trade Commission report found that twelve of the top 25 uranium mining and milling companies in the US were also (or were owned by) oil firms, including five of the top ten.[13] By 1981 about 45% of all US uranium was produced by oil companies.[14] Exxon Nuclear and Shell invested in various uranium

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[11] Raye Carleson Ringholz, *Uranium Frenzy: Boom and Bust on the Colorado Plateau* (W.W. Norton & Co., Inc, 1989); Michael A. Amundson, *Yellowcake Towns: Uranium Mining Communities in the American West* (University Press of Colorado, 2002), 24-25; Tom Zoellner, *Uranium: War, Energy, and the Rock that Shaped the World* (New York: Viking, 2009), 133-135.

[12] See for the hype of radium during the first decades of the twentieth century: Maria Rentetzi, *Seduced by Radium: How Industry Transformed Science in the American Marketplace* (Pittsburgh: University of Pittsburgh Press, 2022); John Samuel Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth century* (Berkeley: University of California Press, 2000), 2-4; Eric W. Mogren, *Warm Sands: Uranium Mill Tailings Policy in the American West* (Albuquerque: University of New Mexico Press, 2002), 20-21; Robynne N. Mellor, *The Cold War Underground: An Environmental History of Uranium Mining in the United States, Canada, and the Soviet Union, 1945-1991* (Ph.D. Diss., Georgetown University, 2018).

[13] Bureaus of Competition and Economics, *Federal Energy Land Policy: Efficiency, Revenue and Competition* (US Government Printing Office, 1976), 684A.

[14] P. Bauder and A.-E. Wagner, 'Uranium: Market, Reserves and Industry,' *Energy Exploration and Exploitation 1981* (New York: Sage, 1981), 5-28.

enrichment projects, including experimental research into laser enrichment. Gulf (together with Shell from 1973 onward) experimented in General Atomic with developing the HTGR, breeder reactors and even nuclear fusion reactors. Some oil companies also participated in nuclear waste reprocessing and storage. With these investments, oil companies expressed an ambition to become full-fledged energy companies and provide solutions for future resource scarcity, environmental pollution, and population growth. Many of these firms, however, would withdraw their investments in nuclear energy during the 1980s and early 1990s in the context of a rapidly changing market with decreasing oil prices and take-over battles, and the influence of a new generation of managers and planners who were more focused on short-term profits.

Studying both the intended and accidental spillovers between the oil and nuclear industries means operating in the relatively new, and not well defined, subfield of energy history. Energy historians work on the intersection of economic, business, environmental and labor history, and the history of science, technology, and instruments. By doing so, they overcome some of the flaws of more specialized subfields. Business historians have often framed the nuclear diversification strategies of, especially major, oil companies during the 1970s and 1980s as a short-lived, not well executed, even panicky reaction to the 1973/74 oil crisis.[15] In this framing the investments in nuclear energy are often regarded as part of the new management tradition of diversification that originated in mostly US and Western-European business cultures during the 1960s.[16] This dissertation shows how nuclear diversification was also, however, part of a more structural entanglement between both industries with roots in geoscientific and engineering spillovers of people, technologies, and practices.

Besides business history, there is a vast body of literature in the history of technology, physics, and instrumentation that studies oil companies as a driving force for technological innovation in a wide variety of fields outside the oil industry, and long before the 1960s and 1970s. In this literature however, an appreciation of how these spillovers fitted within wider business strategies and influenced ideas about the development of new energy sources in the oil industry is relatively understudied.[17] By positioning within the field of energy history, this dissertation weaves together the more specialized subfields of business history and the history of technology and physics, and answers the questions how the oil industry got involved in the development of nuclear energy and why this involvement seemed to halt during the 1980s.[18]

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[15] Francesco Parra, *Oil politics: a modern history of petroleum* (London: I.B. Tauris, 2010), 212-213.

[16] Keetie Sluyterman, *Concurreren in turbulente markten, 1973-2007: Geschiedenis van Koninklijke Shell, deel 3* (Amsterdam: Boom, 2006), 96-99; Alfred D. Chandler, *Strategy and Structure: Chapters in the History of the Industrial Enterprise* (Cambridge, M.A.: MIT Press, 1962); N.D. Fast, *The Rise and Fall of Corporate New Venture Divisions*, vol. III, research for Business Decisions (Ann Arbor: UMI Research Press, 1978).

[17] E.g. Carsten Reinhardt, *Shifting and Rearranging: Physical Methods and the Transformation of Modern Chemistry* (Sagamore Beach, MA: Science History Publications/USA, 2006); Michael Grayson, *Measuring Mass: From Positive Rays to Proteins* (Chemical Heritage Foundation, 2002); Tom Lassman, *Edward Condon's Cooperative Vision: Science, Industry, and Innovation in Modern America* (Pittsburg: University of Pittsburgh Press, 2018).

[18] In doing so this thesis is inspired by the work of Aitor Anduaga and Geoffrey Bowker in the field of energy history: Aitor Anduaga, *Geophysics, Realism, and Industry: How Commercial Interests Shaped Geophysical Conceptions, 1900-1960* (Oxford: Oxford University Press, 2016)**;** Geoffrey C. Bowker, *Science on the Run: Information Management and Industrial Geophysics at Schlumberger, 1920-1940* (Cambridge: MIT Press, 1994).

Weaving together the histories of science, technology, and business

The longer history of diversification

The idea of diversification as a strategy to spread investments risks has a long history, sometimes even being associated with texts in the *Talmud*.[19] In a more economic context, the Dutch-Swiss physicist Daniel Bernoulli argued in his 1738 article on the St. Petersburg paradox that to avoid risk, investors would want to "divide goods which are exposed to some danger into several portions rather than to risk them all together."[20] Although these early notions of "diversification strategies" have sparked the interest of various business historians studying investment strategies in a multitude of early capitalist environments, the popularization of the terminology only took place after the introduction of Charles Darwin's conceptualization of "diversity" as a way to indicate the level of an ecosystem functioning.[21] This concept subsequently was translated to financial markets, where there was an increased awareness of the benefits of financial diversification. Although the focus was more on geographical than on sectoral diversification, after the First World War several firms, including many oil companies, already started new (petro)chemical divisions outside their focus area.[22] From there, the concept was further developed, and slowly incorporated into early studies of risk management that became popular among individual investors and companies after the Second World War. These studies recommended diversification as way to limit vulnerability to disruptions in a firm's sector and to maintain business profits.[23] During the 1950s and 1960s, diversification strategies regained popularity among business managers as an alternative to costly market insurances and thanks to rapid economic growth in Western countries (providing the companies with the capital needed for the diversification investments).[24]

The strategy to divide risks by diversification was supported by the emergence of a new emphasis on long-range planning within, mainly US, business during the 1950s and 1960s. Existing trends were analyzed by futurists and extrapolated into the future, after which professional managers were tasked with incorporating these futuristic visions into their long-term corporate strategies. Prominent management thinkers, such as Peter F. Drucker, also reinforced the idea that managers, when properly trained in the right management techniques, should be able to successfully enter new fields with their

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[19] Ola Mahmoud, 'The Origin of Diversification: An Evolutionary Theory,' *SSRN Electronic Journal* (2017), 1.

[20] Daniël Bernoulli, 'Exposition of a new theory on the measurement of risk,' *Econometrica* 22 (1738), 23-36; Mahmoud, 'The Origin of Diversification: An Evolutionary Theory,' 1.

[21] Janette Rutterford and Dimitri P. Sotiropoulos, 'Putting all their eggs in one basket? Portfolio diversification 1870-1902,' *Accounting History Review* 26, 3 (2016), 285-305; Dimitri P. Sotiropoulos and Janette Rutterford, 'Financial diversification strategies before First World War: Buy-and-hold versus naïve portfolio selection,' *Business History* 61, 7 (2019), 1175-1198; Mahmoud, 'The Origin of Diversification: An Evolutionary Theory,' 1-2.

[22] Janette Rutterford and Dimitri P. Sotiropoulos, 'Financial diversification before modern portfolio theory: UK financial advice documents in the late nineteenth and the beginning of the twentieth century,' *The European Journal of the History of Economic Thought* 23, 6 (2016), 919-945; Joost Jonker and Jan Luiten van Zanden, *Van nieuwkomer tot marktleider, 1890-1939: Geschiedenis van Koninklijke Shell, deel 1* (Amsterdam: Boom, 2006), 324-411.

[23] John D. Martin and Akin Sayrak, 'Corporate Diversification and Shareholder Value: a survey of recent literature,' *Journal of Corporate Finance* 9 (2003), 37-57.

[24] Georges Dionne, 'Risk Management: History, Definition, and Critique,' *Risk Management and Insurance Review* 16 (2013), 147-166; J.C. Chambers, S.K. Mullick, and D.D. Smith, 'How to choose the right forecasting technique', *Harvard Business Review* (1971); Sluyterman, *Concureren in Turbulente Markten*, 96. Also governments increasingly sought refuge to diversification in their energy policies, but this, however, was different kind of diversification – one more tied to securing their overall energy mix. Daniël Yergin, 'Ensuring Energy Security,' *Foreign Affairs* 85, 2 (2006), 69-82.

companies.[25] According to many business historians, this new style of management provided the framework for major oil companies to incorporate their diversification strategies at the end of the 1960s and during the early 1970s. Oil companies like Shell, Gulf Oil, Texaco and Exxon started to invest in a wide range of activities, including building and managing hotels, offering insurance and financial services, manufacturing candles and animal feed, operating cable television channels, and so on. More importantly, however, were their investments in coal production, and developing other alternative energy sources like solar, geothermal, and nuclear energy, thus allowing oil companies to rebrand as "energy companies."[26]

In hindsight, the emergence of the diversification strategy within the management levels of oil industry is often deemed nonsensical. In his insider's history of oil, former Secretary General of the Organization of the Petroleum Exporting Countries (OPEC) Francisco Parra describes the diversification strategy of the major Western oil companies in the 1970s as "sometimes bizarre, comic even" and states that the different oil companies inevitably had to conclude that these practices were not profitable for them and that their ventures "were dumped as quickly and quietly as possible" already at the end of the 1970s.[27] Also, various company histories frame the "diversification episode" of the 1970s as a way to explain the – supposedly almost inevitable – refocus onto the company's core business after a decade of investing based on "false expectations" and "rosy views".[28]

This explanation, however, ignores the structural involvement of the oil industry in nuclear developments, already starting before the Second World War, and does not fully explain why investing in nuclear energy was regarded as a valid strategy for oil companies (which was not necessarily linked to the "main diversification period" of the 1970s as this thesis shows). Already during the Second World War, Standard Oil of New Jersey and Standard Oil of New York (the companies making up today's ExxonMobil) as well as Standard Oil of Indiana (later Amoco – today part of BP) engaged in the Manhattan Project. Even before entering the war, scientists at Standard Oil of New Jersey studied the potential role of nuclear fission in electricity generation, and several oil companies invested in geophysical and chemical technologies based on early knowledge about radioactive decay and quantum mechanics. Therefore, this dissertation argues that the investments of oil companies into alternative energy sources, were not simply the result of a spike in popularity of diversification as a corporate strategy among oil managers. With nuclear energy in particular, such investments were a product of a longer entangled history between the oil and nuclear sectors. This entanglement was shaped by oil geoscientists, versed in atomic physics during the 1920s to 1940s, who had established a network of scientists, industrialists and policy makers spanning both governmental organizations and

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[25] Peter F. Drucker, *The Practice of Management* (New York: Harper and Row, 1954); Chandler Jr., *Strategy and Structure: Chapters in the History of the Industrial Enterprise*; Fast, *The Rise and Fall of Corporate New Venture Divisions*; Sluyterman, *Concureren in Turbulente Markten,* 96.

[26] Joseph A. Pratt and William E. Hale, *Exxon: Transforming Energy, 1973-2005* (Austin: Dolph Briscoe Center for American History, 2013); Grayham D. Taylor, *Imperial Standard: Imperial Oil, Exxon, and the Canadian Oil Industry since 1880* (University of Galgary Press, 2019); Sluyterman, *Concureren in Turbulente Markten,* 102-109.

[27] Parra, *Oil politics: a modern history of petroleum*, 212-213.

[28] Pratt and Hale, *Exxon*, 188; Michael Ollinger, *Organizational Form and Business Strategy in the US Petroleum Industry* (Lanham, Maryland: University Press of America, 1993), 88-92; W.M. Cohen, *Firm heterogeneity, investment, and industry expansion: A theoretical framework and the case of the uranium industry* (Ph.D. Diss, Yale University, 1981); W. Lamont, 'Cash flow and investment: evidence from internal capital markets,' *The Journal of Finance* 52, 1 (1997), 83-109.

the oil and nuclear industries. When these actors became managers of their oil companies during the 1950s and 1960s, they were able to steer their companies into nuclear diversification projects.

In the 1980s, however, a new cadre of managers steered the same companies *out* of nuclear. This thesis argues that although various oil firms' planning departments and their reports underpinned the long-term strategy to get involved with nuclear energy during the 1960s and 1970s, those departments also became the gateway for a new generation of actors to enter the oil industry. This new generation had often graduated in economics and business administration and joined the newly established planning departments during the 1950s and 1960s before finally becoming managers during the 1980s. As executives, they often put an end to their employers' long-term diversification efforts – including diversification into nuclear energy – in favor of short-term profits and increasing shareholder value.

Geoscience spillovers

To show that these oil diversification projects into nuclear energy had a more structural and long-lasting relation than traditionally presumed, this thesis connects business history with the fields of the history of science, technology, and instrumentation. This dissertation argues that the early oil involvement in nuclear energy dates back to the development of early geosciences during the first decades of the twentieth century.[29] As chapter 2 shows, the first technologies based on early quantum mechanics that later would play important roles in establishing the first nuclear industrial projects were developed within the oil industry during the 1930s and early 1940s to search for oil and analyze petroleum products. Both geophysical and chemical technologies, like radioactive well logging and mass spectrometers, found uses in the oil sector and uranium exploration and enrichment. Also, scientists and engineers who were grounded in the development of early geochemistry, geophysics and geology worked in both the oil and nuclear industries during their careers.

Of course, the focus on contributions of oil firms, especially firms with a downstream petrochemical division, to the history of scientific instrumentation in the geosciences is not new. Several historians have cited a variety of oil companies, ranging from Humble Oil to Shell and BP, as early sites of the development of laboratory instrumentation such as mass spectrometry, infrared spectrometry, gas chromatography, and High-Pressure Liquid Chromatography.[30] Also, especially the first chapters of this

[29] In this dissertation, I explicitly make use of the term 'geosciences' over 'geophysics'. Multiple historians have argued that oil companies increasingly invested geophysics as the primary methodology in oil exploration since the late 1940s - a shift that historians Naomi Oreskes and Ronald Doel have argued resulted from a change in methodological and epistemic expectations prioritizing physics and highly mathematized fields over more empirical ones. However, as this dissertation shows, technologies derived from early geochemistry (and geology) also spilled over from the oil to the nuclear industry. Naomi Oreskes and Ronald E. Doel, 'Physics and Chemistry of the Earth,' Mary Jo Ney (eds), *The Cambridge History of* Science, vol. V: *Modern Physical and Mathematical Sciences* (Cambridge: Cambridge University Press, 2002), 544; Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life* (Princeton, NJ: Princeton University Press, 1995); Roberto Cantoni, *Oil Exploration, Diplomacy and Security in the Early Cold War: The Enemy Underground* (New York: Routledge, 2017), 4-5.

[30] Reinhardt, *Shifting and Rearranging*; Grayson, *Measuring Mass*; Lassman, *Edward Condon's Cooperative Vision*; José Ramón Bertomeu-Sánchez and Antonio García-Belmar, 'Practice and Experiment: From Laboratory Research to Teaching and Policy-Making,' Peter J. T. Morris (eds), *A Cultural History of Chemistry in the Modern Age* (London: Bloomsbury, 2022), 51-72; Keith A. Nier, Alfred L. Yergey, and P. Jane Gale (eds), *The Encyclopedia of Mass Spectrometry volume 9 – Historical Perspectives Part A: The Development of Mass Spectrometry* (Amsterdam: Elsevier, 2016).

dissertation draw heavily on the research conducted by Aitor Anduaga on the influence of the, primarily, US oil industry on the development of the academic geosciences during the interwar period, and are inspired by Geoffrey Bowker's studies of the development of electric well logging techniques by the French oil service company Schlumberger.[31]

In fact, for the attentive eye, the historiography is littered with individual references to oil actors involved in "nuclear" technologies, investments and decision making. Within the history of science, specifically within the subfield of science diplomacy, there are several studies uncovering the overlap of some specific technologies and instruments used in both the oil and nuclear industries. Roberto Cantoni and Simone Turchetti have shown how surveillance technologies, like radioactive tracers and aerial mapping, were deployed by state actors and geoscientists in the context of the Cold War to search for both uranium and oil.[32] Kai-Hendrik Barth analyzed the transformation of seismology from a small academic discipline, with uses in early oil exploration, to a large academic-military-industrial enterprise during the 1960s due to the applications in the enforcement of nuclear test ban treaties.[33] The other way around, historians Scott Kaufman and Victor McFarland examined the quest for applications of nuclear energy in the search for oil, sometimes briefly mentioning the involvement of some specific oil companies, both with nuclear explosions in Project Plowshare and in nuclear fracking.[34]

Still, an overarching study of the flows of people, money, materials, technologies, methods, concepts, and knowledge between the oil industry and other sectors, like the early nuclear industry, remains to be written.[35] To show how the geoscientific instruments that were developed within the oil sector and used in the nuclear industry shaped the later diversification of oil actors into nuclear energy, this dissertation uses the concept of the "oil spillover" developed by Cyrus Mody. An "oil spillover" encompasses the various flows of actors, capital and technology between the oil industry and various other fields of scientific research, energy development and technological applications. The "spillover" sometimes can be a two-way flow, or flows into the oil industry, but mostly the concept refers to flows outward from oil firms.[36]

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[31] Anduaga, *Geophysics, Realism, and Industry*; Bowker, *Science on the Run*.
[32] Cantoni, *Oil Exploration, Diplomacy and Security in the Early Cold War*; Simone Turchetti and Peder Roberts (eds), *The Surveillance Imperative: The Rise of the Geosciences during the Cold War* (London/New York: Palgrave, 2014).
[33] Kai Hendrik-Barth, 'The Politics of Seismology: Nuclear Testing, Arms Control, and the Transformation of a Discipline,' *Social Studies of Science* 33, 5 (2003), 743-781.
[34] Scott Kaufman, *Project Plowshare: The Peaceful Use of Nuclear Explosives in Cold War America* (Ithaca: Cornell University Press, 2013); Victor McFarland, 'American Politics and Energy Transitions in the 1970s,' Stephen G. Gross & Andrew Needham (eds), *New Energies: A History of Energy Transitions in Europe and North America* (Pittsburgh: University of Pittsburgh Press, 2023), 95-106.
[35] Cyrus C.M. Mody and Michiel Bron, 'Scientific Instruments and/as Oil Spillovers: The Case of Oil Involvement in the Manhattan Project', *Nuncius* (forthcoming).
[36] Cyrus C.M. Mody, 'Spillovers from Oil Firms to US Computing and Semiconductor Manufacturing: Smudging State-Industry Distinctions and Retelling Conventional Narratives', *Enterprise and Society* (2022), 1-26.

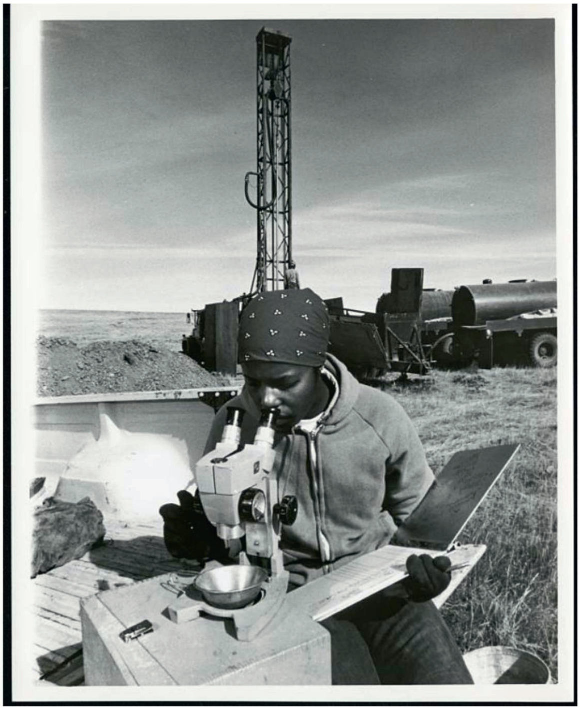

Figure 1: Geologist for the Kerr-McGee Corporation working on a uranium exploration site in New Mexico, 1979. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History), Box 42, folder 60.

By using the concept of "oil spillovers", this dissertation reframes the story from oil companies incidentally involved in the nuclear business to a story about the oil industry itself during the atomic age. By following the flows of technologies, practices, capital, and people in and out the oil and nuclear industries this dissertation reconstructs the history of a cohort of (geo)scientists and chemical engineers developing new, nuclear, technologies within the oil industry. This cohort spilled over into the nuclear industry during and after the Second World War and shaped many of the most important developments in nuclear energy production during the twentieth century. These spillovers were sometimes accidental but were also regularly shaped by the decisions made and forecasts constructed by the members of this cohort. In this way, the spillovers set up the later diversification into the nuclear industry by many oil companies and grounded the technological optimism of many oil actors during the high days of the scarcity and environmental debates during the long 1970s.

By putting this cohort at the forefront, this dissertation ties together the subdisciplines of history of science and technology with that of business history. This thesis shows that the story of interactions between the oil and nuclear sectors had a longer history than assumed within the diversification literature. Therefore, the later diversification during the 1960s and 1970s was more fundamental than an immediate reaction to the 1973/74 oil shock. The role of the Western oil industry as an incubator of nuclear technologies and science was also sometimes strategically used as a frame by (political) actors and oil company executives. As this dissertation shows, the nuclear technological innovations contributed by the oil industry shaped uranium mining practices and their impact on the environment, labor and human health, and oil actors used their investments to shape environmental and scarcity discourse through the second half of the twentieth century. That impact continues to this day.

Managing scarcity, environmentalism, and population growth

By focusing on spillovers between the oil and nuclear sectors, an in particular on the role of a cohort of scientist-engineers in shaping those spillovers, this thesis sheds new light on the historiography of the role of oil actors in debates about resource scarcity, environmentalism, and population growth. In the current context of climate change, energy transitions and environmental degradation, historians have turned to the oil industry to answer the question why more sweeping climate legislation has taken so long while climate change, the fraught geopolitics of oil, and the availability of alternative low-carbon-emission technologies were well-known long before the climate agreements of the 2015 Paris accord.[37] Historians have tended to offer answers to these questions that can be broadly categorized in three ways. The first explanation casts social life as so permeated by oil that we cannot bring ourselves to abandon fossil fuels.[38] That view forms the basis for the academic conceptualization of "petrocultures" and has also been taken up in broader society, for example in exhibitions exploring the limits and meaning of the ubiquity of oil in our society such as the recent *Petromelancholia* by the multidisciplinary, contemporary and performative art space Brutus in Rotterdam.[39]

A second explanation points toward oil companies' willingness to undermine alternative energy by keeping its price high in favor of cheaper oil production, thereby making the energy transition more costly. Already in the 1970s, the diversification of the oil industry into alternative energy sources quickly generated conspiracy theories about how the oil industry had attempted to manipulate energy commodity prices across the board. The flamboyant Democratic senator James Abourezk of South Dakota became a prominent representative of the view that oil companies tried to stifle or even sabotage the development of nuclear energy by gaining a monopoly control over uranium recourses.[40] Historian Meg Jacobs has shown how the wider public shared Abourezk's suspicion that oil companies were gaining ownership of alternative energy sources in order to sabotage their development in favor

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[37] Spencer R. Weart, *The Discovery of Global Warming* (Harvard University Press, 2008); James Rodger Fleming, *Historical Perspectives on Climate Change* (Oxford University Press, 2005); Kairn Kleiman, 'US Oil Companies, the Nigerian Civil War, and the Origins of Opacity in the Nigerian Oil Industry,' *Journal of American History* 99, 1 (2012), 155-165; Nathan J. Citino, *From Arab Nationalism to OPEC: Eisenhower, King Sa'ud, and the Making of US-Saudi Relations* (Indiana University Press, 2002); Geert Verbong, A. van Selm, R. Knoppers, and Rob Raven, *Een kwestie van een lange adem: De geschiedenis van duurzame energie in Nederland* (Aeneas, 2011); Frank N. Laird, *Solar Energy, Technology Policy, and Institutional Values* (Cambridge University Press, 2004).

[38] Christopher Jones, *Routes of Power: Energy and Modern America* (Harvard University Press, 2014); Matthew Huber, *Lifeblood: Oil, Freedom, and the Forces of Capital* (University of Minnesota Press, 2013); Stephanie LeMenager, *Living Oil: Petroleum Culture in the American Century* (Oxford University Press, 2014).

[39] Robert Gross, Odinn Melsted and Nicolas Chachereau, 'Creating the condition for Western European petroculture: The Marshall Plan, the politics of the OEEC, and the transition for coal to oil,' *Journal of Energy History* 10 (2023); Imre Szeman, *On Petrocultures: Globalization, Culture, and Energy* (West Virginia University Press, 2019); Sheena Wilson, Imre Szeman, and Adam Carlson, 'On Petroculture: Or, Why We Need to Understand Oil to Understand Everything Else', Sheena Wilson, Adam Carlson and Imre Szeman (eds), *Petrocultures: Oil, Politics, Culture* (McGill-Queen's Press-MQUP, 2017), 3-19; Brutus, 'Petromelancholia: curated by Alexander Klose (research group Beauty of Oil),' *Petromelancholia* (September 2023), https://brutus.nl/en/programme/current/petromelancholia/ (Acceessed 18 December 2023).

[40] James G. Abourezk, *Advise and Dissent: Memoirs of South Dakota and the US Senate* (New York: Lawrence Hill Books, 1989).

of the existing oil regime.[41] This view was also promoted in contemporary academic studies, such as John M. Blair's study of the power of oil companies.[42] More recently, the view that "Big Oil" sabotaged nuclear energy in favor of continuing oil production has been a recurring theme both in popular culture, such as David Mitchell's *Cloud Atlas* (2004), and in academic literature, most prominently in Timothy Mitchell's *Carbon Democracy* (2011).[43]

In recent years, historians have investigated more carefully the role of oil companies in shaping the discourse and regulations on environmental damage and pollution, leading to a third explanation. This research is particularly focused on when different oil actors already knew about the environmental damage of CO2-emissions and the strategies employed by oil companies to delay and counter state action from the late-1980s onward. By employing strategies of doubt, oil companies frustrated governmental regulations, supported climate denialists and thereby undermined the public's belief in climate change and its willingness to achieve an energy transition.[44] Several subsequent studies have located the moment when oil actors knew exactly the dangers of the emissions of their petroleum products further into the past, even going back to Edward Teller's warnings to the American Petroleum Institute about global warming in the 1950s. Companies then deliberately did not act on, and sometimes even concealed or purposely undermined, this knowledge.[45]

Still, in public oil actors frequently presented their investments in alternative energy sources as potential solutions to environmental problems like air and water pollution. As this thesis argues, alternative energy sources, with nuclear energy in particular, became an essential part of the narrative of technological optimism constructed by the cohort of scientist-engineers that dominated corporate boards in the nuclear and oil industries at the beginning of the 1970s. According to Andrew D. Basiago "technological optimism" entails "the doctrine that a growing number of technological improvements in such areas as food production, environmental quality and energy will sustain life as human population soars."[46] Following this definition, "technological optimism" evolved as a response to the more Malthusian studies produced in the late 1960s and 1970s such as *The Limits to Growth* report (The Club of Rome, 1972) and Paul Ehrlich's *Population Bomb* (1968).[47]

Historian Elke Seefried also connects technological optimism with the status of economic growth as the main criterion of a nation's prosperity: new innovations would enable future economic growth.

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[41] Meg Jacobs, *Panic at the Pump: The Energy Crisis and the Transformation of American Politics in the 1970s* (Farrar: Strauss and Giroux, 2016), 13.
[42] J.M. Blair, *The Control of Oil* (New York: MacMillan Press LTD, 1976), 318.
[43] Timothy Mitchell, C*arbon Democracy: Political Power in the Age of Oil* (New York: Verso, 2011), 170, 177-180, 188; David Mitchel, *Cloud Atlas* (London: Hodder & Stoughton, 2004).
[44] Naomi Oreskes and Erik M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (Bloomsbury, 2010); Christophe Bonneuil, Pierre-Louis Choquet and Ben Franta, 'Early warnings and emerging environmental accountability: Total's responses to global warming, 1971-2021', *Global Environmental Change*, 71 (2021), 102386; Marco Grasso, *From Big Oil to Big Green: Holding the Oil Industry to Account for the Climate Crisis* (Cambridge, MA: MIT Press, 2022).
[45] Geoffrey Supran, S. Rahmstorf, and Naomi Oreskes, 'Assessing ExxonMobil's global warming projections', *Science* 379 (2023); Benjamin A. Franta, *Big carbon's strategic response to global warming, 1950-2020* (Ph.D. Diss., Stanford University, 2022).
[46] Andrew D. Basiago, 'The limits of technological optimism,' *Environmentalist* 14 (1994), 17.
[47] James E. Krier and G.P. Gillette, 'The un-easy case for technological optimism,' *Michigan Law Review* (1985), 405; Paul R. Ehrlich and J.P. Holdren, 'Impact of population growth,' *Science* 171 (1971), 121-127; Basiago, 'The limits of technological optimism,' 17-22.

During the 1970s however, this view was challenged by the rise of sustainability discourse, which highlighted ecological impact of economic growth, forcing a reply from the oil actors embracing the framework of technological optimism.[48] This dissertation argues that as a reaction to increasing environmental debates and new regulations, various oil actors presented the oil industry as a capable, and even the most appropriate, candidate to actually solve these problems. Chapter 5 of this thesis shows that in their public communication about their nuclear investment representatives from various (also major) oil firms did acknowledge the environmental impact of both petroleum combustion and the production energy from "regular" nuclear fission. By presenting their development of "innovative" nuclear technologies such as nuclear fusion and In Situ Leaching as future "environmentally friendly" solutions to these problems, oil actors stressed the role of the market in solving the environmental impact and to protect their nuclear diversification projects. In this discourse, investments in nuclear fission were presented as a necessary step to bridge the gap between an oil fueled economy, and a safe and clean future with inexhaustible energy from nuclear fusion and breeder reactors. However, this technologically optimistic narrative increasingly collided with oil market developments during the 1970s and 1980s. Steered by a new cohort of managers trained in economics and finance, oil firms increasingly exchanged long-term technological optimism for short-term profits to please shareholders.

Temporal, spatial, and archival boundaries

The geographies and temporalities of dealing with oil and uranium.

Studying the spillovers between oil and the atom from a historical perspective means making choices in the spatial and temporal boundaries defining the scope of the research. Both industries are inherently global and encompass an extensive geological history. The formation of uranium and oil deposits, and their eventual extraction, is a story circling through early planetary history, imperialism, and colonialism, continuing in the present and lingering well into the future by casting a shadow radioactivity and global warming. In this dissertation, I use the conceptualization of both "nuclear" and "the oil industry" to set the boundaries for the studied time period. For the definition of "nuclear", I build upon the work of Gabrielle Hecht. In *Being Nuclear* (2012), Hecht shows that there are unique properties of uranium that shape trade flows, regulation, and technological development. Examples of these properties include the steps required in processing uranium before the commodity can be used as fuel in specific nuclear reactors, and the radioactivity and related health and environmental effects of uranium. Hecht summarizes these properties and resulting agency of uranium in one term: "nuclearity". "Nuclearity" for Hecht is a technopolitical, geographical, personal, and temporal phenomenon that is constantly shifting and determines when something is regarded as "nuclear".[49]

The changes in interpretation about what was considered "nuclear" are also evident in the interactions between the oil industry and the "nuclear sector", making it difficult to always fully appreciate the full extent of the entanglement of both industries. In different periods, oil actors interpreted and explained their interactions with uranium and the nuclear fuel cycle in diverse ways, based on the specific goals

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[48] Elke Seefried, 'Rethinking Progress. On the Origin of Modern Sustainability Discourse, 1970-2000,' *Journal of Modern European History* 13, 3 (2015), 379-386.
[49] Gabrielle Hecht, *Being Nuclear: Africans and the Global Uranium Trade* (Boston: MIT Press, 2012), 15.

oil actors aimed for. As chapter 3 will show, various oil companies actively promoted their involvement in “the nuclear sector” during the 1950s, interpreting as “nuclear” a wide range of activities from supplying lubricants to nuclear reactors to researching radioactive isotopes for improving oil products. However, when it came to adjusting the safety rules for miners in the oil companies’ uranium mines during the 1960s, lobbyists from the oil industry argued for these mines not to be labelled “nuclear” and thus considered within the category of more conventional mining without extra regulations.

This dissertation examines the spillovers of people, technologies and practices that enabled oil actors to influence the conceptualization of what was being considered “nuclear” and develop the “nuclear industry” as a whole. These spillovers bind together distinct parts of the nuclear fuel cycle – ranging from uranium exploration and mining to nuclear reactor management – and even technologies and practices that are traditionally not considered “nuclear” such as the production of lubricants used in nuclear reactors. Some of these technologies are grounded in the early development of knowledge about quantum mechanics and radioactivity during the last decades of the nineteenth and first decades of the twentieth century. This thesis therefore uses the early twentieth century (the period from 1895 to 1945) as a starting point for its research. These were the decades - also described as the “first atomic age” by historian Matthew Lavine – in which radioactivity was discovered and various (geo)scientists started applying theories of radioactive decay and quantum mechanics to study the earth and its minerals.[50] Although the second chapter does touch upon the geological forces that formed both uranium and oil deposits, the main focus of this dissertation is determined by the human and corporate actors that were concerned with the exploration and extraction of both resources within the context of the development of knowledge about radioactive decay and applications of early quantum mechanics to study geological sediments.

From there, this dissertation continues its story well into the early 1990s. At that time, nuclear power development in several countries had suffered significant setbacks, and globally the growth of the share of nuclear power in the energy mix came to a halt.[51] While this did not mean that all spillovers between the oil and nuclear sectors came to an end, it was the moment when many of the examined oil actors, partially and sometimes temporarily, stopped their involvement. Within the narrative from the early twentieth century to the late 1980s, this thesis’ strongest emphasis is on the “long-1970s”.[52] This dissertation defines the “long-1970s” as the period from 1967 to 1986 starting with the Six-Day War, the increasing fear of losing access to cheap oil production in the Middle East among major oil companies, and the rapidly developing nuclear bandwagon in the West with many major oil companies such as Gulf Oil starting their nuclear diversification projects.[53] 1986 marks the end-date of this period with the Chernobyl disaster highlighting the decline of nuclear energy developments in Western

[50] Matthew Lavine, *The First Atomic Age: Scientists, Radiations, and the American Public, 1895-1945* (New York: Palgrave Macmillan, 2013).

[51] Astrid Mignon Kirchhof (eds), *Pathways into and out of Nuclear Power in Western Europe: Austria, Denmark, Federal Republic of Germany, Italy, and Sweden* (Deutsches Museum, 2020); John Samuel Walker, ‘The Nuclear Power Debate of the 1970s,’ Robert Lifset (eds) *American Energy Policy in the 1970s* (University of Oklahoma Press, 2014), 227-229; Verbong et al, *Een kwestie van lange adem,* 66

[52] For further use of the ‘long 1970s’ as a distinctive period see: Diarmaid Kelliher, ‘Constructing a Culture of Solidarity: London and the British Coalfields in the long 1970s,’ *Antipode* 49 (2017), 106-124; Angela Romano, ‘Untying Cold War knots: The EEC and Eastern Europe in the long 1970s,’ *Cold War History* 14, 2 (2014), 153-173.

[53] Robert D. Lifset, ‘Nuclear Power in America: the Story of a Failed Energy Transition,’ *Environmental History* 24 (2019), 525-526.

countries.[54] The "long-1970s" were the high days of oil industry involvement in the development of nuclear power in the United States and Europe, with almost all major oil companies investing in several major nuclear power and uranium projects, and oil actors directly influencing policy around diversification publicly and behind the scenes.

The selection of this period also shows that this thesis focuses mainly on oil actors with ties in the Western oil industry. Although the extraction of oil and uranium took place in many different countries around the world, the international oil industry, certainly during the decades studied in the twentieth century, was dominated by Western companies that took advantage of the (neo)colonial networks of the countries where they were headquartered. This Western (sometimes referred to as "free world") oil industry consisted primarily of a US oil industry dominated by the many the many offshoots of Standard Oil, but it also included international oil companies such as Anglo Iranian (later BP), the Royal Dutch Shell Group, and *Compagnie Française Petroleum* (later Total) providing the case studies in this thesis also with a British, Dutch and French dimension.

Of course, these Western oil actors never operated in a vacuum, and spillovers between the nuclear and oil industries were informed by industrial, economic and political interactions with the oil and uranium sectors in the Soviet Union, Middle East and other countries in the Global South.[55] Following the examples of the studies by Geoffrey Bowker and Robynne Mellor, chapter 2 therefore pays ample attention to how developments in applied geophysics emerged at a nexus between the competitive US oil business, the Western European oil industry, and the search for oil and radioactive minerals in Eastern Europe, Brazil, and the emerging Soviet Union.[56] The third and fourth chapters discuss the choices of various Western oil companies whether or not to invest more in the development of nuclear energy during the 1950s and 1960s in the light of developments in the Global South regarding oil and uranium concessions, with the rise of OPEC as the best-known example.[57]

Still, the historical development of the Western nuclear industry established a clear distinction between Western oil-nuclear spillovers and spillovers in other regions. As chapter 2 argues, the Manhattan Project served as an incubator and insulator for the development and scaling-up of nuclear technologies and provided many Western oil actors with access to large-scale nuclear industrial developments. The ensuing Cold War, and the various secrecy policies in Western nuclear countries, further enabled specific, often Western, oil actors to become ingrained in the nuclear industries, creating a rift between the Western oil actors studied in this dissertation and the oil actors that had worked on similar early nuclear technologies in the Soviet Union and the Global South before the Second World War.

Even within the "Western oil industry," however, there are still a lot of differences to account for. One assumption this dissertation starts from is that, despite the ostensible trend toward cartel formation,

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[54] N. Hawkes et all, *Chernobyl: The end of the nuclear dream* (New York: Vintage, 1986).

[55] Christopher R. Hill and Saima Nakuti Ashipala, '"Follow the Yellowcake Road": Historical Geographies of Namibian Uranium from the Rössing Mine,' *Historical Social Research* 69, 1 (2024), 32-54; Michiel Bron, 'The uranium club: Big Oil's involvement in uranium mining and the formation of an infamous uranium cartel,' *Historical Social Research* 69, 1 (2024), 55-76; Hecht, *Beining Nuclear*; Gabrielle Hecht, *Residual Governance: How South Africa Foretells Planetary Futures* (London: Duke University Press, 2023).

[56] Bowker, *Science on the Run*; Mellor, *The Cold War Underground*.

[57] Guiliano Garavini, *The Rise and Fall of OPEC in the Twentieth century* (Oxford University Press, 2019); Dag Harald Claes and Guiliano Garavini (eds), *The Handbook of OPEC and the Global Energy Order: Past, Present and Future Challenges* (Routledge: London, 2020).

the oil industry as a monolithic entity does not, and did not ever, exist. This thesis stresses the fractured nature of the industry and its mutual competition.[58] To address the major differences between types of oil companies with relationships with the nuclear sector, I focus on three major oil companies that between the 1950s and 1970s were considered among the seven biggest oil companies in the world, the so-called 'seven sisters': Exxon (mostly via its predecessor Standard Oil of New Jersey), the Gulf Oil Corporation, and the Dutch-British Royal Dutch Shell Group.[59] In addition, this dissertation focuses on the French, partly state-owned company *Compagnie Française Petroleum* (later Total), which is sometimes referred to as the "eighth sister".[60] In addition, smaller oil firms, often referred to as independent, oil producers and oilfield service companies, made important contributions to nuclear technology, often in interaction with the major companies. For coverage of that part of the oil industry, this dissertation focuses on US independent Kerr-McGee and the French service company Schlumberger, while also adding examples from Phillips Petroleum, ENI, Atlantic Richfield, and the Uranium, Oil and Trading Company.

Archival sources

To study the spillovers between the nuclear sector and these oil companies, this dissertation uses a combination of archival sources. On the one hand, collections in national and state archives, such as the Dutch national archives, provide insight into the many discussions and collaborations surrounding nuclear projects in which oil companies often also played a key role. This includes, for example, the Dutch-British-German uranium enrichment project Urenco in which Shell (via its Dutch nuclear subsidiary *Shell Kernenergie b.v.*) was a shareholder, and the search by the US Atomic Energy Commission for uranium deposits shortly after the Second World War.

This dissertation also makes use of source material from the oil industry itself. Where possible, this includes material from the partly public archives of the studied oil companies. Where these oil companies are still active, the material from these archives, apart from the archive of the French Total SA, consists mainly of annual reports, press releases, leaflets and flyers and remnants of the companies' public lobbying efforts. This applies most strongly to the archives of Shell and ExxonMobil. When the companies, sometimes thanks to hostile takeovers, no longer exist on their own, the archives have sometimes been transferred to public hands and include minutes of board meetings, internal reports and policy documents. In this thesis the case studies of both Kerr-McGee and Gulf Oil benefitted from those companies loss' of independence and subsequent donation of internal documents to public archives. The archives of Total S.A. are a fortunate exception, as the company is

[58] Charles F. Mason, *The Organization of the Oil Industry, Past and Present* (Boston: Now Publishers, 2014); Tyler Priest, 'Crude History,' *Reviews in American History* 43:2 (2015), 333–339.

[59] The label "Seven Sisters" was first coined by the Italian oil entrepreneur Enrico Mattei referring to Exxon, Mobil, Chevron, Texaco, Gulf, BP and Shell. With this gendered frame, Mattei advanced the image of these "big oil" companies as a monolithic entity, working together as a family not willing to fully engage in competition. Anthony Sampson, *The Seven Sisters: The Great Oil Companies and the World They Made* (New York: Viking Press, 1975).

[60] Fransisco Petrini, 'Eight Squeezed Sisters: The Oil Majors and the Coming of the 1973 Oil Crisis,' Elisabetha Bini, Guiliano Garavini, and Frederico Romero (eds), *Oil Shock: The 1973 Crisis and its Economic Legacy* (London & New York: I.B. Tauris, 2016), 90; Louis Turner, 'The Oil Majors in World Politics,' *International Affairs* 52, 3 (1976), 368-380.

still active but does open its archives to researchers working on topics further than 30 years in the past. To a lesser extent, the same is true of the archives for BP, which are accessible up to 1955.

Of course, both the nuclear and oil sectors have a strong tradition of being opaque.[61] The often deliberately constructed difficulties in accessing archival materials are already a manifestation of this. But even in the material revealed, the companies made strong choices then and now about what to present and what framing to apply. It is already telling, for example, that the amount of celebratory material on the entry into nuclear energy projects within some archives far exceeds the number of papers on why certain projects were written off again within a few years. Stories of failures, accidents, waste, and violence are often not found in these archives. However, the archives are still usable. Not only do they sometimes provide a glimpse into the arguments used to justify diversification projects, and they make clear what image the companies themselves wanted to portray, but in combination with other source collections, they also illuminate what stories the companies did not want to present.

This dissertation also investigates the materials compiled during parliamentary hearings, especially those of the US Congress. The specific hearings included are the congressional hearings by the Joint Committee on Atomic Energy (JCAE) during the 1950s, and the 1976 hearings on the international uranium cartel in which several oil actors, including Gulf Oil, participated.[62] In addition, newspaper articles on the involvement of oil actors in nuclear energy projects are analyzed to find the stories untold in the oil archives. These newspapers include the archives of the *New York Times*, *Los Angelas Times*, *Business Week* and *Fortune*, and the extensive online database of Dutch newspapers, *Delpher,* between 1945 and 1990. Moreover, this thesis utilizes some investigative journalists' books on the nuclear industry that appeared in the wake of the Three Mile Island incident, often including interviews with industry insiders and extensive financial analyses; Peter Pringle and James Spiegelman's *The Nuclear Barons* (1982) and Mark Hertsgaard's *Nuclear Inc.* (1983) were particularly helpful in that regard.[63]

Although this dissertation in part focusses on the strategies employed by various oil companies, the involvement in nuclear energy by these companies often revolved around individual actors. In his study of the French oil industry in the twentieth century, the political scientist Douglas Yates correctly points out that although within the context of the law companies are often considered moral actors, in reality the framework of a company primarily exists to enable individual actors to steer capital, develop technologies and improve participation within a broader economic context while reducing personal liability.[64] In other words, to fully understand the many spillovers of technology, capital and people between the oil and nuclear sectors, this dissertation focusses on the individual actors: the scientists, managers, engineers, executives and workers that together formed, shaped and constructed the fluid,

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[61] Alex Wellerstein, *Restricted Data: The History of Nuclear Secrecy in the United States* (University of Chicago Press, 2021); Kleiman, 'US Oil Companies, the Nigerian Civil War, and the Origins of Opacity in the Nigerian Oil Industry,' 155-165.

[62] *International Uranium Cartel: Hearings before the Subcommittee on Oversight and Investigations of the House Committee on Interstate and Foreign Commerce*. 95th Cong., 1st Sess., pt. 2. 1977; for the hearings of the Joint Committee of Atomic Energy, I made use of the online database at Stanford Libraries, 'Joint Committee on Atomic Energy', https://exhibits.stanford.edu/atomic-energy (Accessed 18 December 2023).

[63] Peter Pringle and James Spiegelman, *The Nuclear Barons* (New York: Avons Books, 1982); Mark Hertsgaard, *Nuclear Inc.: The Men and Money Behind Nuclear Energy* (Pantheon Books, 1983).

[64] Douglas A. Yates, 'Life Stories and Family Histories of the French Oil Industry: The Rise and Fall of the Corps des Mines,' Alain Beltran (eds), *A Comparative History of National Oil Companies* (Brussels: P.I.E. Peter Lang, 2010), 55.

and sticky, concept of the "oil industry" that spilled over to the many nuclear developments during the twentieth century.

To study these individual actors and their connections this thesis incorporates personal archives left in depositories of universities, libraries, museums and research centers in the United States, the United Kingdom, the Netherlands, and France. Personal papers often provided valuable insights into the scientific, technological developments and strategic decision making within the oil and nuclear industries, where these actors were employed or hired as external consultants. Such collections include the papers of (geo)scientists like Hans Bethe, Marcel and Conrad Schlumberger, Everette Degolyer, Marion King Hubbert, Morgan Jones Davis, Robert Pohl, Dean McGee, and George Bain, and those of actors with ties to both the political domain and the boardrooms of the oil companies such as John McCloy, Robert S. Kerr and Glenn T. Seaborg/Benjamin S. Loeb. Although this thesis will also study some female geophysicists, like Margareth C. Cobb, most of the actors involved at the upper management levels of the oil and nuclear industries during this period, especially those that left archival collections, were men.

To further understand the scientific and technological developments these actors worked on, and to contextualize the debates in which these spillovers took place, this thesis also makes use of a discourse analysis based on articles published by actors from the oil industry in journals like *Journal of Petroleum Technology*, *Oil and Gas Journal, Bulletin of Atomic Scientists*, and *Geologie en Mijnbouw* (*Geology and mining* in English), and the oral history collections from the Chemical Heritage Foundation/Science History Institute, American Institute of Physics at the Niels Bohr Library and Archives, and interviews with oil and uranium workers in the uranium mining oral history project (1970-1971) conducted under the auspices of the American West Center.[65]

Defining an 'oil actor' in an 'energy addition'

The nuclear energy addition

To study how these oil actors shaped historical oil-nuclear spillovers, this dissertation makes uses of some of the theoretical frameworks and concepts developed within transition studies, sociology, and political science. Several analytical frameworks, the Multi-Level Perspective (MLP) in particular, have been applied within the transition studies literature to analyze the transitions from new technological niches (or energy sources) to commercially viable regimes by studying historical transition pathways.[66]

[65] For the oral history source, I made use of the following online databases: Science History Institute, 'Oral History Collection,' https://digital.sciencehistory.org/collections/gt54kn818 (Accessed 12 December 2023); J. Willard Marriot Digital Library (University of Utah), 'Uranium oral histories,' https://collections.lib.utah.edu/search?facet_setname_s=uum_uoh (Accessed 18 December 2023); American Institute of Physics, 'Oral History Interviews,' https://www.aip.org/history-programs/niels-bohr-library/oral-histories (Accessed 18 December 2023); American West Center, 'Uranium mining oral history project, 1970-1971,' https://archiveswest.orbiscascade.org/ark:/80444/xv03439/ (Accessed 17 July 2024); Atomic Heritage Foundation, 'Voices of the Manhattan Project,' https://ahf.nuclearmuseum.org/voices/ (Accessed 16 July 2024); VPRO, 'Marathon Interviews,' https://www.vpro.nl/programmas/marathoninterview/a-z.html (Accessed 16 July 2024).

[66] E.g. Aleh Cherp et al., 'Comparing electricity transitions: A historical analysis of nuclear, wind and solar power in Germany and Japan,' *Energy Policy* 101 (2017); Sebastian Strunz, 'The German Energy Transition as a Regime Shift,' *Ecological Economics* 100 (2014); Thomas P. Hughes, *Networks of Power: Electrification in Western Society,*

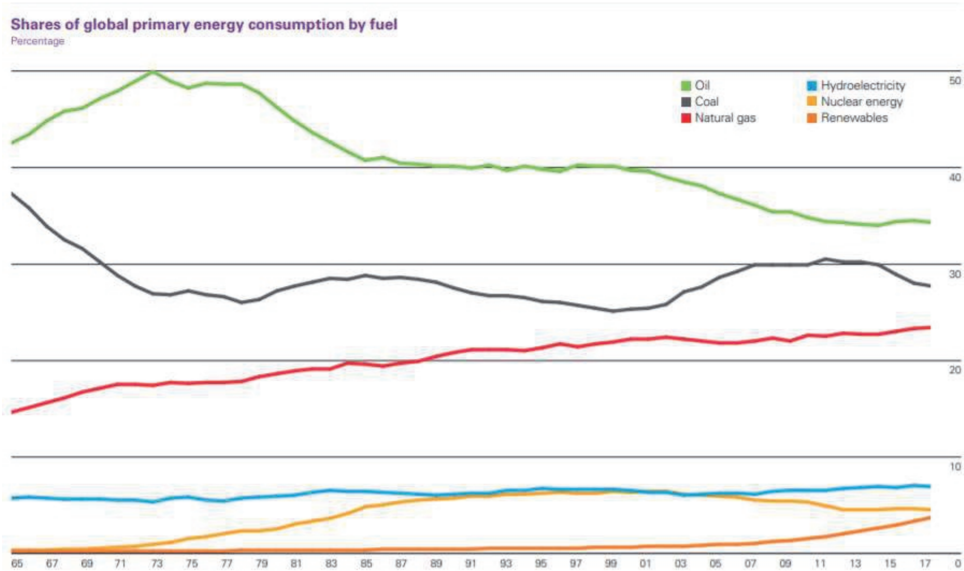

Figure 2: World primary energy mix (1965-2017). British Petroleum, BP Statistical Review of World Energy *(London: The Editor, 2018), 11.*

The concept of an ‘energy transition’, as it was first used in the technocratic response to the 1973/74 oil shock, traditionally presents a shift from one energy source to another. As an answer to the “oil weapon” presumably held by OPEC, US and Western European “experts” presented the concept of an energy transition toward alternative energy sources, like solar and nuclear but also coal and other oil deposits offshore or in tar-sands, as a solution. In later decades, the concept evolved into a narrower focus on a transition from hydrocarbon fossil fuels to a wide, and often debated, variety of renewable energy sources.[67]

MLP focusses on the interactions between three levels: the “niche” level, “regime”, and the “landscape”. Within this framework, the “regime” represents a fixed order of technologies and institutions; “niche innovations” occupy spaces where radical innovations find applications in limited domains that are protected from market developments; and a structural landscape is an overarching collection of (geo)political developments, policies and organisations that can trigger instability in regimes and create opportunities for niches to emerge when they slowly change over time.[68] Within the framework, transitions, or additions, take place when niche developments/technologies break

1880-1931 (Baltimore: John Hopkins University Press, 1983); Wiebe E. Bijker, *Of Bicycles, Bakelites, And Bulbs: Towards a Theory of Sociotechnological Change* (Cambridge, MA: MIT Press, 1995).

[67] Stephen G. Gross and Andrew Needham (eds), *New Energies: A History of Energy Transitions in Europe and North America* (Pittsburgh: University of Pittsburgh Press, 2023), 14.

[68] Adrian Smith, J. Voß, and J. Grin, ‘Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study,’*Research Policy* 39, 4 (2010), 435-448; Frank W. Geels et al., ‘The Enactment of Socio-Technical Transition Pathways: A Reformulated Typology and a Comperative Multi-Level Analysis of the German and UK Low-Carbon Electricity Transitions,’ *Research Policy* 45, 4 (2016), 896-913.

through, start to penetrate, and eventually overtake the regime or when incumbents incrementally or radically shift their focus to adopt niche innovations and/or start looking for alternatives.[69]

Several studies have applied MLP to conceptualize the "innovation journeys", or "transition pathways", of nuclear energy in a variety of countries. In these studies, the first decades following the Second World War (1950 to roughly 1970) are then commonly referred to as a niche period with scientists convincing policy makers to focus on civilian applications of nuclear energy and the establishment of early domestic nuclear industry subsidized by the state and often shielded from market developments. The second period (often placed between 1970 and 1986) is then characterized by a collision period where market mechanisms and public resistance increasingly play a role, often either resulting in a slowing down or phasing out of nuclear energy.[70]

This image of a linear shift, however, often neglects "the messiness of new energy systems by suggesting transitions can be rationally managed, or that they proceed in a linear or straightforward manner."[71] Some historians therefore question whether the concept can fully capture the complexity of changing infrastructural, technopolitical, or knowledge systems around energy, and prefer the use of "addition" instead of "transition" to highlight the extent to which the old energy system remains and the new "alternatives" simply bring forth ever more consumption of energy.[72]

This thesis therefore studies the spillovers between the oil and nuclear sectors within the framework of an "energy addition" as opposed to an "energy transition". Despite sometimes being framed as a (failed) "energy transition", the development of nuclear power is pre-eminently one that should be understood as an addition or shift in emphasis. Nuclear fission never developed beyond a substantial but still relatively minor addition to the world's growing energy production, and its use was distributed quite unevenly among the world's countries. Figure 2 shows the shares of global primary energy consumption by fuel between 1966 and 2017, making clear that nuclear energy, even at its peak in the early 1990s, contributed only seven to eight percent of the global energy mix while fossil fuels remained the primary energy sources.[73]

Still, MLP does well in conceptualizing transition pathways from new niche technologies to new regimes as a process of evolution over time, and it therefore can help historians to understand the energy debates of the twentieth century.[74] Many of the oil actors studied in this dissertation expressed expectations that nuclear power would soon replace coal – and from the early 1950s onward also oil – as the primary energy source with notable examples of oil geophysicists such as Marion King Hubbert, Paul L. Lyons, Pierre Guillaumat, and Dean McGee. To understand these debates on potential energy transitions and reframe early debates about "peak oil" within the context of oil-nuclear spillovers, this

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[69] Jelena Stankovic and Michiel Bron, 'Charting Career Trajectories: Empowering Actor Agency in MLP through Cohort Theory,' *Energy Research & Social Science* (forthcoming).
[70] Frank W. Geels and B. Verhees, 'Cultural legitimacy and framing struggles in innovation journeys: A cultural-performative perspective and a case study of Dutch nuclear energy (1945–1986),' *Technological Forecasting and Social Change* 78, 6 (2011), 910-930; Cherp et al., 'Comparing electricity transitions'.
[71] Gross and Needham, *New Energies*, 14.
[72] Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene Shock*, trans. David Fernbach (New York: Verso, 2017), 101-102; Gross and Needham, *New Energies*, 14; Odinn Melsted, *Icelandic Energy Regimes: Imported Fossil Fuels, Renewable Resource Development and the Making of a Low-Carbon Energy Balance, 1940-1980* (Ph.D. Diss., University of Innsbruck, 2020).
[73] British Petroleum, *BP Statistical Review of World Energy* (London: The Editor, 2018), 11.
[74] Cyrus C.M. Mody, 'Surveying the Landscape: The Oil Industry and Alternative Energy in the 1970s,' W.B. Carlson and E.M. Conway (eds), *Electrical Conquest* (Springer, 2023).

dissertation makes use of some terminology derived from MLP.[75] Examples include concepts such as "the oil regime" to address the status of oil as primary energy source from the 1950s onward, and "the nuclear niche" to position early nuclear technologies (and their promises) as a potential competitor to oil.

Accounting for actor agency in an energy addition

As this dissertation argues, various spillovers of actors, technologies and practices shaped the addition of nuclear energy to the global energy mix. More traditional frameworks often regard the actors associated with the preexisting energy regime as "incumbents", or "vested interests". Within this model, the "vested interests" then employ strategies – called "transition pathways" – to relate to the development of new niche technologies or energy systems in their quest for self-reproduction, either by cooperating with state institutions and altering, or reinterpreting, state goals to their advantage or by exposing the new technology to market pressures.[76] In simpler terms, within these frameworks oil actors could either try to halt or sabotage the development of nuclear energy, try to incorporate the new technology into a 'monolithic' fossil-nuclear regime, or be replaced by a new nuclear regime.[77]

As the next chapters will show, however, many of the studied actors are not easily categorized as incumbents. Over the span of their careers, many of them worked for governmental organizations that would be categorized as 'landscape' organizations, oil 'regime' companies, and nuclear 'niche' industries. There, they shaped the futures of both energy sources. Examples such as the American geologist Philip Merritt worked for various companies in minerals and petroleum exploration during the 1930s, before being enrolled within the Manhattan Project and shaping the uranium policies of the US Atomic Energy Commission.[78] Multiple others followed paths similar to the Dutch chemical engineer Han Hoog, who worked almost his entire career within the oil industry and from there managed the first nuclear subsidiary of Shell before getting involved in the wider nuclear industry via various Dutch (semi)governmental organizations.[79]

MLP has often been criticized for failing to fully explain the interplay among various individual incumbents, or "regime" actors, in establishing and supporting niche technologies.[80] According to proponents of MLP, however, the model accommodates actor agency by focusing on the "increasing

[75] Priest, 'Hubbert's Peak: The Great Debate over the End of Oil,' 47-50; Emma Hemmingsen, 'At the base of Hubbert's Peak: Grounding the debate on petroleum scarcity,' *Geoforum* 41 (2010), 531-540.
[76] Cherp et al., 'Comparing electricity transitions'; Frank W. Geels, 'Regime resistance against low-carbon transitions: introducing politics and power into the multi-level perspective,' *Theory, Culture and Society* 31, 5 (2014), 21-40; G.C.K. Leung et al, 'Securitization of energy supply chains in China,' *Applied Energy* 123 (2014), 316-326.
[77] Strunz, 'The German Energy Transition as a Regime Shift,' 152; Frank W. Geels and Johan Schot, 'Typology of sociotechnical transition pathways,' *Research Policy* 36, 3 (2007), 399-417.
[78] T.E. Gillingham, 'Memorial to Philip Leonidas Merrit, 1906-1981,' *The Geological Society of America* (1981), 1-3.
[79] Kistemaker, *De geschiedenis van het Nederlandse Ultracentrifuge Project*, 31-38; Cees D. Andriesse, *De Republiek der Kerngeleerden* (Bergen: BetaText, 2000), 1.
[80] H. Ahlborg, 'Towards a conceptualization of power in energy transitions,' *Environmental Innovation and Societal Transitions* 25 (2017), 122-141; Kathleen Aroújo, 'The emerging field of energy transitions: progress, challenges, and opportunities,' *Energy Research & Social Science* (2014), 112-121; Adrian Smith, Andy Stirling, and Frans Berkhout, 'The governance of Sustainable Socio-Technical Transitions,' *Research Policy* 34, 10 (2005), 1491-1510.

structuration of activities in local practices", although they do recognize that some types of agency are less developed.[81] To counter this criticism, various scholars have tried to incorporate other theories within the context of MLP. Audley Genus and Anne-Marie Coles for example, argue for the incorporation of more constructivist approaches such as the Social Construction of Technology (SCOT), Constructive Technology Assessment (CTA) or Actor Network Theory (ANT).[82] This dissertation offers a different approach by focussing on the concept of (generational) cohorts as a way to embed the individual agency of the various actors within a wider, structural framework, supporting the addition of nuclear energy.

Cohort theory

To conceptualize the agency of multiple individual actors moving in between a broad "oil regime", governmental organizations, and emerging industries of radioactive mineral mining and nuclear energy, this dissertation applies the theoretical framework of cohorts. A cohort describes a group of individual actors, born during a limited time span, who share a common and distinct social character shaped by shared experiences.[83] Unlike family generations, based on biological lineages, scholars differentiate cohort generations by the changing content of formal education, by peer-group socialization and idiosyncratic historical experiences. This experience can be birth (in a given set of years), but can also include war, revolution, immigration, urbanization, or technological change.[84]

In the case of this dissertation, the common denominator was the shared experience in, and framework provided by, an internationally operating Western oil industry. Where Yates describes a company as a way to structure economic interactions, the concept of a company also provides this dissertation with a way to structure the selection of studied actors.[85] The "oil" in "oil actors" points toward a past, or future, connection with the petrochemical industry as far as this connection helped in shaping an industry primed toward the exploration, extraction, development and selling of petroleum products. For this dissertation, "oil" brings with it an intrinsic, sticky, quality that creates a mark to determine the actors studied in this research. In practice, this means that most of the studied actors were, at least for a part of their career, employed or hired in the oil industry. These actors were often employed by the oil industry due the increasing focus on academic geosciences and engineering in the oil industry (educational background), and experienced the Second World War and the

[81] Frank W. Geels, 'From sectoral systems of innovation to socio-technical systems: insights about dynamics and change from sociology and institutional theory,' *Research Policy* 33, 6-7 (2004), 897-920; Frank W. Geels, 'The Multi-level perspective on sustainability transitions: Response to seven criticisms,' *Environmental Innovation and Societal Transitions* 1 (2011), 24-40; Geels and Schot, 'Typology of sociotechnical transition pathways,' 399-417; B. Turnheim and Frank W. Geels, 'Incumbent actors, guided search paths, and landmark projects in in infra-system transitions: Re-thinking Strategic Niche Management with a case study of French tramway diffusion (1971–2016),' *Research Policy*, 48, 6 (2019), 1412-1428.

[82] Audley Genus and Anne-Marie Coles, 'Rethinking the multi-level perspective of technological transitions,' *Research Policy* 37, 9 (2008), 1436-1445.

[83] Karl Mannheim, 'The problem of generations,' *Psychoanalytic Review* 57, 3 (1970), 378-404.

[84] Mannheim, 'The problem of generations,' 378-404**;** C.L. Jurkiewicz and R.G. Brown, 'GenXers vs. Boomers vs. Matures. Generational Comparison of Public Employee Motivation,' *Review of Public Personnel Administration* 18 (1998), 18-37; B.R. Kupperschmidt, 'Multigeneration employees: strategies for effective management,' *The healthcare manager*, 19, 1 (2000), 65.

[85] Yates, 'Life Stories and Family Histories of the French Oil Industry: The Rise and Fall of the Corps des Mines,' 55.

emergence of nuclear energy as a possible alternative, or addition, to oil (technological change). From these positions they sometimes steered their companies toward diversification, but also often left the oil industry to work for the nuclear industry or nuclear governmental policies or returned to work on petroleum.

Various scholars use this concept of "cohorts" in political science, sociology, art history, and even the history of oil elites.[86] Douglas Yates, in his study of the French oil industry in the twentieth century (2009), focuses on cohorts of prominent actors in the French oil sector. After the Second World War, the modal French petroleum president was an engineer, good in mathematics and physics, graduated in the top ten of his class from the prestigious *Ecole Polytechnique*. From there, he – although there were many female scientists, engineers and workers employed in the oil sector, the executive chairs were almost exclusively taken by men – continued his studies at the *Ecole des Mines*, which prepared him, via some field assignments in the oil or mining sectors and experience of serving during the Second World War, for a position as state engineer in the powerful technical-administrative *Corps des Mines*. Starting to live in Paris, he quickly got an influential position within the Ministry of Industry, the minister's cabinet, or in one of the powerful agencies ranging from oil companies to the nuclear authority CEA before becoming part of the upper management of the French oil industry.[87]

By using this approach, each new cohort offers a possible intermediary in a transformation process, a vehicle providing the possibility for social change to occur. Social change then is defined as a transition in culture, social norms or social behavior.[88] According to Yates, for France one of these social changes happened when the post-war cohort of engineers was slowly replaced by managers trained in economics and finance at *L'École Nationale d'Administration* (ENA) as the dominating elite within the oil sector during the 1980s. This change, "fundamental transformation that revolutionized national oil firms", was privatization. Starting in the 1980s, the French oil industry underwent a process of privatization undertaken by the government in line with the imperatives of the European Commission and spirit of the times. Although the engineers from the *Corps des Mines* certainly did not leave the top management levels in the oil industry completely, the different companies underwent a "metamorphosis from a national enterprise to a private multinational oil corporation, answerable less to the state, and more to their shareholders." This process, reflected, and shaped, a gradual shift in the organizational flow-charts where more liberal managers with a background in finance and

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[86] Ted Underwood, Kevin Kiley, Wenyi Shang, and Stephen Vaisy, 'Cohort Succession Explains Most Change in Literary Culture,' *Sociological Science* 9 (2022), 184-205; K.M. Keyes, R.L. Utz, W. Robinson, and G.H. Li, 'What is a cohort effect? Comparison of three statistical methods for modeling cohort effects in obesity prevalence in the United States, 1971-2006,' *Social Science and Medicine* 70 (2010), 1100-11098; A. Lareau, *Unequal childhoods: class, race, and family life* (Berkeley: University of California Press, 2003); Aaron Reeves, 'Age-period-cohort and cultural engagement,' Laurie Hanquinet and Mike Savage (eds), *Routledge International Handbook of the Sociology of Art and Culture* (London: Routledge, 2015), 116-131.

[87] To Yates, Pierre Guillaumat was the archetype of this cohort, becoming responsible for France's nuclear industry after being a mining corps engineer, graduating top of his class at Polytechnique, and working within the oil industry. Douglas A. Yates, *The French Oil Industry and the Corps Des Mines in Africa* (New York: Africa World Press, 2009), 1-11.

[88] G. Firebaugh, 'Where does social change come from? Estimating the relative contributions of individual change and population turnover,' *Population Research and Policy Review*, 11,(1992), 1–20; N.D. Glenn, 'Distinguishing age, period, and cohort effects,' J. T. Mortimer and M. J. Shanahan (eds), *Handbook of the life course* (New York: Kluwer Academic/Plenum, 2003), 465–476; N.B. Ryder, 'The cohort as a concept in the study of social change', *American Sociological Review*, 30 (1965), 843-861.

economics, like Albin Chalandon at Elf Aquitaine and François-Xavier Ortoli at CFP-Total, rose to the ranks of CEO, or *Président*.[89]

This thesis generalizes some of these French developments and applies them to the wider Western oil industry, arguing that cohorts not only had national substance, but also more global patterns existed in an industry that often crossed the borders of the nation state. In this way, this dissertation adds theoretical depth to the concept of “agency” for a cohort of individual actors shaping nuclear developments. A cohort offers a network in which ideas about future developments can be realized and an addition is shaped in relation to previous and succeeding cohorts. Individual actors from the same cohort can thereby play different roles in the development of a niche technology, the execution of transition pathways undertaken by corporate incumbent interests, and the shaping of landscape features.

By doing so, Cohort Theory provides a way to integrate actor agency within MLP. MLP offers tools to define the “change” the individual actors constitute, in this case the addition of nuclear energy to the global energy mix. By using the concept of a “cohort” as a “surrogate index for the common experiences of many people in each category,” this thesis is then able to observe and study the agency of individual actors without losing sight of the overarching energy additions.[90] In other words, cohort offers a structure through which the agency is exhibited. That structure entails the common education, shared experience and historical location, and same goals and visions for the future, that mobilize individuals’ knowledge of schemas and resources and create a (collective) agency that is able carry out the change.[91]

This dissertation applies these concepts to explain many of the individual spillovers from the oil to the nuclear sector, the nuclear investments of oil companies, and the later demise of these diversification strategies during the 1980s. In the decades leading up to the Second World War, the international oil industry invested extensively in personnel with academic backgrounds in physics and chemical engineering and set up its own geophysical and chemical research and development divisions. Many of the recent graduates, often with knowledge of the newly emerging quantum mechanics, ended up in an oil industry that would take over the position as the primary energy source from coal soon after the Second World War. By the time these scientists and engineers reached the peak of their professional careers during the 1950s and 1960s, the Space Age and the promises of nuclear energy had become enticing to members of their disciplines in Western Europe and the United States. Many of the actors spilled over to organizations like NASA and emerging nuclear projects and semi-governmental organizations. This was a development that caused the still-growing oil industry to face shortages in personnel, especially of geophysicists and engineers, and created a call to offer engineers management positions within the oil industry to tempt them for longer tenures. From these management positions, the scientists and engineers would bring in new diversification projects, including in alternative energy sources, reinforced by debates about the future of the oil industry and the accelerated rise of nuclear power. A lot of these diversification strategies ended however, when, this cohort of scientist-engineers, many of whom were approaching retirement age in the late 1970s,

[89] Douglas A. Yates, ‘The French oil industry under the *Corps des Mines:* From family firms to national champions’, Lars Bluma, Michael Farrenkopf, and Torsten Meyer (eds), *Boom-Crisis-Heritage* (Berlin: De Gruyter, 2022), 64-68.

[90] Ryder, ‘The cohort as a concept in the study of social change,’ 843-861.

[91] W.H.J. Sewell, *Logics of history: Social theory and social transformation* (Chicago: University of Chicago Press, 2005); Stankovic and Bron, ‘Charting Career Trajectories’.

was slowly replaced by a new generation of managers. This new generation, more often emphasizing a background in economics and finance, faced and shaped a changing, increasingly neoliberal, economic context in which short-term profits and shareholder value became ever more important.

The scope of this structure varies depending on social systems in which a collective cohort agency unfolds, however. Although this story bears some similarities to Yates' thesis, the cohort this thesis examines was also more fractured and diluted then the more clear-cut case of the Frech oil elites. Unlike the French elite system where a shared background in the same educational system connected everyone, providing its members with distinctive traits which made them easily recognizable, also for each other, this was less the case in other contexts within the Western oil industry. Also, the extent to which engineers dominated the highest levels of management in France, both in the oil and nuclear industry and in government, was less prevalent in other national contexts. Still, the cohort of scientist-engineers that shaped the spillovers between the oil and nuclear industries in the United States, United Kingdom and the Netherlands were part of a network. They were often knowledgeable about each other, even across borders. Many of them met one another at conferences, read each other's books, articles and opinion pieces in journals like the *Journal of Petroleum Technology*, *The Bulletin of Atomic Scientists*, and *The Oil and Gas Journal*, and even regularly corresponded. In this, the cohort differed from their more fractured successors who were more focused on the well-being of their own companies.[92]

Of course, there were also exceptions, even outside the bandwidth the concept of "cohorts" already allows, to the dominating cohort. Within France, Yates acknowledges that there were also oil executives rising to the highest ranks of oil management who were rejected by the grand corps of both the engineers and administrators. These examples, like Loïk Le Floch-Prigent and Serge Tchuruk, Yates calls the "black sheep". Often bringing their own team with them when they rose to the top levels, they were considered outsiders.[93] This thesis deals with some examples of oil actors spilling over into nuclear developments that do not fit either the cohort of scientist-engineers or economist-managers. For this dissertation, these actors often offer insightful examples of how certain developments and debates were shaped precisely because they regularly went against, or anticipated, the prevailing zeitgeist. A good example is Gerrit Abram Wagner, a Dutch law graduate who steered his company into its biggest nuclear diversification project with the joint venture General Atomic Company together with Gulf Oil as CEO of Royal Dutch Shell, but who was also one of the first international oil managers to publicly embrace new neoliberal ideas about the structuring of society and the role of companies, and also one of the first oil actors to openly dismiss the nuclear investments of oil industry at the end of the 1970s.[94]

Thesis organization

To describe the emergence and succession of the various cohorts within the context of the addition of nuclear energy to the global energy mix, this thesis adopts a chronological approach. In doing so, the next four chapters each deal with one part of the history of spillovers between the oil and nuclear

[92] Mark S. Mizruchi, *The Fracturing of the American Corporate Elite* (Cambridge: Harvard University Press, 2013).
[93] Yates, 'The French oil industry under the *Corps des Mines:* From family firms to national champions,' 58-59.
[94] Harry van Seumeren, *Gerrit A. Wagner: Een loopbaan bij de Koninklijke* (Utrecht: Veen Uitgevers, 1989), 18-72; Marcel Metze, *Hoog Spel: De politieke biografie van Shell* (Amsterdam: Balans, 2023), 266, 276, 294-297.

industries between 1895 and 1993. The development of the cohort of scientists and engineers who shaped many of these spillovers guides the chapters. The first two chapters deal with the formation of the cohort, the historical context in which this occurred, and the rise to power within the oil and early nuclear industries by the various members of this cohort. The last two chapters are then more thematic and partly overlap in chronology. Chapter 4 discusses the high days of the oil sector's publicly visible involvement in nuclear energy development and the role of this emerging energy source in the debates among oil actors on resource scarcity, environmentalism, and population growth during the long 1970s. The fifth chapter also starts during the long 1970s, but then transitions to the 1980s and early 1990s to discuss the changes these debates underwent within the context of the succession of the cohort of scientist-engineers by a new management with more emphasis on short-term profits and shareholder values.

The first chapter (1895-1945) centers around the involvement of the oil industry in the development of atomic bombs in the Manhattan Project. The literature on the Manhattan Project has focused on the involvement of science and government, but, with a few exceptions, has underemphasized the role of contractors.[95] This chapter shows that the Project, in addition to being a scientific and military exercise, was primarily a business endeavor with an exceptionally large role for the American oil industry. This involvement was based on the accumulated geoscientific knowledge related to exploration for radioactive minerals and chemical analysis and processing of gases and fluids within the oil sector during the first decades of the twentieth century. Based on the growing knowledge of radioactive decay, oil geophysicists within the context of a growing research and development sector within the oil industry had developed methods and technologies, like radioactive well logging, which made it possible to find both oil and radioactive minerals like uranium. Also, other technologies developed within the oil industry, such as mass spectrometers, proved useful in the various uranium enrichment projects within the Manhattan Project and the separation of much needed isotopes like boron-10.

The Manhattan Project, and comparable, contemporary and successive, projects in the Soviet Union, France, the UK, and, to a lesser extent, the Netherlands, propelled early nuclear projects to an industrial scale. The third chapter (1945-1967) covers the period in which this emerging nuclear industry was largely influenced by a growing number of technological and personnel spillovers and capital investments from the oil industry. First, the chapter delves into how various oil actors related to the emerging nuclear promises about a future in which nuclear energy would become "too cheap to meter".[96] Various scientists, engineers, wildcatters, and managers of independent oil companies found new opportunities within the framework of the nuclear sector, while others continued to emphasize the future of oil as a primary energy source. These debates were based on (neo)colonial conceptions of resource deposits, of both oil and uranium, in the United States, Canada and the Global South. This chapter therefore focuses on how these prospects, and the nuclear technologies they were shaped by, were further developed within the oil and uranium sector. This discussion then forms the

[95] Examples of literature where different industrial contractors are mentioned are Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon & Schuster, Inc., 1986); Martin V. Melosi, *Atomic Age America* (New York: Routledge, 2013).
[96] Quote attributed to Lewis Strauss, Chairman of the US AEC. Lewis L. Strauss, *Remarks Prepared by Lewis L. Strauss, Chairman, Unites States Atomic Energy Commission, For Delivery at the Founders' Day Dinner, National Association of Science Writers, On Thursday, September 16, 1954* (New York: US Atomic Energy Commission, 1954), 9.

prelude to the last part of this chapter, which discusses how the rise of OPEC and the fear of losing access to cheap oil concessions in the Global South enabled members of the scientist-engineer cohort, who had become managers within even the biggest major oil companies, to embark on a diversification strategy into nuclear energy projects at the end of the 1960s.

The public entry of these oil majors into nuclear energy, like the managers from Gulf Oil at the opening of this introduction, forms the starting point for the third chapter (1967-1979). This chapter discusses the ubiquitous oil presence in nuclear energy during the long 1970s. First, it delves into the strategies employed by the oil actors to provide their companies with a foothold into the entire nuclear fuel cycle. As this chapter argues, overarching strategies to become a competitive player in the accelerating nuclear energy market connected the investments in mining projects, uranium enrichment, reactor development and waste management. These strategies, together with investments in highly experimental research projects in laser enrichment and nuclear fusion, were forecasts to pay off multiple decades into the future; they therefore form the foundation for this chapter's argument that the cohort of scientist-engineers from the oil industry constructed a narrative of technological optimism, based on the abilities for oil capital and expertise to further nuclear developments, as an answer to the, increasingly public debates on resource scarcity, environmental pollution and population growth. A study of the investments in political capital many of the actors within the American oil industry made to publicly lobby against the attempts to break up the diversification of the oil industry around 1976 then reinforces this argument.

Whereas the 1973/74 oil crisis on the one hand provided the diversification of the oil sector with an additional dimension of importance in narratives about resource independence and environmentalism, the energy crisis also provided a breeding ground for new ideas about how to run a business within increasingly volatile markets.[97] The final chapter (1973-1993) deals with the two decades following the first oil shock in which many of the large-scale investments in nuclear energy from the oil sector were phased out and the oil industry refocused to short-term profits. Along with the phasing out of the cohort of scientist-engineers, largely due to approaching retirement age, critical voices arose contending that diversification strategies were not paying off and the oil industry should focus more on its own expertise of oil exploration, extraction and refining, paving the road for a new cohort of a new generation of managers trained in economics and finance. A key mutual factor here was a renewed emphasis on the importance of strengthening profitability, and particularly the role of shareholders within companies. Within the context of rapidly neoliberalizing markets, oil actors increasingly favored short-term profits over long-term investments and research.

The concluding chapter then reflects on the temporal and geographical conditions of these preceding developments. In a time where oil companies again increasingly return to diversification projects in nuclear energy, this dissertation argues that for understanding developments in the energy sector a focus on the technology, people, and knowledge spilling over between various energy sources remains necessary. As this chapter shows, several technologies that originally were introduced by the oil industry continued to play essential roles in nuclear developments to this day. Also, outside the context of the Western oil industry, oil companies remained involved in the development of a wide variety of national nuclear industries. These spillovers constitute a returning link between two of the most controversial energy industries of the twentieth century and will probably continue to do so. However,

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[97] Caleb Wellum, *Energizing Neoliberalism: The 1970s Energy Crisis and the Making of Modern America* (Baltimore, Maryland: John Hopkins University Press, 2023).

the way in which various oil companies exploit this connection is shaped to a great extent by developments within the oil market, the position of the company, and the interpretation of the role of management within the oil industry.

CHAPTER 2

2. “Now it can be told”

The formation of a cohort in the early oil and nuclear industries, 1895-1945

To the men and women of the Manhattan Project.

Today the whole world knows the secret which you have helped us keep for many months. I am pleased to be able to add that the warlords of Japan now know its effects better even than we ourselves. The atomic bomb which you have helped to develop with high devotion to patriotic duty is the most devastating military weapon that any country has ever been able to turn against its enemy. No one of you has worked on the entire project or known the whole story. Each of you has done his own job and kept his own secret, and so today I speak for a grateful nation when I say congratulations and thank you all. I hope you will continue to keep the secrets you have kept so well. The need for security and for continued effort is fully as great now as it ever was. We are proud of every one of you.

- Undersecretary of War Robert P. Patterson, 7 August 1945[97]

[97] Robert P. Patterson, ‘To the man and woman of the Manhattan District Project,’ (Washington D.C. August 1945), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), Box 2.207/G75.

2

"Now it can be told"

On August 6, 1945, Art Conn, director of the process division of Standard Oil of Indiana at Whiting (outside Chicago), heard the news on the radio that an American plane had dropped an atomic bomb over Hiroshima, Japan. "So that was it," he said to himself, "now we're sure what the Manhattan Project was all about."[99] In the preceding two and a half years, Conn directed a secret mission for Whiting Research, a subsidiary of Standard Oil Company (Indiana), within the Manhattan District Project - the US wartime designation for the project that ultimately produced the atomic bomb. For this mission called "No.4 Process Laboratory", the oil company produced boron-10 (B-10), an isotope of the element boron, through a delicate distillation process in the old boiler room located in the heavy oil division of the refinery. B-10 has the property of absorbing neutrons, the nuclear particles that propagate an atomic chain reaction, and is essential to avoiding an unwanted nuclear explosion.[100]

By taking the story of oil actor Art Conn and his company not only as an isolated episode, but rather as part of a larger framework of industrial involvement in the Manhattan Project with the involvement of the oil industry in particular, this chapter frames the Project as a pivotal moment in the history of oil-nuclear spillovers. For the remarkable story of Whiting Research stood not on its own. As part of a much wider involvement of industry in the US war effort, many contractors and industrial partners contributed in, sometimes big, parts of the Manhattan Project. Both oil firms such as Standard Oil of New Jersey, Socony, and Standard Oil of Indiana, as well as multiple individual actors with a background in the oil industry, stand out in that story.[101] However, although the historical literature on the Manhattan Project is littered with references to different contractors, such as Westinghouse Electrical and Manufacturing Company, Dupont and General Electric, a study on why the oil industry specifically was able to contribute to the creation of the atomic bombs on such a large-scale is thus far lacking.[102]

This chapter argues that oil actors' involvement in the atom bomb program emerged from the intertwined histories of increasing knowledge about radioactivity, emerging geosciences, and a professionalizing and diversifying oil sector. During the first decades of the twentieth century, the Western oil business developed into a full-fledged industry with a wide variety of (service) companies competing for a better position in a quickly growing market.[103] To gain a competitive edge, companies

[99] 'Now It Can Be Told: how our scientists at Whiting research contributed to development of A-bomb,' *Standard Torch* (May 1957), 16.

[100] 'Letter A.L. Conn to No.4 Process Laboratory Personnel' (9 August 1945). Whiting-Robertsdale Historical Society.

[101] For literature on the role of industrial parties in the US war effort in general see for example: Johathan Zeitlin, 'Flexibility and mass production at war: aircraft manufactures in Britain, the United States, and Germany 1939-1945,' *Technology and Culture* 36 (1995), 57; Richard Overy, *Blood and Ruins: The Great Imperial War 1931-1945* (London: Allan Lane, 2021), 526-598.

[102] Examples of literature where different industrial contractors are mentioned are Rhodes, *The Making of the Atomic Bomb*; Melosi, *Atomic Age America*; Rorke, *The Manhattan Project, the Du Pont Company, and the Management of new product development*; Ndiaye, *Nylon and bombs*; Houndshell and Smith, jr., *Science and Corporate Strategy*.

[103] David S. Painter, 'Oil and the American Century,' *Journal of American History* 99, 1 (2012), 24-39; Alfred D. Chandler, 'The Structure of American Industry in the Twentieth century: A Historical Overview,' *The Business History Review* 43, 3 (1969), 255-298.

increasingly invested in both chemical and geophysical research within academia and the establishment of new research and development departments in the oil industry.[104] By doing so, the oil sector incorporated new developments in atomic physics, both in measuring radioactivity to explore for oil and analyzing atomic structures of gases, fluids and rocks. As this chapter shows, these technologies later found applications in the industrial scaling-up of both nuclear fission research and production of fissile materials within the Manhattan Project. Geophysical knowledge and chemical engineering developed within the oil industry therefore fulfilled a pivotal role in the radioactive mineral exploration, uranium enrichment, and production of isotopes and lubricants needed to produce the bombs.

These technological and knowledge spillovers are crucial in understanding the involvement of oil actors in the nuclear industry during the Manhattan Project, and the later nuclear diversification projects by oil companies. The accrued geophysical knowledge and technologies based on early quantum mechanics within the industry positioned oil actors in such a way that they were able to participate in early nuclear industry developments. For the actors themselves, the Project then provided access to new, often concealed knowledge and a network of atomic physicists, engineers, and policy makers that would later shape the nuclear developments of the second half of the twentieth century. In this way, this chapter argues, the Manhattan Project served as an incubator for the oil-nuclear cohort of atomic scientists and chemical engineers that will dominate the discussions about the relation between the oil and nuclear industries that are the next chapters’ subject.

First, this chapter uncovers the entangled histories of oil and radioactive mineral exploration by focusing on the geophysical research and technologies based on early quantum mechanics that the oil industry developed between 1895 and 1940. These spillovers then set up the next section that deals with the origins of the oil-nuclear cohort. This section first addresses the increase in the number of geophysicists versed in atomic physics within the oil industry that enabled the development of the new exploration techniques to then focus on another group of atomic physicists and chemical engineers joining the rapidly growing petrochemical industry during the first decades of the twentieth century. These two networks form the basis for the third section of this chapter, which deals with oil actors’ involvement within the Manhattan Project. Based on the stories of the individual oil actors, this section shows how the Project enshrined the cohort of oil (geo)scientists and chemical engineers that shaped the later developments of both the oil and nuclear industries.

Searching for oil, finding uranium: the entangled history of oil and radioactive mineral exploration

The radium boom

The entangled history of oil-nuclear spillovers started with the discovery of X-rays in 1895 by Willem Conrad Roentgen. Impacting the later development of geophysics, geochemistry, and applied geological research, the discovery established new links between the exploration for oil and radioactive minerals in the first half of the twentieth century. The experiments of Roentgen, designed to examine the properties of cathode rays that leaked from a discharge tube, revealed an invisible radiation. As physicists became more adept at detecting this invisible radiation in more places,

[104] Anduaga, *Geophysics, Realism, and Industry*, 22-23

Roentgen concluded that he had discovered a completely new kind of ray – a ray that could pass through solid objects like wood, rubber, human tissue, and tinfoil. Roentgen had discovered the “roentgen rays”, or what he himself would call X-rays.[105]

One year later, the French physicist Antoine Henri Becquerel addressed the question whether X-rays were not electrical in nature but related instead to the fluorescent joint of the cathode tube. By using uranium samples and photographic plates to capture the emission, Becquerel discovered that the uranium emitted invisible, penetrating rays after being subjected to chemical and physical processes. These uranium rays appeared to be neither X-rays nor fluorescence, but radioactivity instead. In the following years, this discovery would serve as the groundwork for the research conducted by the Polish French scientist Marie Skłodowska-Curie and her husband Pierre Curie. Marie Curie quickly found that pitchblende – a compound of uranium, now often referred to as uraninite – emitted more of Becquerel’s mysterious rays then did pure uranium itself, meaning that pitchblende contained another, hitherto unknown element that possessed the same radiating properties. After a yearlong study, the Curies concluded that there were two new ray-emitting elements: polonium and radium.[106]

In the years following Curie's discovery of radium, both scientists and industrial entrepreneurs became interested in the potential practical properties of radioactive elements. Radium found applications in soap, luminescent paints, aircraft dials, radium-laced beers, and even in radioactive water for both drinking and bathing purposes. Scientists searched for medical applications with experiments using radium to cure diabetes, depression, cancers and skin disorders, often followed by exposure to overdoses of radiation for both the patient and the doctor.[107] Historian Maria Rentetzi has argued that in the United States entrepreneurs established an industry geared toward seducing customers to consume radioactivity and extracting ever more radioactive minerals. The discovery of radium by the Curies provoked a boom in mining of the Colorado Plateau, in Navajo territory, and the construction of the first American radium extraction plants. The profitable radium and vanadium mining attracted entrepreneurs and fueled the establishment of mining companies, like Standard Chemical Company and Vanadium Corporation of America.[108]

These entrepreneurs regularly had a link with the oil industry. Some of them were former oil wildcatters – individuals who drilled exploration wells in areas not known to be oil fields before – who had lost their money in the stock market crash in 1929 and then moved into radium and uranium mining, or were entrepreneurs investing their previously earned oil profits in taking over radium mining companies such as the American oil magnate Harry Snyder buying the Canadian Eldorado

[105] Iwan Rhys Morus, *When Physics Became King* (Chicago: University of Chicago Press, 2005), 182-183; Rienk Vermij, *Kleine geschiedenis van de wetenschap* (Amsterdam: Nieuwezijds, 2007), 245-246; Melosi, *Atomic Age America*, 16.
[106] After this discovery, Marie Curie distilled these two elements, cumulating in a shared Nobel Prize with Pierre Curie and Henri Becquerel in 1903. Helge Kragh, *Quantum Generations: A History of Physics in the Twentieth century* (Princeton: Princeton University Press, 1999), 30-31; Gerald Holton and Stephen G. Brush, *Physics, The Human Adventure: From Copernicus to Einstein and Beyond* (New Brunswick: Rutgers University Press, 2005), 384; Melosi, *Atomic Age America*, 17; Rhys Morus, *When Physics Became King*, 187-188.
[107] Lavine, *The First Atomic Age*; Walker, *Permissible Dose*, 2-4; Mogren, *Warm Sands*, 20-21; Mellor, *The Cold War Underground*, 38.
[108] Rentetzi, *Seduced by Radium*; Mogren, *Warm Sands*, 20-26; Mellor, *The Cold War Underground*, 44-46.

Mining Company in 1932.[109] In other cases, the link was seemingly more coincidental. In her study, Rentetzi recalls the story of the small industrial town of Claremore, Oklahoma, where the owner of the town's first oil company, George Eaton, found sulfur-smelling water, rich in radium, while drilling for oil in 1903.[110]

This discovery, transforming Claremore into the "Carlsbad of America", was only one of many examples where radioactive minerals were found while searching for petroleum. The increasing demand not only sparked a radium boom in the United States and Europe, but also in other countries around the world. Previously, miners had discovered uranium in the mines in the Erzgebirge on the border between Bohemia and Saxony. Now, entrepreneurs and scientists were looking for radioactive minerals on a larger scale. Scientists with a background in oil mineralogy and geology also established multiple oil-radium relations in depleted oil wells of the fast-growing oil industry. In an ever competitive industry, oil firms always searched for new ways of replacing old, depleted oil wells. After multiple decades of extracting oil on an industrial scale, many wells that had been drilled during the first decades of the industrial search for oil and had generated great prosperity for the first oil entrepreneurs started to decline at the beginning of the twentieth century. When the wells neared depletion, increasingly bringing up mostly water and mud, this offered new opportunities to repurpose the existing oil fields into training and research laboratories for early geoscientists. [111]

Using the already established infrastructure of oil fields with declining production rates, various geoscientists studying the properties of radioactivity found radioactive minerals. In 1904, the German physicist Franz Himstedt established the presence of radioactivity in the oil sources at Freyberg, Germany, while Eli Franklin Burton found radioactivity while studying oil sources in the United States and Canada in the same year.[112] In the following years physicists such as Arthur Stewart Eve and Douglas McIntosh discovered radium in oil fields in Ontario, Canada, while Richard Ambronn

[109] 'Dale C. Bunker interview, conducted 14 August 1970 by Harry Henslick,' Uranium Mining Oral History Project, 1970-1971 (Online: American West Center), box 2, folder 9; Mellor, *The Cold War Underground*, 55; Robert Bothwell, *Eldorado: Canada's National Uranium Company* (Toronto: University of Toronto Press, 1984), 65-67.
[110] Rentetzi, *Secuded by Radium,* 128-129; L.N. Bogoiavlensky, A.A. Lomakin, and A. Cherepenikov, *Russian Papers on Measurements of Terrestrial Radioactivity* (US Department of Commerce, Bureau of Mines, 1928), 14.
[111] Michiel Bron, 'Transition in residues: On depleted oil wells, radioactive geophysics, and the origins of the Twentieth century's energy mix,' *Berichte zur Wissenschaftsgeschichte* (Forthcoming).
[112] Eli Franklin Burton, 'Petroleum radioactive gas,' *Phys Zs.* 5 (1904), 511-516; Franz Himstedt, 'Radioactive emanation,' *Phys Zs* 5 (1904), 210-213; A. Al-Farsi, *Radiological Aspects of Petroleum Exploration and Production in the Sultanate of Oman* (Ph.D. Diss., Queensland University of Technology, 2008), 2.

Figure 3: Uranium rock sample pictured by Standard Oil of California, 1979. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History), box 42, folder 56.

conducted his research on the oil boreholes near Celle, Germany, and Ernst Hendrik Büchner used the oil boreholes at Baarlo in Dutch Limburg.[113]

Also in Russia, entrepreneurs and scientists often found radioactive minerals in places previously used to search for oil. The uranium ore flowing from the Antunovich mines in the Fergana region and the Tiuia Muiun massif attracted the attention of Vladimir Vernadsky, who would later become a renowned geochemist involved in the first Soviet atomic energy projects. Together with geologist Aleksandr Fersman, Vernadsky founded a radium institute and continued to work on mineral exploration during and after the Russian civil war (1917-1923). The scientists actively searched for new domestic sources of radioactive minerals from 1922 onward, in this way discovering the Tobashar deposit in northern Tajikistan in 1927. In the 1930s, Vernadsky started with the systematic examination of borehole water from oil deposits for radioactivity, a method he based on earlier findings of radium in this type of water at the Ukhta oilfield in the Komi Republic of the Soviet Union. Vernadsky's studies led to the discovery of Mailuu-Suu, a new uranium-vanadium deposit in the Fergana valley. This in turn led to the discovery of another deposit in this region called Uighur-Sai. None of these later discoveries

[113] Arthur Stewart Eve and Douglas McIntosh, 'On the Amount of Radium present in Typical Rocks in the immediate Neighborhood of Montreal,' *The London, Edinburg and Dublin Philosophical Magazine and Journal of Science* 6, 14 (1907), 231-237; Ernst Hendrink Büchner, 'The Radium Content of Rocks,' *Proceedings of the section of sciences* 14 (Amsterdam: Koninklijke Nederlandse Academie van Wetenschappen, 1912), 1063-1066.

would begin mining operations in the 1930s, however, leaving the Soviet Union with the Ukhta oilfield water as the main domestic source of radium after the shutdown of the Tiuia mines in 1936.[114]

Measuring radioactivity to find petroleum

The spillovers between radioactive mineral and oil exploration did not only include prospecting geologists, investments by oil entrepreneurs, or the use of oil boreholes by scientists. In the first half of the twentieth century, it became increasingly clear that radioactive measurements could be used to search for both oil and radioactive minerals. Methods used in applied geophysics are often based on measuring physical qualities changing with geological conditions, such as natural radioactivity. Radiometric instruments like the Geiger counter (developed in 1928) could recognize shallow deposits of radioactive ores by their gamma radiation emissions either at ground level with at the earth’s surface or from low flying airplanes. By measuring gaseous emanation, radon, escaping via joints and gaps from greater depths, it became possible to locate faults and mineral water. Also, the use of gamma spectrometry could deduce the chemical elements existing in the rock.[115]

These methods derived from radiation physics became of special importance for well logging, specially the techniques of gamma logging, gamma-gamma logging, neutron-gamma-logging, and tracer methods and markers. Based on the findings of Becquerel and the Curies, and the studies of Ernst Rutherford and Frederick Soddy on radioactive decay, the Scottish geologist John Joly published his book on radioactivity and geology in 1906. Joly focused on determining the radium content of the surface materials of the earth, improving existing methods of measuring radium. He devised a method for determining the amount of thorium in rocks by radioactivity, thus making it possible to estimate the radioactive qualities of the rocks.[116] In 1926, the German physicist, and later active NSDAP party member, Richard Ambronn used the studies of Joly to measure the radioactivity of cores taken in an oil well at Celle, near Hanover, Germany. In his book on the exploration different minerals, like potash and petroleum, Ambronn brought together his different findings on radioactive measurement and tried to establish the field of “applied geophysics”.[117]

In his, well received, publication *Methoden der Angewandten Geophysik* (later translated into English by the American petroleum geologist Margareth C. Cobb as *Elements of Geophysics as Applied to*

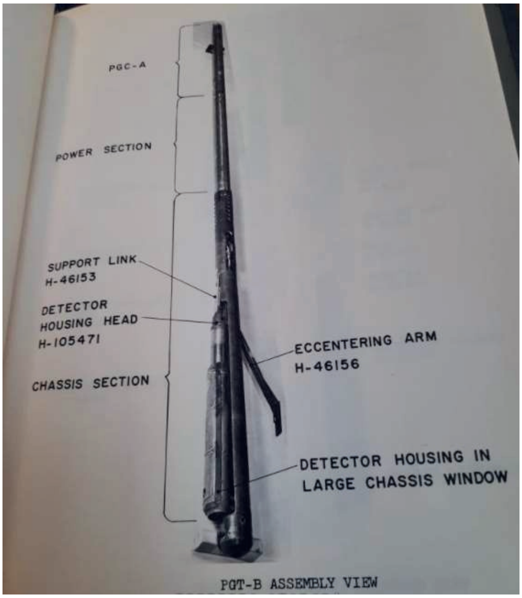
[114] Mellor, *The Cold War Underground*, 41-44, 46-48, 53-54; Kendall E. Bailes, *Technology and Society under Lenin and Stalin: Origins of the Soviet Technical Intelligentsia, 1917-1941* (Princeton: Princeton University Press, 1978), 44-66; David Holloway, *Stalin and the Bomb: The Soviet Union and Atomic Energy* (New Haven: Yale University Press, 1996), *Stalin and the Bomb,* 45; For more on Vernadsky see Kendall E. Bailes, *Science and Russian Culture in An Age of Revolutions: V.I. Vernadsky and his Scientific School, 1863-1945* (Bloomington: Indiana University Press, 1990); Vaclav Smil, *The Earth’s Biosphere: Evolution, Dynamics, and Change* (Cambridge: MIT Press, 2003), 1-26; Alexei B. Kojevnikov, *Stalin’s Great Science: the Times and Adventures of Soviet Physicists* (London: Imperial College Press, 2004).
[115] H.G. Reinhardt and H. Gast, ‘The importance of radioactivity in geoscience and mining,’ *Experientia* 51 (1995), 704.
[116] Louis A. Allaud and Maurice H. Martin, *Schlumberger: The History of a Technique* (New York: John Wiley & Sons, Inc., 1977), 268; Patrick Wyse Jackson, *The Chronologers’ Quest: Episodes in the Search for the Age of the Earth* (New York: Cambridge University Press, 2006), 237-238; ‘John Joly: 1857-1933’, *Obituary Notices of Fellows of the Royal Society* 1, 3 (1934), 268-269.
[117] Richard Ambron, *Elements of Geophysics as Applied to Explorations for Minerals, Oil and Gas*, translated by Margareth C. Cobb (New York: McGraw-Hill Book Company, Inc., 1928); B.G. Egloff, ‘Die Chemie in der modernen Ölindustrie,’ *Erdöl und Kohle 8* (Dortmund: bes. S., 1995); Bron, ‘Transition in residues’.

Explorations for Minerals, Oil and Gas (1928)), Ambronn proposed methods of lowering boxes containing an apparatus suitable for measurements into boreholes. In the boreholes, diverse types of rays (alpha, beta, and gamma) would penetrate gas-filled enclosures in the boxes, showing which radioactive elements amassed together at different heights underground. In this way, Ambronn offered a practical application for the research he had conducted on the muddy boreholes of Celle's oil drilling sites. Not only was it possible to study radioactivity and classify radioactive minerals, but this kind of research also enabled geophysicists to locate specific sedimentary layers where radioactive minerals tend (or do not tend) to deposit, making it easier to pinpoint vaults, deposits, and reservoirs underground.[118]

For research into the measurement of radioactivity in particular, the fact that the boreholes at Celle, Baarlo, and Ontario, were almost depleted proved crucial. In the muddy boreholes, polluted with underground water, measuring radioactive decay by lowering gas-filled enclosures into the boreholes delivered more, and often better, results than comparable techniques like electric well logging. Because radioactivity is not affected by the nature of the mud, while many contemporary electric well logging devices quickly became unreliable in salt- and water-saturated mud, logging based on radioactivity measurements could still produce results in the muddy boreholes that were used to train new oil geophysicists. The use of radioactive logging techniques sometimes also resulted in findings that seemingly depleted oil well wells still appeared to contain unextracted oil reserves.[119]

These findings sparked the interest of pioneers in the oil sector during the following two decades. Before the start of the Second World War, Russian geophysicists had built a logging device based on gamma rays but failed to publish any results.[120] Another attempt was commercially more successful, however. The French family oil prospecting company Schlumberger succeeded in designing an apparatus to record natural radioactivity. Geophysicist Conrad Schlumberger, along with his brother Marcel the founders of the company, had been interested in the idea of using radioactive radiation for oil exploration since the early 1920s.[121] Especially gamma logging, the technique used to register the gamma-quanta of high energy generated by some natural radioactive elements located in magmatic and sedimentary rocks, was helpful to discover sand containing oil or water within clay beds. These beds generally contain more natural radioactive nuclides so by measuring the thickness of layers containing uranium or potassium an indication of the underground deposits could be calculated.[122] In

[118] Ambron, *Elements of Geophysics as Applied to Explorations for Minerals, Oil and Gas*, 108-123; Bron, 'Transition in residues'.
[119] 'Sondage radioactif, étude de Clark Goodman du centre de Ridgefield sur des résultats expérimentaux [notes], 1951,' Archives Marcel Schlumberger (Crèvecoeur-en-Auge: Fondation Musée Schlumberger), AM-69 ; Reinhardt and Gast, 'The importance of radioactivity in geoscience and mining,' 704; Allaud and Martin, *Schlumberger*, 268; Bron, 'Transition in residues'.
[120] Allaud and Martin, *Schlumberger*, 268.
[121] 'Carottage radioactive, instruction d'utilisation pour les sondages de gisements pétroliers: note technique,' Archives Marcel Schlumberger (Crèvecœur-en-Auge: Fondation Musée Schlumberger), folder AM-349; Bowker, *Science on the Run*, 39.
[122] Reinhardt and Gast, 'The importance of radioactivity in geoscience and mining,' 703.



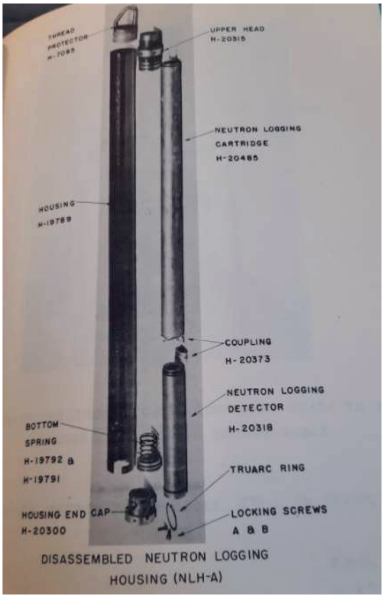


Figure 4 and 5: Assembly view of gamma well log used by Schlumberger's Well Survey Company (left), and a disassembled neutron logging housing used by Schlumberger in 1952 (right). Archives Conrad Schlumberger (Paris: École des Mines), AC-323 and AC-316.

1938, the research conducted by Schlumberger eventually led to the first gamma ray logging, performed in Oklahoma, by Schlumberger's American oil subsidiary Well Survey Company.[123]

The detector in the logging device was an ionization chamber, a gas-filled enclosure made weakly conductive by the gamma radiation. Like all gamma ray systems, it required electronic components in the sonde. Geoscientists working in oil exploration immediately found practical applications, especially for the resumption of production in old wells where no logging had ever taken place, and which now could be studied by correlating the gamma ray log with other types of logs in surrounding wells. The same was true for controlling the drilling of perforating depths. The gamma ray log offered a necessary correction for the problems Schlumberger encountered with accurately measuring the depth of a well and to position the perforator exactly at the right depth.[124]

The oil industry appreciated the results of the gamma well logging devices. After Schlumberger's breakthrough multiple companies started research projects to apply this technique. In June 1942, the geophysical laboratory of The Texas Company (Texaco, later absorbed by Chevron) in Houston issued a report concluding that the equipment was very promising.[125] In addition, the Shell group decided to

[123] Simone Turchetti, *The Pontecorvo Affair: A Cold War Defection and Nuclear Physics* (Chicago: Chicago University Press, 2012), 39-68; S.M. Luthi, *Geological Well Logs: Their Use in Reservoir Modelling* (Berlin: Springer, 2001), 12-25; Allaud and Martin, *Schlumberger*, 268.

[124] 'La radioactivité dans les sondages, étude de Louis Migaux sur les manifestations de la fluorescence et de la radioactivité: note de laboratoire,' Archives Marcel Schlumberger (Crèvecœur-en-Auge: Fondation Musée Schlumberger), folder AM-347; 'Rayons gamma, analyse de expérience d'utilisation de jalons radioactifs par W.B. Steward: rapport,' Archives Marcel Schlumberger (Crèvecœur-en-Auge: Fondation Musée Schlumberger), folder AM-834; Allaud and Martin, *Schlumberger*, 268.

[125] 'Radioactivité dans les sondages, expérience d'application de la Texas Company: rapport,' Archives Marcel Schlumberger (Crèvecœur-en-Auge: Fondation Musée Schlumberger), folder AM-835.

introduce this technique in the years shortly after Schlumberger's experiments.[126] Other methods of detecting radiation-based minerals and oil also began to emerge in the oil world shortly before and during the beginning of the Second World War. After the discovery of the neutron in the early 1930s, geophysicist Robert E. Fearon was able to apply for a patent for the neutron log, and another patent was granted in 1940 to the Dutch physicist and mathematician Folkert Brons.[127] In 1941, Italian physicist and later notorious nuclear spy Bruno Pontecorvo, while working for an American oil company in Tulsa, wrote the article "Neutron Well Logging" in *Oil and Gas Journal*, after which Well Survey Company undertook the first tests.[128]

Developing geophysical technologies in a global context

Although the geophysicists of Western oil companies played a major role in the development of radioactive well logging techniques and the later application of this technology in the uranium industry, the early development of the entanglements between oil exploration and radioactive knowledge was not just a story of the Western oil industry alone. Both petroleum and radioactive minerals, especially uranium, can be, and were, discovered all over the world. Because uranium has a compulsion to combine with oxygen, natural uranium occurs as either an oxide or a silicate. This constraint creates distinct types of uranium based on the combination with oxygen, including uraninite or pitchblende and carnotite. Since carnotite uranium does not intrinsically occur as a pure metal, its compounds can be found in small concentrations in both rocks and water all over the planet, but tend to deposit around decaying biomass, often in petroleum source rock. The mineral occurs naturally a thousand times as frequently as gold and nearly as frequently as nickel and zinc.[129]

Many of the stories traditionally told about radioactive mineral and petroleum prospecting in the Global South often only focus on the Western prospectors – regularly geologists and geophysicists with close connections to the oil industry – who "discovered" the (radioactive) mineral deposits. These stories included the tales of the British entrepreneur Robert Sharp discovering the Shinkolobwe mine in the Katanga province of Belgian Congo in 1915, and the later manager of the uranium reserves within the Manhattan Project Philip Leonidas Merrit working on oil and mineral exploration in South Africa

[126] R.J. Forbes and D.R. O'Beirne, *The technical development of Royal Dutch Shell, 1890-1940* (Leiden: E.J. Brill, 1957), 206-207.

[127] Robert E. Fearon and J.M. Thayer, 'Method and apparatus for neutron well logging' (US Patent); Allaud and Martin, *Schlumberger*, 270-271.

[128] Bruno Pontecorvo, 'Neutron well logging–a new geological method based on nuclear physics', *Oil and Gas Journal* 40, 18 (1941); Bruno Pontecorvo, 'Contribution of Posassium to the Gamma Ray Activity Log,' (October 29, 1940), Serge A. Scherbatskoy Papers (Washington D.C.: NMAH Archives Center), box 1, folder 1; Turchetti, *The Pontecorvo Affair*, 39-68; L. Bonolis, 'Bruno Pontecorvo: From Slow Neutrons to Oscillating Neutrinos', *American Journal of Physics* 73 (2005), 487-499; Frank Close, *Half Life: The Divided Life of Bruno Pontecorvo* (New York: Basic Books, 2015).

[129] Three types of uranium can be found in nature: uranium-234, -235, and -238. The numbers indicate the weight of the nucleus of each isotope, which is based on the number of neutrons and protons. Over 99% of all the uranium found in nature is uranium-238, with the rest being mostly uranium-235. Norman Moss, *The Politics of Uranium* (London: Andre Deutsch, 1981), 2; Mellor, *The Cold War Underground*, 30-31; World Nuclear Organization, 'Supply of Uranium,' *World Nuclear Organization* (2022), http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx (Accessed August 29, 2022); US Department of Energy, 'Uranium Quick Facts,' *DOE Depleted UF6 Management Information Network* (2022), http://web.ead.anl.gov/uranium/guide/facts/ (Accessed August 29, 2022).

and Colombia.[130] Also the geologist Arnold Fletcher studied radioactivity in the sedimentary layers in tunnels through the Andes, and the British geophysicist William Frederick Smeeth conducted research on radium up to a depth of thousand meters in the Kolar gold mine in Karnataka, India.[131]

A lot of the knowledge, technologies and practices that were used to study in early studies to radioactivity and exploration of radioactive minerals, however, were in fact developed in a specific local context with knowledge produced by geophysicists of diverse nationalities and backgrounds. As historians Drielli Peyerl and Silvia Fernanda de Mendonça Figueirôa have shown, Brazilian geographical and geological parties developed the geophysical techniques used to scrutinize Brazilian territory to establish a national oil industry in close collaboration with industrial parties from the United States. Within this geographical context, radioactive well logging techniques were molded to specifically fit the Brazilian circumstances from 1938 onward, offering the US geophysicists ways to further improve their knowledge on how to locate radioactivity and find oil in other places.[132]

These global entanglements emerge even more clearly when looking at the development of radioactive well logging devices in Eastern Europe and the early Soviet Union. Russian physicists and chemists, like Vernadsky, studied oilfield waters to find traces of radioactive minerals – that led to the discovery of the main uranium deposits that produced the resources the early Soviet bomb programs – just like geophysicists in Europe and North America did. Only after Russian oil production collapsed following the revolution and civil war, the Bolshevik government made large-scale investments to bring in Western contractors to revive production and train their people in the use of Western technologies. Companies such as the American Radiore Company and Schlumberger signed contracts with the Soviet government introducing the rotary bit, electrical well logging and new cracking techniques in Russia. The contract with Schlumberger explicitly stated that the French company would train Russian engineers, provide access to the company laboratories, and that Schlumberger would set up new laboratories in the Soviet Union. In addition, Russian scientists gained the opportunity to access the drilling holes for their research saving the costs of expensive exploration drilling. [133]

For Schlumberger, according to historian Geoffrey Bowker, this agreement was on the one hand regarded as a disaster with the Russian branch of the company quickly being taken over by the Soviet government, and on the other hand a success with Schlumberger using this opportunity in the Soviet Union to become experts in well logging and to develop new technologies. The crux for Schlumberger, and for many of the other Western companies that became active in the Soviet Union and Eastern Europe, was that the US oil industry was comparatively large, and extremely competitive. Contracts with the Soviets and other Eastern European governments provided relative long-term security, established a training ground where other Western industrial competitors would not spy on new

[130] Gillingham, 'Memorial to Philip Leonidas Merrit, 1906-1981,' 1; D.D. Hogarth, 'Robert Richard Sharp (1881-1960), Discoverer of the Shinkolobwe Radium-Uranium Orebodies,' *Terrae Incognitae* 46, 1 (2014), 38-39.
[131] Arnold L. Fletcher, 'On the radium content of secondary rocks,' *The London, Edinburg and Dublin Philosophical Magazine and Journal of Science* 6, 23 (1912), 279-291; William Frederick Smeeth and H.E. Watson, 'On the radioactivity of Archean rocks from the Mysore State, South India,' *Philosophical Magazine* 6, 35 (1918), 206-213.
[132] Drielli Peyerl and Silvia Fernanda de Mendonça Figuerôa, 'Applied geophysics in Brazil and the development of a national oil industry (1930-1960),' *History and Technology* 36, 1 (2020), 83-104.
[133] Eleanor Swent, 'Interview with James Boyd,' *The Knoxville Project Western Mining in the Twentieth century Oral History Series* (Berkeley: University of California, 1986), 39; Bowker, *Science on the Run*, 58; A.C. Sutton, *Western Technology and Soviet Economic Development, 1917-1930* (Stanford: Stanford University Press, 1968), 363-372.

technologies, and provided access to a rich arsenal of qualitative local scientists who could co-develop the new technologies that later could be applied in within the US oil business.[134]

The origins of a cohort: atomic (geo)physicists and chemical engineers in the oil sector

Geophysics as industry

The emergence of new, geophysical, technologies based on the measurement of radioactivity, and the accumulation of radioactive knowledge within the oil sector, were direct results of the industry investing in geophysical science during the first decades of the twentieth century. Within the competitive oil market, oil firms, especially Western ones, increasingly invested in academic geophysics and established geophysical subsidiaries to gain a competitive edge.[135] These developments caused (geo)physicists, often with a background in early atomic physics, to spill over into the oil industry. This was also the case for Paul Darwin Foote. After obtaining a degree of Doctor of Philosophy in Physics in 1916 at the University of Minnesota, Foote taught classes on radiation theory for fellow younger staff members like John Torrence Tate and Arthur Compton. At the university, Tate convinced Foote to focus his research on atomic processes. After publishing the influential *Origins of Spectra* (1922), Foote became the director of his own section on Radium, X-rays, and Atomic Structure in the optics division of the Bureau of Standards.[136]

After five years and seventy publications, Foote decided to leave government service and accepted the position of Senior Industrial Fellow on a new fellowship in oil production technology established by the Gulf Oil Corporation at the Mellon Institute of Industrial Research in 1927. In his new job, Foote's primary task was to establish a new research direction on the application of physics to the discovery of oil fields and production of crude oil from these fields. Together with E.A. Eckhardt, who was also a physicist and had already been engaged with geophysical work in the oil industry, Foote created a rapidly growing Geophysical Division. This division expanded quickly and, when it grew too big for the Mellon Institute, transferred as a new research department to the laboratory building of Gulf Oil. In 1933, the division became the Gulf Research & Development Corporation, a full-fledged subsidiary of Gulf Oil, and Foote became its Director of Research and Executive Vice-President of the Gulf Refining Company, providing him with a seat on the board of directors of the Gulf Oil Corporation before he

[134] Bowker, *Science on the Run*, 58.

[135] Anduaga, *Geophysics, Realism, and Industry*, 22-23; John W. Servos, 'To explore the borderland: the foundation of the geophysical laboratory of the Carnegie Institution of Washington,' *Historical Studies in the Physical and Biological Sciences* 14 (1984), 148; Hatten S. Yoder, *Centennial History of the Carnegie Institution of Washington: The Geophysical Laboratory, Vol. III* (Cambridge: Cambridge University Press, 2004), 134-143; Naomi Oreskes, 'Why Predict? Historical Perspectives on Prediction in Earth Science', D. Sarewitz, R.A. Pielke Jr. and R. Byerly Jr. (eds), *Prediction: Science, Decision Making, and the Future of Nature* (Washington D.C.: Island Press, 2000), 23-40; Tyler Priest, 'Hubbert's Peak: The Great Debate over the End of Oil,' *Historical Studies in the Natural Sciences* 44, 1 (2014), 42-44; Forbes and O'Beirne, *The technical development of Royal Dutch Shell*, 60.

[136] Bureau of Standards, *Annual report of the Director Bureau of Standards for the fiscal year ended June 30, 1921* (Washington D.C.: Washington Government Printing Office, 1921), 73-74; 'John Torrence Tate', *Biographical Memoirs* 47, 464 (Washington D.C.: National Academy of Sciences, 1975); A.V. Astin, 'Paul Darwin Foote: March 27, 1888-August 2, 1971', *Biographical Memoirs Vol. 50* (Washington D.C.: National Academy of Sciences, 1979), 178-180.

would return to nuclear developments by becoming a member of the industrial advisory group for the US Atomic Energy Commission in the 1950s.[137]

Foote's transfer from government service as an atomic physicist to a position as a geophysicist in the oil sector is a telling example of the (geo)physicists, versed in atomic physics, spilling over to the oil industry during the first half of the twentieth century before returning to nuclear developments later in their careers. Like in the case of Gulf's geophysical department, also other oil companies established research departments and trained recently graduated academic physicists to become geophysicists in the oil industry. Shell assigned the German geologist Heinrich Moritz Emil Schürmann to manage the training program for new (geo)physicists. Schürmann, graduated in mineralogy at the University of Bonn, joined the Royal Dutch Shell Group in 1913. In 1930, he was appointed as the first chief of the newly established Geological Department to train new physics graduates in geophysics and geology in the oil sector.[138] One of these graduates was Edward Crisp Bullard, who finished his Ph.D. in atomic physics, combining his studies with work as a geophysical consultant for the Anglo-Saxon Oil Company (subsidiary of Shell). After the Second World War, Bullard continued consulting for several oil companies, including Burmah Oil and Royal Dutch Shell, and worked for the British Atomic Energy Authority in creating a new nuclear industry and develop techniques to register nuclear bomb tests.[139] Schürmann, at that point retired from Shell would also become involved in the establishment of the nuclear industry by advising the Dutch government on possible uranium mining in New Guinea and Suriname.[140]

The newly established geophysical research and development departments became the places where recent technologies based on early atomic physics, like radioactive well logging, were developed. These technologies were designed at companies such as Gulf Oil, Shell, but most visibly at Schlumberger's geophysical research departments. Geoffrey Bowker describes Schlumberger as a foremost geophysical company heavily investing in geophysical research. The company made use of privileged access to the oldest European oil field, Pechelbronn, in Alsace. This oil field was already nearly depleted which made it expensive to drill for oil and there was an urgent need for new, innovative methods to reduce costs. Access to this oil field proved to be a good opportunity for the Schlumberger brothers, especially for Conrad who was physics professor at the *Ecole des Mines* and is often referred to as the "father of geophysics," to experiment with geophysical techniques which kickstarted their career as an oil service company. Pechelbronn also served as a site for the apprenticeship of the new geophysical engineers of Schlumberger, offered an opportunity for independent entrepreneurs and scientists to do their experiments, and became a major connector for early geophysicists. In this way, Schlumberger could use Pechelbronn to analyze, meet, and possibly

[137] 'Organization chart research laboratory Gulf Producing and Pipe Line Cos,' Mellon Institute of Industrial Research (Pittsburgh, Carnegie Mellon University Archives); Paul Darwin Foote, 'Petroleum: then and now,' *The Scientific Monthly* 74, 5 (1952), 280-290; Astin, 'Paul Darwin Foote', 181-182.
[138] J.J. Dozy, 'Obituary H.M.E. Schürmann (1891-1979)', *Geologie en Mijnbouw* 58, 3 (1979), 289-290; Forbes and O'Beirne, *The technical development of Royal Dutch Shell*, 60.
[139] Anduaga, *Geophysics, Realism, and Industry*, 204; R.J. Howarth, 'Bullard, Sir Edward Crisp (1907-1980)', H.C.G. Matthew and B. Harrison (eds), *Oxford Dictionary of National Biography* (Oxford: Oxford University Press), 600-603.
[140] 'Nota: Instelling Commissie voor onderzoek aanwezigheid splijtbare materialen in Nederlands-Nieuw-Guinea en Suriname,' Archives Directorate of Nuclear Energy of the Ministry of Economic Affairs (The Hague: Dutch National Archives, 1956), box 2.06.101., folder 735.

sabotage or recruit other geoscientists trying to research ways of finding oil and other minerals, many of them with a background in atomic physics.[141]

Atomic physicists in petroleum chemistry and chemical engineering

Where Foote became an oil geophysicist, other scientists with a background in atomic physics spilling over into the oil sector made careers in chemistry and chemical engineering within the oil industry before returning to nuclear developments. After studying mathematics and physics at the University of Groningen and a doctorate with Hans Kramers on quantum mechanics and multipole radiation, Henri Coenraad Brinkman transferred to the *Bataafsche Petroleum Maatschappij* (BPM), the Dutch branch of Shell, in the mid-1930s, where he conducted research on the viscosity of liquids. Following his career at BPM, Indonesia, Brinkman published *De bouw der atomen en moleculen* (*The structure of atoms and molecules*, 1949) before he aided in establishing Dutch nuclear fusion research from 1957 onward after an employment as lecturer at the technical university in Bandung.[142] Other examples include Brinkman's Ph.D. supervisor, Hans Kramers, who started working for Shell in 1942 and became involved in the early Dutch efforts to establish a uranium enrichment industry based on gaseous diffusion, and the later director of the Dutch atomic research center RCN, Maarten Bogaardt, who started working for Shell before the Second World War after finishing his studies in chemics and atomic physics.[143]

Like Foote's transition to geophysics, these examples of the chemists at Shell were not isolated events. During the decades before the Second World War, Shell made large-scale investments in establishing a chemical research department.[144] The laboratory in Amsterdam became the pivotal point of research, growing from thirty employees in 1920 and to 1355 in 1938.[145] Shell was not the only company to invest in chemical research, however. After the First World War, several oil companies lobbied with the US government for more investments in academic education in chemistry and chemical engineering to meet the increasing focus on chemical research within the oil sector, in this

[141] Examples of atomic physicists becoming geophysicists for Schlumberger after doing experiments at Pechellbron are the Régis family and Henri George Doll. Bowker, *Science on the Run*, 33-39, 117; Yates, *The French Oil Industry and the Corps des Mines in Africa*, 46-49; 'Carottage radioactive, instruction d'utilisation pour les sondages de gisements pétroliers: note technique,' Archives Marcel Schlumberger (Crèvecoeur-en-Auge: Fondation Musée Schlumberger), folder AM-349.

[142] H.W. Broer and H.S.V. de Snoo, 'Mathematisch fysicus H.C. Brinkman,' *Nederlands Tijdschrift voor Natuurkunde* (October 2021), 31-32.

[143] 'Letter H.J. Rijks and GJ.L. Caviët to Kramers, 28 July 1942,' 'Letter H.J. Rijks to Kramers, 9 December 1942,' 'Letter H.J. Rijks to Kramers, 16 August 1943,' and 'Letter H.J. Rijks to Kramers 1 July 1944,' Kramers Correspondence (Utrecht: Archive of the History of Quantum Physics), section 11, microfilm; Max Dresden, *H.A. Kramers: between tradition and revolution* (New York), 500; Friso Hoeneveld, *Een vinger in de Amerikaanse pap: Fundamenteel fysisch en defensie onderzoek tijdens de vroege Koude Oorlog* (Ph.D. Diss., Utrecht University, 2018), 95; Andriesse, *De Republiek der Kerngeleerden*, 180-181.

[144] Jonker and Van Zanden, *Van nieuwkomer tot marktleider, 1890-1939*, 334-352.

[145] Ton van Helvoort and Ernst Homburg, *Een eeuw chemische technologie in Nederland* (Delft: Stichting Hoogewerff-fonds, 2021), 35-37; Koninklijke/Shell Laboratorium Amsterdam, *Research aan het IJ: LBPMA 1914 – KSLA 1989* (Baarn: Market Books, 1989).

way creating a corps of engineers "well grounded in basic physics and highly skilled in developing and operating large industrial chemistry complexes."[146]

There also were considerable investments within the oil companies themselves. As within the Shell Group, Standard Oil of New Jersey established a subsidiary called Research and Development Company in 1930 to study the development of chemical processes utilizing petroleum materials.[147] The first Director of this new Research and Development Company, Eger Vaughan Murphree, was a chemist with a background in physics and mathematics. He majored in chemistry and mathematics at University of Kentucky in 1920 and graduated in chemistry in 1921 before he was employed as chemical engineer with the Solvay Process Company. In 1930, he started as the new director of the Standard Research and Development Company where he focused on different research projects that proved significant during the Second World War such as the development of synthetic and butyl rubbers and the development of fluid cracking techniques for the cracking of oil. Murphree's most important contribution to the US war effort, however, was to the development of the atomic bomb in the Manhattan District Project. Murphree led Standard Oil of New Jersey's involvement in the bomb program, which consisted of providing its expertise in constructing big industrial projects at great speed and then managing their continuous operation. Other companies possessed similar expertise; but the choice for Jersey Standard was also largely based on the specific knowledge of chemistry gained in its laboratories.[148]

The most notable technology in this regard was mass spectrometry. The analytical technique used to measure the mass-to-mass charge ratio of ions could be applied to both pure samples of gases, liquids or solids and complex mixtures. The first scientists working on mass spectrometry were academic physicists, like John Tate, focusing on the analysis of elements and pure compounds. Although these studies taught scientists much about stable isotopes, the oil industry further developed the technology to analyze complex mixtures like crude oil, containing a multitude of hydrocarbons that had to be refined into usable gasoline, diesel fuel, lubricating oils, or asphalt. Several historians have shown how oil companies, such as Humble Oil, Shell, and Standard Oil of Indiana, and companies providing services to the oil industry like Westinghouse, and the trade organization American Petroleum Institute (API), became early sites of development of mass spectrometry.[149]

[146] Richard G. Hewlett and Oscar E. Anderson Jr., *The New World, 1939-1945: A history of the United States Atomic Energy Commission, Vol. 1* (The Pennsylvania State University Press, 1962), 49-50.
[147] E.R. Gilliland, 'Eger Vaughan Murphree: November 3, 1898-October 29, 1962,' *Biographical Memoirs* (Washington D.C.: National Academy of Sciences, 1969), 230.
[148] Eger Vaughan Murphree, ''Adventures in Applied Chemistry': speech given for The American Section of The Society of Chemical Industry,' ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History, 1950), box 2.207/L13C; Gilliland, 'Eger Vaughan Murphree: November 3, 1898-October 29, 1962', 227-232.
[149] Grayson, *Measuring Mass*, 33-40; Lassman, *Edward Condon's Cooperative Vision*; Reinhardt, *Shifting and Rearranging*; J.D. Williams and D.J. Burinsky, 'Mass spectrometric analysis of complex mixtures then and now: the impact of linking chromatography and mass spectrometry,' *International Journal of Mass Spectrometry* 212, 1-3 (2001), 111-133; M.S. Rakow, 'Petroleum oil refining,' G.E. Totten, S.R. Westbrook, R.J. Shah (eds), *Fuels and Lubricants Handbook* (West Conshohocken, Pennsylvania: ASTM International, 2003), 3-30; Seymour Meyerson, 'Reminiscences of the early days of mass spectrometry in the petroleum industry,' *Organic Mass Spectrometry* 21, 4 (1986), 197-208.

A network of atomic physicists

Archetypical examples such as Paul Foote, Henri Brinkman, and Eger Murphree, show the establishment of a new cohort. This cohort was composed of academically trained geophysicists and chemists versed in early atomic physics who started their career in the newly founded research and development departments within the oil industry who then got involved in industrial nuclear developments during the decades following the outbreak of the Second World War. The members of this cohort were mostly men, but included also female geoscientists like Margareth C. Cobb at the American Petroleum Institute and Amerada Petroleum Company, and Belva Brown who identified and isolated chlorophyll molecules with the help of a mass spectrometer and a gas chromatograph at Socony's research laboratory.[150] In a 1938 report to the Geological Society of America, Barnard College professor Ida H. Ogilvie stated that geology – "that practical science which appeals to the rugged, outdoor type of man" according to *The News* – attracted more and more women. According to the report, the majority of women working in geology were connected in some ways to the oil industry, being employed in the offices of petroleum companies but also conducting research in oil fields.[151]

The origins of this cohort are roughly situated between 1925 and 1940. During this extended decade, the oil industry started investing in recruiting more academically trained personnel, focusing on graduates in physics and chemical engineering, to run the newly established research and development centers. Trying to gain a competitive advantage, the research laboratories became incubators for innovative technologies that were often based on principles established in early quantum mechanics and studies measuring natural radioactivity, like mass spectrometry and radioactive well logging. The technologies and expertise emerging from oil firms' laboratories would lay the groundwork for oil actors within this cohort to spill over into the later nuclear developments.

While developing these technologies and setting up research and development departments, the atomic physicists and chemists working in the oil industry were part of an overarching network. Although on the company level oil firms often competed, their scientists also published in journals read throughout the industry and met each other at conferences, workshops, and other events such as industry-oriented, but primarily social local oil clubs in Houston or Oklahoma City or events organized by disciplinary societies like the American Geophysical Union, by trade organizations such as the American Petroleum Institute (API), or alumni organizations of the universities they shared a link (e.g. the Universities of Kansas, Oklahoma, and Texas in the US as well as more elite Universities such as Stanford, Rice and Caltech, and the Delft, Leiden and Utrecht Universities in the Netherlands). Some of the members of this cohort also served together on committees for trade organizations, and even on National Research Committees advising the federal government trying to tear down the walls between the fields of geology, chemistry, and physics.[152]

Examples of the journals were *Petroleum Technology* (the predecessor of *The Journal of Petroleum Technology*), *Science* and *Nature*, but also *The London, Edinburg and Dublin Philosophical Magazine and Journal of Science*. Especially the latter regularly featured articles from the beginning of the

[150] 'Discovery about composition of petroleum: new scientific knowledge sheds light on its origin,' (1964), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F160.
[151] 'Women Enter Geology Field,' *The News* (December 7, 1938), 17.
[152] Geophysicist Marion King Hubbert served on the Interdivisional Committee on Borderland Fields Between Geology, Chemistry, and Physics (an offshoot of the National Academy of Sciences). Mason Inman, *The Oracle of Oil: a Maverick Geologist's Quest for a Sustainable Future* (New York: W.W. Norton & Company, 2016), 64.

twentieth century onward about research conducted into measurements of radioactivity in oil reservoirs and boreholes.[153] Academic geologists like John Joly, Arnold Fletcher, and Arthur Stewart Eve, published these articles, but also increasingly geophysicists working for the oil industry such as Margaret Cobb.[154]

This network was not limited only to the oil industry itself. In the decades following the First World War, atomic physics and chemistry flourished with an increasing number of scientists studying the properties of radioactivity and researching early quantum mechanics. Partly funded by the philanthropical schemes of oil and steel magnates like Carnegie and Rockefeller, an international network spanning North America, Europe and the Soviet Union emerged with scientists and graduates visiting conferences and research institutes with fellowships and travel funds. As various historians have argued, the networks built on the money provided by funding schemes, like the Rockefeller fellowships, were not always deliberately meant to profit the oil industry.[155] Still, many of the scientists that would end up in the oil, and later nuclear, industries did profit from Rockefeller fellowship funding to establish an international network and get trained in atomic physics during their studies.[156] Also, oil companies, like Gulf Oil at the Mellon Institute for Industrial Research, themselves funded fellowships at research institutes and universities for their personnel to train in, and conduct, fundamental research.[157]

The scientists and engineers working within the oil sector were often well-established in this international milieu, encompassing academic research projects, company laboratories, and the offices of governmental policy makers. During his time at Shell Hendrik Brinkman, for example, often visited international conferences to discuss the progress of the research in the field of chemistry on the structure of atoms and molecules, culminating in his publication of *The Structure of Atoms and Molecules* in 1949.[158] Also, Paul Foote, as vice president of Gulf Oil and manager of Gulf's research and development department, operated in a broad network of scientists, industrialists and policy makes studying the properties and applications of the growing field of atomic physics. During his time at the Gulf Geophysical Department, Foote attended lecture series by Merle Antony Tuve who worked at the Nuclear Physics Program at the Carnegie Institution of Washington. Foote also worked together with

[153] Bron, 'Transition in residues,'; Eve and McIntosh, 'On the Amount of Radium present in Typical Rocks in the immediate Neighborhood of Montreal,' 231-237; Fletcher, 'On the Radium content of Secondary Rocks,' 279-291.
[154] Ambronn, *Elements of Geophysics as Applied to Explorations for Minerals, Oil and Gas*, ix; Arthur Stewart Eve also positively reviewed this book for *Science*: Arthur Stewart Eve, 'Applied Geophysics,' *Science* 67, 1729 (1928), 192-193.
[155] On the contrary, the Rockefeller Institute explicitly tried to move away from associations with the industry their wealth was derived from by investing in fields outside the direct research areas of the petroleum scientists. Robert E. Kohler, 'A Policy for the Advancement of Science: the Rockefeller Foundation, 1924-29,' *Minerva* 16, 4 (1978), 480-515; Finn Aaserud, *Redirecting Science: Niels Bohr, philanthropy, and the rise of nuclear physics* (Cambridge, 2003), 22; Robert E. Kohler, 'Philanthropy and Science,' in *Proceedings of the American Philosophical Society*, Vol. 129, No. 1 (March 1985), 9-10; R. Weatherall, 'The International Education Board,' *Nature* 148 (1941), 398-401.
[156] 'Letters to H.A. Kramers from Rockefeller Foundation' (1946-1947), Kramers Correspondence (Utrecht: Archive of the History of Quantum Physics, 1946-1947), section 11, microfilm.
[157] 'Patents and reprints for fellowship No. 106, 1914-1929' and 'Patents and reprints for fellowship No. 106, 1930-1939,' Mellon Institute of Industrial Research (Pittsburgh: Carnegie Mellon University Archives), box 94, folder 9-10.
[158] Broer and De Snoo, 'Mathematisch fysicus H.C. Brinkman,' 31-32.

many of the leading US hospitals and roentgenologists, and visited Europe to present a second gift of radium to “his friend” Marie Curie at the request of the US Secretary of Commerce, Herbert Hoover.[159]

Within this context, the scientists and engineers working in the oil industry were aware of efforts to split the atom. In the 1930s, physicists and chemists studied research on the nuclear reaction, or radioactive decay process, in which the nucleus of an atom splits into two or more smaller, lighter, nuclei. The process of nuclear fission produces gamma rays and releases an exceptionally large amount of energy. When Otto Hahn and Frits Strassman along with Lise Meitner and Otto Robert Frisch succeeded in splitting an atom in December 1938, scientists quickly acknowledged the enormous potential for producing energy, which could possibly be used in an atomic bomb, and started trying to split different atoms themselves.[160] Although no way was yet known of bringing about a self-sustaining process of chain reaction, which would release more energy than it consumed, many tried – including within the research and development departments of various oil companies. For example, Eger Murphree’s department at Standard Oil of New Jersey in 1940 conducted studies into the possible peaceful uses of atomic energy.[161] Those studies set up the oil industry for the first large scale industrial development of nuclear energy during the Second World War.

Forging a cohort: Oil actors in the Manhattan Project

The Manhattan Project as industrial enterprise

Up until the early 1940s, the network of scientists in the oil industry working on atomic (geo)physics or chemistry had been global, although dominated by Western actors. Most of the scientists in that network, including Soviet and Brazilian geochemists and -physicists, focused on developing applications for the exploration, refining and analyses of oil products. This changed, however, when the Second World War erupted. The Western oil industry, especially US companies with the addition of some British, Dutch and French firms, had always had an advantage over oil industry research elsewhere due to its competitiveness, wide range of companies, and industrial and imperial infrastructures; but Western oil companies now also got something new with access to rapid developments in nuclear technology. Although geoscientists in other countries did continue to develop applications for radioactive well logging technologies within the oil and radioactive mineral industries, and some of the Soviet scientists such as Vladimir Vernadsky also got involved in atomic bomb projects, the Second World War and the ensuing Cold War created rifts between the different oil actors getting involved in nuclear energy developments.[162]

During the Second World War these developments most notably took place within the US, British and Canadian Manhattan District Project. With a few exceptions, the historiography and official reports on the Manhattan Project has, sometimes deliberately, not paid a lot of attention to the participation of

[159] Astin, ‘Paul Darwin Foote,’ 178-182; on connection with Merle Antony Tuve: L.R. Hafstad, ‘In Memoriam Merle Antony Tuve, 1901-1982’, *John Hopkins APL Technical Digest* 3, 2 (1982), 209.
[160] Melosi, *Atomic Age America*, 35-37.
[161] Standard Oil of New Jersey, *Oil and the Atom* (1955), 1-2, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/LD12_D.
[162] V.M. Zaporozhetz and E.M. Filippov, ‘The Use of Accelerators of Charged Particles in Investigating Bore-Holes by the Methods of Radioactive Logging,’ Nicholas Rast (eds), *Applied Geophysics USS.R.* (New York: Pergamon Press, 1962), 397-422; Holloway, *Stalin and the Bomb,* 45.

industrial parties in the Project.[163] Recently, however, historian Cyrus Mody and I have argued that the Manhattan Project actually has to be regarded as an industrial – and commercial – endeavor though-and-through. In this article, we focused on the omnipresence of the oil industry in the development of the atomic bomb and showed how the knowledge and expertise built up in that industry proved crucial to the development of the atomic bombs and the industrial scaling-up of the nuclear technologies needed for uranium extraction, refining and enrichment.[164] This industrial involvement paved the way for many members of the Western cohort of oil geoscientists and engineers to get involved in the early nuclear *industrial* developments.

From the beginning, industrial parties were explicitly involved in establishing the foundations of the Manhattan Project. Even before the project was officially launched, the 1941 planning committee researching the feasibility of the project consisted of representatives from companies like Westinghouse Research Laboratories, M.W. Kellogg Company (an engineering company specializing in refinery and pipeline construction) and Union Carbide & Carbon (a chemical company), and was headed by Eger Murphree of Standard Oil of New Jersey’s Research and Development Company (later Exxon Research & Engineering).[165] For Murphree and Standard Oil this early involvement meant a stepping stone for the integral part the oil actors would later play in the project itself, with Murphree managing a pilot plant for uranium enrichment focused on the use centrifuges, and his employer constructing a heavy water production plant in Trial, British Columbia.[166]

Also, other firms played important roles as contractors, including many oil companies. The introduction of this chapter already mentioned the involvement of Standard Oil of Indiana’s subsidiary Whiting Research in producing boron-10 isotopes, but also other companies like Socony-Vacuum Oil Company (later Mobil) became involved with producing lubricants for enrichment devices that could handle high amounts of radiation.[167] Individual actors with a background in the oil industry were recruited for the project too. Especially concerning the search for uranium deposits, oil actors with experience in petroleum exploration got leading roles, with former Shell geologist Paul L. Guarin in charge of mapping the worldwide reserves of uranium, and former petroleum and gold prospector Philip L. Merrit managing the extraction and transport of the resource to the laboratories in the US.[168]

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[163] On the Smyth Report’s obscuring of the bomb program’s industrial dimension, see Rebecca Press Schwartz, *The making of the history of the atomic bomb: Henry Dewolf Smyth and the historiography of the Manhattan Project* (Ph.D. Diss., Harvard University, 2008). Partial overviews of that literature can be found in Rosemary B. Mariner and G. Kurt Piehler (eds), *The Atomic Bomb and American Society* (Knoxville: University of Tennessee Press, 2009); Michael Kimmage, ‘Atomic Historiography,’ *Reviews in American History* 38, 1 (2010), 145-152. See also Alex Wellerstein, ‘Manhattan Project,’ *Encyclopedia of the History of Science* (October 2019), https://ethos.lps.library.cmu.edu/article/id/35/ (Accessed April 9, 2024).

[164] Mody and Bron, ‘Scientific Instruments and/as Oil Spillovers’.

[165] Standard Oil of New Jersey, *Oil and the Atom* (1955), 1-2, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/LD12_D; Hewlett and Anderson Jr., *The New World, 1939/1946*, 49-50, 62; H.C. Hottel, ‘Warran Kendall Lewis, 1882-1975,’ *Biographical Memoirs* (Washington D.C.: National Academies Press, 1969), 6-7.

[166] Hewlett and Anderson Jr., *The New World*, 64**;** Gilliland, ‘Eger Vaughan Murphree: November 3, 1898-October 29, 1962,’ 230; Standard Oil of New Jersey, *Oil and the Atom* (1955), 1-2, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/LD12_D.; B. Cameron Reed, ‘Centrifugation during the Manhattan Project,’ *Physics Perspectives* 11 (2009), 427.

[167] ‘Letter A.R. Purdy to R.H. Crist’ (29 August 1945), ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/G75.

[168] Gillingham, ‘Memorial to Philip Leonidas Merrit, 1906-1981,’ 1-3; Leslie R. Groves, *Now it can be told: the story of the Manhattan Project* (New York: Da Capo Press, 1962), 185-187; Standard Oil of New Jersey, *Oil and the*

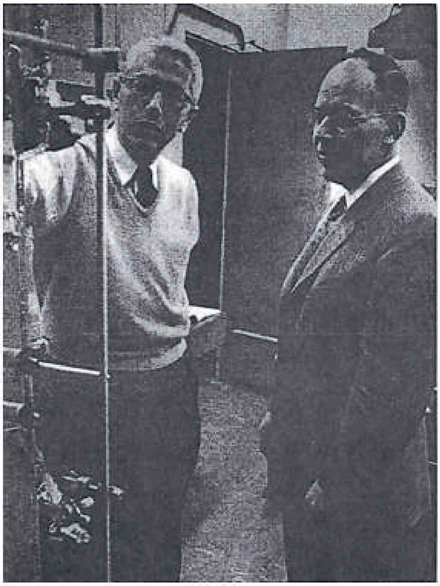

Figure 5: Seymour Meyerson (left) and Art Conn with a mass spectrometer of the type used during the B-10 project. 'Now It Can Be Told: how our scientists at Whiting research contributed to development of A-bomb,' Standard Torch *(May 1957), 20.*

The omnipresence of the oil industry in the Manhattan Project was based on the technologies and expertise in atomic physics compiled within the industry during the decades prior to the Second World War. This was particularly the case with the oil industry's involvement in uranium exploration. Based on the knowledge and geophysical methods developed in the oil industry, Paul Guarin, assisted by George Bain, the later professor in geophysics at Amherst College, established a program consisting of geologists and geophysicists, many of whom were recruited from companies like Union Carbide & Carbon, Humble Oil and the Carter Oil Company.[169] In 1944, this program published a report on the various known locations of fissile materials around the world, connecting the oil industry even more to the search for uranium. In his studies for the report, Bain concluded that uranium, due to its property to amass in porous sedimentary layers, tended to deposit in petroleum source rock. Not only had the petroleum industry developed technologies to measure radioactivity underground, the knowledge to find oil now also proved essential to discover new uranium reserves.[170] This knowledge

Atom (1955), 1-4, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/LD12_D; R.F. Robison, *Mining and Selling Radium and Uranium* (New York: Springer, 2015), 231-232; Zoellner, *Uranium*, 48-49; Jonathan E. Helmreich, *Gathering Rare Ores: The Diplomacy of Uranium Acquisition, 1943-1954* (Princeton: Princeton University Press, 1986), 43.

[169] Standard Oil of New Jersey, *Oil and the Atom* (1955), 4, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/LD12_D; Robison, *Mining and Selling Radium and Uranium*, 231-232; Zoellner, *Uranium*, 48-49; Helmreich, 43.

[170] Parts of the Guarin geological report are reproduced in A.C. Brown and C.B. MacDonald, *The Secret History of the Atomic Bomb* (New York: Dell, 1977); Zoellner, *Uranium*, 48-49, 300; *Helmreich*, *Gathering Rare Ores*, 44-45.

paved the way for even more oil geologists and geophysicists to contribute to the nuclear developments within the Manhattan Project and the succeeding US Atomic Energy Commission.[171]

The large-scale use of technological equipment to analyze the processed elements needed to produce the bombs offers another example of technology and expertise fostering oil-nuclear spillovers in the Manhattan Project. Especially production and use of mass spectrometers rapidly increased during the project. Mass-spectrometry enabled scientists and engineers working in the Manhattan Project to analyze essential reactor materials like the heavy elements uranium and plutonium, and the light elements hydrogen, lithium, and boron.[172] Also here, the technologies that previously mainly had industrial applications in the petrochemical industry attracted many oil actors specialized in using mass spectrometers to the Manhattan Project. Examples include the chemist, probable spy for the Soviet Union, and expert in mass spectrometry George C. Eltenton from the Shell Oil Company, but also the involvement of Whiting Research in producing boron-10.[173] In December 1943, the company was approached to set up a project to separate boron-10. Although Leslie Groves, the general in charge of the Manhattan Project, thought the job should be straightforward and the company should be able to do it fast, in the end over seventy employees worked on the project, including chemists from the research department and engineers from the manufacturing department. One of the researchers who received an "A" award from the Manhattan District for exceptional service was Seymour Meyerson, who worked on the mass spectrometer used during the B-10 project and would later get a permanent position as a chemist for Standard Oil of Indiana.[174]

Bringing oil actors to nuclear industrial developments

By enlisting oil actors versed in atomic physics and chemical engineering, the Manhattan Project served as an incubator for the cohort that during the ensuing decades would further shape the Western nuclear industry. First, the Project embodied a wide variety of efforts to harness the power of nuclear fission that later became crucial to the development of the postwar nuclear industries. For example, within the Project four different methods were experimented with to find an efficient way to enrich uranium, often in collaboration with industry. Besides the efforts made by Standard Oil of New Jersey to enrich uranium based on a centrifugal method, the uranium isotope separation plants at Oak Ridge, Tennessee consisted mainly of: Stone and Webster's electromagnetic enrichment plant (operated by Tennessee Eastman, a chemical company);[175] the gaseous diffusion plant built by Kellex (a new subsidiary of M. W. Kellogg), which Union Carbide and Carbon operated; and the thermal diffusion plant built by an engineering company, HK Ferguson. Plutonium production mainly took place at the

[171] See Chapter 3 for the later role of oil geophysicists in the US AEC.

[172] Although several other elements, such as aluminium and zirconium, are used largely in nuclear reactors, analysis of their isotopic composition is not necessary because the change in isotopic compositions are very small due to their low capture cross sections. A.E. Cameron and C.M. Stevens, 'Mass Spectrometry,' C.J. Rodden (eds), *Analysis of Essential Nuclear Reactor Materials* (United States, 1964), 987.

[173] See for the involvement of George C. Eltenton: Kai Bird and Martin J. Sherwin, *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer* (New York: Random House, 2005), 175, 195-201, 237-8.

[174] 'Oral History Interview with Seymour Meyerson,' (Philadelphia: Chemical Heritage Foundation, Oral History Program, 7 March 1991), https://digital.sciencehistory.org/works/xs55md06z (Accessed 16 July 2024); 'Now It Can Be Told: how our scientists at Whiting research contributed to development of A-bomb,' *Standard Torch* (May 1957), 16-21.

[175] Charles O. Jackson, *City Behind a Fence: Oak Ridge, Tennessee, 1942-1946* (Knoxville: University of Tennessee Press, 1981), 79-80.

facility built and operated by Dupont at Hanford, Washington.[176] Although many of these attempts would ultimately not contribute to producing the actual bomb, the technologies became more advanced and scaled up than they would have been without the Project's investments in research, money and industrial commitment. Consequently, for some of these technologies, these investments allowed them to play a significant role in the later nuclear industry. For example, despite the disappointing results with centrifugal enrichment during war, postwar contributions by Shell and other oil companies contributed to it becoming the standard approach to isotope separation and enrichment today.[177]

With the industrial scale-up of these technologies owing much to the oil industry, and the use of the geophysical knowledge needed to find uranium, the Manhattan Project created a knowledge and technological infrastructure for oil actors to get involved in later nuclear developments. Eger V. Murphree became part of the General Advisory Committee of the US Atomic Energy Commission (AEC) from 1950 to 1962, while also being employed as vice-president of Jersey Standard and President of the Permanent Council of the World Petroleum Congress. Also Marion W. Boyer, a former executive vice president of Jersey Standard, became the general manager of the AEC from 1950 to 1953.[178] In addition, oil geologists and geophysicists like Wallace Pratt, Philip Merrit, Everette Degolyer (co-founder of DeGolyer and MacNaughton and an innovator in oilfield instrumentation such as torsion balances and seismometers), and Morgan Davis (Humble Oil and Refinery Company), took a seat in the AEC's Raw Materials Advisory Committee.[179] The following chapters further discuss the roles that various of these actors would go on to play within the postwar nuclear developments, but what is important here is that the interpretation of the Manhattan Project as an industrial endeavor with commercial parties ensured that many of these actors were able to take these steps in the first place. Without the contribution of Standard Oil of New Jersey in the Manhattan Project, Wallace Pratt, Marion Boyer and certainly Eger Murphree probably would not have moved into crucial positions within the AEC.

In this way, the Manhattan Project established a network of scientists and engineers moving in and out of (and often between) the nuclear and oil industries. Chapter 4, for instance, will look at how the famous nuclear physicist, Nobel Laureate and crucial member of the scientific inner circle of the Manhattan Project, Hans Bethe, would later help Exxon (the successor of Standard Oil of New Jersey) to set up its nuclear enrichment projects during the 1970s.[180] Also, other Manhattan Project veterans like Samuel King Allison and Norman Paulson Heydenburg would later aid their connections in the oil

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[176] 'Walter S. Carpenter Interview, interview by Stephane Groueffe Wilmington, January 25, 1965,' Voices of the Manhattan Project (Online: Atomic Heritage Foundation), https://ahf.nuclearmuseum.org/voices/oral-histories/walter-s-carpenters-interview/ (Accessed 16 July, 2024).

[177] Susanna Schrafstetter, and Stephen Twigge, 'Spinning into Europe: Britain, West Germany and the Netherlands: Uranium Enrichment and the Development of the Gas Centrifuge 1964-1970,' *Contemporary European History* 11, No. 2 (2002), 253-272; Streefland, *Jaap Kistemaker en uraniumverrijking in Nederland, 1945-1962*, 256.

[178] Thomas W. Ennis, 'Marion W. Boyer, Oil Executive,' *New York Times* (November 23, 1982).

[179] 'Atomic Energy Commission,' Everett DeGolyer Collection (University Park: Southern Methodist University – DeGolyer Library), box 54, folder 3490; Lon Tinkle, *Mr. De: A Biography of Everette Lee DeGolyer* (Boston: Little, Brown and Co., 1970); 'US Atomic Energy Commission,' George W. Bain Papers (Amherst: College Archives and Manuscript Collections), box 15; A. Salvador, 'Memorial to Wallace Everette Pratt, 1885-1981,' *AAPG Bulletin* 66, 9 (1982).

[180] G.A. Gonzales, *Energy and Empire: The Politics of Nuclear and Solar Power in the United States* (New York: Sunny Press, 2012), 30.

industry with consulting work, maintain correspondence with oil chemists and physicists on research projects based on radioactive isotopes, or obtain oil funding for nuclear research projects.[181] Seymour Meyerson even was contracted by Standard Oil of Indiana after his service as army liaison at Whiting Research’s boron production project to conduct further work on mass spectrometry.[182] Also, the other way around oil companies were regularly asked to reflect on nuclear developments by the AEC, or would even aid in providing technologies, lubricants, knowledge and personnel for nuclear industrial projects, such as the Dresden nuclear reactor.[183]

This network further established a cohort consisting of chemical engineers, chemists and (geo)physicists originating from the oil industry and having access to new industrial developments. Its geographical limits – with the Manhattan Project being foremost a US, British and Canadian effort – and the ensuing secrecy surrounding the succeeding industrial developments made the cohort even more distinctive. With the following Cold War further enlarging a rift between nuclear developments in the West, the Soviet Union and the non-aligned countries, the oil-nuclear cohort researched in this dissertation truly became a Western-oriented cohort from the Second World War onward. Even within the West, however, there were many differences based on the accessibility of nuclear knowledge.[184] In France, US secrecy and the French wish to establish an independent oil and nuclear industry created a typical French network of French oil engineers and geophysicists that would become involved in setting up the French nuclear industry. On the other hand, however, as the next chapters will show the internationally oriented oil industry also helped to bridge the knowledge gaps between the cohort members in different countries by organizing international exhibitions, contributing to conferences and publishing research in international, but Western oriented, journals, thereby expanding the oil-nuclear cohort to other Western countries such as the Netherlands.

Tracing back the oil-nuclear cohort: concluding observations

Shortly after the Second World War and the dropping of the atomic bombs employees of Whiting Research were informed that, with their production of boron-10, they actually had been involved with the Manhattan Project via a letter to “all men and woman of the Manhattan Project” from the Undersecretary of War, Robert P. Patterson. In an attached letter, however, director Art Conn immediately emphasized that they were not allowed “to reveal the nature of your activities or any

[181] ‘Charles William Tittle to Norman P. Heydenburg’ (November 9, 1954), Nuclear physics program records (Washington D.C. DTM Archives, Carnegie science archives – Earth & Planets Laboratory), box 5, folder 9; Samuel King Allison, ‘Institute for Nuclear Studies, The University of Chicago,’ *The Scientific Monthly* 65, 6 (1947), 483.

[182] ‘Oral History Interview with Seymour Meyerson,’ (Philadelphia: Chemical Heritage Foundation, Oral History Program, 7 March 1991), https://digital.sciencehistory.org/works/xs55md06z (Accessed 16 July 2024); also other oil majors hired physicists and chemists that had previously been employed by the Manhattan Project, like later infamous nuclear spy Russel McNutt and the engineer and mathematician Philip Cooperman: Lou Blazquez, ‘Dr. Phil Cooperman, 1918-1983,’ *Life of Jamie Times* (1983), 4-6; ‘Black notebook of Alexander Vassiliev, translated by Philip Redko,’ Wilson Center Digital Archive (2009), https://digitalarchive.wilsoncenter.org/document/vassiliev-black-notebook (Accessed 19 December, 2023).

[183] Wallace E. Pratt, ‘The Impact of the Peaceful Uses of Atomic Energy on the Petroleum Industry,’ *Report of the Panel on the Impact of the Peaceful Uses of Atomic Energy* 2, 89 (Washington D.C.: Joint Committee on Atomic Energy, 1956), 273-275; W.J. Shanahan (eds), ‘Power from the Atom,’ *Oil Power* 60, 2 (Date Unknown), 12-13. ExxonMobil Historical Collection. DBCAH. Box 2.207/F160.

[184] John Krige, ‘Hybrid knowledge: the transnational co-production of the gas centrifuge for uranium enrichment in the 1960s,’ *The British Journal for the History of Science* 45, 3 (2023), 337-357.

details of the process used at No.4 Process Laboratory."[185] Only in 1957 the US military declassified this information, followed by an article in the May issue of *Standard Torch*, the employee magazine of Standard Oil of Indiana, headed "Now It Can Be Told", in which the story of Whiting Research and Art Conn was revealed.[186]

This secrecy is telling for how the Manhattan Project and ensuing Cold War policies established the demarcation lines that defined the Western oil-nuclear cohort that the next chapters study. This chapter argued that the petroleum and nuclear industries were already entangled since the early applications of quantum mechanics and research to radioactive decay on the muddy boreholes of depleted oil wells in various places all over the world. This early entanglement led to various spillovers of technologies, practices and scientists between the early petroleum and radioactive mineral industries and research, already long before the Second World War.

Especially regarding the actors that spilled over between both industries salient points of overlap can be found in their careers. As this chapter has showed, in addition to an often-active career in the oil industry and strong involvement in nuclear developments, these points consist of a shared academic background, experience with recent technologies based on early quantum mechanics, and a shared professional network. The academic background here was primarily grounded in the rapid development of academic (geo)physics and chemistry during the first decades of the twentieth century, with atomic physics becoming an important part of curriculum, and its industrial applications within fields such as applied geophysics. The oil industry played a significant role both by stimulating the growth of academic studies and by setting up its own Research and Development departments where recently trained academics found employment.

These developments created an influx of young (geo)physicists, chemists and chemical engineers in the oil industry well versed in the new developments of atomic physics. Once employed within the rapidly growing oil sector, these scientists and engineers developed knowledge and technologies that were initially aimed at further developing the oil industry, but later proved to have applications within the early nuclear industry. These applications and knowledge formed the basis for the involvement of many oil actors in nuclear developments.

The Manhattan Project served, at first primarily within the participating countries, as both an incubator and insulator of a cohort of oil actors with nuclear ties by providing opportunities to participate in (or later to access) the industrial scale-up of technologies that spanned the two sectors; the common experience of participation in activities and organizations at the oil-nuclear seam also led to the creation of a network connecting members of this cohort, but excluded many of the geoscientists that were located outside the West. The cohort would also contribute personnel who held crucial positions within the nuclear and oil industries in the ensuing decades and who exerted a major influence on nuclear developments during the remainder of their careers between 1945 and 1986.

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[185] 'Letter A.L. Conn to No.4 Process Laboratory Personnel' (9 August 1945). Whiting-Robertsdale Historical Society.

[186] 'Now It Can Be Told: how our scientists at Whiting research contributed to development of A-bomb', *Standard Torch* (May 1957), 16-21; see also the blog post of the Whiting-Robertsdale Historical Society: F. Vargo, 'How Whiting's Standard Oil Company Helped End Second World War,' (June 2020) https://www.wrhistoricalsociety.com/how-whitings-standard-oil-company-helped-end-world-war-ii (Accessed 29 March 2022).

With this, the actors mentioned in this chapter are illustrations of broader developments rather than isolated examples. The next chapters to come will show how oil actors such as Eger V. Murphree, Wallace E. Pratt and Paul Darwin Foote in the US, and Hendrik Brinkman, Maarten Bogaardt and Han Hoog in the Netherlands, played decisive roles in the development of the national nuclear industries, while at the same time remaining involved in the international oil sector. The tensions and questions raised by this dual involvement in two, potentially competing, energy sources guide the remainder of this thesis. To understand these roles, however, it is crucial to understand the shared background, network and knowledge of the various actors described in this chapter. These shared origins will prove a crucial factor in the rapid rise of nuclear energy technologies, and the oil industry's involvement in them, during the first decades after the Second World War and the eventual stagnation of these developments from the late 1970s onward.

CHAPTER 3

3

3. Shaping Nuclear Developments

The oil-nuclear cohort at the dawn of the second Atomic Age, 1945-1968

[The] Western world would in [the] event [that] confidence in [the] Canal is not restored seek alternative methods [of] shipment, alternative source[s] [of] petroleum and be forced by necessity, [the] "mother of invention" [to] produce new sources [of] energy.

- Robert B. Anderson, Dhahran, 23 August 1956[186]

[186] Quote as represented in John W. Carrigan, 'Telegram from the Consulate General Dhahran to the Department of State, Dahran, 23 August 1956,' *Foreign Relations of the United States*, 1955–1957, *Volume XVI: Suez Crisis, July 26-December 31, 1956*, 16:274.

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Shaping Nuclear Developments

After a subtle hand gesture, the cups of coffee were taken away. CIA station chief Wilbur Crane Eveland and the American diplomat Robert B. Anderson sat silently for hours, drinking coffee, while waiting to be received by the Saudi king Saud ibn Abdul Aziz and his brother, crown prince Faisal. It was August 23, 1956, shortly after Egypt's President, Gamal Abdel Nasser, had blocked the Suez Canal. This canal was the Middle East's transit route to Europe and allowed two thirds of Europe's oil to pass through; oil that would otherwise have to take the longer and more expensive route around the African continent. After consultation with Exxon president Howard Page, the US delegation had been sent by President Dwight Eisenhower to pressure the Saudi king, who derived his wealth from the oil trade, to distance himself from Nasser's policies.[188] "Your Majesty must understand", Anderson threatened, "we've made great technological advances and are now on the threshold of sources of power that will be cheaper and more efficient than oil." After Saud ibn Abdul Aziz asked what this alternative to cheap Arab oil should be, Anderson simply replied: "nuclear energy."[189]

Of course, this was a bluff by Anderson, meant to scare the Saudi king and partly constructed based on orientalist views about the knowledge of nuclear energy available to the Saudis. In 1956 nuclear energy was nowhere near overtaking the crucial role of cheap Middle Eastern oil in fulfilling the energy needs of the Western world. Crown prince Faisal quickly called the bluff, however. Faisal, who had been reading up on nuclear engineering, knew perfectly well that nuclear energy was a promising energy source that had developed from a niche technology to a starting industry during the last decade, but was also aware that his oil played a pivotal role as the primary energy source in the world.[190] Ever since First Lord of the Admiralty Winston Churchill decided to equip the British navy with oil-burning engines instead of coal during the First World War, oil had rapidly gained strategic importance. In the years that followed, production increased significantly, and after the Second World War demand for oil in the Western world grew quickly due to increasing prosperity and population growth, and policies to stimulate oil consumption.[191] In the 1950s oil definitively dethroned "King Coal" as the primary energy source.[192]

The yield of the Arab oil fields played a key role in fulfilling these needs. After the end of the Second World War, Western oil companies started looking for oil on the Arabian Peninsula, something an agreement among the various companies had previously prevented. This so called "Red Line

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[188] Salim Yaqub, *Containing Arab Nationalism: The Eisenhower Doctrine and the Middle East* (Chapel Hill: The University of North Carolina Press, 2004), 49.

[189] As quoted in Wilbert Crane Eveland, *Ropes of Sand: America's Failure in the Middle East* (New York, Open Road Media, 2018), 210-212.

[190] Yaqub, *Containing Arab Nationalism*, 49.

[191] Gross, Melsted and Chachereau, 'Creating the condition for Western European petroculture'.

[192] Stephen G. Gross, 'The Politics of Creative Destruction: West German Hard Coal and the Postwar Oil Transition,' Stephen G. Gross and Andrew Needham (eds), *New Energies: A history of energy transitions in Europe and North America* (Pittsburgh: University of Pittsburgh Press, 2023), 48-61; Joseph A. Pratt, 'The Ascent of Oil: The Transition from Coal to Oil in Early Twentieth-Century America,' Lewis J. Parelman, August W. Giebelhaus and Michael D. Yokell (eds), *Energy Transitions: long-term perspectives* (Routledge, 1981).

Agreement", signed between the Anglo-Persian Company (later British Petroleum), Royal Dutch Shell, *Compagnie Française Petroleum* (CFP), the Near East Development Corporation (a subsidiary of Socony and Standard Oil of New Jersey), and the Armenian oil entrepreneur Calouste Gulbenkian, prevented the companies from independently seeking for oil in territory that was previously part of the Ottoman Empire. With the end of the War, the American companies claimed the agreement had been dissolved, and after a long legal process the companies were able to explore for oil in the previously off-limits regions. In 1948, the companies discovered the Ghawar field, the largest oil field on land, and in 1951, the largest offshore field in the world, the Safaniya Oil Field. Together with big oil finds in other Arab countries like Kuwait, cheap Middle Eastern oil became essential to what Western oil insiders called the "free world" (or World Outside Communist Areas, WOCA) economy, and crown prince Faisal knew this.[193]

However, Anderson's nuclear bluff was not a complete lie. After the detonation of the atomic bombs on Hiroshima and Nagasaki, a new era of nuclear technology had started, an era that can also be called "the second nuclear age".[194] The potential power of nuclear fission was demonstrated and countries around the world considered establishing independent bomb-making programs. In the process, governments and industrial parties were also looking at the possibilities of harnessing this destructive energy and converting it into usable energy to produce electricity for motive power deployed on ships, trains, planes, spaceships, and automobiles.[195] When in 1954 the first nuclear power plant in Obninsk, Soviet Union, was connected to the grid, a transition seemed to have started enabling a future world supplied with energy that would become "too cheap to meter".[196] This vision was further reinforced by President Eisenhower's "Atoms for Peace" speech in 1953, promising that fissionable material would be "allocated to serve the peaceful pursuits of mankind. Experts would be mobilized to apply atomic energy to the needs of agriculture, medicine, and other peaceful activities. A special purpose would be to provide abundant electrical energy in the power-starved areas of the world."[197]

The rise of nuclear power thus also promised growing competition for the oil regime. If nuclear energy was indeed going to provide the world with enough cheap energy to "melt the snow before it falls to the ground" as the president of the University of Chicago predicted in 1952, it would be able to compete with coal and oil to become the global primary energy source and fuel the Western

[193] Daniël Yergin, *The Prize: The Epic Quest for Oil, Money and Power* (New York, 1991), 413-419.
[194] Following Matthew Lavine's definition of "the first atomic age" as the period between 1895 and 1945. Lavine, *The First Atomic Age.*
[195] Irene Cieraad, 'The Radiant American Kitchen: Domesticating Dutch Nuclear Energy,' R. Oldenziel (eds), *Cold War Kitchen: Americanization, Technology and European Users* (Cambridge: University Press, 2009); J.J. O'Neill, *Almighty Atom: The Real Story of Atomic Energy* (New York, 1945), 59, 60, 73, 75, 90; Pringle and Spiegelman, *The Nuclear Barons*, 149.
[196] Quote attributed to Lewis Strauss, Chairman of the US AEC. See footnote 96 (page 31).
[197] '*Atoms for Peace Speech*, addressed by Mr. Dwight D. Eisenhower, President of the United States of America, to the 470th Plenary Meeting of the United Nations General Assembly,' (2016), IAEA, https://www.iaea.org/about/history/atoms-for-peace-speech (Accessed January 20, 2023).

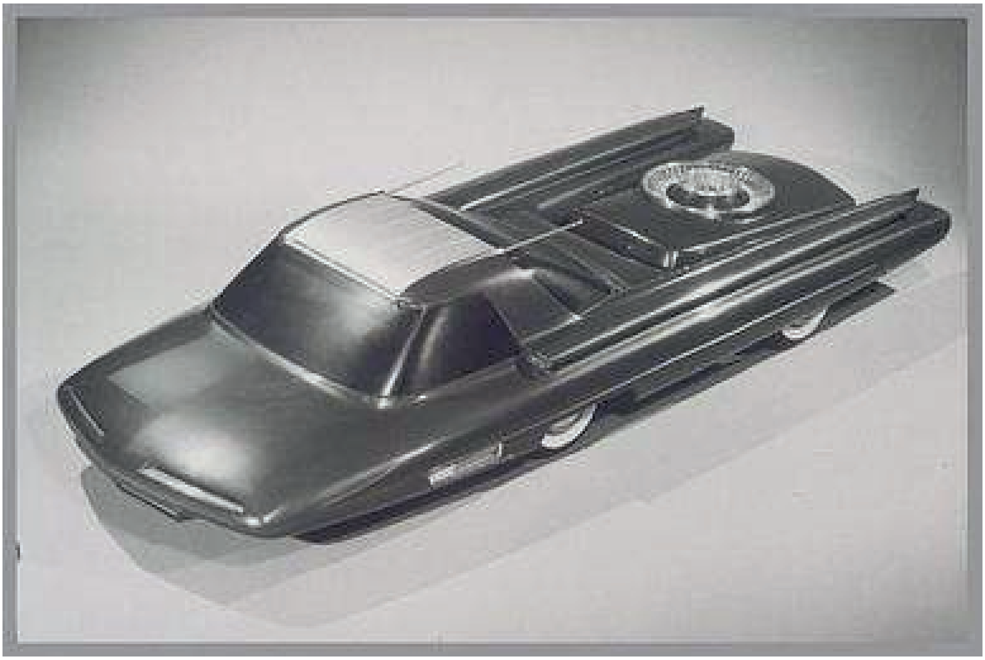

Figure 7: In 1957 Ford designed a car powered by a small nuclear reactor called the "Ford Nucleon". A fitting example of how nuclear energy promised to directly compete with oil. Wikimedia, 'Ford Nucleon,' Wikipedia *(31 October, 2017), http://en.wikipedia.org/wiki/File:Ford_Nucleon.jpg (Accessed 27 July 2024).*

economies.[198] From this perspective, the aforementioned interaction between Anderson and Faisal was exemplary of the new discussions oil actors had to relate to. In a decade suffering from an abundance of oil, a new source of energy loomed over future energy predictions, promising wealth for everyone who jumped on the nuclear bandwagon at the right time. Oil entrepreneurs, geoscientists, engineers, and executives had to decide how to react to, and shape, the opportunities, and challenges for nuclear energy on the one hand, while also steering their companies and careers within the still dominant oil regime.

This chapter shows how the different members of the oil-nuclear cohort, introduced in the previous chapter, shaped the postwar nuclear developments, the debates about the future of atomic energy and oil, and the decisions by various oil companies to join the nuclear bandwagon. Following the oil industry's involvement in the Manhattan Project, oil scientists, geologists, and engineers got ever more involved in the worldwide search for uranium and the building of a nuclear industry. Also, companies made decisions whether to jump on the nuclear bandwagon or hold back. As this chapter shows, the move toward the nuclear industry by the many individual engineers and geoscientists proved problematic for the oil industry, however. Companies that were not involved in large-scale nuclear energy projects encountered problems finding new petroleum geophysicists and engineers due to students' and scientists' growing preference for careers within the nuclear sector. The oil industry's answer to this problem was as simple as it was effective: to make the scientists and engineers that would otherwise go to work within the nuclear arena managers within the oil industry. By offering them more control and responsibilities, a cohort of scientist-engineers, part of the first generations of

[198] As quoted in Christophe Flavin, *Nuclear Power: The Market Test*, Worldwatch paper 57 (1983), 11.

academically trained scientists within the oil sector and often introduced to the oil industry after finishing their studies in the 1930s and 1940s, were put in charge of managing the oil industry's biggest companies in the 1950s and 1960s. This new generation of managers steered even the biggest oil companies toward nuclear energy at the end of the 1960s, a decision reinforced by their declining access to cheap oil in the Middle East and the accelerating nuclear bandwagon.

The first part of this chapter focusses on how different oil geophysicists and economists shaped the debates concerning the future of oil and nuclear energy, and which decisions oil executives made regarding nuclear investments during the 1950s and early 1960s. I show how access to cheap oil explains the initial hesitation of bigger, international, oil companies to join the nuclear bandwagon, while smaller companies without access to cheap oil concessions in the Middle East invested in nuclear projects to fund their oil projects. The second part of this chapter examines the labor and colonial aspects of this oil involvement in nuclear energy by focusing on the increasing demand for geophysicists from the oil sector to aid in the worldwide race to locate and mine the uranium resources needed to produce nuclear weapons and electricity. The last part examines the return of the major, international, oil companies to nuclear energy developments within the context of their fear of losing access to cheap oil due to increasing resentment toward Western colonialism and the rise of the Organization of Petroleum Exporting Countries (OPEC) during the 1960s. As this chapter argues, members of the scientist-engineering cohort promoted this strategic shift, since by then they had become oil managers in charge of business decisions relating to entry into new fields of energy production.

A New Hope: The oil-nuclear cohort and the promise of nuclear energy

"An oil man looks at atomic energy"

In 1956, James Terry Duce and A.H. Chapman, oil economists from Arabian American Oil Corporation (Aramco), published an article for the *Journal of Petroleum Technology* called "an oil man looks at atomic energy". Building on their earlier studies on the future worldwide energy requirements and reacting to the 1956 Geneva Atoms for Peace Conference, the authors argued that atomic energy could play a vital role in filling the gap left by future deficiencies of coal and oil. According to them the oil sector should embrace nuclear energy. Oil men should not view the atomic future "with the trepidation of the buggy whip manufacturer who saw the automobile as the ruination of his business", but "at the time where demand for energy is following such a sharply ascending curve" should instead "welcome the contribution of the atom to the overall energy supply and thus to the prosperity of the world."[199]

With their vivid statements, Chapman and Duce represented the increasingly heated debates taking place within the oil industry about the future roles of oil and atomic energy during the 1950s. Based on various calculations of increasing energy demand due to population and welfare growth, as well as of available oil and uranium reserves, many oil actors engaged in a lively debate on the future of the oil and nuclear industries.[200] This debate covered wide-ranging, and often extreme, positions. Some

[199] James Terry Duce and A.H. Chapman, 'An Oil Man Looks at Atomic Energy,' *Journal of Petroleum Technology* 8, 1 (1956), 13; A. H. Chapman and James Terry Duce, 'Economics of the International Petroleum Industry,' *Journal of Petroleum Technology* (1955).

[200] See for examples of the various new reports on predictions of resource abundance and/or scarcity: Pratt, 'The Impact of the Peaceful Uses of Atomic Energy on the Petroleum Industry,' 273-275; L.G. Weeks, 'Highlights on

even went as far as to state that petroleum geophysicists should stop exploring for oil completely, and instead should only focus on uranium exploration. One of the most outspoken examples was Paul L. Lyons, president of the American Society of Exploration Geophysicists. In his 1955 article on the future of geophysics, he stated that "like death itself, the ultimate decline of our complex and wonderful oil industry is already distantly in view. Any discussion on the future of geophysics as we know must contemplate the ultimate role of geophysics in finding ores for atomic energy."[201]

Another famous oil geophysicist arguing about the future of nuclear energy was Marion King Hubbert, working at Shell Oil's geophysical laboratory in Houston. In 1956 Hubbert, who already was a well-known geophysicist at the time, published a paper that retrospectively would become famous for introducing the concept of "peak oil". Based on the calculations of economic geologist D.F. Hewett on the life cycles of mining districts, Hubbert plotted oil production over time, curving into a peak and then trending toward zero. In his article, he predicted peak oil for US production would occur somewhere around the beginning of the 1970s. Often unacknowledged, however, is that Hubbert's paper, entitled "Nuclear Energy and Fossil Fuels", also explicitly argued for nuclear energy as an alternative to oil consumption. As figure 8 shows, Hubbert expected an exciting potential for nuclear energy as the needed successor to oil, especially for innovative technologies such as the breeder reactor, in which the nuclear reactor generates more fissile material than it consumes because of its high neutron economy.[202]

Hubbert and Lyons were among the most outspoken proponents of an "end of oil" and a refocus toward atomic energy within the oil sector. However, as the statements of Duce and Chapman already showed, other oil actors also saw the necessity for atomic energy. Nuclear power would provide a useful energy source to help tackle the rising energy demand due to the growing population and welfare in the Western World. For instance, in a presentation for the Oklahoma City men's dinner club in 1959, Dean McGee, the co-founder of the American oil company Kerr-McGee, pointed out that the four main sources of energy were coal, oil, gas, and uranium. After predicting a future energy shortage in gas and oil, he then stated his belief that uranium was necessary to make up the deficit.[203] In France, former petroleum engineer and now director general of the French Atomic Energy Commission (CEA), Pierre Guillaumat, had already published an article in 1955 entitled "from coal to uranium", describing the development of energy consumption in France. This article stressed the need for quadrupling French uranium production (mainly in Africa) to decrease the dependency on oil as the primary energy source and prepare France for future energy demands.[204]

1947 Developments in Foreign Petroleum Fields,' *BAAPG* 32, 6 (1948), 1094; Wallace E. Pratt, 'The Earth's Petroleum Resources,' in L.M. Flanning (eds), *Our Oil Resources* (New York: McGraw-Hill, 1950).

[201] Paul L. Lyons, 'The Future of Geophysics,' *Geophysics* 20, 3 (1955), 508.

[202] Marion King Hubbert, 'Nuclear Energy and Fossil Fuels,' Publication No. 95, (Houston: Shell Development Company, Exploration and Production Research Division, 1956); Priest, 'Hubbert's Peak: The Great Debate over the End of Oil,' 47-50; Emma Hemmingsen, 'At the base of Hubbert's Peak,' 531-540.

[203] Dean A. McGee, ''Atomic Energy and Exotic Fuels,' speech before the Independent Petroleum Association of America, Phoenix, May 3, 1959,' Dean A. McGee Collection (Lawrence, Kansas: University of Kansas-Kenneth Spencer Research Library), box 175, folder 13.

[204] Pierre Guillaumat, 'Du charbon à l'uranium,' *Annales des Mines, Vol. 6* (1955), 15-16.

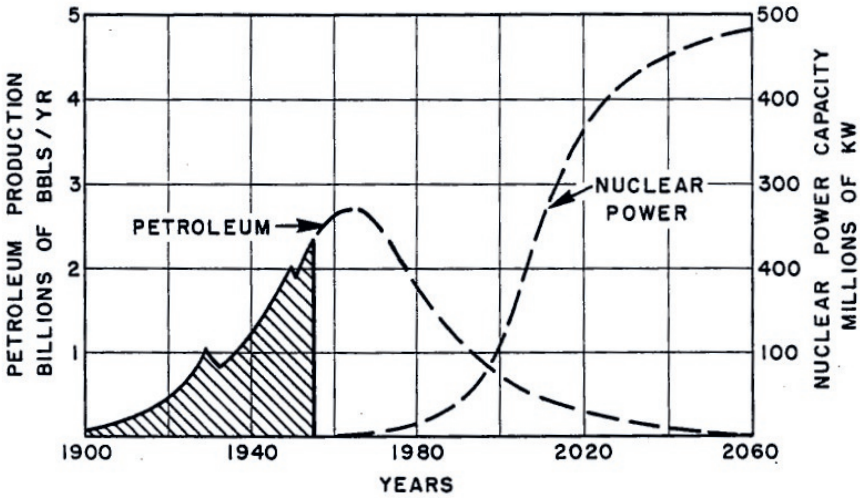

Figure 8: The predictions by Marion King Hubbert on the decline of petroleum production and rise of production of nuclear power in the United States. Marion King Hubbert, 'Nuclear Energy and Fossil Fuels,' Publication No. 95 *(Houston: Shell Development Company, Exploration and Production Research Division*, *1956), 36.*

This line of reasoning, however, also met fierce resistance from other oil geophysicists and economists. The 1950s was also the time that the oil sector dealt with an increase in the exploration of phenomena known as "elephants", or excessively big oil fields. Especially after abandoning the Red Line Agreement, allowing oil majors to explore for oil in the Middle East, oil seemed to be abundant.[205] In 1953, Everette DeGolyer, the eminent oil geophysicist and adviser to the AEC, had already predicted one of the nightmares of the oil industry: overproduction.[206] World oil production increased from 438 million tons a year in 1948 to 2.1 billion in 1972, decreasing the price for a barrel of oil from 15 dollars to 10 dollars between 1954 and 1970.[207] Consequently, this abundance caused geophysicists in the oil industry to fiercely criticize ideas about peak oil and a total refocus on nuclear energy. Hubbert took the brunt of his colleague's criticisms. Vincent McKelvey, senior research geologist and later director at the US Geological Survey, and Morgan Jones Davis, geophysicist and president of Humble Oil, emerged as outspoken opponents of Hubbert's ideas. Although both also served as advisors to the AEC, they saw no immediate role for nuclear power as a substitute for oil. Oil, in their view, would remain the primary energy source for a long time to come.[208]

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[205] Martin V. Melosi, *Coping with Abundance: Energy and Environment in Industrial America* (Philadelphia: Temple University Press, 1985), 241-243.

[206] 'Letter to Wallace E. Pratt by Everette DeGolyer,' (March 7, 1956), Everette DeGolyer Papers (University Park, Texas: Southern Methodist University – DeGolyer Library), box 12, folder 1513; Cantoni, *Oil Exploration, Diplomacy and Security in the Early Cold War,* 170; Yergin, *The Prize*, 482.

[207] Yergin, *The Prize*, 481-482; Parra, *Oil Politics*, 73-74.

[208] According to Marion King Hubbert, Morgan Davis was assisted in his attacks by Humble Oil's in house economist Richard J. Gonzales who repeatedly argued that there was more oil to be found than Hubbert estimated. When petroleum engineer Carl Reistle (a proponent of Hubbert's ideas) took over at Humble Oil, Gonzales was eased out. 'Letter too Ray P. Walters by Marion King Hubbert,' (October 30, 1977), Wallace E. Pratt Papers (Lawrence: University of Kansas – Kenneth Spencer Library), box 2, folder 35; 'Letter to Kenneth E. Hill by Richard J. Gonzales,' (February 14, 1956), Morgan Jones Davis Papers (Austin: Dolph Briscoe Center for American

Who earns money with abundant oil? The role of access to cheap oil in nuclear decision making

In 1954, the Shell Group board addressed the future of oil concerning the rise of nuclear power for the first time in their annual report. The board recognized that there were increasing discussions about the roles of energy sources like oil, coal, and atomic power. Within these discussions, however, the Shell board still envisioned a role for oil as the primary source of energy in the future and argued that the company should primarily keep focusing on oil production. In 1954 Shell noted with satisfaction that the growth in the relative importance of oil as a source of energy was again evident. According to a conservative estimate, the world energy requirements over the next quarter of a century would rise on average by three percent per year and consequently would double by around 1980. Whatever the precise percentages would turn out to be, for many years, "and certainly until such time as new sources of energy, for instance atomic energy, become a significant factor", the oil industry would be "called on to make an increasing contribution, in particular in the form of fuel oil."[209] For now, nuclear research would actually mostly be beneficial for increasing oil consumption as was stated in Shell's monthly magazine: "It is certain, however, that the development and future applications of nuclear energy will greatly stimulate the consumption of petroleum products".[210]

With this logic, the board of Shell referred to the research conducted into using radioactivity and quantum mechanics to develop new oil exploration and analyzing techniques, and to further improve the quality of their petroleum products such as lubricants. At the *Het Atoom* (*The Atom*) exhibition at the Schiphol Airport, the Netherlands, Shell presented several improvements in lubricants, based on their research on radioactive isotopes in 1957.[211] Similarly, Mobil regularly campaigned with their research on measuring radiation, radioisotopes for lubricants, and well-logging technologies.[212] In 1959, Socony Mobil officially opened its Nuclear Research Center at Stony Brook, near Princeton. The center, operating as a subdivision of Socony Mobil's Central Research Division, conducted research in nuclear physics and chemistry to discover new ways to convert petroleum into more high-quality products, mainly with the help of a 2 billion electron-volt Van de Graaff accelerator providing high-energy electrons, protons, X-rays and neutrons for basic research. One important area of research was the study of catalysts used in refinery processes and petroleum chemical manufacturing.[213]

In other ways, too, various oil companies tried to use nuclear developments to stimulate oil production and usage, such as in finding applications of small reactors as propulsion for oil tankers so that, potentially, more oil could be transported over longer distances.[214] The most exotic application, by far,

History), box 3X302_2; Morgan Jones Davis, 'The Dynamics of Domestic Petroleum Reserves,' *Proceedings of the American Petroleum Institute* 38 (1958), 22-27; Priest, 'Hubbert's Peak,' 52.

[209] Royal Dutch Petroleum Company, *Royal Dutch Petroleum Company: Annual Report 1954* (Royal Dutch Petroleum Company, 1955), 16.

[210] Translation from Dutch by author, original quote "Vast staat echter dat de ontwikkeling en de toekomstige toepassingen van kernenergie het verbruik van aardolie-produkten in grote mate zal stimuleren". 'Aardolie en atoomenergie,' *Olie: Nederlands maandblad voor het personeel van de Koninklijke Shell Groep* (1957), 237 (The Hague: Royal Dutch Library).

[211] 'Inventaris van de tentoonstelling,' (1957), 259 Tentoonstelling "Het Atoom" (Amsterdam: City Archives Amsterdam), box 18.

[212] W.J. Shanahan (eds), 'Power from the Atom,' *Oil Power* 60, 2 (Undated), 14-15, ExxonMobil Historical Collection (Austin: The Dolp Briscoe Center for American History), box 2.207/F160.

[213] 'Discovery about composition of petroleum: new scientific knowledge sheds light on its origin,' (1964), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F160.

[214] In 1956, Shell's subsidiaries, BPM and Shell Tankers, partnered with the Dutch nuclear authority RCN to research the possibilities for developing nuclear-powered tankers. In the United States, Esso Standard Oil also

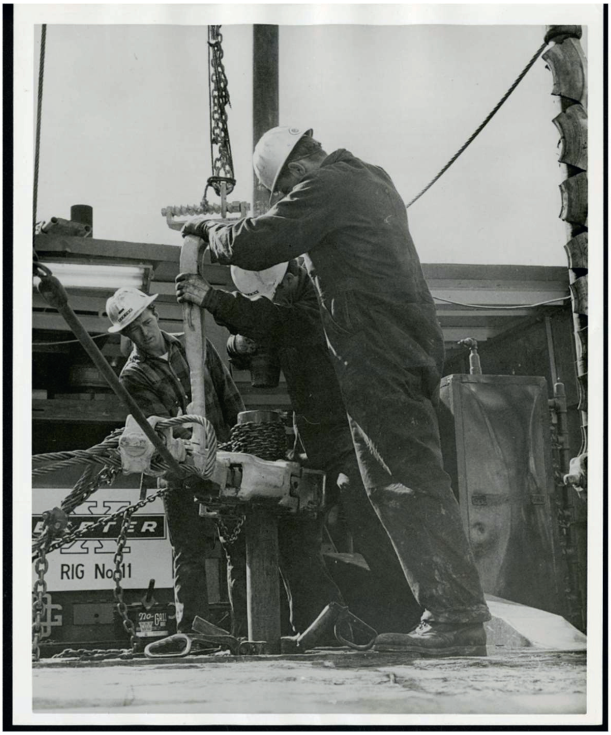

Figure 9: Rio Blanco, sponsored by the US AEC and CER Geonuclear Corporation Inc., was the last in a series of natural gas wells that used nuclear explosives to free gas that was trapped in underground rock formation within the framework of Project Plowshare, 1978. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History), Box 42, folder 34.

was to use nuclear explosions to drill for oil and gas. Conceptually, the proposal was rather simple: instead of using an uncontrolled nuclear explosion in a bomb device, use the powerful explosion for more peaceful purposes. From there, the ideas went more extravagant. As historian Scott Kaufman and historical geographer Scott Kirsch showed, the ideas ranged from digging a second Panama Canal, reclaiming the Mediterranean, opening remote areas in Alaska by creating space for harbours, and to get access to resources of oil and gas that were tedious to reach. These ideas took form in the United States, from 1957 onward, in a project called Project Plowshare, although similar projects were set up in the Soviet Union and India.[215] Several oil companies showed great interest in these developments.[216]

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worked on nuclear propulsion together with Westinghouse in 1959. 'Kan Nederland Atoomschepen bouwen?,' *Gereformeerd Gezinsblad* (21 December 1957); *Westinghouse: first in Atomic Power*, (Pittsburgh: Westinghouse Electric Corp., October 1958), 4-15, Westinghouse Electric Corp. Collection (Pittsburgh: Heinz History Center - Detre Library and Archives), box 177, folder 20.

[215] Scott Kirsch, *Proving Grounds: Project Plowshare and the Unrealized Dream of Nuclear Earthmoving* (New Brunswick: Rutgers University Press, 2005); Kaufman, *Project Plowshare*.

[216] After the announcement of the first tests in 1957, Continental Oil started a research program concerned with the feasibility of conducting an underground nuclear explosion in non-productive, hydrocarbon-bearing formations. Also, the three testing projects within Project Plowshare where nuclear explosives were used to drill for oil and gas involved oil companies, such as the Austral Oil Company. Henry F. Coffer, Bruge G. Bray, and Carrol F. Knutson, 'Applications of nuclear explosives to increase effective well diameters,' *Engineering with nuclear explosives: proceedings of the third Plowshare symposium* (U.S. Atomic Energy Commission, December 1965),

Also, managers at other, internationally active Western oil companies expressed similar voices. In 1960, the board of Socony looked ahead to the end of the 1960s and expected demand for petroleum energy to grow faster than the increase in demand for other energy sources, prompting the board to primarily focus on oil production for the future. On nuclear energy, the board stated that "much had been said about the prospects for atomic power […] Even by 1970, however, it appears that the atom will be supplying no more than 2% or 3% of the world's vastly enlarged energy requirements."[217]

To make this assessment, the Socony board relied on research by in-house oil economists, such as Albert J. McIntosh, who claimed that "when the presently planned atomic power plants are completed, it is estimated that about one percent of the US's total electric power will come from them." According to McIntosh, who contrary to King Hubbert and Lyons framed the future of nuclear energy in terms of an energy addition instead on a transition, nuclear power was indeed going to compete with oil in a few areas, initially especially the least profitable ones such as the production of electricity, but the prospects for nuclear energy becoming a partner of petroleum "in the great task of raising living standards all over the world" were much more significant.[218]

Smaller oil companies and oil service firms contrasted these doubts with more positive expectations about the rapid development of nuclear power. Dean McGee, geologist and one of the founders of Kerr-McGee, was especially well-known for his comments that nuclear energy would become the next big thing, and that the uranium business was going to be good.[219] This did not stop at words alone, as Kerr-McGee pursued an active policy of diversification into uranium mining and milling from the early 1950s. In 1954, 10% of all the company's capital expenditures consisted of investments in the uranium sector, a percentage that even increased to 52% in 1959 with more than $15 billion.[220] Kerr-McGee's venture into nuclear was aided in Washington by its other founder, Senator Robert S. Kerr of Oklahoma, who was closely involved with the creation of the AEC legislation about industrial involvement in nuclear developments, leading to various accusations that Kerr had succeeded in altering the AEC's allocation program in favor of smaller companies that wanted to expand their domestic uranium mining projects in the American mid-West (in this way helping Kerr-McGee).[221]

Here, access to cheap-to-produce oil in markets struggling with overproduction played a key role. The only way to make money from oil in these markets was to extract oil for such low production costs that the investments in exploration and extraction would not outgrow the profits. This became increasingly difficult for oil companies drilling for oil within the United States during the 1950s. In 1959 John S. Bell,

269, 2.06.101 Archives Directorate of Nuclear Energy of the Ministry of Economic Affairs (1957) 1956-1971 (1972) (The Hague: Dutch National Archives), folder/box 683; D.C. Ward and C.H. Atkinson, 'Project Gasbuggy: A Nuclear Fracturing Experiment,' *Journal of Petroleum Technology* 18, 2 (1966), 139-145; H.C. Carpenter, 'Recovering Oil by Retorting a Nuclear Chimney in Oil Shale,' *Journal of Petroleum Technology* 19, 6 (1967), 727–34: Kirsch, *Proving Grounds*, 201.

[217] Socony Mobil Oil Inc., *Annual Report 1960 Socony Mobil Oil Company, Inc* (Socony Mobil Oil Inc, 1961), 3.

[218] Albert J. McIntosh, 'Atoms, oil and the future of energy' (1955), 2-4, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/F160.

[219] Dean A. McGee, 'Supply and Demand for Uranium in Years Ahead,' *Commercial and Financial Chronical* 684 (1969), 4.

[220] John Samuel Ezell, *Innovations in Energy: The Story of Kerr-McGee* (Norman: University of Oklahoma Press), 298-299.

[221] 'Remarks of Senator Robert S. Kerr (Congressional Record, August 13, 1954, page 13654) In opposition to Conference Report on Atomic Energy Bill,' Robert S. Kerr Collection (Norman: University of Oklahoma – Carl Albert Center), box 10, folder 31; June Taylor and Michael D. Yokell, *Yellowcake: The International Uranium Cartel* (New York: Pergamon Press, 1980), 31.

Figure 10: A Phillips Petroleum Company's uranium mining project in northwest New Mexico, 1978. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History), Box 42, folder 53.

from the Humble Oil & Refining Company, concluded in a market evaluation that the return on investments in the domestic oil industry had declined from 27.9 percent in 1948 to 10.2 percent in 1958.[222]

Companies primarily working in the domestic oil market, therefore, had to find other ways to make money. Some companies managed to start diversifying into early offshore drilling, but other companies found their paths in the search for oil on both land and sea blocked because of the financial risks. Kerr-McGee especially had to deal with increasing problems regarding getting access to profitable opportunities for oil drilling. Although the company managed to establish an off-shore branch, the limited opportunities for new oil production projects opened the way for the companies founds to diversify into the more profitable mining of uranium. In a 1973 interview, Dean McGee was outspoken about the situation at the time: “It was clear [in 1952] that the oil business was headed for trouble, and that medium-sized companies such as ours could get badly hurt.”[223] In 1952 already McGee’s assistant, Frank C. Love, stated it even more boldly: “a company the size of Kerr-McGee has to compete. If it doesn’t get the opportunities, it is looking for in one area, it must direct its efforts in other directions.”[224]

[222] John S. Bell, ‘Engineer’s Oil: A Challenge and An Opportunity,’ *Journal of Petroleum Technology* 11, 11 (1959), 11-14.
[223] ‘Bob Leder, KTUL-TV Tulsa, interview with Dean A. McGee,’ (19 September 1973), Dean A. McGee Collection (Lawrence: University of Kansas-Kenneth Spencer Research Library), box 170, folder 9.
[224] Frank C. Love, ‘Introduction,’ *Kermac News* (1952), 13; Ezell, *Innovations in Energy*, 210.

This was contrasted by the international major oil companies that had created the glut that the smaller companies suffered from. Because of their access to cheap Middle East oil, the big companies were less affected by increasingly expensive oil production in the United States. As Wallace E. Pratt stated in his report to the US Joint Committee of Atomic Energy on the role of peaceful atomic energy for the oil industry, the attitude of the petroleum industry "toward its new rival, atomic energy, is conditioned by its own analysis of the probable demand and supply of energy over the next 20 years."[225] With the elimination of the Red Line Agreement, a select group of oil companies, including Socony, Shell, and Gulf Oil, had gained access to abundant oil production, with the discoveries of big 'elephants' in Kuwait and Saudi Arabia, and was squeezing smaller competitors out of the oil market. For these bigger companies, there were therefore fewer pressing reasons to diversify into nuclear energy. The access to cheap Middle Eastern oil provided them with the opportunity to wait and assess whether and when nuclear energy would develop into a competitive energy regime. Reports from the economic planning departments of these companies underpinned this strategy. For example, Gulf Oil's planning board predicted in 1958 that cheap crude oil dominance of the market would only increase in the upcoming decade.[226]

Getting their ducks in a row

To be able to judge whether nuclear energy really would fulfil its promise the major companies needed to stay connected with atomic energy developments. In a conversation between the head of Shell's research laboratory in Amsterdam, Hendrik Slotboom, and the organization behind the Dutch 1957 atoms for peace inspired exhibition *Het Atoom* (*The Atom*) at Schiphol Airport Slotboom made this strategy of "getting their ducks in a row" explicit. The Dutch branch of Shell funded the organization of the exhibition, supplied equipment, and presented their research on radioactive isotopes. In conversation with the exhibition's main organizers, Slotboom, himself a chemical engineer, made Shell's purpose clear by stating that their main goal was to learn from other developments, like well-logging techniques, and proposed to expand the one-time event toward a permanent exhibition and nexus point for showcasing cutting-edge nuclear research. This would provide Shell with an opportunity to stay in touch with nuclear developments.[227]

Similarly, Mobil regularly presented their research on measuring radiation, radioisotopes for lubricants, and well-logging technologies at various exhibitions on nuclear energy.[228] In 1959, Socony Mobil officially opened a nuclear research center at Stony Brook, near Princeton. The center employed a staff of fifteen scientists conducting research in nuclear physics and chemistry to discover new ways

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[225] Pratt, 'The Impact of the Peaceful Uses of Atomic Energy on the Petroleum Industry,' 274.

[226] Gulf Oil Corporation, Planning and Economics Dept, 'United States Energy Consumption 1910-1970' (June 1958), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box 3, folder 4.

[227] 'Notulen gesprek Slotboom 22 April 1955' (22 April 1955), 259 Tentoonstelling "Het Atoom" (Amsterdam: City Archives Amsterdam), box 3; 'Notulen Het Atoom, 10 mei 1955' (10 May 1955), 259 Tentoonstelling "Het Atoom (Amsterdam: City Archives Amsterdam), box 3; 'Inventaris van de tentoonstelling' (1957), 259 Tentoonstelling "Het Atoom" (Amsterdam: City Archives Amsterdam), box 18.

[228] W.J. Shanahan (eds), 'Power from the Atom,' *Oil Power* 60, 2 (Date Unknown), 14-15, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/F160.

to convert petroleum into more high-quality products.[229] The Anglo-Iranian Oil Company (later BP) also conducted research with radioactive isotopes to measure engine wear at Sunbury Research Station.[230] Other oil companies funded nuclear research groups at various universities. For instance the Institute of Nuclear Physics at Chicago University, led by nuclear physicist and Manhattan Project veteran Samuel King Allison, was funded by the Standard Oil Company of Indiana, Standard Oil Company of New Jersey, the Shell Development Company, and the Sun Oil Company, and also MIT specifically targeted oil companies to be lead donors for its nuclear research.[231]

In some instances, research in the oil sector also found applications within the early nuclear industry. In 1956, Shell officially announced that they supplied lubricants which were more radiation-resistant for a new nuclear reactor at Calder Hall.[232] Another example was the Dresden, Illinois, nuclear power station, which was operated thanks to 4,600 gallons of Mobil DTE oil 797 from Mobil Oil, specifically tested for the effects of radiation on the condition of the oil.[233] For the Calder Hall project, the Shell Group was also involved in manufacturing the moderator graphite necessary for the nuclear reactors.[234] In this way, although large companies like Shell did not really invest in big nuclear industrial projects yet, the research they carried out ensured involvement in new nuclear energy developments, and thus also provided contacts which could prove helpful in the case of future diversification into the atomic business.

The involvement of former oil chemists and (geo)scientists in the new nuclear institutional network – crossing the boundaries between nuclear industries, incumbent oil companies and governmental levels in many Western countries after the Second World War – further enshrined these spillovers. In the US, an Atomic Energy Commission (AEC) had been created on the first of August 1946, with the Atomic Energy Act, which gave the AEC "a virtual monopoly over atomic energy development, including exclusive control and ownership over fissionable materials."[235] The AEC constituted an elaborate administrative system of several committees overseeing, or advising on, key aspects of the military and civilian development of nuclear energy in the United States. Many of the actors, both scientific, military, and industrial, who had been involved in the Manhattan Project found new roles in these committees, including oil actors such as Eger V. Murphree, who in the meantime had been

[229] 'Discovery about composition of petroleum: new scientific knowledge sheds light on its origin' (1964), ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/F160.
[230] Anglo-Iranian Oil Company, Limited, *Annual Report and Accounts for the year ended 31th December, 1953* (London: British Petroleum, 1954), 27 (Coventry: BP archives).
[231] 'Proposal to the Gulf Oil Corporation by the Massachusetts Institute of Technology,' (1946), MIT Office of the President [Compton and Killian] (Cambridge, Massachusetts: MIT Distinctive Collection), box 161, folder 13; Allison, 'Institute for Nuclear Studies, The University of Chicago,' 483; Joe Martin, 'The Simple and Courageous Course: Industrial Patronage of Basic Research at the University of Chicago, 1945-1953', *Isis* 111, 4 (2023), 713.
[232] Royal Dutch Petroleum Company, *Royal Dutch Petroleum Company: Annual Report 1956* (The Hague: Royal Dutch Petroleum Company, 1957), 51; Stephen Howarth, A *Century in Oil: The "Shell" Transport and Trading Company 1897-1997* (London: George Weidenfield & Nicolson Ltd., 1997), 246-247.
[233] W.J. Shanahan (eds), 'Power from the Atom,' *Oil Power* 60, 2 (Date Unknown), 12-13, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/F160.
[234] Already in 1947, Shell scientists had conceived the first ideas for finding a pure carbon material suitable for the manufacture of graphite forms, useful for producing better engines but also useable as moderators in atomic reactors. Through technical and technological experiments, carried out in cooperation with the British government, it was found that petroleum coke could be manufactured of the high purity needed for producing moderator graphite without complicated, and expensive, purification. Royal Dutch Petroleum Company, *Royal Dutch Petroleum Company: Annual Report 1958* (The Hague: Royal Dutch Petroleum Company, 1959), 56.
[235] Melosi, *Atomic Age America*, 73.

promoted to vice-president of research and engineering at Standard Oil of New Jersey and who became a member of the General Advisory Committee of the AEC, providing advice on scientific and technical matters.[236]

On the other side of the Atlantic, Shell experienced a veritable exodus of physicists, geophysicists, and engineers who found work setting up a Dutch nuclear industry. Many of the scientists and engineers who had joined Shell before the Second World War, like Hendrik Brinkman, Maarten Bogaardt, Robbert van Erpers Royards and from 1963 also Hendrik Slotboom became employed in the emerging Dutch nuclear industry.[237] Brinkman left Shell in 1949 to work, after a professorship in theoretical physics in Bandung, from 1958 on the establishment of a Dutch nuclear fusion research institute.[238] Van Erpers Royards studied electrical engineering at the University of Applied Sciences in Delft before joining Shell as a seismologist. In 1963, however, he took another step by becoming project manager of the nuclear power plant at Dodewaard, of which he would eventually become the director.[239] Chemical engineer Bogaardt also started his career with Shell before the Second World War. From 1957 onward, however, Shell seconded him to the Dutch Reactor Center (RCN, a governmental and industrial foundation managing nuclear industrial developments in the Netherlands), where he helped establish a Dutch nuclear industry and focused specifically on building a nuclear ship reactor. In 1959, Bogaardt became a permanent employee of RCN, playing a major role in establishing the Dutch uranium enrichment project and the first nuclear reactors.[240] After retiring from his position at Shell in 1963, Slotboom became chairman of TNO and a member of the Central Council for Nuclear Energy, an advisory body to the Dutch government on nuclear industrial developments.[241]

In France, the trend of enlisting petroleum engineers into the emerging nuclear industry took place via an “old boys-network” established at the prestigious *Ecole Polytechnique*. As political historian Douglas Yates argued, after the Second World War, the modal French petroleum president was an engineer, good in math and physics, and who had graduated in the top ten of his class from *Polytechnique*, often continuing his studies at the *Ecole des Mines* which prepared him, via some field assignments in the oil or mining sectors, for a position as state engineer in the powerful technical-administrative *Corps des Mines*. There they quickly got an influential position within the Ministry of Industry, the minister’s cabinet, or in one of the powerful agencies ranging from oil companies to the nuclear, state-level

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[236] As the previous chapter also stated Marion W. Boyer, former executive vice president of Standard Oil of New Jersey, even became the general manager of the AEC from 1950 to 1953. Melosi, *Atomic Age* America, 73; Gilliland, ‘Eger Vaughan Murphree: November 3, 1898-October 29, 1962’; Ennis, ‘Marion W. Boyer, Oil Executive’.
[237] With the risk of becoming too listy, there were more examples of chemical engineers and (geo)physicists at Shell that spilled over to the Dutch nuclear industry like Francis Edmund Boon and Hendrik Kramers. Boon had joined BPM as an engineer in 1938, but in 1949 became professor of chemical tools and control engineering at Delft University of Technology from where he was involved in the construction of nuclear reactors from 1958 and became a nuclear energy consultant for the Dutch government. Hendrik Antony Kramers was already a famous physicist before Second World War but had gone to work for Shell during the occupation to teach young students there. After the war, Kramers continued working on his ideas on gas diffusion, the theory of which was applied by Jaap Kistemaker in his research on uranium enrichment. Dresden, *H.A. Kramers: between tradition and revolution*, 500; Harry Snelders, *De geschiedenis van de scheikunde in Nederland 2: De ontwikkeling van chemie en de chemische technologie in de eerste helft van de Twintigste Eeuw* (Delft: Delft University Press, 1997), 175.
[238] Broer and De Snoo, ‘Mathematisch fysicus H.C. Brinkman,’ 31-32.
[239] Felix Eijgenraam, ‘Robbert van Erpers Royaards: Vasthoudende voorvechter van kernenergie,’ *NRC Handelsblad* (2 May 1988).
[240] Andriesse, *De Republiek der Kerngeleerden*, 180-181.
[241] Kistemaker, *De geschiedenis van het Nederlandse Ultracentrifuge Project,* 21.

authority CEA.[242] With Pierre Guillaumat as the archetype of this cohort, becoming responsible for France's nuclear industry at CEA and minister of industry after being a petroleum engineer, a network was established connecting the French government with the nuclear and oil industries.[243] Pierre Taranger, who had become director in the CEA's nuclear production program, for example could get this position despite being "an oilman" thanks to his close relation to Pierre Guillaumat, as they both were members of the corps.[244] In this way, a network was established that linked the oil sector to the nuclear industry both in terms of knowledge and people.

"You know…drilling for uranium is no different than drilling for oil"

3

For oil companies with no access to cheap oil concessions in the Global South, uranium mining did become an interesting option to diversify. A rapidly increasing demand for uranium and the technological and geoscientific expertise accumulated in the oil industry created the opportunity for smaller oil companies to invest in uranium mining. The destructive property of fission reactions demonstrated with the detonation of the atomic bombs at the end of the Second World War made uranium a mineral wanted in countries around the world. Governments tried to secure access to the resource needed to create new destructive weapons and produce nuclear energy. The United States in the first years after the Second World War pursued an active policy of making deals with countries whereby the US would supply radioactive isotopes, the residual product of the nuclear weapons industry, in exchange for access to the raw materials such as uranium, thorium and boron.[245] Also other, often colonial, powers like France and the Netherlands started searching for uranium in their colonies, or tried to buy uranium reserves, even from countries within the Soviet bloc.[246]

The search for uranium became a top priority for the AEC, which established a committee on finding and obtaining fissile materials called the Raw Materials Advisory Committee. This committee included many geologists with a background in the oil industry, with Wallace Everette Pratt, Paul L. Merrit, Vincent E. McKelvey and Everette Lee DeGolyer among the most well-known.[247] Pratt was one of the first geologists with an academic background who started working in the oil industry in the 1910s, working his way up to become a board member of Standard Oil of New Jersey in 1942. After retiring in 1946, he became a consultant to the oil industry and the Atomic Energy Commission.[248] DeGolyer, like Pratt, was one of the first geophysicists with a scientific background in the oil industry, where he worked to introduce applied geophysics and spent twenty years as director of the American Petroleum

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[242] Yates, *The French Oil Industry and the Corps des Mines in Africa*, 3.
[243] Ibidem, 3; Christian Stoffaës, 'Ingénieur d'Etat', Georges-Henri Soutou and Alain Beltran (eds), *Pierre Guillaumat: La passion des grands projets industriels* (Paris: Éditions Rive Droite, 1995), XVII-XXV.
[244] Claude Bienvenue quoted in Jean-Francois Picard, Alain Beltran, and Martine Bungener, *Histoire(s) de l'EDF. Comment se sont prises les décisions de 1946 à nos jours* (Dunod, 1985), 191; Hecht, *Radiance of France*, 82.
[245] Jacob Darwin Hamblin, *The Wretched Atom: America's Global Gamble with Peaceful Nuclear Technology* (New York: Oxford University Press, 2021), 2-4.
[246] See for the Italian company *Ente Nationale Idrocarburi* (ENI) buying uranium reserves from the Soviet Union: Cantoni, *Oil Exploration, Diplomacy and Security in the Early Cold War*, 218-219; Lavista, 'Political Uncertainty and Technological Development,' 52.
[247] 'US Atomic Energy Commission,' George W. Bain Papers (Amherst: College Archives and Manuscript Collections, Amherst College), box 15.
[248] Salvador, 'Memorial to Wallace Everette Pratt, 1885-1981'.

Institute before being appointed to the Raw Materials Advisory Committee by President Truman in 1948.[249]

The 1944 report by the Murray Hill Area research group, with Paul Guarin and George Bain, had established that uranium was not only found in the already known big deposits in Canada, Belgian Congo, Germany, Czechoslovakia, and the Soviet Union, but was also to be found near hydrocarbon-bearing materials like coal and petroleum. Exploration for uranium could therefore be combined with exploration for other strategic resources.[250] In his studies for the AEC directly after the Second World War, Bain further defined the properties of uranium that would help to identify new deposits. His reports on the "geology of fissionable materials" elaborated on where to find the needed quantities of uranium, explicitly stating that especially petroleum source rocks were highly radioactive "due partly to thorium but principally to uranium." All oil fields, and oil shale areas, were therefore suspected to hold uranium resources, but especially the thin shales, mostly located in the sandstone sediments in the Colorado Plateau and Ferghana, held the highest hope of yielding supplies of uranium.[251]

However, the AEC was not able to conduct uranium exploration by itself. In 1948, the AEC introduced a program offering to buy all uranium, leaving the exploration and mining to private parties. This offer guaranteed a source of income for uranium mining entrepreneurs and caused a real uranium rush. Wildcatters, often with a background in oil exploration, tried their luck in the search for uranium. This included famous wildcatters like Charles Steen and Stella Dysart. Dysart, a Los Angeles businesswoman, had spent the decades prior to the Second World War looking for oil on her sheep range called Ambrosia Lake northwest of Grants, New Mexico, before moving into uranium exploration in 1950.[252] Steen too, switched from oil to uranium exploration. After resigning from Standard Oil of Indiana, Steen hit the biggest uranium strike in the history of the Colorado Plateau in 1950, enabling him to establish the Uranium, Oil and Trading Company and crowning Steen as the unofficial "uranium king".[253] The success of Dysart and Steen inspired many more wildcatters, like restaurant owner Bob Adams, who after discovering uranium in the Crook's Gap Area at Rawlins, Wyoming, founded the Lost Creek Oil and Uranium Company in 1955.[254]

The previous chapter already showed how the ubiquitous involvement of the oil industry in global uranium exploration and mining was a product of the accumulated geological and geophysical knowledge in the oil industry and the presence of the necessary technologies to detect uranium. The story of "uranium king" Charles Steen offers a fitting example of the superiority of the oil industry's knowledge of sandstone geology in uranium mining on the Colorado Plateau. When Steen decided on the main targets for his search, he focused on an area previously labelled worthless by government geologists. Contrary to mining geologists, Steen was convinced that uranium could form deposits deep underground, just like reservoirs of oil, and then leech upward into more solid sedimentary layers. Based on his experience gained during his time as an oil geologist at Standard Oil of Indiana, he focused

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[249] 'Atomic Energy Commission,' Everett DeGolyer Collection (University Park, Kansas: Southern Methodist University – DeGolyer Library), box 54, folder 3490; Tinkle, *Mr. De: A Biography of Everette Lee DeGolyer*.

[250] Brown and MacDonald, *The Secret History of the Atomic Bomb;* Zoellner, *Uranium*, 48-49, 300; Helmreich, *Gathering Rare Ores*, 44-45.

[251] George Bain, 'Geology of Fissionable Materials,' IV, George W. Bain Papers (Amherst: College Archives and Manuscript Collections, Amherst College), box 10.

[252] Viriginia, T. McLemore, 'Uranium industry in New Mexico – history, production, and present status,' *New Mexico Geology* (August 1983), 46; Amundson, *Yellowcake Towns*, 24-25.

[253] Ringholz, *Uranium Frenzy*; Amundson, *Yellowcake Towns*, 24-25; Zoellner, *Uranium*, 133-135.

[254] Amundson, *Yellowcake Towns*, 24.

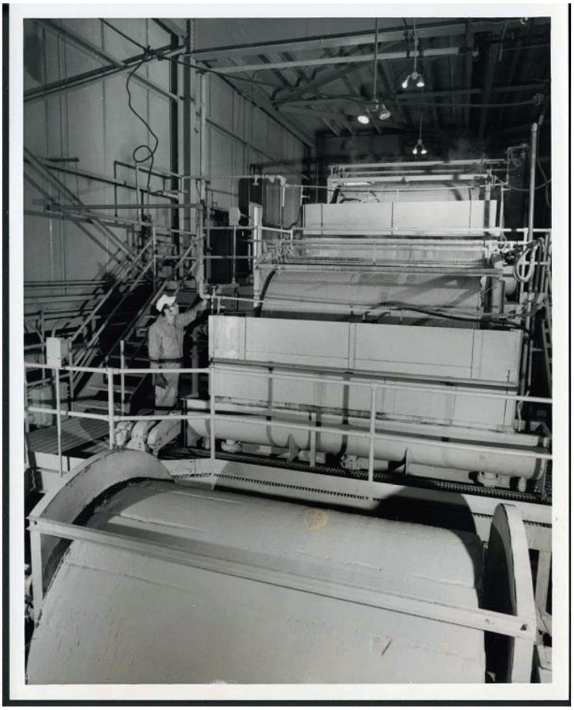

Figure 11: uranium concentrates (yellowcake) dry on filters at Kerr-McGee uranium processing mill in Ambrosia Lake area of New Mexico (undated). American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History, 1978), Box 42, folder 57.

on downward-sloping structures, mostly known for their ability to trap oil reservoirs, located behind existing claims of where tiny amounts of uranium had been found. While in this way neglecting established practices used by mining companies, he successfully struck one of the biggest uranium deposits in the United States.[255]

In addition to the necessary geological knowledge of sandstone, the oil sector also possessed an edge in measuring the radioactivity of minerals in drilling holes. Generally, oil exploration was done using well-logging. In the case of Stella Dysart, old oil drilling logs and rock samples played a crucial role in eventually finding the uranium deposits. Geologist Lewis B. Lothman managed to obtain the drilling logs left over after Dysart's unsuccessful attempts to find oil in this area in 1955. Lothman used these logs to estimate the drilling depths to the Morrison sandstones around the dome and tested the leftover rock samples for radioactivity.[256] In April of the same year, Lothman began a wildcat drilling program for Dysart in the Ambrosia Lake area and encountered mineralized sandstones in the Westwater Canyon Member in his second hole.[257]

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[255] Ringholz, *Uranium Frenzy*, 13, 60.

[256] A.E. Saucier, *Grants uranium region guidebook, Albuquerque to Ambrosia Lake* (New Mexico: New Mexico Bureau of Mines and Mineral Resources, Unpublished field guide for 1979 symposium on Grants uranium region, 1979), 15.

[257] McLemore, 'Uranium Industry in New Mexico,' 46.

Wildcatters were not the only actors with connections to the oil sector who got involved in the exploration, mining, and processing of uranium in the United States. The new finds in Wyoming, Utah, and New Mexico were "all made by either damn fools or oil companies," as one AEC geologist recalled.[258] After Dysart and Lothman discovered uranium in Grants, AEC geologists quickly showed that almost seventy percent of US uranium reserves were located below Ambrosia Lake. However, unlike the deposits discovered by earlier wildcatters, these deposits were located too deep for small mining companies to be able to make the necessary investments to mine and mill the uranium. Instead, bigger companies, including oil companies like Phillips Petroleum, Getty Oil and Kerr-McGee, jumped in, sometimes working together in joint ventures such as Petrotomics (co-owned by Getty, Kerr-McGee and Skelly Oil).[259] Dysart too, decided to sell the leasing rights to her lands to Kerr-McGee. These companies also had the capacity to operate the milling plants needed to extract the wanted uranium concentrate, or "yellowcake," needed for the US weapon and nuclear energy program. By 1958, four mills were operating at Ambrosia Lake.[260]

Also, for the companies, the technologies and knowledge accumulated in the oil industry provided a competitive edge in the uranium market. The *Journal of Petroleum Technology* regularly featured new articles about the benefits of radioactive well-logging to find additional oil reserves in mudded boreholes.[261] Socony and the Anglo-Iranian Oil Company in particular, invested in new research on radioactive well-logging methods. In the decades following Schlumberger's invention, Socony worked on gamma-ray devices that picked up the presence of radioactivity emitted by minerals to see if there were new oil reservoirs to be found, while Anglo-Iranian used radioactive well logging techniques in a variety of test sides.[262] In 1960, a report by J. G. Beckerley from the International Atomic Energy Agency (IAEA) found that from the sixty thousand boreholes drilled yearly in the US for petroleum exploration, ten thousand were researched utilizing radioactive well-logging techniques. In the Soviet Union, radioactivity logging was used on 3,500 kilometers of drill holes in 1954.[263] Also, the community of nuclear geologists, established in 1954, enthusiastically adopted the use of radioactive well-logging in uranium exploration. In their 1954, foundational symposium on nuclear phenomena in the earth sciences, Charles William Tittle from the Gulf Research and Development Company extensively elaborated on the benefits of using neutron and gamma-ray logging methods directly derived from the oil sector.[264]

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[258] Quote as represented in Taylor and Yokell, *Yellowcake*, 26-27.

[259] George C. Cobb, '2nd amendment of partnership: Agreement – Petrotomics' (1961), Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library) box 119, folder 7; Ollinger, *Organizational Form and Business Strategy in the US Petroleum Industry*, 18.

[260] 'Donald T. Adams interview, conducted 1970 by Mitch Haddard,' Uranium mining oral history project, 1970-1971, ACCN 1322 (Online: J. Willard Marriot Digital Library, The University of Utah), Box 1, Folder 1; Amundson, *Yellowcake Towns,* 24-25.

[261] R.E. Bush and E.S. Mardock, 'The Quantitative Application of Radioactivity Logs,' *Journal of Petroleum Technology* 3, 7 (1951), 191-198; R.H. Widmyer and G.M. Wood, 'Evaluation of Porosity Derivation from Neutron Logs,' *Journal of Petroleum Technology* 10, 5 (1958), 57-60.

[262] 'Oiflied technicians use radioactivity,' *Naft Magazine/BP Magazine* (June 1951), 7-9 (Conventry: BP archives); 'For Uranium, the Future is Now,' *Mobil Overview* 2, 1 (1978), 6, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120.

[263] J.G. Beckerley, *Nuclear Methods for Subsurface Prospecting* (International Atomic Energy Agency, 1960), 228-229.

[264] Henry Faul, 'Nuclear Logging of Drill Holes for Mineral Exploration and Soil Studies,' in Henry Faul, *A Symposium on Nuclear Phenomena in the Earth Sciences* (New York: John Wiley & Sons, 1954), 250.

One of the best examples of the success of the radioactive well-logging method directly transferred from the oil industry to the uranium sector was the entry of Kerr-McGee into the uranium business in 1952. When the company decided to focus more on the uranium industry, it appointed geologists, previously working on oil exploration, to search for new uranium sources. Kerr-McGee embarked on an exploration effort that extended from Arizona to as far north as Utah and Wyoming. To avoid the expensive "trying to feel your way around by drilling and blasting and mining to do your exploration work", the company geologists used a "shothole", or seismograph rig, to quickly drill more small holes close to each other and in this way find the uranium beds that were small and easily missed. To accommodate the analysis of the boreholes, geologist Virgil Janeway built what was one of the first portable logging instruments in the uranium business – a Geiger counter with a probe on a cable reel. This permitted Kerr-McGee to successfully map all the drilling holes and made possible profitable finds in New Mexico and Wyoming.[265] As the company's co-founder, geologist Dean McGee, used to gloat on many occasions, "you know…drilling for uranium is no different than drilling for oil, for gas, or any other minerals!"[266]

The oil empire strikes ore: the Western oil industry in a global uranium market

222,570 Accident-Free-Hours

Regardless, and partly due to, this tough talk, the oil industry and the technologies spilling over definitely played their part in the industrial, environmental, and social transformations that took place during the scaling-up of the American uranium industry. Over the last few decades, various scholars have increasingly paid attention to the founding of various uranium towns on the Colorado Plateau, the intrusion of the radioactive mineral into cultural life, and the regressive and colonial practices towards the indigenous Moab and Navajo population to convince them to work in the uranium mining industry established on their territory – often deliberately keeping them ignorant of the potential dangers of radiation exposure and local environmental contamination from the mining projects.[267] Oil firms made up a large share of this new industry, including the milling, conversion and testing of the mineral, enabling much of its development through their technologies and knowledge.[268]

The main aim for the oil companies involved in the 1950s uranium industry was, of course, to make profits. Following the new AEC regulations opening uranium mining to private entrepreneurs in the

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[265] John A. Hermann and P.C. Ellsworth, *Selection and Construction of Gamma Ray Probe Curve for Estimation of Pacific Uranium Orebody* (Kerr-McGee Oil Industries Inc, 1957), 3, Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 48, folder 6; Ezell, *Innovations in Energy*, 212-214.
[266] Dean McGee as quoted by Frank C. Love, Edwin L. Kennedy and Dean Terrel in Ezell, *Innovations in Energy*, 210.
[267] Robert Roscoe, Kyle Steenland, William Halperin, James Beaumont, and Richard Waxweiler, 'Lung Cancer Mortality Among Nonsmoking Uranium Miners Exposed to Radon Daughters,' *The Journal of the American Medical Association* 262 5 (1989), 629-633; 'Medicine: Uranium Miners' Cancer', *Time Magazine* 26 (1960); Robert Roscoe, J. A. Deddens, A. Salvan, and T. M. Schnorr, 'Mortality among Navajo Uranium Miners,' *American Journal of Public Health* 85 4 (1995), 535-40; Ann Oncol, 'Radon: A Likely Carcinogen at All Exposures,' *Annals of Oncology* 12 10 (2001), 1341-1351.
[268] Phillips Petroleum was involved in managing the material testing sites for the US AEC. United States Atomic Energy Commission, *Nineteenth Semianual Report of the Atomic Energy Commission* (Washington D.C.: Government Printing Office, 1956), 54.

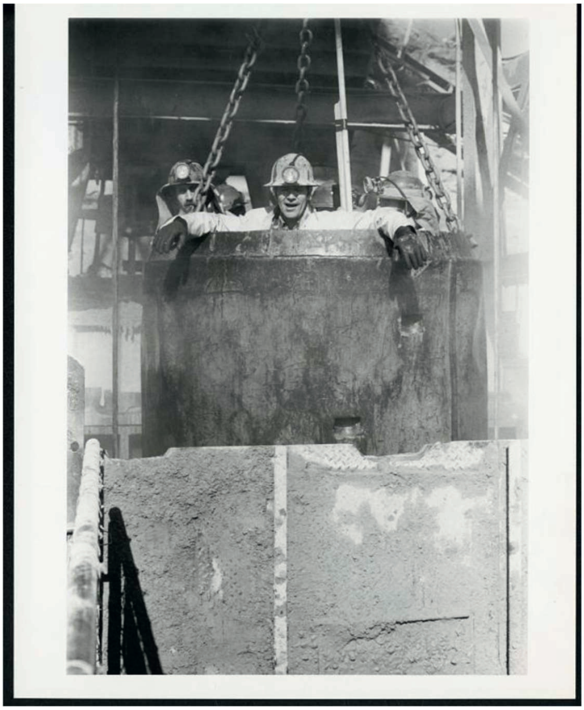

Figure 12: "With steam rising form the 1,300-foot-deep mine, Frank Anderson and crew are lowered by a steel bucket. The miner at Phillips uranium mine has 16 years experience in mine work. He says concentration is the key to on-the-job safety." Phillips Petroleum Co., Phillips News *(March 19); American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History, 1978), Box 42, folder 50.*

United States, producers increased their output from almost zero in 1950 to 17,640 tons in 1960. During this decade, the AEC prices ranged from $8,53 to $12,51 per pound, making profits in excess of three dollars per pound possible with average costs of only about five dollars per pound.[269] Such profits attracted smaller oil companies that were not able to profit from the neocolonial practicing of producing cheap oil in the Middle East.

To reduce costs and increase profits with their uranium projects, companies like Kerr-McGee often deliberately cut back on safety regulations or actively lobbied to get exceptions to new, often stricter, nuclear regulations. Although in 1962 Kerr-McGee celebrated its safety measures by publishing a pamphlet to highlight that their mining project moved "into safety spotlight with 222,570 Accident-Free-Hours", the company also actively, and successfully, lobbied to reduce the liability for radioactive contamination and accidents at their facilities by trying to exclude their uranium mining and milling plants from the definition of a "nuclear facility," arguing that it was more of a regular mining operation without extra risks of radioactive contamination for workers.[270]

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[269] Ollinger, *Organizational Form and Business Strategy in the US Petroleum Industry*, 128; Anthony Owen, *The Economics of Uranium* (New York: Praeger Publishers, 1985).

[270] 'Section 24 Mine Moves into Safety Spotlight With 222,570 Accident-Free-Hours' (September 1962), Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 126, folder 10; Howard Davis, 'Nuclear Energy Liability Exclusion Endorsement to Liability Policy No. CL 1196' (November 30, 1960), Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 117, folder 4.

The resulting notoriously bad working conditions incited the rise of organized labor within the oil-nuclear industry. Although some of the physicists, engineers and chemists working within the oil industry had already unionized themselves during the 1930s and 1940s, such as the participation of the nuclear chemist George C. Eltenton in the Federation of Architects, Engineers, Chemists, and Technicians (FAECT) at Shell, many oil companies had actively tried to discourage participation in labor unions by their employees.[271] Still, oil companies were regularly faced with strikes organized by unions.

Also, unions often targeted oil companies working in the *nuclear* industry. In the United States, the Oil Workers International Union (OWIU) and the United Gas, Coke and Chemical Workers of America (OGCCW) merged together to form the Oil, Chemical and Atomic Workers Union (OCAW) in 1955, again signaling how much overlap there was between these industries.[272] OCAW, representing approximately 210,000 workers in all industries, organized strikes and other labor actions at nuclear and oil companies over the 1950s and 1960s.[273] Especially within companies where they were particularly well organized, like the Kerr-McGee company, their actions resulted in multiple strikes.[274]

Still, conditions frequently remained poor, especially for Indigenous people who were often not affiliated with the various unions. They were often recruited to work in uranium mines on the Colorado Plateau such as the Kerr-McGee owned mining operations at Shiprock, NM, in Navajo territory, which became infamous for its many Navajo workers who died of lung cancer or fibrosis (133 of the 150 workers died within a decade of working in a mine at Shiprock).[275] In some cases, these conditions were specifically related to the fact that companies had spilled over from the oil industry. Not only did the aim to earn profits with uranium mining to counteract the decreasing petroleum prices lead the companies to cut back on safety regulations, but their experience with oil fields was accompanied by a mindset of reducing production costs in the uranium market. Oil companies, accustomed to low development costs, regularly ran into problems with the more expensive mineral mining projects. Contrary to oil production, often multiple test holes needed to be sunk to know where the deposit was located, and when the ore was too far beneath the surface shafts and tunnels were needed to bring

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[271] Elisabetta Bini and Francesco Petrini, 'Labor politics in the oil industry: new historical perspectives,' *Labor History* 60, 1 (2019), 1-7; Touraj Atabaki, Elisabetta Bini and Kaveh Ehsani, *Working for Oil: Comparative Social Histories of Labor in the Global Oil Industry* (Cham: Palgrave MacMillan, 2018), 1-10; Bird and Sherwin, *American Prometheus*, 175; In an 1963 interview about the Civil Rights Act, the manager of Phillips Petroleum, K.S. Adams, argued specifically against the regulations on union membership which would make it harder to withhold promotions for union members: 'As I see it: A Monthly Interview with K.S. Adams, Chairman,' Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library, 1963), box 104, folder 19.

[272] In his 1960 analysis of the various union mergers in the petrochemical industry management scholar Arnold R. Weber stated that the unions in these industry were tied to each other by the "conditions of technology rather than the conventional attributes of market structure", suggesting that the many technological spillovers between the nuclear and petrochemical industries formed the basis for OCAW. This also would be an interesting field of further research. Arnold R. Weber, 'Competitive Unionism in the Chemical Industry,' *Industrial and Labor Relations Review* 13, 1 (1959), 17; Ray Davidson, *Challenging the Giants: Oil, Chemical and Atomic Workers International Union* (Denver, CO: The Union, 1988).

[273] Rebecca Logan and Dorothy Nelkin, 'Labor and Nuclear Power,' *Environment: Science and Policy for Sustainable Development* 22, 2 (1980), 6-34; Laurie Adkin, *The Politics of Sustainable Development: Citizens, Unions and the Corporations* (Tonawanda: Black Rose Books, 1998).

[274] 'Kerr-McGee – OCAW Union Matters' (1975), Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library, 1963), box 158, folder 3.

[275] Saleem H. Ali, *Mining, the Environment, and Indigenous Development Conflicts* (Tucson: University of Arizona, 2003); 'A Brief history of the Shiprock Mining and Milling Operations on the Navajo Indian Reservation' (1963), Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 104, folder 1.

miners in. These tunnels offered unfamiliar problems for the oil actors, ranging from unexpected flooding by high water and extra capital investments required. Many mining companies, more experienced with the costs involved, for this reason expressed doubts about the AEC's buying program. Mining actors argued that the program would not last long enough to justify the expenses, whereas the oil companies that joined the 1950s "uranium booms" limited their expenses so much that unsafe mining operations were the inevitable result.[276]

The Western oil industry in a global uranium market

The sandstone sediments on the Colorado Plateau were only one of many places where uranium could be found around the world. In October 1954, the French nuclear authority CEA labelled "purchase zones" for uranium ores in Brittany and in the Central Massif in Metropolitan France, where the CEA was ready to help "private individuals" by buying their production. Just like what happened on the Colorado Plateau with the AEC's promise to buy uranium, private prospectors and operators (among which were several small companies), that were often previously related to oil exploration, began to appear on the scene.[277] Also, in a more (neo)colonial context Western oil actors were closely involved in the establishment of a uranium industry. Together with the United Kingdom and Canada, the AEC established neo-colonial, long-term contracts with Belgian Congo in 1945 to ensure uranium supplies and keep Congolese uranium out of the hands of the Soviet Union. Uranium and monazite contracts with India and Brazil were secured too, basically trading access to resources of fissionable materials for granting supplies of radioactive isotopes.[278] Geoscientists, such as George Bain, conducted extensive studies on possible fissionable resources in Korea for the AEC at the beginning of the 1950s, concluding that the gold-bearing rivers in Korea also were particularly rich in uranium, in this way increasing the strategic importance of the Korean peninsula.[279]

Other colonial powers from Western Europe got involved in securing access to uranium, with oil actors often playing important roles. Although the Netherlands had had access to a limited amount of yellowcake since the 1930s, which had been hidden from the German invaders in the cellars of the University of Applied Sciences in Delft during the Second World War, establishing a potential nuclear industry required more resources.[280] In 1956, a committee was formed to investigate whether uranium could be found in the Dutch colonies of New Guinea and Surinam. Former Shell geologist, and director of Shell's geophysical training center before the War, Herman Schürmann, served on this committee. In the following year, the committee, which also included former Prime Minister Willem Schermerhorn, would lead exploratory geological research in the colonies and advise on the feasibility of possible economic exploitation of available fissionable material.[281]

[276] Taylor and Yokell, *Yellowcake*, 27.
[277] Antoine Paucard, *La Mine et Les Mineurs de l'Uranium Français, Vol. 1 : Les Temps Légendaires (1946-1950)* (Thierry Parquet, 1992).
[278] Mellor, *The Cold War Underground*, 130; Hamblin, *The Wretched Atom*, 14-15.
[279] George Bain, 'Korean Monazite,' George W. Bain Papers (Amherst: College Archives and Manuscript Collections), box 11.
[280] Machiel Kleemans, 'Secrecy and the Genesis of the 1951 Dutch-Norwegian Nuclear Reactor,' *Historical Studies in the Natural Sciences* 51, 1 (2021), 48-86.
[281] 'Nota: Instelling Commissie voor onderzoek aanwezigheid splijtbare materialen in Nederlands-Nieuw-Guinea en Suriname' (1956), Archives of the Directorate of Nuclear Energy of the Ministry of Economic Affairs (The Hague: Dutch National Archives), box. 735; Dozy, 'Obituary H.M.E. Schürmann (1891-1979),' 289-290.

France too, drew heavily on the expertise available in the oil sector in setting up its nuclear industry. From the early 1950s, the CEA enlisted primarily members of the *Ecole des Mines*, a small elite of polytechnic graduates with a strong focus on geophysics and engineering, to establish a national nuclear industry. Many of these engineers involved in the nuclear industry had backgrounds in the oil sector. Their most prominent foreman was Pierre Guillaumat, formerly involved in oil exploration in Algeria, Morocco, and Tunisia and now in charge of the CEA and the creation of an independent nuclear industry. This desire for independence, separate from the knowledge and technologies available in the United States, translated into a focus on domestic and (neo) colonial uranium projects both in France and, partly former, French colonies such as Gabon and Niger.[282]

The contracts with Gabon and Niger dealing with uranium, oil, and other strategic minerals, reflected the new neo-colonial bond between France and its former colonies in Africa. Engineers and policymakers in France described access to both oil and uranium as forwarding France's "energy independence" from the United States' nuclear dominance and Middle Eastern oil, often without acknowledging the neo-colonial implications of this phrase. Although Gabrielle Hecht argues that, especially at first, the French techno-politics of uranium and oil remained separate with the oil business mainly focusing on profits while the uranium production was focused on getting "power and prestige" instead of profits, the involvement of CEA directors with a background in the oil industry like Guillaumat and Pierre Taranger shows there were still many overlapping actors involved in both oil and uranium exploration in France and Africa.[283]

The return of Big Oil

Oil executive chairs for scientist engineers?

As this chapter has argued, contrary to companies such as Kerr-McGee major oil companies often refrained from committing to full-fledged diversification projects into nuclear energy projects during the 1950s. The strategy of keeping their ducks in a row turned around, however, during the 1960s when the cohort of scientist-engineers that was versed into nuclear energy developments got the opportunity to steer their companies from newly acquired management positions. Due to increasing problems in finding, and keeping, scientists and engineers to work for the industry, companies needed to produce extra incentives to stay attractive. One of the ideas to tackle this problem, and to compete with the nuclear industry where many scientists and engineers got more interesting research and management positions, that gained traction within the oil industry during the 1960s was put clearly by L. G. Weigle of the Humble Oil and Refining Company: the oil industry had to offer "executive chairs for engineers".[284]

[282] Hecht, *The Radiance of France*; Hecht, *Being Nuclear*; Georges-Henri Soutou and Alain Beltran, *Pierre Guillaumat: La passion des grands projets industriels* (Institut d'Histoire de l'Industrie et Editions Rive Droite, 1995).
[283] Hecht, *Being Nuclear*, 118-119.
[284] L.J. Weigle, 'Executive Chairs for Engineers?,' *Journal of Petroleum Technology* 17, 3 (1965), 254-256.

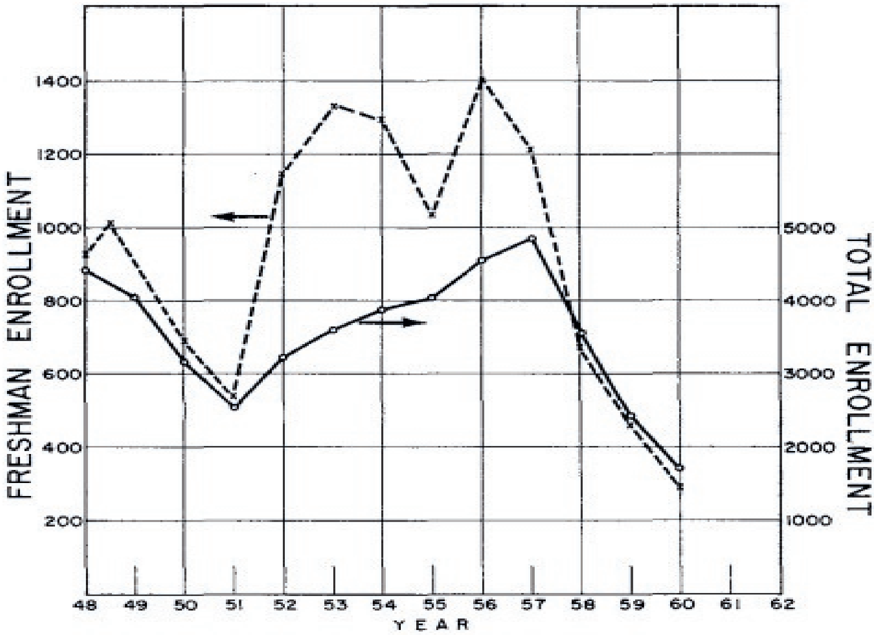

Figure 13: Annual freshmen enrolment and total petroleum engineering enrolment for the years 1948-1960. As represented in Holbrook G. Botset, 'The Vanishing Petroleum Engineering Student,' Journal of Petroleum Technology *(June 1961), 518.*

During the mid-1960s the oil industry not only dealt with debates about the political and economic problems concerning their decreasing influence on oil production in OPEC countries but also dealt with more direct problems within their ranks concerning its attractiveness as employer for scientists and engineers. The number of petroleum engineers and geoscientists started to decline. From 1955 to 1965, the recruitment of new petroleum engineering students declined sharply. Figure 13 shows how the annual first-year enrolment and total petroleum engineering enrolment in the United States also starts to decline from 1958 onward. This became an urgent issue that oil managers and academics at the colleges were increasingly scratching their heads about. Debates about what to do about this "implosion" of the petroleum industry, as Holbrook G. Botset, member of the American Institute of Mining Engineers, described it, became more frequent.[285]

Also outside of the United States, the training programs that oil companies recruited from experienced a declining number of students interested in petroleum engineering and geophysics. Sir Edward Crisp Bullard, a consultant for both Shell and the UK atomic energy authority and supervisor for the geophysical fellowships for Shell students at Cambridge University, complained frequently in his letters to contacts within Shell about the declining number of students in the geophysics program and Ph.D. students interested in oil geophysics. "It is a pity," Bullard wrote already in 1957, "that some of these

[285] Holbrook G. Botset, 'The Vanishing Petroleum Engineering Student,' *Journal of Petroleum Technology* (June, 1961), 517-518.

young men cannot be persuaded to take an interest in geophysics, since we always have difficulty in getting good students and there are lots of jobs and lots of interesting things to be done."[286]

In his letters, Bullard also offered a striking explanation for the declining number of students: the students would be more interested in studying atomic physics than petroleum geophysics. When discussing aiding a student in getting a position within a training program, Bullard sighed that "the trouble is made worse by far too many people insisting on doing nuclear physics." Even when Bullard tried to convince the student to join his geophysics program and asked him if he was sure that he wanted to do nuclear physics, the student insisted that "he really did want to go on with it."[287] This explanation seems consistent with the observations by the academic chemical engineer Holbrook Botset. In his paper on "the vanishing petroleum engineering student", Botset proposed that one of the causes of the low petroleum engineering enrolment probably was "the glamour of the space age." According to Botset young people were "so bombarded with publicity on missiles in TV, toys, and books that they scarcely know that other areas of engineering are as vital to our survival as are missiles and atomic energy." Students had asked him, Botset proclaimed, if there would be "much need for petroleum in 10 years or so when atomic power takes over!"[288]

These anecdotes were the products of a longer-lasting campaign in which prominent figures within the nuclear industry would specifically call on potential petroleum engineers and geophysicists to consider working within the nuclear industry. In his preface to the comic *Learn how Dagwood Splits the Atom* (1949), the Manhattan Project's director, Leslie R. Groves, called on schoolchildren to focus primarily on careers in the nuclear industry. There they were to work on atomic-powered trains, planes, and automobiles. Vehicles that until then had always operated on fossil fuels.[289]

The declining number of students enrolled in petroleum engineering and geophysics was part of a larger trend in which geoscientists and engineers left the oil sector to work in the developing nuclear industry. Whereas prior to the Second World War, atomic physicist graduates often found work in the oil industry and then retrained as oil engineers or geophysicists, the nuclear industry was now offering more work. Consequently, this increasing growth encouraged scientists and engineers with backgrounds in the oil sector to switch to nuclear projects. Especially during the period when the major oil companies themselves did not fully join these developments yet, companies that did become widely involved employed former oil engineers and scientists. For instance, two former oil actors joined the board of the Westinghouse Electric Corporation (along with General Electric one of the two leading nuclear reactor manufacturers in the US) during the 1950s. James H. Wright had been a chemical engineer for Gulf Oil for four years, working on designing, constructing, and operating oil refineries, and had worked as chief chemist for Moutray Oil Company before he joined the board of Westinghouse in 1956 as reactor designer and as manager of advanced system's research in the application engineering department, focusing on the field of radio-chemistry. Physicist William E. Abbot followed a similar career trajectory. Although starting his career at Standard Oil of California, he joined

[286] 'Edward Crisp Bullard to J.A. Oriel' (4 March 1957), Papers of Sir Edward Crisp Bullard (Cambridge, United Kingdom: Churchill Archive Centre, University of Cambridge), section E, folder 197.
[287] 'Edward Crisp Bullard to J.A. Oriel" (9 November 1956), Papers of Sir Edward Crisp Bullard (Cambridge, United Kingdom: Churchill Archive Centre, University of Cambridge), section E, folder 195.
[288] Botset, 'The Vanishing Petroleum Engineering Student,' 518.
[289] Leslie R. Groves, 'Introduction,' Joe Musial, *Learn how Dagwood Splits the Atom* (King Features Syndicate Inc., 1949), 1-2; Scott C. Zeman and Michael A. Amundson (eds), *Atomic Culture: How We Learned to Stop Worrying and Love the Bomb* (Boulder, CO: University Press of Colorado, 2004), 2-3.

Westinghouse in 1956. There he became the manager of Reactor Development, responsible for the nuclear and mechanical design for the reactor program of the Atomic Power Department of Westinghouse.[290]

The attractiveness of the nuclear industry over the petroleum business forced a response from the oil sector. By offering executive chairs to scientist engineers, the various oil companies hoped to provide new opportunities and challenges for future students and the scientist-engineers already working in the oil sector, also for the longer term. Oil executives were henceforth required to keep up with "the accelerated pace of new knowledge", that characterized the oil industry in the 1960s. The keen analytical minds of the engineering student became a valued feature for the new generation of oil executives. This slowly replaced the archetypal executive of the flamboyant entrepreneur, the wildcatter who, with hard work and a lucky oil strike, had built an oil empire out of the ground, and who had dominated the board rooms of the oil industry for decades. As Humble Oil economist L.J. Weigle wrote in his article in the *Journal of Petroleum Technology* in 1965: "the executive of today is different from the rugged individualist of 50 years ago".[291]

Not only Weigle noticed this new trend within the oil industry. Halbert Halbert Jr. and D. A. Woolf, both working for the University of Oklahoma, stated in 1966 that "in recent years the position of the engineer in industry has undergone a transition… As the engineering function has grown, many people with technical backgrounds have found their way into management positions."[292] This included many of the previously discussed oil actors, like Han Hoog who became the manager of Shell's new Dutch subsidiary for their nuclear projects in 1967, and chemical engineers like Karel Swart and E.J.G. Toxopeus who would become leading figures within Shell's board and in the oil company's diversification efforts into nuclear energy during the late 1960s and 1970s.[293] Also, in other major oil companies chemical engineers and geophysicists would steer their companies as managers to join nuclear projects. Chemical engineer H. Eugene McBrayer (later CEO of Exxon) headed Standard Oil of New Jersey's nuclear subsidiary, Jersey Nuclear (later Exxon Nuclear), and geophysicists like Curtis Johnson and V.H. King managed Mobil's nuclear diversification efforts into uranium mining.[294]

Big Oil's nuclear diversification during the late 1960s

These scientist-engineer managers could steer their companies into nuclear diversification projects when the profits from the cheap oil concessions in the Middle East and North Africa seemed to decline for the oil industry. Weary of the colonial ties, and willing to claim a bigger share of the profits made from the oil concessions, various governments in the Global South started a process of nationalization

[290] 'Westinghouse: first in Atomic Power' (Pittsburgh: Westinghouse Electric Corp., October 1958), 79-81, Westinghouse Electric Corp. Collection (Pittsburgh: Heinz History Center - Detre Library and Archives), box 177, folder 18.
[291] Weigle, 'Executive Chairs for Engineers?,' 254-256.
[292] Halbert Halbert Jr. and D.A. Woolf, 'Engineers Managing Engineers: A Practicable Principle of Uncertainty,' *Journal of Petroleum Technology* 18, 3 (1966), 288-292.
[293] 'Shell in toekomst als kernenergiehandelaar,' *Het Vrije Volk: democratisch-socialistisch dagblad* (March 19, 1971); 'Shell via Gulf op kernenergiemarkt,' *Tubantia* (June 5, 1973); Metze, *Hoog Spel*, 379.
[294] 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' Oral History Transcript #0144 (Philadelphia: The Chemical Heritage Foundation, Science History Institute, 11 May 1995); 'Double-Duty Prospectors' (1968), 19, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120.

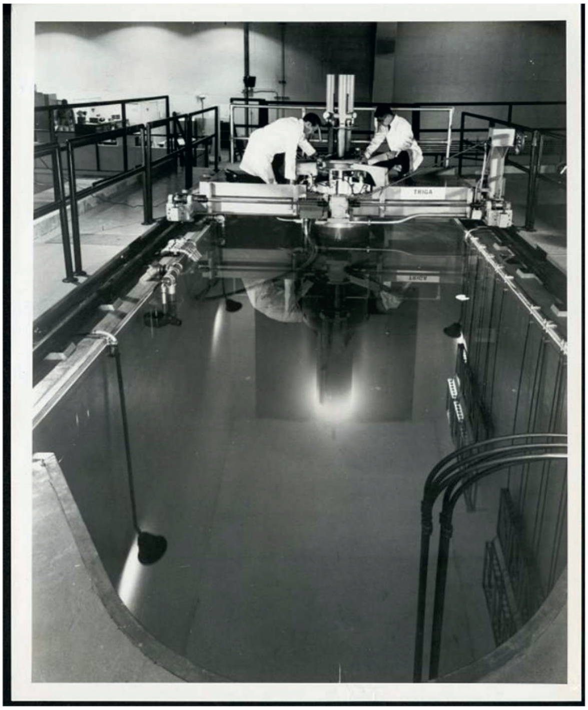

Figure 14: Scientists at General Atomic present a pulsing feature on an early TRIGA model, 1979. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History, 1978), Box 42, folder 46.

of the domestic oil industry, claiming more ownership over the concessions. This development, combined with the increasing cooperation between the countries in the Organization of the Petroleum Exporting Countries (OPEC), startled the Western oil industry during the 1960s.[295] Both in the US and Western Europe, board members of the various companies that previously had access to cheap oil production expressed fears about the future of the Western oil industry, expecting a decline in oil profits.[296] Although the industry expected to add over half a million barrels per day from new oil fields outside the United States in 1967 and had added about three hundred million barrels of crude oil and condensate to the US reserves from new pools and fields, pessimistic outlooks for the future dominated the debates within the sector. Increasing self-awareness of foreign, especially Arab, governments, brought about renegotiations of the original concession contracts established between the international oil companies and the governments, also already before Iran and Libya nationalized oil assets in 1969-1970 sparking a nationalization wave in oil producing countries. The increasing number of government-sponsored, or even state-owned, companies that were able to drill for oil themselves and compete with Western companies magnified this development. Slowly, the international companies were losing their grip on the abundant and cheap oil of the Middle East, and these companies expected this trend to only gain more traction.[297]

[295] Parra, *Oil Politics*; Garavini, *The Rise & Fall of OPEC in the Twentieth century*.
[296] Van Seumeren, *Gerrit A. Wagner*, 35-36.
[297] T.D. Lumpkin, 'The long-range outlook for the petroleum industry' (1967), 2-4, Gulf Oil Corporation Records (Pittsburgh Heinz History Center - Detre Library and Archives), box 1, folder 20.

Combined with increasing concerns of domestic governments paying greater attention to the growing problem of air and water pollution – a problem recognized by the oil industry as being a product of their own doing (see chapter 4) – oil companies looked to a strategy of diversifying into alternate sources of energy. Internal reports considered shale oil, synthetic liquids, and gasification of coal all as alternatives for the expected decreasing profits from traditional oil production; nuclear energy, however, was recognized as the main sector to diversify into.[298] Emerging from the fierce competition between Westinghouse and General Electric, the two leading nuclear reactor manufacturing companies, a market had developed where the utility industry was increasingly convinced that nuclear power was a safe, reliable, less polluting, and cost-competitive alternative to fossil fuels. Energy historian Robert Lifset shows that, inspired by concerns about meeting rapidly increasing power consumption, electric companies ordered sixty-eight nuclear reactors between 1966 and 1968, more than three times the number of orders between 1955 and 1965.[299] The different oil companies closely monitored this development. As T.D. Lumpkin, a petroleum engineer at Gulf Oil, proclaimed in his long-range outlook for the petroleum industry for the society of petroleum engineering in 1967: "There is no doubt that nuclear energy had come of age and will be a big competitor".[300]

Under the new management of many scientist-engineers, often with a keen interest in nuclear technology, the turn toward a new future as an energy company was made over almost the whole range of the oil industry, with companies often returning to the technologies that had established links between the oil industry and nuclear developments during the Manhattan Project in the first place. This was, for example, the case for Shell's early involvement in uranium enrichment in 1967. As in many countries, the Netherlands tried to establish its nuclear industry during the 1950s. One of the main research efforts became the enrichment of uranium by means of centrifugal force, based on research by Hans Kramers, a former Shell employee. Although this technology, which Eger Murphree's Standard Oil of New Jersey studied within the Manhattan Project, had not contributed to the fuel for the original atom bomb, Dutch scientists still thought this technology would be the most efficient way to provide fuel for nuclear power reactors. This research would eventually come to fruition in the URENCO collaboration between the Netherlands, Germany, and Britain and become one of the standard approaches to uranium enrichment. Before that happened however, the effort, supported by former Shell employees Hendrik Slotboom and Maarten Bogaardt, encountered many struggles in the early 1960s in obtaining funding and arousing interest in Dutch industry. The project's fortunes changed in 1967, however, when Shell surprisingly joined the efforts, eventually becoming a ten percent shareholder in the Dutch part of Urenco, providing the vice chairman of the board (chemical engineer Han Hoog), and establishing a Dutch subsidiary for nuclear projects.[301] For Shell, the

[298] *1967 Annual Report Gulf Oil Corporation*, 16.
[299] Lifset, 'Nuclear Power in America,' 525-526.
[300] T.D. Lumpkin, 'The Long-Range Outlook for the Petroleum Industry,' Paper for the Society of Petroleum Engineers of AIME (Pittsburgh: Gulf Oil Corporation, 1967). Gulf Oil Corporation Records. Heinz History Center - Detre Library and Archives. Box 1, folder 20.
[301] Kistemaker, *De geschiedenis van het Nederlandse Ultracentrifuge Project*, 18-23; Streefland, *Jaap Kistemaker en uraniumverrijking in Nederland, 1945-1962*, 256; Dresden, *H.A. Kramers: between tradition and revolution*.

Figure 15: Uranium exploration by Gulf Oil's geophysicists in Canada, 1978. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History, 1978), Box 42, folder 50.

centrifugal technologies provided one of the main reasons to join this specific research effort. Based on their experience with handling highly toxic and corrosive chemicals the oil company was already focusing on enrichment. Their experience with centrifuges would then provide the perfect link to join this centrifugal research project.[302]

Other international oil companies also started entering the nuclear market. In 1967, Gulf Oil bought General Atomic, a company founded in 1955 as part of the General Atomic division of General Dynamics. The company was most famous for the TRIGA nuclear research reactor and its participation in Project Orion, where they worked on nuclear propulsion rockets for NASA's space missions. After the takeover, the company was renamed Gulf General Atomic and focused on developing high-temperature gas-cooled reactors (HTGR).[303] Besides taking over companies already established within the nuclear industry, Gulf Oil also entered the uranium market by buying several uranium mining and milling projects in Canada and western areas of the United States.[304] Within this market, Gulf Oil was not the only major oil company starting to diversify its expenditures. Following incentives from the US Atomic Energy Commission, requesting American oil companies to aid in a "hunt for scarce and vital uranium", several internationally active oil companies, like Mobil Oil's subsidiary General Petroleum,

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302 'Stroom gegevens over geheim uraniumproject,' *Algemeen Dagblad* (February 23, 1968); 'Hoe werkt de ultracentrifuge,' *Algemeen Handelsblad* (March 1, 1968); Kistemaker, *De geschiedenis van het Nederlandse Ultracentrifuge Project,* 18-23; Streefland, *Jaap Kistemaker en uraniumverrijking in Nederland, 1945-1962*, 256.
303 'TRIGA,' Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 21.
304 Gulf Oil Corporation, *1967 Annual Report Gulf Oil Corporation* (Pittsburgh: Gulf Oil Corporation, 1968), 16.

started using their test holes, originally drilled for finding oil, to search for radioactive minerals. Other oil companies quickly followed this step by investing in uranium mining programs.[305]

Also here, the oil companies explicitly leveraged their knowledge of the overlapping technologies used both in the oil sector and within the nuclear industry that had gotten the companies involved in the first nuclear industrial developments during the 1940s. When Curtis H. Johnson, previously geophysicist with General Petroleum and then-President of the Society of Exploration Geophysicists, and V.H. King, manager at General Petroleum, explained why Mobil Oil's subsidiary General Petroleum wanted to join the uranium exploration efforts in 1968, they stated that because of the gamma-ray log, "a device already in use in oil-well drilling", oil companies could easily find uranium. Together with the benefit of having already drilled many test holes for oil exploration, and the knowledge to test the materials drilled from these holes in the same way as the material from shallow seismic exploration holes, the oil company was well-equipped to "discover an important deposit of radioactive material, badly needed for national security, and at the same time make a profit for the operator."[306]

Oil scientists and engineers shaping the Atomic Age: concluding observations

When crown prince Faisal of Saudi Arabia denounced the threats by Anderson in 1956 to replace the oil from the Middle Eastern oil fields with nuclear energy, he had not been wrong. Both in the short- and medium-to-long-term nuclear energy did not replace the cheap oil extracted from reservoirs in the Middle East. Still, the development of nuclear energy and technologies accelerated during the 1950s and 1960s. Until the Second World War, nuclear phenomena were almost exclusively relevant for a few geoscientific applications and in fundamental scientific research. The Manhattan Project in the United States and nuclear weapons projects in other countries provided an enormous boost to nuclear research, with industrial parties, including multiple oil companies, playing an increasingly vital role. This chapter showed that this development continued after the end of the Second World War with the setting up of nuclear industrial projects in the United States, France, and the Netherlands.

Based on calculations of potential oil and uranium reserves, oil geophysicists such as Paul L. Lyons and Marion King Hubbert argued that oil would not be the primary energy source for much longer. Other oil actors refuted these claims by pointing towards the discoveries of the giant oil fields in the Middle East. Access to these oil fields with their cheap production costs became a decisive factor in the strategic choice whether to diversify into nuclear energy, as this chapter has argued. Bigger, international companies with access to Middle Eastern oil opted to wait and see if, and when, nuclear energy would become competitive to oil, employing a strategy of "getting their ducks in a row". Oil companies that experienced trouble with investing in new, profitable, projects in US oil fields, however, choose to rush into uranium mining already during the 1950s.

The multiple spillovers of oil technologies, actors, and practices into the nuclear sector sparked a uranium boom that impacted the environment and health conditions of local workers and communities, both within the United States and in various (former) colonies of Western countries. In their search to quickly make profits, oil firms borrowed practices from petroleum production. These

[305] 'Double-Duty Prospectors' (1968), 19, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120.
[306] 'Double-Duty Prospectors' (1968), 19, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120.

practices were specific to the oil industry's involvement in uranium mining (i.e., they were not found other firms' mines), and created unsafe working conditions. Oil firms also deliberately tried to alter the conceptualization of what was considered 'nuclear' in order to avoid safety regulations, and established (post)colonial ties between the Western oil and uranium industries and countries in the Global South.

When confronted with an increasing threat of nationalization of oil projects in the Global South and an exodus of available petroleum engineers to the growing nuclear industry, even the big multinational oil firms returned to nuclear energy investments. This chapter showed that the managers within the oil world who made this switch possible were part of a cohort of scientist-engineers who had risen to power in the oil sector in the 1950s and 1960s. These scientist-engineer managers used their knowledge of overlapping technologies, and of the contacts they had within the nuclear sector, to allow their companies to enter the nuclear market.

The following chapter looks at this period by examining the strategies followed by the various companies to gain a dominant position in the nuclear market. In particular, the technological optimistic frame employed by this cohort of scientist-engineers shaped the nuclear innovations developed by the oil companies and also guided oil firms' intervention in the growing discourse on resource scarcity, environmentalism and alternative energy.

CHAPTER 4

4

4. Heydays

The ubiquitous oil involvement in nuclear energy, 1968-1979

20 major oil companies may not acquire in the future and must divest themselves now of companies and interests in coal, uranium, geothermal, solar energy and other alternative sources of energy.

Amendment Senator Edward M. Kennedy 1975[306]

[306] As represented in 'Horizontal Divestiture' (14 May, 1976), 1, John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43.

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Heydays

On October 22, 1975, Senator Edward M. (Ted or Teddy) Kennedy proposed an amendment wanting to put an end to horizontal divestiture by energy companies, aiming specifically at the diversification of oil companies into alternative energy sources. With this amendment, Kennedy reacted to the growing involvement of oil companies in the development of alternative energy sources from the end of the 1960s onward. Propelled by a cohort of scientist-engineers as managers in the oil sector, Western oil companies diversified profusely into alternatives to crude oil production in the Middle East. In addition to increased investment in drilling for oil offshore and producing from oil fields in areas previously deemed unprofitable, four alternative energy sources were dominant within this diversification strategy: coal, oil shale, solar, and uranium.[308]

In 1973, fourteen oil companies were represented among the top thirty-two owners of coal reserves in the United States, contributing fifteen to twenty percent of the country's coal production and owning about one-fifth of the more readily minable coal reserves. Between 1964 and 1974, oil companies received forty-nine of the fifty-two synthetic coal conversion patents issued by the government. The research and development work in the business of shale oil production was, besides the involvement of TOSCO and Cleveland Cliffs Mining Co., completely conducted by petroleum companies (according to US lawyer and diplomat John J. McCloy, who assisted many of the oil companies during the 1960s and 1970s, TOSCO was not considered an oil company, although they owned several oil refineries). Oil companies participated in the US developments of this new alternative energy source already since 1969 (Exxon) and 1973 (Shell).[309]

Also in the nuclear industry, the involvement of oil companies had grown. In 1975, approximately eighty companies were searching for US uranium reserves. Twenty of these were oil companies, controlling about one-half of the country's uranium reserves and contributing about one-third of uranium production. Especially Kerr-McGee stood out, owning about seventeen percent of the US uranium reserves and production. The remaining nineteen oil companies possessed about twenty-five to thirty percent of the reserves and were responsible for ten to fifteen percent of the production.[310] Gulf Oil's subsidiary General Atomic sold 18 percent of all nuclear reactor orders in the US in 1971. Service companies previously mostly focusing on the oil industry, like Enserch, Fluor, and Halliburton, established a 21.3 percent market share in the nuclear reactor engineering sector by 1981, with oilfield service company Stone & Webster possessing a twenty-four percent market share on its own.[311]

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[308] 'Horizontal Divestiture' (14 May, 1976), 2-8, John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43; Paul Sabin, 'Crisis and Continuity in US Oil Politics, 1965-1980,' *Journal of American History* 99, 1 (2012), 177-186; Tyler Priest, 'The Dilemmas of Oil Empire,' *Journal of American History* 99, 1 (2012), 236-151.
[309] 'Horizontal Divestiture' (14 May, 1976), 3-8, John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43; For oil and geothermal energy see Odinn Melsted and Candida Sanchez Burmester (ongoing work) and for oil companies' involvement in early solar energy Jelena Stankovic (ongoing work).
[310] 'Horizontal Divestiture' (14 May, 1976), 4-5, John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43.
[311] Hertsgaard, *Nuclear Inc*, 282-287.

The growing involvement of oil companies in alternative energy sources sparked national debates in the United States on the desirability of this newly acquired status as energy companies.[312] The oil crisis of 1973/1974 was followed by rapidly increasing resource prices, including petroleum and uranium. These price increases were sometimes blamed on the oil companies themselves. Public and political concerns raised about oil companies deliberately increasing resource prices by restraining the developments of new technologies and refusing to go to maximal production. The flamboyant Democratic senator James Abourezk of South Dakota became a prominent representative of the view that oil companies tried to stifle or even sabotage the development of nuclear energy by gaining a monopoly control over uranium recourses, and joined Kennedy's effort to end divestiture.[313] Also in France, the national government actively discouraged horizontal diversification by oil companies. In 1979, executives from the oil company ELF had seen the possibility of acquiring Kerr-McGee to expand its nuclear division in the United States. However, when engineer and chairman Albin Chalandon traveled to New York in 1980 to prepare for the acquisition, the deal was called off by the French Ministry of Industry.[314] This ministry maintained the dogma that "diversification strategies were only a component of the company's national mission, and that the public owners are the only judges in the matter of extending the external domain."[315]

This chapter argues that several of the major oil companies clearly perceived the diversification debate as a big threat to their future business model in 1970s. Oil actors claimed that their very existence as a company depended on their diversification projects. As Gulf Oil stated: "Gulf, like most major (and many smaller) oil companies has expanded its operations into other fields of energy. We cannot afford to limit ourselves to oil and gas operations when some estimates indicate that these two resources will be largely depleted in this country in the foreseeable future. To deprive the 15 to 20 largest oil and gas companies of the right to compete in alternate fields of energy would be to deprive them ultimately of the right stay in business."[316]

This chapter shows how the oil industry became omnipresent in the Western nuclear sector by focusing on the various investment and R&D strategies employed by oil majors, and the ways these companies framed their nuclear investments. As this chapter argues, oil companies that wanted to gain a foothold in the nuclear market to counter the nationalization of oil assets in the Global South relied on strategies derived from the oil industry. By introducing the concept of the "nuclear fuel cycle," companies such as Gulf Oil, Shell and Exxon tried to establish an integrated position with investments ranging from uranium mining to reactor manufacturing, and from uranium enrichment to reprocessing. To do so, the scientist-engineers in charge of the nuclear diversification projects embraced a framework of technological optimism by focusing on developing innovative, and

[312] "Without this kind of amendment," Kennedy explained "we feel that competition may very well be stifled with a resultant tendency to raise prices, restrain the development of new technology and impede maximum production." 'Horizontal Divestiture' (14 May, 1976), 1-2, John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43.
[313] Abourezk, *Advise and Dissent*.
[314] Pierre Péan and Jean-Pierre Séréni, *Les Emirs de la République : L'avonture du pétrole tricolore* (Paris: Seuil, 1982), 213, 229, 239 ; Yates, *The French Oil Industry*, 160-161.
[315] Quoted in Péan and Séréni, *Les Emirs de la République*, 210-211.
[316] Gulf Oil Corporation, 'Divestiture: a crossroad for the nation' (1976), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 21; also, ELF's CEO Albin Chalandon grew increasingly anxious with the French government blocking the company's diversification efforts. Albin Chalandon, *Quitte ou Double* (Paris : Grasset, 1986), 232 ; Yates, *The French Oil Industry*, 160-162.

sometimes very experimental, technologies that were only meant to become profitable in the long-term, such as nuclear fusion.[317] These strategies were grounded in the scenarios produced by the new planning departments within the various oil companies, and were used to frame their nuclear investments both as a necessary solution to future resource scarcity and to many environmental problems.

Building the Shell of the Atom

Investing in the nuclear fuel cycle

In 1970, the French petroleum engineer turned nuclear manager, André Giraud, became the new chairman of the French atomic authority CEA. He quickly realized the landscape of the Western nuclear market was evolving rapidly with major oil companies joining the nuclear bandwagon. Just like his predecessor and mentor Pierre Guillaumat, Giraud was an *Ecole des Mines* graduate and worked as a petroleum engineer before getting involved in the French nuclear industry. He knew the oil sector well and was quick to recognize the strategies employed by the new main players in the nuclear industry. Giraud feared that a handful of major companies would dominate the nuclear industry. Just like the "seven sisters," Giraud expected there would be "seven brothers" in the nuclear industry.[318] To establish the CEA as the seventh brother in the nuclear sector, the former petroleum engineer thought, the CEA had to develop all parts of the nuclear fuel cycle in France. "We are at the position of Shell in about 1910," Giraud stated, "it is up to us to build a Shell of the Atom."[319]

The nuclear fuel cycle is generally perceived to consist of so-called *front-end* steps that prepare the uranium for being used as fuel in nuclear reactors and *back-end* steps to manage the spent nuclear fuel (Figure 15). For the front-end of peaceful nuclear energy production, economist Geoffrey Rothwell distinguishes three different steps after a first phase of uranium exploration: (1) uranium mining, milling and conversion; (2) uranium enrichment (increasing the concentration of the U-235 isotope, so that the isotope can be separated); and (3) reconversion and fuel fabrication. The step of uranium enrichment (2) converts the uranium oxide powder, known as yellowcake, which is a product of the conversion process, into uranium hexafluoride (a gas) to transform natural uranium into a product that can be used as a fuel for specific types of nuclear reactors, most commonly the light-water reactors. Natural uranium can also be manufactured into fuel directly for some other reactor types, such as graphite reactors. The back end then involves the steps after the used fuel is removed from the reactor: (5) used fuel storage; (6) optional reprocessing (making the "cycle" complete); and (9) radioactive waste management. For the military application, Rothwell includes the production and dismantling of nuclear weapons using highly enriched uranium or plutonium.[320]

[317] According to Andrew Basiago, 'technological optimism' entails "the doctrine that a growing number of technological improvements in such areas as food production, environmental quality and energy will sustain life as human population soars". Basiago, 'The limits of technological optimism,' 17-22; Seefried, 'Rethinking Progress,' 379-386.
[318] The companies Giraud expected to become the "nuclear brothers" were Standard Oil of New Jersey (later Exxon), Gulf Oil, General Electric, Westinghouse, one British, and probably one German. Pringle and Spiegelman, *The Nuclear Barons*, 332-345.
[319] '…Shell of the Atom,' *l'Express* (March 22, 1971).
[320] Geoffrey Rothwell, *Economics of nuclear power* (London: Routledge, 2016), 6-7.

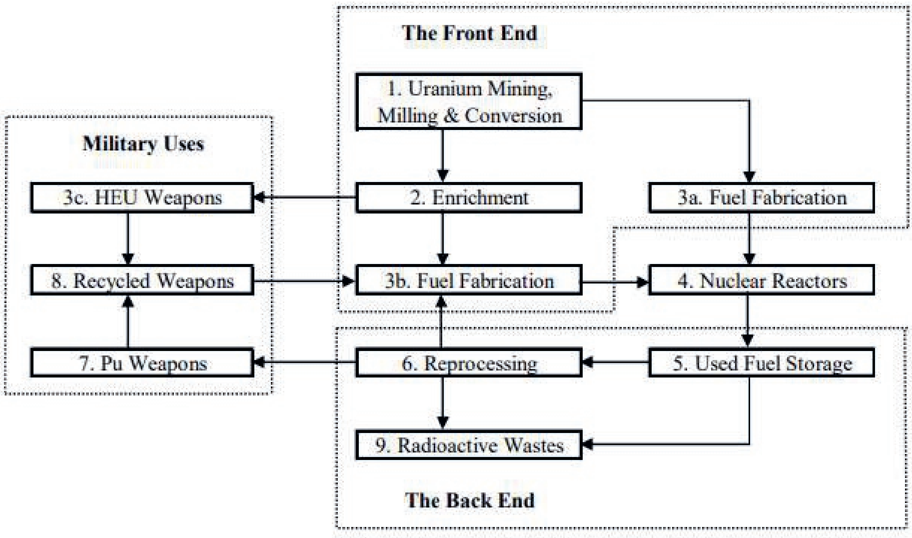

Figure 16: Nuclear fuel cycles as presented in Rothwell, Geoffrey, The economics of nuclear power *(London: Routledge, 2016)*, 6.

For many of the oil majors their (re)introduction to the nuclear industry started with investments in uranium mining projects.[321] In April of 1968, Gulf acquired some 3,5 million acres of mineral exploration permits in the Wollaston Lake area of northern Saskatchewan, Canada. This Rabbit Lake mine turned out the be the largest uranium deposit in a Western country.[322] Leonard C. Stevens, an executive vice president of Mobil's North American division in charge of exploration and producing, started an exploration program based in Denver in 1968. From there, exploration in California and Alaska was coordinated, while a second Houston-based division was soon added to coordinate exploration programs in the Southwestern states.[323] Exxon also started leasing acres of lands across the United States to search for uranium during the early 1970s.[324] In the 1970s, the French company *Compagnie Française des Petroles* (CFP) was heavily involved in uranium mining enterprises in former French colonies like Mauritania and Senegal, but also in mining projects in Colombia and Australia.[325]

[321] Not for all companies though. In 1970, Shell turned down several requests to start a uranium mining project in Niger together with the French CEA. Shell Kernenergie N.V., 'Uraniumexploratie in Niger' (June 16, 1970), Archives of the Directorate of Nuclear Energy of the Ministry of Economic Affairs (The Hague: Dutch National Archives), box 738.
[322] 'The Rabbit Lake Operation' (1979), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives0, box B, folder 14.
[323] 'For Uranium, the Future is Now,' *Mobil Overview* 2, 1 (1978), 6-8, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120.
[324] 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' Oral History Transcript #0144 (Philadelphia: The Chemical Heritage Foundation, Science History Institute, 11 May 1995), 21.
[325] By means of subsidiaries like *Total Compagnie Miniere et Nucleaire* (TCMN) and *Societé Centrale de l'Uranium et des Minerals et Metaux Radioactifs* (SCUMRA), CFP invested both in the exploration and extraction of radioactive minerals, and in developing technologies and methods to further improve the uranium mining industries. 'Accord de Transfert,' Total S.A. Archives (Paris), box. 50ZZ520, folder 6.

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Figure 17: The Rabbit Lake mine and mill in northern Saskatchewan, Canada, produced 5.5 million pounds of uranium in 1978. American Petroleum Institute Photograph and Film Collection *(Washington D.C.: National Museum of American History, 1978), Box 42, folder 52.*

The nuclear activities of these oil companies quickly expanded into further stages of the nuclear fuel cycle. Already in 1967, the board of the Gulf Oil Company had told their shareholders during the annual shareholders meeting that "our interest in nuclear energy will be broader than [uranium mining]. Just as Gulf traditionally has sought to obtain an integrated position in petroleum, we will likewise seek integration in the nuclear energy business."[326] Like Gulf Oil, Exxon also wanted to become a dominant market force in the nuclear fuel cycle. As H. Eugene McBrayer, chemical engineer and former manager of the Exxon Nuclear division (later becoming CEO for the Exxon company between 1985 and 1992), stated in a 1995 interview: "we went into exploration for uranium, discovered some good uranium deposits. Mining the ore like exploring for oil was good, but we needed to be broader. GE [General Electric] and Westinghouse basically controlled the nuclear power reactor business, but there was this broad area of the fuel cycle. Nuclear power, if it was going to be successful, had to have an integrated nuclear fuel cycle."[327]

For Exxon, this included trying to establish a uranium enrichment enterprise. American light water reactors were dependent on enriched uranium to produce energy. Notably the light water reactors distributed by Westinghouse and General Electric had become the most common type built in Europe and the United States. These reactors were mostly dependent on enriched uranium from the three

[326] Gulf Oil Corporation, *1967 Annual Report Gulf Oil Corporation* (Pittsburgh: Gulf Oil Corporation, 1968), 18.
[327] 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' Oral History Transcript #0144 (Philadelphia: The Chemical Heritage Foundation, Science History Institute, 11 May 1995), 19; Also, the 1972 Exxon annual report stated: "Exxon continued to build a strong position in the important and rapidly growing nuclear fuel field…. Exxon continued development work during 1972 for broadening its activities into other sectors of the nuclear fuel cycle." Exxon, *Exxon annual report 1972* (Exxon, 1973), 11.

enrichment plants operated by the AEC within the US. Although at the beginning of the 1970s both France and the United Kingdom operated small enrichment plants, these plants were primarily used for the enrichment of uranium needed for production of nuclear weapons and lacked the capacity to fulfil the growing demand for power reactors. This left the US AEC with a virtual monopoly on the buyer's side of the uranium market. This was already noted by the American chemist and chairman of the AEC, Glenn T. Seaborg, in 1969 when he wrote to the Science Advisor of the US President that "although enriching plants exist in the US, U.K., France, USSR, and Communist China, the US is essentially the sole supplier of enriched fuel for free world power reactors."[328]

Because the AEC preferred buying domestic uranium resources and had a virtual monopoly over the enriched uranium necessary for the nuclear power stations sold by Westinghouse and General Electric, various governmental organizations outside the US, like the French CEA, tried to establish new domestic enrichment projects, often together with their national oil industry. Seaborg noted that there was "a general trend in Europe and elsewhere to develop independent capability to produce enriched uranium."[329] To develop this technology, the French electrical utility company, and political competitor to the CEA, EDF built a new industrial complex. Giraud also got the French *Compagnie Générale des Matières Nucléaires* (Cogema) involved.[330] After getting involved in 1967 with a 10% share in the Dutch enrichment project, Shell continued their involvement in the Netherlands too. From the beginning the Shell chemical engineer Han Hoog had been a board member of the Dutch uranium company. After his retirement from Shell in 1971, Hoog became chairman of the Dutch nuclear reactor centre (RCN) providing him with a continued seat in the board of the Dutch enrichment project, while he also stayed involved with Shell as a consultant. The Shell chair, however, would be taken by Hein Hooykaas, later president of the Dutch branch of Shell, thereby establishing multiple "Shell seats" within the board. Hooykaas would also become the new director of the Dutch enrichment company in 1975, together with Maarten Bogaardt, another former Shell employee.[331]

Also in the US, many companies, among which the oil company Exxon was the most prominent, wanted to be able to enrich the uranium themselves. In 1971, the US Senate conceded and agreed that a select group of companies should get access to previously classified AEC enrichment technologies to study them and prepare for a privatized enrichment strategy. The Industrial Access Program of 1971 enabled two consortia to further invest in the enrichment industry by 1974: a combination of the chemical and construction companies Union Carbide and Bechtel with the addition of Westinghouse, and a partnership between General Electric and Exxon.[332] For Exxon (previously Standard Oil of New Jersey),

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[328] 'Letter to Dr. Lee Dubridge,' *Office Diary Glenn T. Seaborg* ((1969), Benjamin S. Loeb Papers (Washington D.C.: Library of Congress), box 16, folder 2.

[329] Glenn T. 'Letter to Dr. Lee Dubridge,' *Office Diary Glenn T. Seaborg* (1969), Benjamin S. Loeb Papers (Washington D.C.: Library of Congress), box 16, folder 2.

[330] Cogema was a company established in 1976, and fully owned by the CEA, to manage parts of the French nuclear fuel cycle. Pringle, and Spiegelman. *The Nuclear Barons*, 342-345.

[331] Kistemaker, *De geschiedenis van het Nederlandse Ultracentrifuge Project*, 31-38; Schrafstetter and Twigge, 'Spinning into Europe,' 253-272.

[332] 'Prepared statement of Larry Hobart, Assistant General Manager, American Public Power Association,' United States Congress. Joint Committee on Atomic Energy. *Future structure of the uranium enrichment industry [microform]: hearings, Ninety-third Congress, first (-[second]) session* (Washington D.C.: US Govt. Print, 1973-1975), 134.

this meant a return to the gaseous centrifugal technology that their former vice-president Eger V. Murphree had developed during the Manhattan Project.[333]

In similar ways as with uranium mining and enrichment, oil companies got involved in fuel reprocessing and production, uranium conversion (the gasification of uranium oxides into uranium hexafluoride (UF_6) to make it suitable for enrichment), radioactive waste management, and reactor manufacturing. Figure 18 shows a 1968 projection by the consultancy firm Arthur D. Little Inc. for the US AEC of the different companies expected to be involved in the domestic nuclear fuel cycle by 1970 based on AEC nuclear power installation forecasts and estimates of unit prices. Oil companies already involved in uranium mining and milling, like Kerr-McGee and Getty Oil, were likely to further diversify into conversion projects, together with major companies like Gulf Oil. The consultancy firm also expected Getty Oil and Atlantic Richfield to start fuel reprocessing facilities, and Gulf Oil to join the fuel fabrication process.[334]

To get into these later stages of the nuclear fuel cycle, the oil companies had to compete with the already established dominance of General Electric and Westinghouse with their light water reactors.[335] In 1967, Gulf Oil acquired General Atomic to develop a new High Temperature Gas Cooled Reactor (HTGR) model, working with a graphite moderator that did not need enriched uranium, as an alternative to the Westinghouse reactor. In 1967, a 40-megawatt pilot plant at Peach Bottom, Pennsylvania, went online, while in 1968 construction began of the first commercial-scale HTGR, a 220-megawatt demonstration plant, near Fort Saint Vrain, Colorado. In 1971, the first reactors were ordered in the United States.[336] In 1973, the Royal Dutch Shell Group joined Gulf Oil with a fifty percent share in General Atomic to further develop the HTGR.[337] The goal of Shell, and Gulf Oil, was in this way

[333] See chapter 2, page 52. In 1975, Exxon concluded that a competitive private uranium enrichment industry would not emerge from the application of diffusion technology, even stating that this technology had only been able to survive because of its operation within the context of a government monopoly. With 20%-30% lower capital costs than for diffusion-based enrichment however, enrichment based on gaseous centrifuge was sufficiently demonstrated to form the most economic basis for adding new enrichment capacity and simultaneously achieve the objective of nucleating a broad-based private enrichment industry. 'Exxon Nuclear Company Summary Conclusions from its Centrifuge Enrichment Study Program' (Discussion draft: 1977), Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 31, folder 10.

[334] Arthur D. Little, Inc., *Competition in the nuclear power supply industry* (US Atomic Energy Commission, 1968), 10.

[335] Those two companies had become the two biggest Western nuclear industrial actors during the 1960s by offering so-called "turnkey" contracts for their nuclear reactors. These contracts were deals with utility companies that involved agreements on guarantees of supply of cheap uranium for the entire period the reactor would run. This meant that both Westinghouse and General Electric were dependent on an enduring dominance in the nuclear reactor market and a steady supply of cheap uranium resources. Getting into the whole nuclear fuel cycle therefore offered one way for the oil companies to start competing with these companies. Lifset, 'Nuclear Power in America: The Story of a Failed Energy Transition,' 525-526.

[336] Convinced by these developments, that already in 1968 were described as "more likely than ever to sell a large-scale nuclear steam supply system on a commercial basis", the AEC proposed to subsidize the HTGR developments with approximately $50 million per year in their FY 1975 budget. Gulf Oil Corporation, *Frontiers of Energy* (1972), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 22; Arthur D. Little, Inc., *Competition in the nuclear power supply industry*, 13; 'An overview of the commercial HTGR program' (1974), Westinghouse Electric Corp. Collection (Pittsburgh: Heinz History Center - Detre Library and Archives), box 177, folder 21.

[337] Formally, this step was promoted by Shell as their official introduction to nuclear energy and is often presented as such, although this investment clearly was part of an ongoing strategy to get involved in all parts of the nuclear fuel cycle with earlier investments in the Dutch uranium enrichment project. Sluyterman, *Concurreren in turbulente markten, 1973-2007*, 103-104.

to establish a nuclear fuel cycle separate from the fuel cycle needed for the light water models. In 1973, the joint venture of Shell and Gulf Oil even decided to divest Gulf Oil's light water reactor fuel fabrications operations, based in Elmsford, New York.[338]

Other major oil companies instead tried to get influence on the reactor manufacturing part of the fuel cycle by further investing in the enrichment and reprocessing facilities needed for the light water reactors to work. Sometimes in cooperation with reactor manufacturing companies like Westinghouse, Exxon Nuclear established plants for producing the fuel needed for light-water reactors near the actual light-water reactors. In this way, Exxon could more easily exert influence in making price agreements with the management of the nuclear reactor, often a local utility company. In Lingen, Germany, for example, Exxon Nuclear constructed a plant to enrich the uranium for the close-by light-water reactors in Emsland-Linge built by Westinghouse. This cooperation was so successful that Exxon received a permit to expand the plant's capacity for the manufacture of fuel elements in 1982.[339] These various strategies employed by the oil companies involved in the nuclear industry clearly show how the oil industry did not function as one monolithic entity. Although the overall strategy of getting involved in multiple parts of the nuclear fuel cycle – and the introduction of the concept 'nuclear fuel cycle' itself - was shared among multiple oil actors, the various companies developed their individual strategies to diversify into the nuclear industry.

[338] Although the companies would stay involved in a joint venture with Allied Chemical Corporation to build a reprocessing plant at Barnwell, S.C., that could be used for the fabrication of fuel for light water reactors. 'Gulf Oil to divest a light-water unit,' *The New York Times* (December 4, 1973); Victor K. McElheny, 'Amid Confusion, A Primer on Nuclear Energy Policy,' *The New York Times* (April 9, 1977), 25-26; Royal Dutch Shell, *Annual Report 1973* (The Hague: Royal Dutch Shell 1973), 14.

[339] 'Interne mededeling aan gedeputeerde Ankersmit' (July 23, 1982), Provincial Government of Overijssel, Gedeputeerde Staten and Provinciale Staten Collection 0025.6 (Zwolle: Historic Center Overrijssel), box 6683.

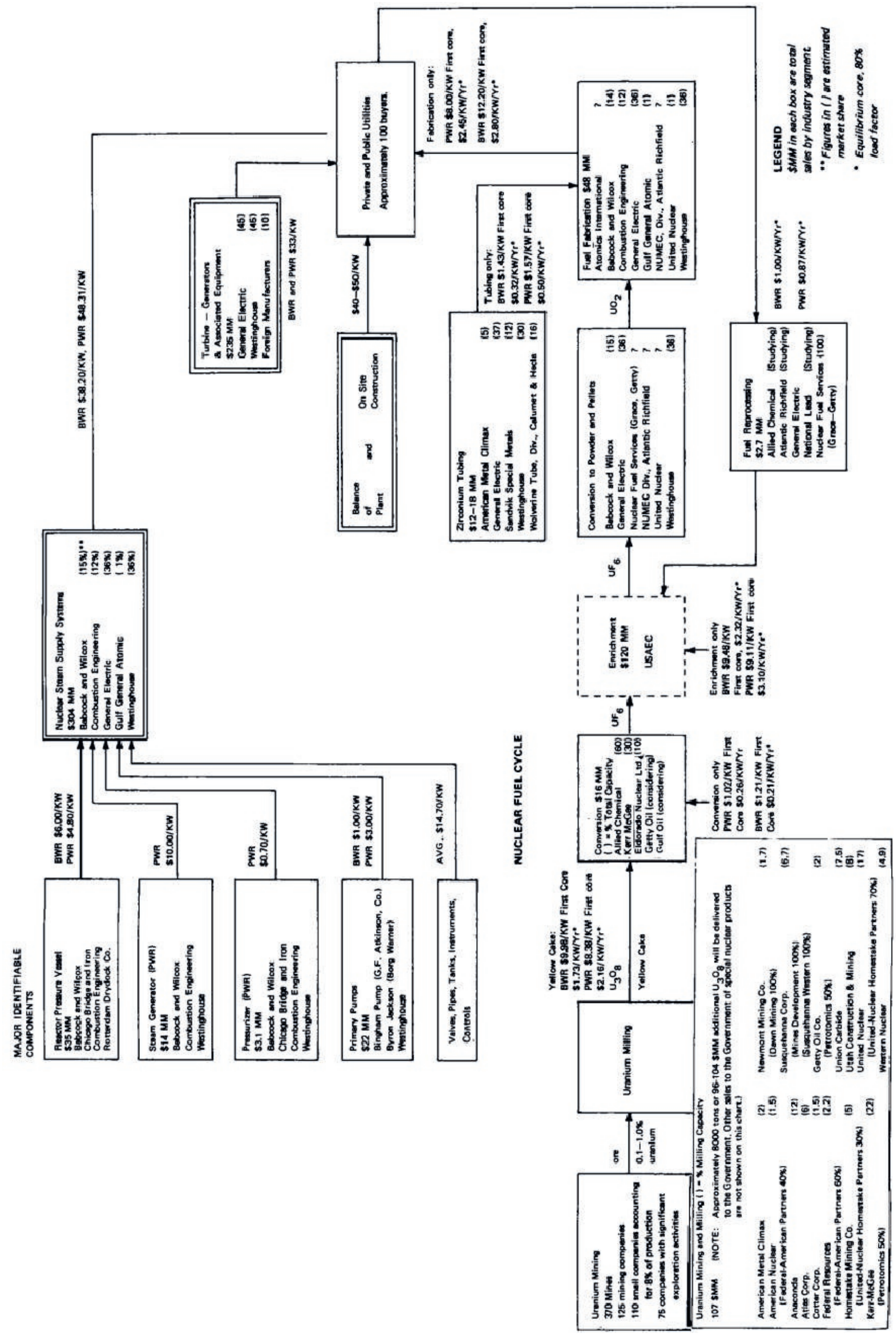

Figure 18: Arthur D. Little, Inc., Competition in the nuclear power supply industry *(US Atomic Energy Commission, 1968), 10.*

"We developed technology to become a player in the nuclear fuel cycle"

The strategies deployed by the various oil companies to get a foothold in the nuclear industry strongly relied on the perceived technological expertise that they could bring. Previous chapters already showed how technologies used to find oil and analyze petroleum components found applications in uranium exploration, enrichment, and nuclear reactor manufacturing. The major oil companies re-entering the nuclear fuel cycle accelerated the amount and pace of these technological spillovers even more. Various companies worked on improved well logging techniques such as pulsed neutron logging and radioactive tracers. A new invention by Mobil's Dallas Field Research Laboratory, called a Delayed Fission Neutron Log, quickly became popular in both the oil and uranium industries.[340] This new influx of technology and manpower quickly resulted in an increasing amount of located uranium deposits, sometimes also in sedimentary layers previously unknown to hold radioactive minerals.[341] These new discoveries included some of the biggest uranium deposits in the Western World, like the Rabbit Lake Mine in Canada, by Gulf Oil.[342]

Besides the technological development of nuclear well logging techniques, also other spillovers from the oil sector to the uranium industry occurred. One of the most important of these inventions was In Situ Leach mining, or ISL. With ISL, minerals are dissolved with chemicals while still underground and then the mineral-solvent solution is pumped out and the minerals are precipitated. Based on engineering techniques that were common in the oil industry, ISL is used in the recovery of copper, nickel, gold, iron, phosphate, salt, potash, and uranium. Dissolving uranium with chemicals and then pumping up the solution bears similarities to the technique of chemical waterflooding that oil firms used to increase the recovery of oil, providing oil companies with an advantage in developing this technique for the uranium industry. Compared to the previously standard mining techniques, like open pit and underground mining, the process of ISL is also much cheaper because it requires no excavation of ore and reduces the handling of large volumes of ore materials.[343]

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[340] 'Double-Duty Prospectors' (1968), 19, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center of American History), box 2.207/F120. Pulsed neutron logging in particular slowly replaced more traditional ways of well logging, since it was relatively insensitive to commonly occurring changes in borehole size and fluid type, making it easier and cheaper to use for logging boreholes in various kinds of sediments: A.H. Youmans, Millis, C.W., Hopkinson, E.C. and Bishop, W.D., 'The Neutron Lifetime Log,' *Trans.*, SPWLA Sixth Annual Symposium, Dallas, Texas (1965); L. Ryback and A.H. Youmans, 'New Nuclear Logging Methods,' *Bull. Ver. Schweiz. Petroleum-Geologer und-Ingenieure* 35, 86 (March 1968); Lloyd Fonds, 'Some Pulsed Neutron Logging Contributions to Improved Formation Evaluation,' *Journal of Petroleum Technology* 22, 4 (1970), 424-432. These developments in well logging were accompanied by new research and applications of radioactive tracer surveying, which were primarily run-in production and injection wells to investigate dynamic conditions of fluid flow and around a wellbore, and applications of nuclear magnetic resonance (NMR) techniques to study the properties of fluids in porous media: W.F.N. Kelldorf, 'Radioactive Tracer Surveying – A Comprehensive Report,' *Journal of Petroleum Technology* 22, 6 (1970), 661; A. Timur, 'Pulsed Nuclear Magnetic Resonance Studies of Porosity, Movable Fluid, and Permeability of Sandstones,' *Journal of Petroleum Technology* 21, 6 (1969), 775-786.

[341] V. Ziegler, 'Essai de classification métallo technique des gisements d'uranium,' *Formation of Uranium Ore Deposits* (Vienna: IAEA, 1974), 661–677; F.J. Dahlkamp, 'Classification of uranium deposits,' *Mineral. Deposita* 13 (1978), 83–104; Bron, 'The uranium club,' 58-60.

[342] 'The Rabbit Lake Operation' (1979), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 14; L.P. Tremblay, 'Geology of the uranium deposits related to the sub-Athabasca unconformity, Saskatchewan' *Geological Survey of Canada: Paper 81-20* (1982), 12-14.

[343] Gavin Mudd, *An Environmental Critique of In Situ Leach Mining: The Case Against Uranium Solution Mining* (Fitzroy: Research Report for Friends of the Earth, 1998), 11.

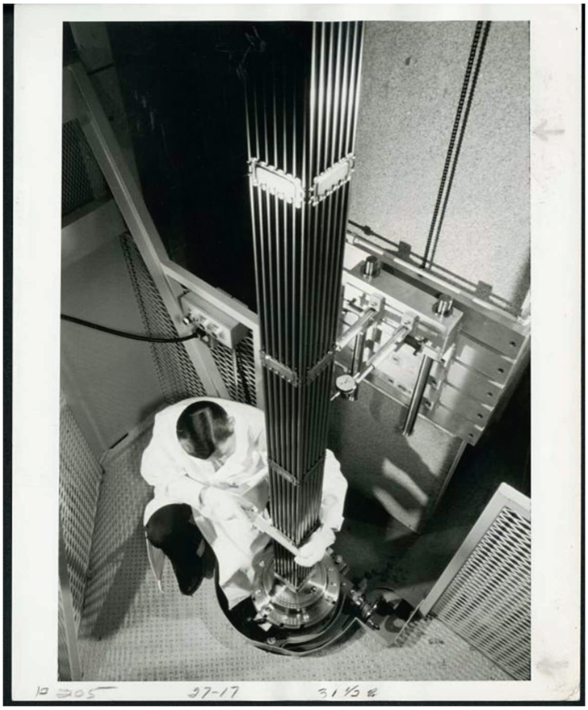

Figure 19: A bundle of uranium-containing rods designed by Exxon Nuclear Company, 1975. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History, 1975), Box 42, folder 55.

The first serious experiments with In Situ Leaching in uranium mining were conducted starting in the mid-1960s in the United States before some major oil companies scaled up this technique in the 1970s.[344] From 1968 onwards, scientists at Mobil developed the leaching technique in several pilot plants, such as the Bruni pilot plant, before starting the construction of commercial plants. In the ten years following the entry of Mobil into the uranium market, the company spent $36 million dollars on uranium exploration, and built up a resource base of some 50 million pounds located in south Texas and New Mexico.[345] In Australia, two of the four biggest ISL projects were directly managed by oil companies.[346] Also in the United States, especially in Texas where waterflooding techniques for oil

[344] Attila I. Evrenos, Jack K. Heathman, and James Ralstin, 'Impermeation of Porous Media by Forming Hydrates in Situ,' *Journal of Petroleum Technology* 23, 9 (1971), 1059-1066; Bron, 'The uranium club,' 64-66.
[345] This is the equivalent of nearly two year's supply for the US consumption in 1978, with about $11 million for domestic exploration budgeted for exploration per following year. Mobil Energy Minerals Division, 'Leaching: Mining Uranium in Nature's Way,' ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120; 'For Uranium, the Future is Now,' *Mobil Overview* 2, 1 (1978), 6-8, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120.
[346] The Beverley deposit in South Australia was discovered in 1969 by the Oilmin-Transoil-Petromin group of companies, and the Manyingee deposit, located in northern part of the Carnarvon basin in Western Australia, was discovered in 1974 by a joint venture led by Total Australia, the Australian subsidiary of *Compagnie Française Petroleum* (CFP, later Total). IAEA, *In Situ Leach Uranium Mining: An Overview of Operations* (Vienna: International Atomic Energy Agency, 2016), 14-16.

extraction were already popular, ISL quickly gained popularity with oil companies like Atlantic Richfield and Mobil Oil taking the lead.[347]

As H. Eugene McBrayer stated in his 1995 interview on Exxon's diversification into nuclear energy, oil companies also invested in research and development projects to develop new "technology to become a player in the nuclear fuel cycle."[348] These efforts were especially focused on improvements in, for oil companies, newer parts of the nuclear fuel cycle, like enrichment and nuclear reactor manufacturing, and some oil companies proved willing to invest years of research in laboratories and experimental plants before being able to actually profit from the applications. The oil firms developed technologies with the explicit prospect that they would not become commercially viable within 10 years – a deadline normally applied to business cases in the oil industry. The next section discusses how these projects included fundamental research into nuclear fusion energy, but oil firms also invested in experimental ways to enrich uranium.

Besides Exxon's return to gaseous centrifugal enrichment projects, the company also invested in experimental laser enrichment – which was particularly attractive in recovering U-235 from diffusion plant tailings, but was only hoped to reach commercial scale by 1985.[349] Uranium enrichment is a process in which natural uranium (uranium-238) is separated into enriched (uranium-235) and depleted uranium. This process of concentrating specific isotopes of the uranium element by removing other isotopes, also called isotope separation, by using tunable, irradiating lasers to separate the isotopes had the potential to be a more efficient way to enrich uranium. To be able to construct a commercial plant of 3000 SWU capacity by the mid-1980s, Exxon supported three research groups that conducted research on uranium enrichment by means of laser heating. To further review the future applications of the program and advise on the research Exxon recruited highly regarded nuclear experts and former politicians, such as Hans Bethe, Keith Glennan, Peter Auer, and Gerald F. Tape.[350]

Based on an extensive research report by the famous Manhattan Project veteran, and Nobel laureate, Hans Bethe, Exxon ultimately decided to focus solely on the Linden branch of Exxon's research efforts. In the Linden technique, vaporized uranium was exposed to selectively chosen laser radiation, forming ions of uranium-235 which could then be separated out.[351] Although hardly mentioned in the historiographical literature relating to Bethe's career, his as consultant to the oil industry's diversification efforts into nuclear energy is telling for the commitment of firms such as Exxon to

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[347] D.H. Underhill, 'In-Situ leach uranium mining in the United States of America: past, present, and future,' *Proceedings of a Technical Committee Meeting held in Vienna, 5-8 October 1992* (Vienna: IAEA, 1992), 26.

[348] 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' Oral History Transcript #0144 (Philadelphia: The Chemical Heritage Foundation, Science History Institute, 11 May 1995), 19.

[349] 'Exxon Nuclear Company Summary Conclusions from its Centrifuge Enrichment Study Program' (1977), Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 31, folder 10.

[350] 'Exxon Nuclear and AVCO announce formation of laser enrichment review panel' (Exxon Nuclear Press Release, 1978), 21, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/H19B. Exxon Nuclear was also not the only oil company to hire famous nuclear scientists and politicians as consultants: Glenn T. Seaborg for example worked as consultant for Occidental Oil's shale oil projects: 'Letter from Armand Hammer to Glenn T. Seaborg,' (May 9, 1975), Glenn T. Seaborg Papers (Washington D.C.: Library of Congress), box 561, folder 6.

[351] 'Correspondence with Ray Dickeman' (April 27, 1977), Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 31, folder 10; 'Nuclear Power: Helping to Meet Our Energy Needs, Exxon's Role in Supplying Nuclear Fuel,' (1981), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/H19B. Pp. 21.

establishing multiple experimental research projects with the prospect that most of them would not become a success.[352] Beside the Linden group, Exxon Nuclear was conducting experiments in their Los Alamos research facility too. Exxon also invested in a joint venture with Avco Everrett Research Laboratory that conducted research into multi-photon processes and established the scientific proof of the principle of the laser enrichment technology. It was only after Bethe drafted his report in 1977 that Exxon made the choice to focus their efforts solely on the uranium metal process studied in Linden. This project, which would be rebranded as Jersey Nuclear-Avco Isotopes (JNAI), became a jointly owned subsidiary with Exxon Nuclear in the lead with 87% of the shares.[353]

Like Exxon's investments in nuclear research and development, also Gulf Oil was willing to invest in nuclear technologies that had not yet proven themselves to be competitive. When Gulf took over General Atomic in 1967, the HTGR was still in the development phase and it was unsure that it would ever succeed.[354] Still, Gulf Oil embarked on various experimental projects to develop a competitive reactor. Based on the theoretical concepts produced by scientists at General Atomic, multiple engineering projects were conducted between 1968 and 1979 with each project based on altered design approaches and engineering details. Starting with the smaller atomic power station at Peach Bottom in 1967, primarily meant to assess the HTGR concept, Gulf Oil immediately started development of the much bigger demonstration reactor at Fort Saint Vrain. Already before finishing the Fort Saint Vrain reactor, Gulf Oil announced construction of a 2.300 mega kilowatt nuclear power plant together with the Philadelphia Electric Company in 1971. This new power plant had to become an advanced and larger version of the Fort Saint Vrain reactors, and was planned, although still being very experimental, to have “the highest net operating efficiency of any large commercial nuclear plant in the world.”[355] Each of these contracts evolved into major research and development undertakings, compounding many novel and highly development components and plant features, “with attendant unknowns, risks and uncertainties.”[356]

Both these projects by Gulf Oil and Exxon were examples of oil companies’ investing in experimental technologies with no absolute guarantee for success. Already in 1969, George T. Piercy, a senior vice president and director of Jersey Standard Oil (later Exxon), clearly stated that his company was entering the nuclear fuel business based on the belief that they had ways of making “a significant,

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[352] Silvan S. Schweber, *In the Shadow of the Bomb: Bethe, Oppenheimer, and the Moral Responsibility of the Scientists* (Princeton: Princeton University Press, 2000); Silvan S. Schweber, *Nuclear Forces: The Making of the Physicist Hans Bethe* (Cambridge, MA: Harvard University Press, 2012); Gerald E. Brown and Chang-Hwan Lee (eds), *Hans Bethe and his Physics* (New Jersey: World Scientific Publishing, 2006).

[353] F.A. Long, ‘Visit to Exxon Nuclear Company Facilities at Richland, Washington, July 29-30, 1976’ (Memorandum for Record: August 20, 1976), Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 31, folder 10.

[354] Gulf Oil's competitor Westinghouse did not think much of Gulf efforts with the HTGR. As was concluded in an internal evaluation of the HTGR development by Westinghouse in 1974: “I believe that within a year or so, or perhaps even less since the major actions are entirely within Gulf Corporate's hands, we'll be able to look back and conclude that one descriptive characterization of the GA involvement with the high temperature gas-cooled power program…..can be taken from Gunnar Myrdal's statement in in 1965: “The idea of overcoming practical difficulties by trying something much bolder and even more difficult is, like all exaggerated gallantry, attractive but unrewarding.”” ‘An overview of the commercial HTGR program’ (1974), Westinghouse Electric Corp. Collection (Pittsburgh: Heinz History Center - Detre Library and Archives), box 177, folder 21.

[355] Gulf Oil Corporation, *Frontiers of Energy* (1972), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 22.

[356] ‘An overview of the commercial HTGR program’ (1974), Westinghouse Electric Corp. Collection (Pittsburgh: Heinz History Center - Detre Library and Archives), box 177, folder 21.

positive contribution” in innovating the nuclear business.[357] These experimental innovations existed out of various efforts, including the expensive building of three reactors by Gulf Oil and the partnering with famous scientists and politicians in Exxon's projects, while it was not always clear to the oil companies that every research project would become profitable. This shows a long-term commitment within the board rooms of the oil companies to develop technologies that only potentially would become profitable with the influx of capital, manpower, and technological and scientific expertise.

“A major step towards fusion power”

This technological optimistic “can do” mentality that was omnipresent among the scientist-engineers that steered the oil companies into nuclear diversification projects was even more clearly visible in oil firm’s investments in long-term experimental nuclear research projects. While many of the previous discussed oil firms’ investments the nuclear industry mostly focused on medium-term competitive participation – ranging from ten to fifteen years before these projects would yield a commercially viable product – they also tried to develop technologies that were more speculative and only potentially could become competitive in twenty years or more. During the 1970s and early 1980s, the research departments of various oil companies tried to develop fundamental and experimental nuclear research, regardless of expectations that practical applications would be achieved soon. Especially, nuclear fusion research stands out in this regard with Gulf Oil and Shell's joint venture General Atomic continuing their investments in various fundamental research projects, and Mobil, Exxon, and Phillips Petroleum’s embarking on new fusion initiatives.

Producing electricity from nuclear fusion had for long been a dream among various scientists. Already since the 1930s, atomic physicists speculated how to harness the energy released with the fusion of two atomic nuclei. After the Second World War, scientific research tried to control the fusion process that was demonstrated to yield an enormous potential after the thermonuclear bomb tests in 1951. Although theoretically it seemed possible to stabilize a fusion reaction long enough to produce electricity from a fusion reactor, it proved difficult to engineer such a reactor. After a couple of failures and false claims of success, worldwide fusion research efforts declined during the 1960s.[358] Then in 1968, Soviet scientists claimed to have reached a breakthrough. With their donut-shaped tokamak reactor, based on the 1950 model of Andrey Sakharov, Russian fusion scientists claimed to be able to stabilize the plasma long enough to produce the fusion reaction and reach higher temperatures. After confirmation of this claim by a team of British scientists, led by Nick Peacock, the tokamak seemingly brought a new future for nuclear fusion.[359]

In the 1970s, fusion scientists, government and industry formulated a long-term strategy for the, heavily government-funded, development of fusion energy. The three biggest tokamak research

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[357] ‘Executive says Jersey Standard's nuclear work will expand competition and efficiency’ (Jersey Standard Press Release: October 30, 1970), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/K96B.

[358] Robin Herman, *Fusion: The Quest for Endless Energy* (Cambridge University Press, 1990); Simon Märkl, *Big Science Fiction: Kernfusion und Popkultur in den USA* (Bielefield, 2019); Michiel Bron, ‘Oil’s Nuclear Frames: The oil industry shaping the environment with innovative nuclear technologies since the long 1970s,’ *Journal of Energy History/Revue d'Histoire de l'Énergie [Online]* (Forthcoming).

[359] N.J. Peacock, D.C. Robinson, M.J. Forrest, P.D. Wilcock, and V.V. Sannikov, ‘Measurement of the Electron Temperature by Thomson Scattering in Tokamak T3,’ *Nature* 224 (November 1969), 488-490.

Figure 20: Aerial view of the General Atomic Company's facilities at San Diego, California, 1979. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History), Box 42, folder 43.

projects in the Western world needed to accomplish three different steps: scientific feasibility, technical feasibility, and commercial feasibility. The European JET reactor, the Japanese JT-60, and the TFTR at the Princeton laboratory of plasma physics aimed to show the scientific feasibility of creating a controlled fusion reaction. Within the ideal scenario, bigger reactors would follow these research projects to show the technical feasibility. To do so, the reactors needed to reach a breakeven point – producing the same amount of energy as the reactor needed to establish the fusion reaction. The last step would be a "demo" reactor showing the commercial feasibility by establishing an output of at least seven times the input.[360]

Although countries such as the US, Europe, the Soviet Union, and Japan restarted their fusion programs during the 1970s, often investing in expensive experimental reactors, the expectation among different oil actors was still that nuclear fusion could only become commercially applicable at least two decades in the future. In their internal employee magazine, the manager of laser fusion studies at Exxon Research and Engineering Company, Dan Grafstein, plainly stated in 1976 that "fusion power offers the best hope for providing commercial power for the future – certainly for the next century", but added that it would be at least thirty years before the first power-producing fusion plant would go into operation and another decade before large scale commercial fusion plants would begin producing power.[361] Still, oil companies like Mobil, Exxon, Gulf Oil and Shell, invested in various experimental

[360] C.M. Braams and P.E. Stott, *Nuclear Fusion: Half a Century of Magnetic Confinement Fusion Research* (Bristol: Institute of Physics Publishing, 2002), 227.
[361] Quoted as represented in 'Fusion: as old as the sun; as new as tomorrow,' *Exxon Manhattan* (July 23, 1976), 2-3, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/K96B.

fusion projects. At the Laboratory of Laser Energetics of the University of Rochester, New York, Exxon engaged in a project called Omega X to demonstrate that with a laser of ten kilojoules scientific breakeven would be possible.[362] Exxon also joined the efforts to reach breakeven (extract the same amount of energy from the fusion process as is used to ignite the reactor) with the big tokamak project, TFTR, at the Princeton Plasma Physics Laboratory (New Jersey).[363] Mobil, and its predecessor Socony, had been in experimental fusion science already since 1969. In Princeton, New York, several Mobil plasma physicists tried to make detailed measurements on the density of the plasma – the thin cloud of energetic, charged particles that provide reactor fuel.[364]

Also, Shell and Gulf Oil, through their joint venture General Atomic, supported big experimental fusion projects. Physicist Tihiro Ohkawa had worked for General Atomics since the 1960s, conducting research on radioactive isotopes and plasma physics. He had theorized that multipole magnetic fields could stabilize plasma in a tokamak, but only after the Russian breakthrough could he confirm his theories by experiments. From there, Ohkawa developed a series of tokamaks with vertically elongated plasma cross sections, called the *doublet*, for General Atomic, now owned by Gulf Oil. This line of research resulted in three experimental reactors built by General Atomic during the 1970s and early 1980s, used to study ways better stabilizing the plasmas inside the reactor.[365] Especially the Doublet III, the third reactor in the series, became the flagship of Gulf Oil and Shell's investments in nuclear fusion. In pamphlets and press releases Shell and Gulf Oil promoted their “largest privately-owned center engaged in fusion research, development, design and construction” by stating that the Doublet III was “a major step towards fusion power.”[366]

General Atomic not only invested in the doublet reactor series to conduct experimental research, but also experimented with other reactor types. In the early 1980s, the Gulf Oil Company looked for a partner to help subsidize work by General Atomic on a compact circular pinch reactor, also designed by Tihiro Ohkawa, called OHTE.[367] The Phillips Petroleum Research and Development Division was convinced by Gulf Oil that OHTE would potentially be better suited for commercial application than the larger, and more expensive, tokamaks. Although still very much an experimental concept, Phillips Petroleum agreed to a joint venture with Gulf Oil to finance the first research with approximately $15

[362] ‘Fusion: as old as the sun; as new as tomorrow,’ *Exxon Manhattan* (July 23, 1976), 2-3, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/K96B.
[363] Weston M. Stacey, *The Quest for a Fusion Energy Reactor: An Insider’s Account of the INTOR Workshop* (Oxford: Oxford University Press, 2010), 133.
[364] ‘Mobil Probe Aids Search for Controlled Nuclear Energy’ (Mobil Press Release: May 18, 1969), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F160.
[365] ‘Interview of Tihiro Ohkawa by Stuart "Bill" Leslie on 2006 May 23,’ (College Park, MD: Niels Bohr Library & Archives, American Institute of Physics), www.aip.org/history-programs/niels-bohr-library/oral-histories/35130 (Accessed 16 July 2024).
[366] ‘Doublet III: A Major Step Towards Fusion Power’ (General Atomic Company Pamphlet, 1978), Princeton Plasma Physics Laboratory Records (Princeton, New Jersey: Princeton University), box 6, folder A; ‘Doublet III’ (General Atomic Company Pamphlet, 1978), Princeton Plasma Physics Laboratory Records (Princeton, New Jersey: Princeton University), box 6, folder A
[367] Short for “ohmically heated toroidal experiment”, which is pronounced “oh-tay”, meaning “checkmate” in Japanese.

million in 1980. For the following years, both companies planned to further invest in a $150 million upgraded version of OHTE.[368]

Nuclear diversification to address future resource scarcity

"Roll with the punch"

With investments in experimental projects like the fusion research projects, oil actors not only showed a commitment to participate in multiple stages of the nuclear fuel cycle, but also a willingness to stay in the nuclear industry for decades to come. Forecasts of the future development of energy production underpinned this long-term commitment to nuclear energy by the oil industry. Business historians Bretton Fosbrook and Keetie Sluyterman have argued that Shell's forecasts accelerated the decision to further diversify their business at the end of the 1960s.[369] Historian Thomas Turnbull describes how "forecast gurus" Pierre Wack and Edward Newland developed the first scenario-based forecasts at Shell during the second half of the 1960s and early 1970s.[370]

Coinciding with the rise to management positions in the oil industry by the scientist- engineer cohort, Shell's Group planning department, formed by Edward Newland and Pierre Wack, issued an in-house study of the company's prospects up to the year 2000 in 1967. The report was based on the methods used by physicist and futurologist Herman Kahn, infamous for developing the nuclear strategy of "mutual assured destruction."[371] This approach was more focused on "metaphors and historical analogues" instead of statistics, and, even more importantly, promised that actors could construct the futures rather than passively await them. In this report, Newland concluded that Shell should diversify into coal and nuclear power, both because oil-producing nations were likely to nationalize their oil and because alternative fuels, such as coal and nuclear, might threaten oil's position as the world's primary energy source.

In 1971, the forecast team developed four different scenarios on the future role of oil. While predicting increasing demand rates and governmental control over the oil industry's operations, Wack and his colleagues presented (1) a surprise free scenario with continuing increasing oil demand with increasing producer taxes, (2) a crisis scenario in which increasing governmental tariffs would slow demand, (3) a low economic growth scenario, and (4) a scenario that nuclear energy and coal would grow at much

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[368] 'Interview of Tihiro Ohkawa by Stuart "Bill" Leslie on 2006 May 23,' (College Park, MD: Niels Bohr Library & Archives, American Institute of Physics), www.aip.org/history-programs/niels-bohr-library/oral-histories/35130 (Accessed 16 July 2024); Herman, F*usion*, 203-204.

[369] Bretton Fosbrook, *How Scenarios Became Corporate Strategies: Alternative Futures and Uncertainty in Strategic Management* (Ph.D. Diss.: York University, 2017), 151; Sluyterman, *Concurreren in turbulente markten, 1973-2007*, 96.

[370] Before that time, executives at Shell had relied on a forecasting method called the Unified Planning Machine (UPM). This econometric model was based on mapping six-year trends in oil prices, based on calculations and papers ledgers extrapolating past performances. Although the model was popular at the level of senior management, the model proved inaccurate in predicting unexpected events, like the rise of OPEC during the 1960s. The immediate threat of OPEC wanting to implement 'global rationing' and the foresight of the major Western oil companies losing concessions to nationalized companies, created an environment within the oil companies where new forecasts methods to better anticipate such threats could be developed. Thomas Turnbull, ''No Solution to the Immediate Crisis': The Uncertain Political Economy of Energy Conservation in 1970s Britain,' *Contemporary European History* 31 (2022), 574-577; Fosbrook, *How Scenarios Became Corporate Strategies*, 85.

[371] Turnbull, ''No Solution to the Immediate Crisis',' 574-577.

increased rates at the expense of oil. After extensive lobbying by Wack and his colleagues focusing on the promoting the likelihood of a crisis in the oil sector, these scenarios formed the basis for a more extensive report on this crisis scenario called the 'Pink Book' led by Napier Collyns. In this report, Collyns focused on increased government takes, and coal and nuclear opportunities, concluding that long-term diversification would be the best answer to ensure Shell's market position.[372]

These scenarios proved a convenient resource for the various scientist-engineers who had become managers within the oil company. In 1968, chemical engineer Karel Swart had already led an internal study group within Shell that researched potential diversification projects for the company. This first report, that had already mentioned projects in food, transportation and nuclear energy, had paved the way for Shell's participation in the Dutch ultracentrifuge project and the later acquisition of the mining company Billiton. Swart and other new managers, including Shell's research director and chemical engineer E.J.G. Toxopeus, however, also openly lobbied for more nuclear diversification projects.[373] In 1971, Swart's research group – Swart was now member of Shell's Committee of Managing Directors – published a second report. Based on new forecasts from the planning department, the report concluded that the share of oil and gas in the energy mix would stabilize and even decrease from 1980 onward. If Shell wanted to continue its growth, diversification into nuclear energy was necessary.[374]

Similar forecasts laid the foundation for the diversification into nuclear energy pursued by Gulf Oil. As the previous chapter showed, in-house economist T.D. Lumpkin warned about the emergence of national oil companies and the growing influence of alternative energy sources already in 1967. In a long-range outlook for the petroleum industry presented for the Society of Petroleum Engineers, he went even further by stating that the management of Gulf Oil should "respond to problems by being flexible." There, he emphasized that, to stay relevant, oil companies should turn into broader focused energy conglomerates. "We live in a dynamic world- one where change is constant and oftentimes dramatic," Lumpkin stated before adding that they expected "nuclear power to make big strides in the electrical generation field and, due to the enormous energy required for the fast-growing electrical demand, cause significant changes in the energy source breakdown." Lumpkin supported these claims by showing how they expected average annual volume growth rate for nuclear energy of thirty five percent between 1966 and 1967, compared to a growth rate of five percent for liquid fuels and 2.5 percent for solid fuels. According to Lumpkin "managements of the future, as in the past, with the ability to "roll with the punch" and regard themselves as in the energy business "were the ones who would continue to lead their companies on to success."[375]

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[372] Thomas Chermack, *Foundations of Scenario Planning: The Story of Pierre Wack* (London: Routledge, 2018), 59-60, 70; Turnbull, ''No Solution to the Immediate Crisis',' 574-577.

[373] **'**Shell in toekomst als kernenergiehandelaar,' *Het Vrije Volk: democratisch-socialistisch dagblad* (March 19, 1971), 25; 'Shell via Gulf op kernenergiemarkt,' *Tubantia* (June 5, 1973), 9; Metze, *Hoog Spel*, 379.

[374] Tourism and pharmaceutics were also regarded as potential diversification projects, but those two were quickly dismissed by the managing directors. Stephen Howarth and Joost Jonker, *Stuwmotor van de koolwaterstofrevolutie, 1939-1973: Geschiedenis van Koninklijke Shell, deel 2* (Amsterdam: Boom, 2006), 379.

[375] T.D. Lumpkin, 'The long-range outlook for the petroleum industry' (1967), Gulf Oil Corporation Records (Pittsburgh Heinz History Center - Detre Library and Archives), box 1, folder 20.

Battling resource scarcity with nuclear energy

In 1973, this line of reasoning had completely permeated the major oil companies' board rooms. As this chapter has shown, many of even the biggest oil majors had established their nuclear diversification projects with large scale investments in multiple stages of the nuclear fuel cycle, now framing themselves as 'energy companies' instead of traditional oil companies.[376] The 1973/74 oil shock then offered opportunities, and perceived necessities, to frame these nuclear investments as the oil industry's contribution to energy independence. Especially in the United States, the industry was increasingly accused of causing, or profiting from, the energy crisis.[377] So much so, that various companies and the industrial lobby organization the American Petroleum Institute (API) started a public campaign to show that the oil industry was actually trying to solve the crisis by contributing to the larger of the United States becoming energy independent induced by President Nixon's Project Independence after the 1973/74 oil crisis.[378]

This campaign was part of an overarching argument introduced by various oil actors to present their diversification efforts as a solution to perceived resource scarcity, and to lobby for more governmental support for their nuclear investments. In his 1974 speech on oil and the US energy crisis, Z.Q. Johnson, Executive Vice President of Gulf Oil, explicitly lobbied for more investments in nuclear energy needed to fulfil the government's plans to become "energy independent". Nuclear energy production, with the help of the oil companies, would be able to grow to 15 percent of national energy demand in 1985 according to Johnson.[379] Also in 1978, Mobil Oil Chairman Rawleigh Warner, Jr. expressed these arguments in his speech for stockholders at the firm's annual meeting. To ensure an efficient transition to the alternate sources that would fuel the future a national energy policy needed to encourage the "development of oil, natural gas, coal, and nuclear energy," Warner stated.[380]

For these arguments, the companies relied on the forecasts of future energy developments by their planning departments that now also focused on the need for Western countries to become energy independent. In May 1974, Warren B. Davis, head of Gulf Oil's planning department, presented different scenarios to deal with the US energy crisis. In the short-term, the United States should import additional requirements or had to limit demand. In the long-term, however, with US oil consumption predicted to grow from 36 million barrels per day in 1973 to 53 million barrels per day in 1985, demand would have to be sharply limited or other US sources, like shale oil, coal liquefaction, and nuclear energy, would have to be developed.[381] Outside the US, companies like Shell and British Petroleum used their scenarios to call for more investments in nuclear energy. Following increasing debates on

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[376] Gulf Oil Corporation, *Frontiers of Energy* (1972), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 22.
[377] Jacobs, *Panic at the Pump*.
[378] E.g. Apache Corporation, 'If the energy crisis is real…why didn't someone warn us?' (Pamphlet, 1973), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 9; American Petroleum Institute, 'Who Owns Big Oil?' (Pamphlet, 1975), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 9.
[379] 'Oil and The US Energy Crisis' (1974), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box 2, folder 5; 'The US Energy Crisis' (1974), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box 2, folder 5.
[380] 'Mobil urges boost in nuclear program,' *The Oil and Gas Journal* (May 15, 1978), 38, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F160.
[381] 'Responsibilities for Business, government and the public for the US Energy Crisis' (1974), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box 2, folder 5.

future Dutch energy demand during the 1970s, both British Petroleum and Shell published public energy predictions about developments in energy consumption in the Netherlands. In these scenarios, Shell examined various energy sources of energy, including solar, coal, and nuclear fission and fusion, and concluded that more investments and less governmental regulation of nuclear energy were needed.[382]

Also, outside the major oil companies, various (geo)physicists, often with ties to the oil industry, engaged in the debates on potential resource scarcity and energy independences that arose after the publication of the *Limits to Growth* report by the Club of Rome in 1972 and the 1973/74 oil crisis. In an extensive reaction to *Limits to Growth,* geophysicist George Bain (who had worked on mapping uranium deposits during the Manhattan Project) already expressed critical thoughts about the inevitability of "limits to growth", especially concerning the report's proposed timeframes.[383] Later he would further elaborate that new oil sources, like oil shale and lignite liquification, would already solve many of the acute problems. There were also alternative energy sources, according to Bain, although they required to be constant and dependable. Only nuclear energy fulfilled these requirements, and therefore the development of this energy sources needed to continue and "the harassment of nuclear plants by 'activists'" had to be "eliminated" Bain concluded.[384]

Hans Bethe – while consulting for Exxon – also actively engaged in the debates on resource scarcity that dominated the 1970s. In a speech called "Energy Crisis and Nuclear Power", Bethe stated that energy independence for the US was not a "luxury or a matter of prestige, but a matter of survival."[385] Contrary to Bain however, Bethe was less sure about the availability of sufficient oil reserves. He foresaw the countries of Western Europe, the US and Japan competing for the scarce oil supply in the world market and insufficient coal resources. Energy independence was only to be achieved by energy conservation and nuclear energy according to Bethe.[386]

To infinity and beyond

That nuclear energy would play such a key role in the oil industry's claims about fulfilling future energy demand was not a given. Although the uranium market actually experienced an oversupply, causing various governments and companies including Gulf Oil to join an international uranium cartel, the

[382] Shell Briefing Service, *Nuclear Energy: Physics, Technology, Resource base, Costs, Contribution* (1981), 2.02.28 Archives of the Lower House of the States General (The Hague: Dutch National Archives), box. 738, folder 5623; Shell Nederland B.V., *Zonne-energie* (The Hague: Shell Nederland B.V., 1978); A. van Selm and G. Verbong, 'De belofte van duurzame energie: van Energienota tot de BMD,' in Verbong, G., A. van Selm, R. Knoppers and R. Raven (eds), *Een kwestie van lange adem: De geschiedenis van duurzame energie in Nederland* (Boxtel: Aeneas, 2001), 72.
[383] George Bain, 'Comments on "Limits to Growth"' (1972), George W. Bain Papers (Amherst: College Archives and Manuscript Collections), box 10.
[384] George Bain, 'Facts of the Energy Problem' (1979), George W. Bain Papers (Amherst: College Archives and Manuscript Collections), box 10.
[385] Hans Bethe, 'Energy Crisis and Nuclear Power' (1974), 2, Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 20, folder 8.
[386] Hans Bethe, 'Energy Crisis and Nuclear Power' (1974), 6, Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 20, folder 8. Various historians have pointed out that several oil companies also actively endorsed the proposal of energy conservation as solution for future scarcity: Turnbull, ''No Solution to the Immediate Crisis''; Geert Buelens, *Wat we toen al wisten: de vergeten groene geschiedenis van 1972* (Amsterdam: Querido, 2022), 111.

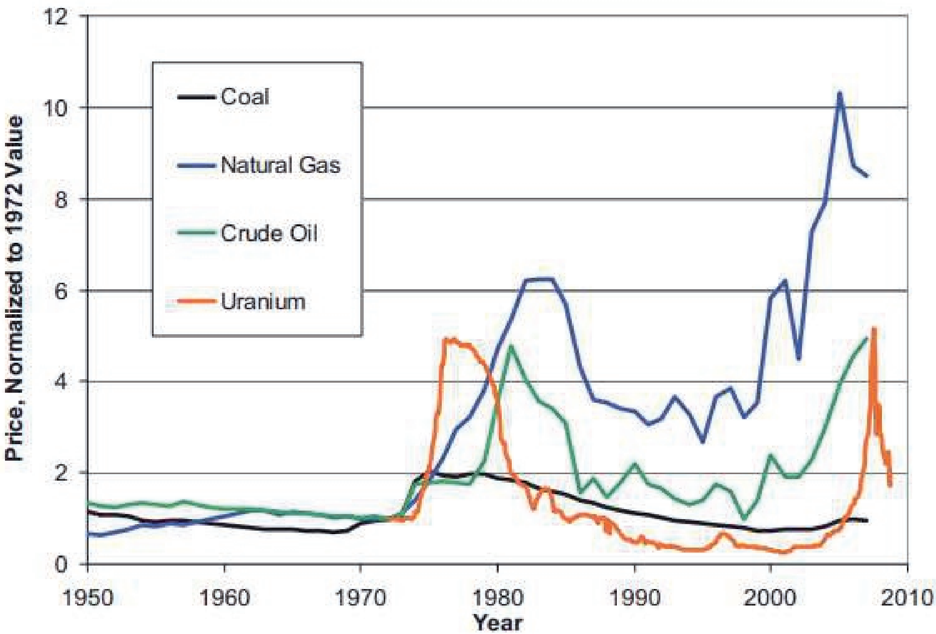

Figure 21: Inflation-adjusted uranium and fossil fuel prices, 1972–2008. 1972 price = 1. Shropshire, D.E. et all, Advanced Fuel Cycle Cost Basis *(Idaho National Laboratory, 2009), A1-40.*

resource needed to fuel the popular light water reactors was perceived as finite.[387] When the price of raw uranium also experienced a price surge at the beginning of the 1970s (figure 21), a possible future scarcity of the resource was increasingly posed as a problem for regular nuclear fission. Various oil actors acknowledged this as well. Shortly after the publication of *Limits to Growth*, a committee of prominent figures in Dutch public debate, including Shell's CEO Gerrit Wagner, published a public response called *Work for the Future* (Dutch: *Werk voor de toekomst*, 1972) that acknowledged many of the findings of the MIT team on resource scarcity, population growth and environmental pollution.[388] Although the authors did not expect a bright future for alternatives like solar energy, the pamphlet made clear that fossil fuels had significant drawbacks in terms of resource scarcity and environmental problems. Nuclear energy too, encountered major drawbacks according to the authors,

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[387] Gulf Oil did actually join the cartel because they were afraid that the addition of their big uranium deposits in Canada would decrease the price of uranium, making their mining projects unprofitable. Uranium price committee, 'The Price of US Uranium 1971-1995' (1972), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box 7, folder 5; B.L. Cooper and M.R. Turner, 'The Price of US Uranium, 1975-2000' (1974), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box 8, folder 3; Bron, 'The uranium club'; Debora L. Spar, 'Yellowcake: The Rise and Decline of the International Uranium Cartel,' Debora L. Spar (eds), *The Cooperative Edge: the internal politics of international cartels* (Ithaca: Cornell University Press, 1994), 88-136.

[388] In more popular accounts, *Work for the Future* is regularly perceived as mostly critical to the methods employed by the MIT-team with critics often pointing to the pamphlet's arguments against the "widely spread misconception" that *Limits* was a precise prediction of the future. Still, the authors of *Work for the Future* actually did agree with the geophysical constraints posed by the MIT-report concerning population growth, resource scarcity and environmental pollution. Bron, 'Oil's Nuclear Frames,'; W.J. Beek et all., *Werk voor de toekomst* (The Hague: Stichting Maatschappij en Onderneming, 1973), 4-13. See for popular accounts on *Work for the Future*: Jaap Tielbeke, *We waren gewaarschuwd: over een profetisch milieurapport en wat we er (niet) mee deden* (Amsterdam: Das Mag, 2022); Metze, *Hoog Spel*, 375.

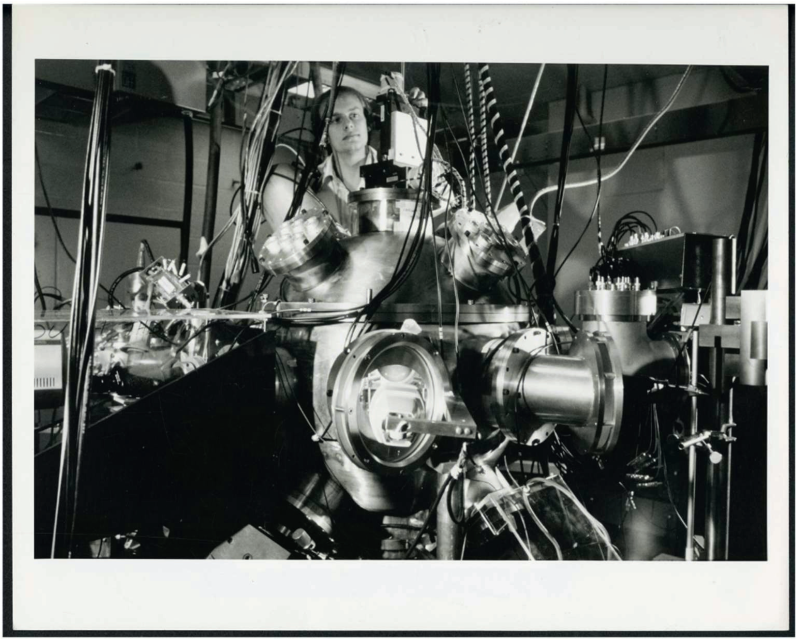

Figure 22: Inside a fusion target chamber at Exxon, a specially fabricated deuterium pellet is heated to extremely elevated temperatures by four powerful laser beams focused through chamber ports onto the pellet, 1975. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History), Box 42, folder 43.

especially regarding the health and environmental hazards posed by nuclear waste and potential accidents, but also due to the expected scarcity of uranium.[389]

Although various technologies derived from the oil industry like radioactive well logging and leaching already aided in the discovery and cheaper extraction of more uranium deposits, various oil actors also held high expectation for future nuclear technologies that would solve the problem of resource scarcity forever. In *Work for the Future*, the authors already expressed high hopes for technological innovations within the nuclear sector that would solve the scarcity problems; Hans Bethe also discussed several technofixes for the scarcity problems; according to H.C. Kauffman, president of Exxon Corporation, too, there was a growing concern about uranium shortages: "surely, bringing new skills, technology and resources into exploration and development of that fuel may be as important to the nation as discovering more oil and gas," he stated for the National Press Club.[390] Within this debate, two technologies bore the highest expectations for the future: the nuclear breeder reactor and nuclear fusion. Both technologies were still very experimental and would not be available on a large scale soon, but they represented the future for nuclear energy with the current investments in fossil fuels and regular nuclear fission serving as a bridge to this future. According to Hans Bethe, fusion was the most important of the alternatives to non-fossil energy. With the emergence of the tokamak reactor the prospects for fusion looked better than ever before, he stated. However, Bethe acknowledged that

[389] Beek et all., *Werk voor de toekomst*, 16-17.

[390] H.C. Kauffmann, 'A view of divestiture' (Published speech: April 8, 1976). John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43.

due to engineering problems and the long time it would take to upscale fusion to an industrial power plant, at least thirty years still had to be bridged.[391]

Various oil companies framed their nuclear fusion research projects as potential solutions for future resource scarcity. According to Dan Grafstein, manager of laser fusion research for Exxon, the company was participating in the research because fusion power offered the best hope for providing commercial power for the future. “It is widely recognized that our fossil fuel resources are finite and that we are likely to see the end of petroleum’s use as a fuel sometime in the next century,” he stated. “The earth’s coal resources will probably last several hundred years, providing some margin of safety. Supplies of low-cost uranium are expected to be tight by the end of the century and it is unlikely that the various types of solar and geothermal energy will satisfy more than a small portion of the future energy demand, even assuming advances in technology. Obviously, then, we better look for new ways of producing energy to satisfy the world’s long-range requirements. That is one reason why we are involved in fusion research.”[392]

The breeder reactor was the second technological innovation that bore high hopes of solving potential resource scarcity in the future. Being fueled with more abundant isotopes like uranium-238 and thorium-232, the reactor establishes a neutron economy that is sufficient to create more fissile fuel than it uses by irradiating so-called “fertile material”.[393] The previous chapter already discussed how the concept of a breeder reactor was regarded as the future for nuclear energy by geophysicist Marion King Hubbert in 1956, and during the 1960s several experimental plants were built in the UK and the US. The reactors were, although still very experimental, operational and the technology potentially offered one of the best answers to future scarcity of uranium. In this way, the breeder reactors offered a road map to the nuclear future: from regular fission reactors, via breeders, to nuclear fusion. As Hans Bethe stated in his speech on the energy crisis “the development of the breeder reactor is certainly technically feasible (in contrast to fusion power), and while the first large-size breeder reactor is enormously expensive, I am confident that the cost will come down, and that adequate safety can be established.”[394]

Also, *Work for the future* debated recent technologies as an answer to the potential future scarcity of uranium when regular nuclear fission would be scaled up. According to the authors, improving the effectiveness of already existing technologies and the transition to breeder reactors were needed to

[391] Hans Bethe, ‘Energy Crisis and Nuclear Power’ (1974), 4-6, Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 20, folder 8; Beek et all., *Werk voor de toekomst,* 17; ‘Wagner (Shell): andere bronnen energie aanboren,’ *NRC Handelsblad* (April 20, 1972).

[392] Quotes as represented in ‘Fusion: as old as the sun; as new as tomorrow,’ *Exxon Manhattan* (July 23, 1976), 2, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/K96B.

[393] Maria Padovan, ‘The French fast breeder program and the European nuclear integration,’ *Entrepresises et Histoire* 1, 114 (2024), 89-102; Matteo Gerlini, ‘Energy Independence vs. Nuclear Safeguards: the US Attitude toward the European Fast Breeder Reactors Program,’ Elisabetta Bini and Igor Londero, *Nuclear Italy: An International History of Italian Nuclear Policies during the Cold War* (Trieste: University Press Italiane, 2017), 141-150.

[394] Hans Bethe, ‘Energy Crisis and Nuclear Power’ (1974), 17, Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 20, folder 8.

reduce the use of uranium. "If it proves possible, to start using breeder reactors on a large scale instead of ordinary nuclear reactors, there will be enough uranium in the world for quite some time."[395]

The oil industry's nuclear environmental frames

"Growth with Environmental Quality"

When in 1972 *Work for the Future* was published in the Netherlands as an industrial response to the *Limits to Growth* report, the authors did not only include discussions on future resource scarcity. Also various environmental problems were discussed, ranging from rising levels of carbon dioxide in the atmosphere to thermal pollution and the loss of biodiversity.[396] Regarding these topics, oil companies had already built up a disputed reputation during the 1960s and early 1970s, with environmental disasters like the Santa Barbara oil spill in 1969.[397] Also regular nuclear fission was increasingly considered to be harmful to the environment by environmentalists and anti-nuclear activists. Several lawsuits in the US, such as the verdict in *Calvert Cliffs Coordinating Committee v. Atomic Energy Commission* (1971), determined that the companies involved in nuclear energy production should consider environmental values at every distinctive and comprehensive stage of getting a license from the AEC, something the various companies regarded as a potent threat for their nuclear investments.[398]

Therefore, oil actors presented themselves as being able to ensure economic growth and abundant energy for the future in an "environmentally friendly" way. Besides individual oil actors like Wallace E. Pratt campaigning against water pollution from oil and gas wells, and oil actors promoting the environmental warnings of *Limits to Growth* and organizing major international conferences on the environment, various major oil actors acknowledged the role of the oil industry in polluting air and water.[399] In a study on the content of trade journals such as *Oil and Gas Journal*, Andrew Hoffman showed a surge in articles concerning 'the environment' and its problems during the late 1960s and early 1970s, often celebrating the industry's efforts and opportunities to develop new, innovative

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[395] Quote translated from Dutch by author. Original quote: "Mocht het mogelijk blijken, om op grote schaal kweekreacotren in plaats van gewone kernreactoren te gaan gebruiken, dan is er voor geruime tijd voldoende uranium in de wereld voorhanden". Beek et all, *Werk voor de toekomst,* 17.

[396] Beek et all., *Werk voor de toekomst*, 24-32.

[397] Teresa Sabol Spezia, *Slick Policy: Environmental and Science Policy in the Aftermath of the Santa Barbara Oil Spill* (Pittsburgh: University of Pittsburgh Press, 2018).

[398] Warren Davis, from Gulf Oil's planning department, presented four cases how the US energy mix could develop toward 1985, with a most optimal case in which the government would fully support companies in their endeavors to invest in national oil production by leasing lands, providing "adequate economic incentives", and solve controversies about environmental issues. The worst case (4) represented "a likely outcome if disputes over environmental issues continue to constrain growth in output of all fuels". 'Gulf Oil Corporation – 1971 long range corporate forecast' (1971), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box 7, folder 6; David A. Repka and Tyson R. Smith, 'A Dose of History: Nuclear Energy Cases That Shaped Environmental Law,' *Natural Resources & Environment* 15, 1 (Summer 2010), 28.

[399] Following the publication of *Limits to Growth*, various oil actors, like Maurice Strong, George Mitchell, Joseph Slater, and Robert O. Anderson, got involved in organising and shaping the international debates on resource scarcity and environmentalism based on the findings of the Club of Rome. Simone Schleper, *Planning for the Planet: Environmental expertise and the International Union for Conservation of Nature and Natural Resources, 1960-1980* (London: Berghahn Books, 2019), 48; Mody, 'Spillovers from Oil Firms to US Computing and Semiconductor Manufacturing,' 619. For Pratt see: Salvador, 'Memorial to Wallace Everette Pratt, 1885-1981'; Bron, 'Oil's Nuclear Frames'.

technologies that could solve many of the problems posed by air and water pollution that were produced by the petrochemical industry.[400]

The major international oil companies, too, acknowledged environmental limits. In a colorful magazine, Exxon in 1975 presented their company as a responsible and, above all, environmentally friendly oil company. “Some forget that oilfields are not forever; when their production life is over, the land remains for the productive use of the people,” the magazine argued expressing a productivist vision. Although oil production certainly did temporarily alter the environment, the fields would soon be usable again for houses, towns and farming fields.[401] Beside stating the temporality of oil extraction sides, the magazine also featured an extensive interview with economist John Kenneth Galbraith arguing for more regulation for big business, and an article on “America’s quest for clean air” in which the emission reductions by the petroleum industry between 1965 and 1975 were celebrated. This last article also ended with an overview of the research conducted at Exxon Research’s Fuel Research Laboratory that under the direction of Dr. Richard R. Cecil had concluded research on “virtually every aspect of automotive air pollution,” ranging from evaporation losses to the “effects of fuel composition upon emission.”[402]

Shell’s CEO Gerrit Wagner offers the most explicit example. Not only did he, as one of his first acts as the new CEO of Shell in 1972, participate in the Dutch committee reacting to *Limits of Growth*, he also repeated many of its ideas in various public outings and speeches as CEO of Shell.[403] In a speech on “the environment and the enterprise”, Wagner presented a view on ‘the environment’ that elaborated on the idea” presented in *Work for the Future*. Building on an already established distinction between “Man” and “Nature”, Wagner prioritized humankind over that of plant, animal, water, earth, and air. These other creatures and natural elements were simply there to serve human welfare, and because they are essential to continue the wellbeing of humankind they should not be exploited. In doing so, Wagner acknowledged the dangers that unrestricted industry posed for the environment, stating that the protection of the environment should not be left solely to the same industry that was responsible for the threats. Without governmental supervision and regulations, the industry would often fail to pay attention to the environment. Market mechanisms alone would not be sufficient to protect the environment.[404]

In this rhetoric, nuclear energy played a two-sided role. In 1973 Dean McGee, one of the founders of the Kerr-McGee company, gave a fascinating speech as chairman of a public forum on “Growth with Environmental Quality”. In his opening remarks, McGee presented nuclear energy as an essential part of a strategy to foster American economic growth in an environmentally friendly way by making

[400] Andrew J. Hoffman, ‘Trends in Corporate Environmentalism: The Chemical and Petroleum Industries, 1960-1993,’ *Society & Natural Resources* 9 (1996), 47-64.
[401] ‘Accompanying Note,’ *Exxon USA* XVII, 1 (1978), President’s Office Martin Meyers Papers (Philadelphia: University of Pennsylvania), box 273, folder 4.
[402] Frank Brothers, ‘America’s Quest for Clean Air,’ *Exxon USA* XVII, 1 (1978), 26, President’s Office Martin Meyers Papers (Philadelphia: University of Pennsylvania), box 273, folder 4.
[403] Gerrit A. Wagner, ‘De onderneming en het milieu: “Tussentijds bestek”, Paleislezingen, Amsterdam, 27 april 1973,’ *Beschouwingen van een ondernemer*, (Kampen: J.H. Kok, 1979), 72-81; Geert Buelens, ‘The ubiquity of Royal Dutch Shell in the Netherlands as a case of banal petroculture,’ *Journal of Energy History/Revue d'Histoire de l'Énergie [Online]* 10 (29 August 2023); Van Seumeren *Gerrit A. Wagner*, 18-72; Metze, *Hoog Spel*, 266, 276, 294-297; Buelens, *Wat we toen al wisten*, 111; Beek et all., *Werk voor de toekomst*, 4.
[404] The speech was part of a lecture series organized by the Dutch royal house in 1973. Wagner, ‘De onderneming en het milieu: “Tussentijds bestek”, Paleislezingen, Amsterdam, 27 april 1973,’ 74-75.

possible new technologies and continuous energy consumption.[405] Also, both utilities and reactor manufacturers like General Electric had presented nuclear energy as an environmentally friendly alternative for fossil fuels as a response to growing fears of air pollution in the United States during the 1960s.[406] Other oil actors however, had been more critical of how environmentally friendly nuclear energy production really was. *Work for the Future*, endorsed by Shell's CEO Wagner, discussed both "the impact of ionizing radiation on human health" and the thermal pollution produced through the cooling water needed for nuclear reactors as reasons that nuclear fission was problematic. [407]

However, to overcome the problems with regular nuclear energy production, industry was to be supported in developing new, cleaner and safer, nuclear technologies according to Wagner.[408] Embracing this technological optimistic frame, the general manager of Exxon Nuclear, Raymond Dikeman, also elaborated on the environmental aspects of nuclear power in a radio recording organized by Exxon. Although he was less critical than Wagner – even nuclear fission, according to Dikeman, was more environmentally friendly than conventional fuels – he acknowledged that nuclear power faced environmental problems from radioactive waste during various stages of the nuclear fuel cycle. However, innovative technologies could easily solve these problems: other forms of nuclear power, storing waste in glass or blasting it away into space, and cleaner mining techniques.[409]

"Environmentally friendly" technologies

One of these "cleaner" mining techniques that oil actors posed as a solution for the environmental problems was In Situ Leaching. In a series of pamphlets and public statements, oil companies developing this modern technology framed ISL as an "environmentally friendly" way of mining by focusing on the small impact on the surface and the reduced waste piles. Mobil's outward communications about their leaching projects presented the environmental benefits of ISL over traditional uranium mining as the main reason to invest in this "innovative" technology. Not only in the colorful flyer *Mining Uranium in Nature's Way* (figure 23), but also in pamphlets, articles and interviews, Mobil's managers emphasized that leaching involved only limited above-ground disturbance of nature, did not create piles of waste rock, and posed no threat to the groundwater.[410]

This frame often deliberately neglected the environmental impact posed by the introduction of leaching. Although it was not until the 1990s that more fundamental criticism of leaching methods

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405 'Summary of Opening Remarks by D.A. McGee, Moderator, Energy Panel of the National Forum on Growth with Environmental Quality' (1973), Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 137.

406 Lifset, 'Nuclear Power in America: the Story of a Failed Energy Transition,' 525; Scott Dewey, *Don't Breathe the Air: Air Pollution and US Environmental Politics, 1945–1970* (College Station: Texas A&M Press, 2000).

407 Beek et all, *Werk voor de toekomst,* 17; 'Wagner (Shell): andere bronnen energie aanboren'. *NRC Handelsblad***.** April 20, 1972.

408 Gerrit A. Wagner, 'Economie niet denkbaar zonder multinationale onderneming,' *Beschouwingen van een ondernemer* (Kampen: J.H. Kok, 1979), 82-87.

409 '"Exxon and Nuclear Energy", Guest: Raymond L. Dikeman, President, Exxon Nuclear Company' (Exxon Conversations, Recorded: October 6, 1975), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207, folder K96B.

410 'Leaching: Mining Uranium in Nature's Way' (Mobil Corporation, 1978), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207, folder F120; 'For Uranium, the Future is Now,' *Mobil Overview* 2, 1 (1978), 6-8, ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120.

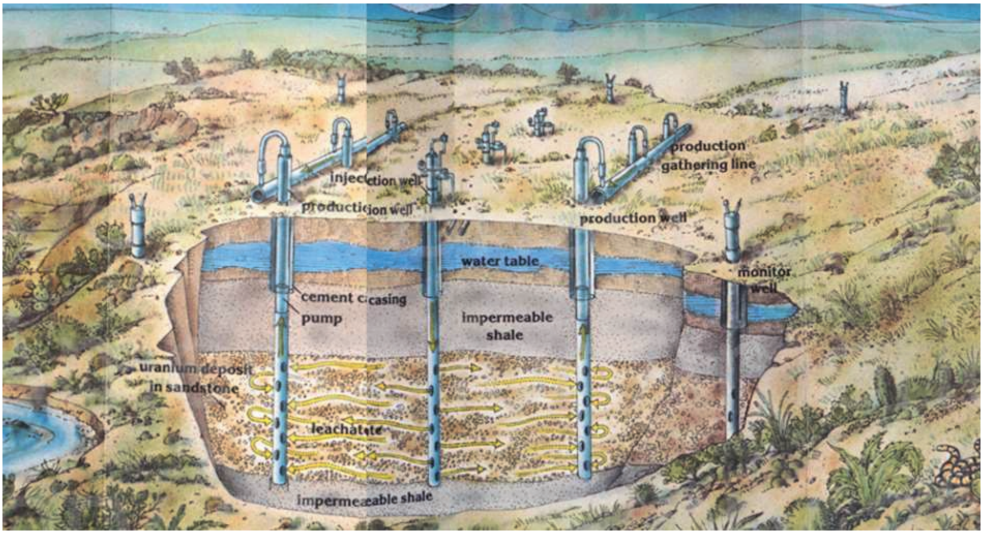

Figure 23: Snakes, birds, vegetation, and a healthy, clean river surround a small selection of pipes peeping through a lush surface. Underneath, pipes carefully penetrate several sedimentary layers to subsequently pump up the uranium accumulated over millennia in the deposits beneath. A colorful and peaceful image. Cut out from 'Leaching: Mining Uranium in Nature's Way' (Mobil Corporation, 1978). ExxonMobil Historical Collection, DBCAH. Box 2.207, folder F120.

would be raised from the ranks of environmentalists, partly in response to some large-scale environmental accidents with leaching projects around the Straz mines in the Czech Republic, many of the problems were already known to scientists, policy makers and the industry in 1978.[411] These problems included the expensive and difficult restoration of the local environment. Gypsum precipitation, higher salinity and the spread of heavy metals and radionuclides proved to be recurring problems as well. There were serious doubts whether natural attenuation could restore the groundwater quality and geochemical conditions in an acid leached aquifer zone.[412]

From the start, oil firms involved in ISL tried to counter these arguments and present the technique as an environmentally friendly way of mining. In a 1979 lawsuit on the environmental impact of a pilot uranium extraction project near Crownpoint, NM, sponsored by Mobil Oil, the oil company intervened to display the environmental benefits of the plant. Local newspapers and professional mining journals closely followed the suit, which they regarded as a testcase for the leaching industry. The oil company's arguments convinced the US District judge, who issued an order that the economic and social impacts appeared "to be overwhelmingly favorable."[413] These advantages were not to be "offset by the very minor and speculative environmental impacts plaintiffs assert," according to the judge, causing an editorial in the *Albuquerque Journal* to conclude that "those sincerely concerned with protecting the environment, as distinguished from those determined to halt any and all energy projects and to

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[411] Mudd, *An Environmental Critique of In Situ Leach Mining*, 75-79; L.C. Hebel et all, 'Report to the American Physical Society by the Study Group on Nuclear Fuel Cycles and Waste Management,' *Reviews of Modern Physics* 50 (1978), S1-S185.

[412] Gavin M. Mudd, 'Critical review of acid in situ leach uranium mining: 1. USA and Australia,' *Cases and Solutions*, 41 (2001), 390.

[413] 'Crownpoint: A Landmark Opinion,' *The Miner* 1, 4 (1979), ExxonMobil Historical Collection (Austin: The Dolph Briscoe Center for American History), box 2.207/F120.

escalate fuel costs, should welcome and applaud the innovative project launched by Mobil near Crownpoint."[414]

Similar strategies were employed by the oil industry regarding their investments in nuclear fusion research. Like with In Situ Leaching, oil actors presented their nuclear fusion reactors as an "environmentally friendly" technological innovation that would guarantee the continuation of human prosperity in a healthy environment. In the promotional material for the Doublet III from 1977, researchers and managers at General Atomic stated that the promise of inexhaustible power would be "an empty one if there are safety problems or adverse environmental side effects" and that their fusion reactors did not encounter these problems.[415] The total amount of fusion fuel present in a fusion reactor at any one time would be small, and the physics of a fusion process would make a runaway reaction impossible, even if parts of the reactor system failed. Also, General Atomic claimed there was no risk of thermal pollution – a way of environmental pollution that is caused by the heating of cooling water from rivers in regular nuclear fission plants.[416] There also were no risks of biological hazards by radioactivity or the release of chemical combustion products to the atmosphere, making nuclear fusion both safer and cleaner than nuclear fission and the burning of hydrocarbons. according to the oil-funded company.[417]

Nuclear fusion was thus the perfect example of the technological innovation developed by the industry that was working to find solutions to environmental and resource scarcity problems. However, what the promotional material ignored was that it was well known within the industry that nuclear fusion *did* produce radioactive waste. After frequent use, the reactor wall would become damaged by the particles blasted away which caused the material to become radioactive. The tritium needed to establish a fusion reactor was also radioactive. This information was already known by fusion scientists at the beginning of the 1970s, but oil firms regularly neglected this to position fusion as a clean and safe alternative to regular fission for funding purposes.[418]

Oil's nuclear heydays: concluding observations

When Ted Kennedy presented his amendment to limit oil firms' diversification in 1975, he sparked a full-fledged counter campaign within the industry. Gulf Oil published a pamphlet in 1976 named *Horizontal Divestiture: A Choice Critical to America's Energy Future*. This booklet presented an analysis of "an issue of major concern to all of us" with the goal to offer "facts and potential consequences in this booklet so they can be more effectively understood." In particular, the pamphlet argued for oil companies being active in more than one energy field, specifically petroleum, coal, shale oil, uranium, and/or geothermal energy. In their pamphlet, Gulf Oil added that over the period of 1965 to 1973, the

[414] 'Editorial', *Albuquerque Journal* (September 13, 1979).
[415] Quote from 'Doublet III: A Major Step Towards Fusion Power' (General Atomic Company Pamphlet, 1978), Princeton Plasma Physics Laboratory Records (Princeton, New Jersey: Princeton University), box 6, folder A.
[416] John Samuel Walker, 'Nuclear Power and the Environment: The Atomic Energy Commission and Thermal Pollution,' *Technology and Culture* 30, 4 (1989), 964-992; Per Högselius, 'Atomic Shocks of the Old: Putting Water at the Center of Nuclear Energy History,' *Technology and Culture* 63, 1 (2022), 1-30.
[417] 'Doublet III: A Major Step Towards Fusion Power' (General Atomic Company Pamphlet, 1978), Princeton Plasma Physics Laboratory Records (Princeton, New Jersey: Princeton University), box 6, folder A.
[418] Hans Bethe, 'Energy Crisis and Nuclear Power' (1974), 6, Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 20, folder 8; Anouck Vrouwe, *Hittebarière: Vijftig jaar plasmafysica bij FOM-Rijnhuizen* (Rijnhuizen: FOM-Rijnhuizen, 2009), 66.

oil industry had accounted for almost the entire growth in uranium produced in the US, and only big companies with the required expertise and financial capabilities were able to pull off the technological innovation necessary for developing new, "environmentally friendly", energy production in the future.[419]

The arguments in Gulf Oil's pamphlet closely resembled the statements made by other American oil companies.[420] In their lobbying campaign, oil firms framed their diversification projects on the one hand as a necessity to solve future resource scarcity and become energy dependent, and on the other hand stressed the added value of oil companies' investments in alternative, clean, energy sources given their research capabilities and possibilities to bring in the capital needed for large scale development of these new technologies. Especially the nuclear diversification projects were framed as essential in establishing an "environmentally friendly" economic growth.[421]

In the end, the oil lobby would fend off the proposed divestiture in 1976. The US Senate did not pass legislation to force the oil companies to divest their subsidiaries into alternative energy sources such as nuclear energy. The oil industry's successful lobbying for a nuclear future, and the political and public capital invested in that lobbying, was exemplary for the decade between 1968 and 1979, a period I describe as the heydays of oil's involvement in nuclear energy. Reinforced by the fear of losing access to – and in the end losing full control over – cheap oil production in the OPEC-countries, even the biggest oil companies started focusing on alternatives like coal, shale oil, solar, and nuclear energy.

These investments were no mere accident, but instead grounded in decades of spillovers of technologies, people, knowledge, and practices that were familiar to the leading cohort of scientist-managers within the oil industry. With their diversification strategies these oil actors expressed an omnipresent optimism about the eventual success of their technological expertise and were willing to invest in long-term experimental research projects with limited prospects for direct commercial viability. While on the one hand relying on the technologies and knowledge already developed within the oil industry to further develop the uranium exploration and mining business, oil firms also got involved in various innovative, and sometimes highly experimental, nuclear research projects. With these developments, companies such as Exxon and Gulf Oil framed their investments as solutions to both predicted resource scarcity and the environmental problems that fossil fuels and regular nuclear energy production posed.

Multiple forecasts made within the oil industry about the future role of nuclear energy, the growing demand for energy, and difficulties with the future oil supply, underpinned these frames. These forecasts predicted a growing importance of nuclear energy production in fulfilling future energy needs. The forecasts legitimized the diversification projects of the oil companies, but also served as

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[419] Gulf Oil Corporation, 'Horizontal Divestiture: a choice critical to America's energy future' (Pamphlet: 1976), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box B, folder 21.
[420] 'Important facts you should know about divestiture and what its impact would be on the oil industry,' (Exxon pamphlet: 1976), John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43; American Petroleum Institute, 'Dismembering the oil companies: higher costs, more imports, less efficiency, fewer jobs' (Pamphlet: 1976) John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43; *Petroleum Today* (special issue) 2 (1976), Hans Bethe Papers (Ithaca: Cornell University Rare and Manuscript Collection), box 21, folder 22.
[421] William P. Tavoulareas, 'Why divestiture won't work: the case for America's oil companies,' (Published statement: 1976), John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 38, folder 43.

lobbying tools for oil companies to get governmental support for their nuclear investments. Especially when politicians proposed plans to force the biggest companies to divest their projects in alternative energy sources, oil firms started a wide-ranging lobby to ensure the future of their nuclear endeavors.

CHAPTER 5

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5. Phasing out

Declining oil interest in nuclear energy and the end of oil-nuclear cohort, 1973-1993

Another indirect and longer-term effect of the fall in crude oil prices is the renewed competitiveness of petroleum products, particularly fuels, compared with other energy sources. In the medium term, barring a sudden rise in prices or a tax handicap, this phenomenon will result in a return to some growth in sales for the refining and distribution sector.

- Francois-Xavier Ortoli, President of CFP-Total, 26 November 1986[421]

[421] Quote translated from French by author: "Un autre effet indirect et à plus long terme de la baisse du prix du brut est le regain de compétitivité des produits pétroliers, et tout particulièrement des fuels, face aux autres sources d'énergie. A moyen terme, sauf remontée brutale des prix ou handicap fiscal, ce phénomène se traduira pour le raffinage-distribution par un retour à une certaine croissance des débouchés." 'Réunion d'information avec les analystes financier,' 3, Francois-Xavier Ortoli Papers (Florence: EUI - Historical Archives of the European Union), folder 136.

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Phasing out

When in 1984 François-Xavier Ortoli entered the office of *président* of the French oil company CFP-Total he was a unicum. A couple of days earlier, Ortoli, according to his own recollection, had not even known that his new position would become vacant.[423] The engineer Granier de Lilac, who was Ortoli's precursor at *Compagnie Française Petroleum* (CFP), had been in power for more than a decade. During these years, De Lilac had preceded over a company run by the polytechnicians from the *Ecole des Mines*, with his close colleagues all being part of the famous group *les dix*, named after the top ten percent of their classes at the *Ecole Nationale de Polytechnique*. These men had steered the oil company to being one of the most diversified oil companies in the sector.[424] Pressured by the loss of access to the Middle-Eastern and the North African oil fields, which had hit CFP especially hard, the engineers at the top of the company had made way for the company to develop activities in thermal heating, geothermal energy production, solar energy, uranium mining, and nuclear fuel production. Especially the uranium business had grown to full-sized subsidiaries with mining projects in Ireland, Australia, Mauritania, Colombia, and the United States. In 1984 Granier de Lilac retired, however, leaving open the position of president of CFP-Total.[425]

His successor, Ortoli, was no engineer. His background was in finance and law. Before joining the French prime-minister Georges Pompidou's office as an economic advisor, working as the French Minister of Industrial and Scientific Development, and becoming European commissioner and serving as the head of the European Commission, he did his studies at another *École Nationale*, the *École Nationale d'Administration* (ENA), learning management, finance and economics. It was therefore actually quite surprising that he gained the presidency of CFP-Total. He was the first former ENA-student to become president of this oil company, and even one of the first from ENA to lead the oil company at all. The company run by engineers was not supposed to be managed by someone from ENA. In fact, there was another candidate, the vice-president of CFP-Total, Louis Dény, who colleagues perceived as particularly cut out for the job. Dény had a career in petroleum engineering after finishing top ten of his class at the *École Polytechnique*. Everyone at the company expected him to become the new president, and some managers threatened to resign if Ortoli would be named the new president. However, the Ministry of Industry, still owning twenty-five percent of the company, wanted Ortoli. Seeing how the partly state-owned company struggled to recover from the loss of oil concessions, they wanted an executive trained in finance and economics, someone who would refocus the oil company back to oil.[426]

On this wish, Ortoli delivered. Ortoli was already known for his liberal ideas on a market-oriented economic policy, and according to the French historian of CFP-Total, Hervé l'Huillier, "Ortoli defined a

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[423] Quoted in Yates, *The French Oil Industry and the Corps des Mines in Africa*, 176.
[424] Leslie E. Grayson, *Who and How in Planning for Large Companies: Generalizations from the Experiences of Oil Companies* (New York: St. Martin's Press, Inc. 1987), 200.
[425] Yates, *The French Oil Industry and the Corps des Mines in Africa*, 175-177.
[426] Ibidem, 175-177.

strategy adapted to the new conditions of running an oil business."[427] This strategy included a renewed focus on oil and gas production. Ortoli prioritized the company's oil activities because since the oil crises of 1973/74 and 1979, oil and gas production had been the source of the company's capital and profits. To underline this shift in focus, the company symbolically changed its name from CFP-Total to Total-CFP (Total was the trademark for the firm's gasoline brand).[428] This redeployment also meant a divestment of assets employed in various alternative energy sources, most notably in nuclear fuels. There, Ortoli started a process that would end with Total-CFP completely abandoning their nuclear investments in 1993.[429]

This shift in priorities at Total-CFP guided by Ortoli's management is a telling example of a broader development within the oil industry during the 1980s. The 1970s were the heydays of the oil industry's involvement with nuclear developments. The 1980s, however, saw many oil companies divesting their nuclear diversification projects. This chapter deals with the way Western oil firms managed this divestment process and argues that a cohort-shift toward managers trained in economics was responsible for an increased focus on short-term profits in the oil market, to the detriment of long-term investments, including those in nuclear projects.

At the end of the 1970s and beginning of the 1980s, the development of nuclear energy bogged down. To explain this unexpected turn of events, oil actors invoked a variety of reasons ranging from environmental and labor activism to increasing liability costs. Still, many of the nuclear projects remained modestly profitable or continued to have an outlook on future profits. The main reason for the oil companies to divest their nuclear projects, this chapter argues, therefore was not the developments within the nuclear industry *per se*, but more a refocus to higher *short-term* profits from sales of petroleum. Due to rising capital costs for oil and nuclear projects, and an increasing pressure from shareholders to divest the diversification projects, oil firms abandoned their nuclear projects, including their very long-range nuclear fusion research.

This period also marked the end of the nuclear-oil cohort that was the focus of the previous chapters. The scientist-engineers that had steered oil companies into their nuclear diversification projects now reached the age of retirement, opening the way for a new kind of manager, trained in economics, business, and finance. By making this argument, this chapter positions itself in a wider debate about the perceived stagnation of nuclear developments during the 1980s. Recently, historian Mar Rubio-Varas has argued that one of the most important reasons for the decline of nuclear reactor orders was economic in nature. Even more than environmental concerns and technological setbacks, the structures of the national electricity markets, the industrial base, financing, and interest rates determined the fate of the nuclear developments.[430] Some business historians have also claimed that

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[427] Hervé l'Huillier, *Histoire de Total-CFP* (Paris: Service Central des Archives Total, 1996), 26; Yates, *The French Oil Industry and the Corps des Mines in Africa,* 177-178; Laurent Warlouzet, 'The European Commission facing crisis: social, neo-mercantilist and market-oriented approaches (1967-85),' *European Review of History: Revue européene d'histoire* 26, 4 (2019), 715; Laurent Warlouzet, *Governing Europe in a globalizing world: neoliberalism and its alternatives following the 1973 oil crisis* (London: Routledge, Taylor & Francis Group, 2018).
[428] Yates, *The French Oil Industry and the Corps des Mines in Africa*, 178
[429] Tristan Gaston-Breton, *Total, Un Esprit Pionnier* (Paris: Total S.A., 2019), 268. Remarkably, Total-CFP kept their solar business running, as only one of the few oil companies at the time. See Jelena Stankovic (ongoing work).
[430] Mar Rubio-Varas, 'Economic Context Influencing Nuclear Decisions,' Arne Kaijser, Markku Lehtonen, Jan-Henrik Meyer, and Mar Rubio-Varas (eds), *Engaging the Atom: The history of nuclear energy and society in Europe from the 1950s to the present* (Morgantown: West Verginia University Press, 2021), 52-83; Lifset, 'Nuclear Power in America: the Story of a Failed Energy Transition,' 527-528.

the divestment of their nuclear projects for the oil companies during the 1980s was mostly due to a correction of nuclear forecasts in light of economic reality – in hindsight the forecasts always were unrealistic according to these historians.[431] In part, this chapter agrees with this focus on the economics of nuclear energy projects. However, as this dissertation also shows, the 1980s were not simply a correction to an economic reality. It was a deliberate choice, although prompted by market developments (sometimes incited by state polices that transferred more power to shareholders), to refocus the strategies within various oil companies from long-term diversification projects to short-term profits to increase shareholder value. And that choice, I argue, was made more likely by the ascendance of a new generation of oil managers trained in finance rather than science and engineering.

"Nuclear Energy: What Went Wrong?"

Bogged down nuclear developments

In 1979, professor of management and former General Manager of the AEC, Carroll Wilson, wrote an elaborative commentary in the *Bulletin of Atomic Scientists* called "Nuclear Energy: What Went Wrong?" As one of the first chairmen of the American AEC, Wilson recollected how a commission led by Oppenheimer had estimated in 1948 that by 1968 half of the new power plants ordered could be nuclear, given sufficient investments and "quite a bit of luck along the way."[432] Surprisingly much of this prediction had come true. Governments invested billions, industry entered the nuclear business, and in 1968 about half of the new electric power plants in the United States ordered that year were nuclear. However, nuclear energy had not fulfilled the promise to continue this remarkable growth, Wilson concluded. In the second half of the 1970s, the increase of new orders in the US had halted. Where in 1973 utility companies ordered forty-one new reactors, two years later there were only four annual orders. Between 1978 and 1982, zero new reactors would be ordered, while an increasing number of orders were cancelled.[433]

Outside the US the number of orders for nuclear reactors also declined. US reactor exports dropped from twenty-seven between 1971 and 1974 to only ten in the 1975-1981 period, with zero reactor orders in 1980 and 1981.[434] Although this fall in exports is partly explained by the internationalization of the nuclear industry, with new domestic reactor manufacturers emerging outside the United States, also in various Western European countries nuclear projects were increasingly postponed or cancelled. In the Netherlands, plans for two to four new nuclear reactors that were proposed at the beginning of the 1970s by succeeding governments were postponed in 1977 and would eventually be abandoned completely.[435] Similar developments took place in other European countries, with France and some Central and Eastern European countries as exceptions, with the discontinuation of the building of a nuclear reactor at Wyhl, Germany, after increasing protest of local citizens and farmers in 1975. In Austria, Italy, Denmark, and Portugal governments changed their energy policies to no longer include

[431] Pratt and Hale, *Exxon*, 188.
[432] Carroll L. Wilson, 'Nuclear Energy: What Went Wrong?,' *Bulletin of Atomic Scientists* (June 1979), 13.
[433] Wilson, 'Nuclear Energy: What Went Wrong?,' 13-16; Hertsgaard, N*uclear Inc*, 288.
[434] Hertsgaard, N*uclear Inc*, 290.
[435] Also, later in the 1980s various nuclear projects, like the German-Dutch-Belgian breeder reactor at Kalkar, were decommissioned, and research projects like the suspension test reactor in Arnhem, were abandoned. Andriesse, *De Republiek der Kerngeleerden*.

nuclear power, while Sweden decided to phase out nuclear power and Spain temporarily halted their nuclear programs.[436]

Within this context, industrial parties also divested their nuclear projects and other diversification investments. During the 1970s, especially the large multinationals had benefited from the high oil prices which had funded their diversification efforts. In the early 1980s, however, declining oil prices meant much thinner profit margins and an end to diversification. In 1983, for instance, Exxon terminated its horizontal growth strategy and moved away from all nonoil business, except coal/ In addition to shuttering their uranium mining projects, Exxon also sold their uranium enrichment facilities to the German company Kraftwerk Union (part of the Siemens Company) in 1987, before completely dismantling their subsidiary Exxon Nuclear.[437] A couple of years earlier, Gulf Oil had to tried to divest their investments in General Atomic after their forced merger with Chevron in 1984.[438] At that time, Shell had already scaled down their share in the joint venture with Gulf (although Shell stayed in a joined venture, called Valley Pines Associates charged with the obligation to clean up the environmental pollution surrounding the high enriched nuclear fuel fabrication facility located in San Diego and used for the benefit of the demonstration HTGR at Fort St. Vrain).[439]

Even companies that previously had established themselves as nuclear-oil companies with big capital investments in nuclear energy relative to oil investments divested their nuclear projects during the 1980s and early 1990s. During the 1970s and early 1980s, although Kerr-McGee benefitted less from the increased oil prices compared to other companies, the company had still decided to further concentrate on its already existing investments in nuclear energy. This changed, however, during the 1980s, when the company started to refocus on oil production and divested many of their uranium mining projects and other activities in the nuclear fuel cycle that had been part of the company since the 1950s.[440] Also Phillips Petroleum, which had a strong tradition in uranium mining projects and in the beginning of the 1980s also joined the nuclear fusion research projects of General Atomic, sold many of its shale oil, coal, and uranium assets after 1984.[441]

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The disenchantment with nuclear power

A decade later, H. Eugene McBrayer (chemical engineer and former CEO of Exxon) reflected on Exxon's diversification endeavors into nuclear energy during the 1970s. With the accident at Three Mile Island,

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[436] Mans Lönnroth and William Walker, *The viability of the civil nuclear industry* (London: The Rockefeller Foundation, 1979), Robert O. Pohl Papers (Ithaca: Cornell University, Rare and Manuscript Collections), box 3, folder 8; Arne Kaijser, Markku Lehtonen, Jan-Henrik Meyer, and Mar Rubio-Varas (eds), *Engaging the Atom: The history of nuclear energy and society in Europe from the 1950s to the present* (Morgantown: West Verginia University Press, 2021), 3-4.
[437] 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' Oral History Transcript #0144 (Philadelphia: The Chemical Heritage Foundation, Science History Institute, 11 May 1995), 20; Ollinger, *Organizational Form and Business Strategy in the US Petroleum Industry*, 92-93.
[438] Bill Ritter, 'Denver Firm to Pay More than $50 Million: Energy Company to Buy GA Technologies,' *Los Angelas Times* (August 14, 1986).
[439] Royal Dutch Shell, *Royal Dutch Shell Annual Report 1979* (The Hague: Royal Dutch Shell 1980), 18; Nuclear Regulatory Commission, 'General Atomic Technology Corp seeks consent of the NRC to transfer control of General Atomic,' (May 7, 1986), retrieved via: https://www.nrc.gov/docs/ML0303/ML030300494.pdf (Accessed August 26, 2024).
[440] Ollinger, *Organizational Form and Business Strategy in the US Petroleum Industry*, 94.
[441] Ibidem, 95.

he stated, "along came the great slippage, the disenchantment with nuclear power."[442] This disenchantment, and the following slowing down and stopping of nuclear power plant construction, was mostly due to growing anti-nuclear activist movement, at least according to involved industrialists. John D. McCloy in a letter to the president of Atomic Energy of Canada Limited, James Donnelly, explained that nuclear projects faced extreme opposition "by environmentalist groups and local governments reflecting a mixture of genuine concern and political opportunism and inability of government regulators to cut through this morass with prompt corrective decisions."[443]

Various oil companies presented environmental verdicts as reasons to halt new investments and divest existing projects. Specifically, the environmental problems caused by radioactive waste often returned in the arguments posed by nuclear actors. In the case of Kerr-McGee, in 1987 the company faced multiple court and administrative proceedings that related to the its thorium ore processing facility in West Chicago (already closed in 1973). These proceedings, which investigated methods for decommissioning the facility but foremost the liability of Kerr-McGee for the management of the waste produced at the plant and its environmental impact, led the company to divest the plant sites, and was one of the most important reasons to halt further investments in nuclear energy according to its board.[444] Also Carroll Wilson, in his 1979 reflection on the demise of the nuclear industry, referred to the increasing societal problems associated with the environmental impact of radioactive waste. In his commentary, Wilson focused on the technological problems encountered when looking for an answer for how to deal with the radioactive waste produced by nuclear plants and decommissioned reactors. According to Wilson there had been "no interest on the part of chemists or chemical engineers in dealing with waste. It was unglamorous, there were no careers, it was messy, nobody got brownie for doing things about nuclear waste."[445]

Oil actors also presented the increasing resistance from the labor movement as an argument for divesting their nuclear projects, taking an even harder stance than was common for oil firms in the 1950s and 1960s. The reactions to the lawsuits following the infamous, and very controversial, story of the Texan-born Karen Gay Silkwood illustrate well the hard stance toward unions by the management of Kerr-McGee. Silkwood, a metallographic laboratory technician, worked at Kerr-McGee's Cimarron River plutonium plant in the early 1970s. There, she joined the union of Oil, Chemical and Atomic Workers (OCAW), becoming the first female member of the bargaining committee, and had participated in the protracted strike of the plant. Also, she conducted research and reported on spills, leaks, and missing plutonium, before testifying for the AEC that she had been overly exposed to radiation in at least three unusual moments. On November 13, 1974, when she was on her way to meet an AEC official and a reporter for the *New York Times*, she died in an automobile crash. Her death became the subject of a long-lasting legal battle between Kerr-McGee and OCAW.[446] When the verdict in a 1979 court case by the OCAW against Kerr-McGee, shortly after the Three Mile Island accident, determined that the company had to pay a $10.5 million award to the Silkwood estate, industry spokesmen contended before *New York Times*-reporters that if the verdict survived in an

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[442] 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' Oral History Transcript #0144 (Philadelphia: The Chemical Heritage Foundation, Science History Institute, 11 May 1995), 20.
[443] John J. McCloy, 'Letter to James Donnelly' (August 19, 1983), John J. McCloy Papers (Amherst: College Archives and Manuscript Collections), box 48, folder 63.
[444] Kerr-McGee, *Kerr-McGee Annual Report 1987* (Kerr-McGee Corporation, 1988), 39.
[445] Wilson, 'Nuclear Energy,' 14-15.
[446] Melosi, *Atomic Age America*, 248-249.

expected appeal, it "could lead to power shortages, higher utility rates, higher uranium prices, or higher insurance costs for companies which handle plutonium."[447]

These insurance costs, and potential legal liability, would become a recurring feature in the statements of oil actors from the end of the 1970s onward. On March 21, 1983, chemical engineer Robert P. Luke of Kerr-McGee Nuclear Corporation contemplated the development of the nuclear industry. In a lecture to the Atomic Industrial Forum, he argued that the US nuclear industry was at a crossroads. Over previous decades, two major phases had occurred in the relationship between state and private industry. In the first phase, the government collaborated closely with companies to jointly build a nuclear industry. Beginning in the early 1970s, however, this relationship had increasingly turned around with new regulations on the environment, safety, and liability. According to him companies were increasingly taxed. 1983 therefore was a tipping point: the government had to become more involved in the nuclear sector again and assume a share of the liability.[448]

The question of liability had always been a critical issue for industrial parties involved in the nuclear business. From the outset, it had been clear that the enormity of the risks involved in commercial nuclear energy development could not be covered without liability insurance. In both the US and Western Europe, the emergence of civil nuclear power therefore bolstered the establishment of a nuclear insurance industry that defined the risks and corresponding costs. In the United States, the Senate, already in 1954, made several amendments to the Atomic Energy Act to encourage private investments in the nuclear market, most famously the Price-Anderson Indemnity Amendments. These amendments secured a two-tiered liability protection system of $60 million in private insurance and $500 million in governmental safeguards, and extended compensation to all parties in an accident, regardless of their role in its occurrence. Private industry at the time, including oil firms, endorsed this regulation.[449] In Western European countries private companies often bore even less liability during the 1950s due to heavy state involvement.[450]

In later years, changes to the legislation surrounding the development of nuclear power in the United States were limited to the provisions offered by the Price-Anderson framework for privatizing the development of nuclear power. This included the creation of the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Agency (ERDA), and often had the goal to rationalize the administration of governmental responsibilities and increase the predictability of the costs of potential liabilities in making investment decisions. After the incident at Three Mile Island, the discussion about liability within the nuclear industry took on a new dimension, however. Pressured by increasing public resistance, several subsidies for nuclear projects were discontinued and new legislation was instituted that increased the liability, and the costs, for private companies involved in nuclear energy in various

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[447] Winston Williams, 'Industry Fears Decision Could Slow Nuclear Power,' *The New York Times* (May 19, 1979).
[448] Robert P. Luke, 'US Uranium – A Focus on the Future' (March 21, 1983), Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 233, folder 7.
[449] Gerald Turkel and William S. Lofquist, 'Privatizing Nuclear Power and the Price-Anderson Act: Establishing Limits to Liability,' *Studies in Law, Politics, and Society* 11 (1991), 143-169.
[450] R.H. Lange, 'The Insurance Industry Enters the Atomic Era,' *The Review* (November 2, 1956), 1071-1074; Lorraine Daston, 'What is an insurable risk? Swiss Re and Atomic reactor insurance,' Niels Viggo Haueter and Geoffrey Jones (eds), *Managing Risk in Reinsurance: From City Fires to Global Warming* (Oxford: Oxford University Press, 2017), 230-232; Alexandros-Andreas Kyrtsis and Maria Rentetzi, 'From lobbyists to backstage diplomats: how insurers in the field of third party liability shaped nuclear diplomacy,' *History and Technology* 37, 1 (2021), 25-43; D. Gugerli, 'Cooperation and Competition: Organization and Risks in the Reinsurance Business 1860-2010,' H. James (eds), *The Value of Risk* (Oxford: Oxford University Press, 2013), 147-233.

countries.[451] Also, the insurance companies in the US and Western Europe were less inclined to provide insurance for new nuclear projects or increased their insurance costs.[452]

The increasing costs for insurance also returned in the forecasts the oil companies made for their nuclear investments. In his 1995 interview McBrayer explicitly stated that "when the outlook slipped, we decided to sell that business."[453] Various historians have also focused on the new outlooks to explain the end of nuclear diversification by oil companies like Exxon. In the early 1980s, Exxon started to reevaluate its long-term commitment to nuclear energy. With this decision, according to business historians Joseph Pratt and William Hale, the management of Exxon corrected the "false expectations about the growth of nuclear power" that had "plagued" Exxon Nuclear from the 1960s to through the early 1980s.[454] According to the business historians, the company's planners projected a "rosy view of the economics of nuclear construction" by overestimating demand for nuclear power, while underestimating the effects of political and environmental risks and the impact of the double-digit inflation flowing the 1979 oil crisis concluding even as late as 1981 that nuclear power remained economically viable.[455]

Divesting profitable projects

The reasons provided by the oil actors to divest their nuclear projects only *became* reasons from the end of the 1970s onward, even though their existence was known long before and had been priced into the industry's earlier "rosy" forecasts. The question of how to deal with nuclear waste, for one, had already been on the mind of actors involved with nuclear energy in the preceding decades.[456] Also

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[451] For example, the 1982 Nuclear Waste Policy Act in the US established that the "generators and owners of high-level radioactive waste and spent nuclear fuel have the primary responsibility to provide for, and the responsibility to pay the costs of, the interim storage of such waste and spent fuel until such waste and spent fuel is accepted by the Secretary of Energy in accordance with the provisions of this Act". Nuclear Waste Policy Act of 1982, 42 USC. 10101 §§ 111 (2004), https://www.energy.gov/articles/nuclear-waste-policy-act; Barry P. Brownstein, 'The Price-Anderson Act: Is It Consistent with a Sound Energy Policy,' *Cato Institute Policy Analysis* 36 (1984); Herman Kahn, *The Coming Boom* (Washington: Simon and Schuster, 1982), 131; Eugene A. Rosa and William R. Freudenburg, 'The historical development of public reactions to nuclear power: implications for Nuclear Waste Policy,' Riley E. Dunlap, Michael E. Kraft, and Eugene A. Rosa (eds), *Public Reactions to Nuclear Waste: Citizens' Views of Repository Siting* (Durham: Duke University Press, 1993), 32-63.

[452] J.V. Rees, *Hostages of Each Other: The Transformation of Nuclear Safety since Three Mile Island* (Chicago: University of Chicago Press, 1994), 93-94.

[453] 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' Oral History Transcript #0144 (Philadelphia: The Chemical Heritage Foundation, Science History Institute, 11 May 1995), 19-20.

[454] Pratt and Hale, *Exxon*, 188.

[455] John Samuel Walker, *Three Mile Island: A Nuclear Crisis in Historical Perspective* (University of California Press, 2004), 7-17; Pratt and Hale, *Exxon*, 188.

[456] In fact, in the years before many oil actors had thought about this problem. Even beside oil companies like Shell, Gulf Oil and Kerr-McGee, investing in reprocessing plants, also long-term disposal had been on the radar. Marion King Hubbert, then still employed by Shell Oil, served as part of a panel already between 1955 and 1965, examining ways to store nuclear waste for over multiple centuries, while the Continental Oil Company experimented with injecting radioactive fluids in fractures. Also, the US Environmental Protection Agency had published several reports on considerations of environmental protection criteria for radioactive waste and had organized multiple public forums to gather information. Oil representatives, like Samuel Bard for Exxon Nuclear, also served in the Nuclear Waste Management Technical Advisory Group. 'Memorandum on the report of Committee on Radioactive Waste Management' (April 20, 1981), Marion King Hubbert Papers (Laramy, Wyoming: American Heritage Centre), box 48, folder D; D.A. Shock, 'Letter to H.H. Hess' (June 3, 1958), Marion

environmental protests and actions by labor unions had not been reasons to divest before. To the contrary, previous chapters showed how oil actors framed nuclear innovations as "environmentally friendly" answers to multiple environmental problems. Regarding labor unions, as chapter 3 discussed the oil industry already had a long tradition of fighting off strikes, and the power of labor unions actually declined rapidly during throughout the 1980s.[457] Still, various oil companies decided to divest in multiple large-scale nuclear projects.

Although liability indeed increasingly became an issue, the oil companies had always been aware that their nuclear investments would be expensive compared to their oil projects. Their 1971 long-range corporate forecast expected the expenditures for Gulf Oil's investments in nuclear fuels and minerals to increase "dramatically" from $30 million per year in the 1968-1971 period to $104 million per year in the 1975-1979 period. These projected costs made the company's nuclear fuel investments close to ten percent of its total capital expenditures.[458] Also regarding many of the investments in more experimental nuclear research projects, including nuclear fusion, the involved oil companies had always made explicit that the first twenty to thirty years would not deliver any return on investments.[459]

During the 1980s, with a few exceptions, many of the nuclear projects run by oil companies continued to be profitable, even after accounting for increasing costs for environmental and health protection and insurance.[460] More than fifteen years later, McBrayer pointed out that Exxon Nuclear's enrichment program had developed "good technology" and that Siemens still successfully operated their former fuel fabrication plants using Exxon's technology and people: "I still run across the people whom I helped recruit into that organization, who are still involved with Siemens. The young man who is running Siemens Power in the United States today is one of the young fellows I brought into that organization twenty years ago."[461]

King Hubbert Papers (Laramy, Wyoming: American Heritage Centre), box 161, folder A; US Environmental Protection Agency, *Considerations of Environmental Protection Criteria for Radioactive Waste* (Washington D.C., 1978), Robert O. Pohl Papers (Ithaca: Cornell University, Rare and Manuscript Collections), box 1, folder 14; Interagency Review Group on Nuclear Waste Management, *Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste* (1978), 1, Farouk El-Baz papers (Washington D.C.: National Museum of American History Archives Center), box 36, folder B.

457 Mizruchi, *The Fracturing of the American Corporate Elite*, 187-191.

458 'Gulf Oil Corporation – 1971 long range corporate forecast' (1971), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box 7, folder 6.

459 'Fusion: as old as the sun; as new as tomorrow,' *Exxon Manhattan* (July 23, 1976), 2-3, ExxonMobil Historical Collection (Austin: Dolph Briscoe Center for American History), box 2.207/K96B.

460 The HTGR test reactor at Fort Saint Vrain had significant budget overruns and technological problems. Already in 1974, six utility companies canceled their reactors at General Atomic, and in 1975 the decision was made to withdraw from four more supply contracts. When the joint venture with Allied Chemicals for reprocessing also ended following the termination of government subsidies for reprocessing on Carter, and partner Gulf Oil became embroiled in a series of lawsuits after participating in an international uranium cartel, Shell exited almost all of General Atomic Company's operations at a loss of five hundred million dollars. Royal Dutch Shell, *Royal Dutch Shell: Annual Report 1979* (The Hague: Royal Dutch Shell, 1980), 18; Sluyterman, *Concurreren in turbulente markten*, 106-109; Bron, 'The Uranium Club,' 69-73.

461 'H. Eugene McBrayer: transcript of an interview conducted by James J. Bohning at Mercer Island, Washington,' Oral History Transcript #0144 (Philadelphia: The Chemical Heritage Foundation, Science History Institute, 11 May 1995), 20. Also business historians Joseph Pratt and William Hale state that Exxon Nuclear at the beginning of the 1980s just started to become profitable. Pratt and Hale, *Exxon*, 189.

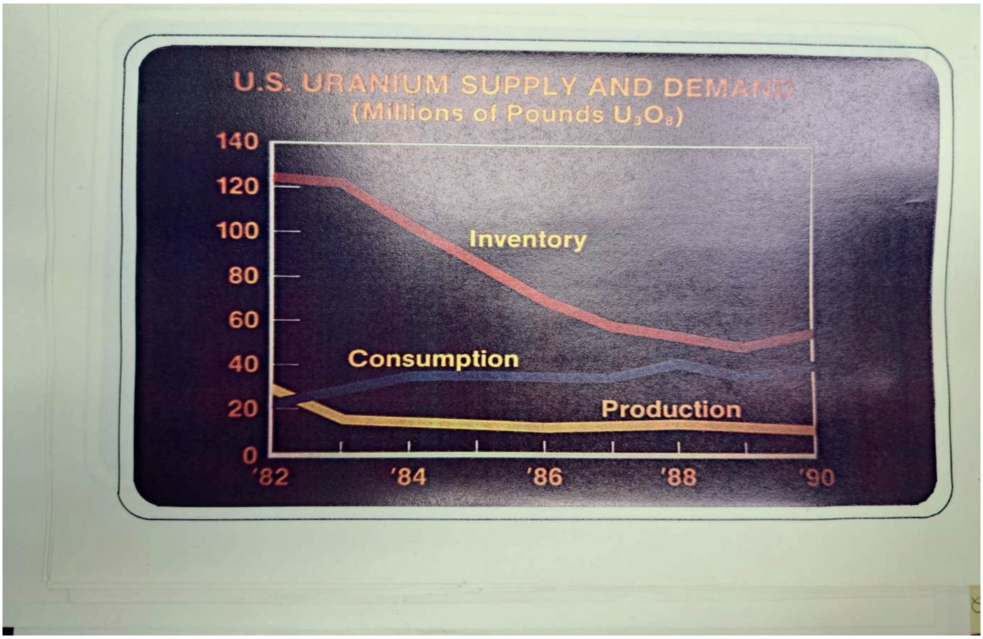

Figure 24: Predictions for future US uranium production and consumption from Kerr-McGee. 'Remarks by F.A. McPherson' (April 24, 1984). Kerr-McGee Corporation. Oklahoma Historical Society, Box 8, folder 1.

Within the uranium industry, there were still future profits to be made too. In a 1984 presentation for the board of Kerr-McGee, the planning committee presented a projection for the future development of US uranium supply and demand. As figure 23 shows, consumption still outgrew production with the US strategic reserve making up for the deficit. This development suggested future price increases, and therefore a continuing possibility for current investors to make profits out of uranium mining projects which actually would be better than in the 1970s, when worldwide production of uranium had vastly outpaced uranium requirements.[462] These projections actually ended up quite closely resembling the actual developments during the 1980s and 1990s. As figure 24 shows, even worldwide requirements for uranium outgrew production of the resource, creating a market where the various remaining producers would have the opportunity to increase their prices. Also, according to a 1981 report by the consultancy branch of investment bank Morgan Stanley, hired by Kerr-McGee, nuclear investments for the company would still be profitable over the 1981-1984 period.[463]

Still, the nuclear industry did experience increasing problems with remaining profitable in the short-term. In a 1979 working paper issued by the Rockefeller Foundation, Mans Lönnroth and William Walker identified a structural issue in the concept of the nuclear fuel cycle. Because most nuclear reactors in the West ran on enriched uranium as a fuel, investments in the nuclear fuel cycle would always depend on new reactor orders. If these orders were cancelled and no new orders made, which

[462] 'Remarks by F.A. McPherson' (April 24, 1984), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 8, folder 1.

[463] Morgan Stanley, *Purchase Recommendation: Kerr-McGee* (1981), Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 251.

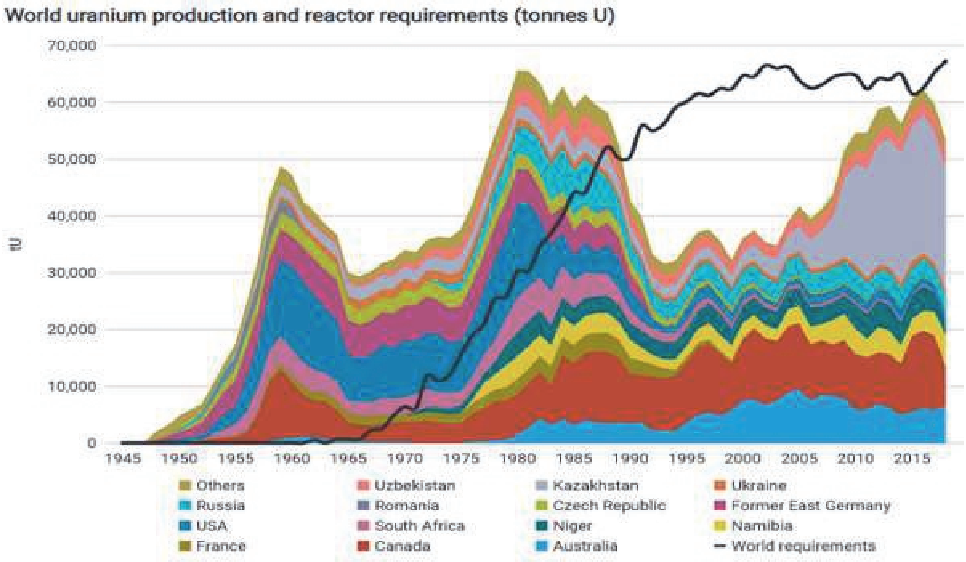

Figure 25: World uranium production and reactor requirements (tonnes U). World Nuclear Association, 'World Uranium Mining Production' (December 2020), https://www.world-nuclear.org/information-library/Nuclear-Fuel-Cycle/Mining-of-Uranium/World-Uranium-Mining-Production.aspx (Accessed 23 July 2021).

happened at the end of the 1970s, also new investments in uranium mining, conversion and enrichment would be endangered in the short-term.[464] Military applications were a notable exception where companies could still use some of their nuclear projects to make profits. Kerr-McGee for example, used their uranium conversion plants to make uranium hexafluoride for the US military and to produce depleted uranium for the manufacture of conventional weapons (armor piercing tank shells for example), in this way ensuring the profitability of their nuclear projects.[465]

Long-term vs. short-term

Oil over nuclear

In the week that the Federal Trade Commission gave its final approval to Chevron's $13.3 billion acquisition of Gulf Oil in 1985, Standard Oil of Indiana asked its shareholders to approve a list of options to repel hostile takeovers and presented its plans to divest their mining subsidiaries. Texaco also announced the closing of another large refinery, and Exxon continued to artificially increase their stock prices by buying the shares of their company on the open market. As New York Times reporter Winston Williams remarked "from high-rise corporate headquarters to the massive rigs that dot the Gulf of Mexico, it is clear that a shakeout is in full force in the oil industry… Concentrating on what they know

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[464] Mans Lönnroth and William Walker, *The viability of the civil nuclear industry* (London: The Rockefeller Foundation, 1979), Robert O. Pohl Papers (Ithaca: Cornell University, Rare and Manuscript Collections), box 3, folder 8.

[465] Morgan Stanley, *Purchase Recommendation: Kerr-McGee* (1981), 14, Dean McGee Papers (Lawerence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 251; 'Board of Directors Meeting Minutes, 1985,' (May 7, 1985), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 9, folder 4.

best, they are selling off non-oil subsidiaries that increases their dependency on weak and uncertain core petroleum business."[466]

In a period where the investments in nuclear energy became less profitable, and scenarios for future nuclear developments became more uncertain, various oil companies decided to refocus more on production of oil. Like Francois Xavier-Ortoli concluded in 1986 at Total, also for other companies it became increasingly clear that petroleum products, especially compared to other energy sources, would become more competitive in the short-term. Off-shore exploration and extraction projects, especially in the North-Sea, proved increasingly profitable. Several companies that had previously focused on the nuclear industry, like Norsk Hydro, now turned toward the oil industry to drill for oil off-shore.[467] Also, the development of new technologies in fracking to produce natural gas from shale rocks, most notably by the Texan company Mitchell Energy and Development, opened up new profitable ways for extracting oil and gas.[468] Put in more simple terms: oil companies could more easily make profits with projects in coal, fracking and off-shore drilling with a higher return on investments within the short-term than with projects in nuclear energy.

With this shift, oil companies increasingly preferred the short-term higher profitability of oil investments over the long-term return on investments in highly uncertain nuclear projects. The increasing importance, and use, of evaluations of the financial short-term prospects of various investments within the oil industry conducted by big consultancy firms reinforced this shift. Companies such as Gulf Oil and Kerr-McGee hired these firms to report on financial management and get advice on which projects were most profitable.[469] Although Morgan Stanley noted that the Kerr-McGee's investments in the nuclear business were still profitable and had the chance to increase again for the 1981-1984 period, the consultancy firm concluded that, based on an extensive review of all the investment projects of the oil company, the expected growth for Kerr-McGee was mainly located in the increase in domestic oil production, the rise of natural gas output, and the company's first North Sea production.[470]

The consultancy firm, which explicitly only focused on a three-year period, made clear that with this brief period domestic oil production would probably increase by ten percent in 1981, accompanied by higher prices as a result of new decontrol regulations. Also, natural gas output could rise by fifteen percent per year, even without any modifications to existing regulations. The firm concluded that "in view of the fact that average domestic natural gas prices are at around 32% of parity to crude realizations, it is worth noting that Kerr-McGee's current domestic output is two-thirds weighted toward gas on an energy equivalent basis. Substantially higher production at rising prices should propel domestic upstream net income from an estimated $60 million in 1980 to $125 million in 1984."[471]

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[466] Winston Williams, 'Big Oil Starts Thinking Smaller,' *The New York Times* (March 17, 1985).

[467] Helge Ryggvik, 'A Short History of the Norwegian Oil Industry: From Protected National Champions to Internationally Competitive Multinationals,' *Business History Review* 89 (2015), 8-10.

[468] Dian Davids Hinton, 'The Seventeen-Year Overnight Wonder: George Mitchell and Unlocking the Barnett Shale,' *Journal of American History* 99, 1 (2012), 229-235.

[469] E.g. 'Financial analysis of a group of petroleum companies' (1982), Gulf Oil Corporation Records (Pittsburgh: Heinz History Center - Detre Library and Archives), box C, folder 35.

[470] Morgan Stanley, *Purchase Recommendation: Kerr-McGee* (1981), 1-2, Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 251.

[471] Morgan Stanley, *Purchase Recommendation: Kerr-McGee* (1981), 1, Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 251.

The rather moderate profits of Kerr-McGee's nuclear projects contrasted with these prospects. According to Morgan Stanley, the "dramatic slowdown that occurred in bringing nuclear plants onstream and the virtual halt in new orders has caused the Company to suspend operations at two of its eight operating mines in New Mexico and to reduce output at two open-pit mines in the South Powder River Basin, Wyoming, to minimum levels until at least 1982." Due to its business in producing depleted uranium and uranium hexafluoride for military purposes, the nuclear operations remained "modestly profitable", the consultancy firm stated, but future increases in profits would have to wait until at least the second half of the decade.[472]

The revenge of the market

The shift from long-term nuclear developments to the higher return in investments on oil projects happened within a wider context of growing uncertainty within the oil industry. After a period of rapidly increasing oil prices with the first oil crisis in 1973/74 and a second crisis in 1979, the role and scale of oil companies, especially the large multinationals, had changed drastically. On the one hand, increasing oil prices meant that oil company profits skyrocketed, while on the other hand the sums expended on off shore drilling projects and oil extraction in previously unprofitable areas had vastly increased the scale of their investments.[473] Even more expensive were the new liquified gas (LNG) schemes, like supplying gas from off-shore Australia to Japan, which various companies now operated. Billions of American dollars had to be committed in the many phases of the project, ranging from the new pipeline systems and liquification plants to the dedicated tankers and receiving terminals. Also in more conventional projects, like the petroleum refining industry, costs escalated.[474]

Also, a new development of static or even declining demand in major oil markets emerged. Planners within the oil industry increasingly admitted the difficulties with making long-term demand forecasts given the rapidly changing prices and preceding oil shocks. There were various predictions that in markets like the United Kingdom oil demand in the year 2000 would not be higher than in 1987. Former Shell executive T.D. Ross claimed in 1987 that "only in the developing world is there a firm prediction of growing oil demand if economic growth is to be achieved, but that, too, is conditional on the assumption that these countries can actually afford the import costs that will be involved. If, for a generation you have lived within the phenomenon of 5-10 percent demand growth, regarding it almost as a fact of nature, and your programs, systems, personnel procedures and culture are geared thereto, to go into reverse is somewhat of a shock."[475]

At the same time, the oil market that the industry operated in changed considerably. At a meeting called for by the French Society of Financial Analysists in 1986, Total-CFP's Francois Xavier-Ortoli reflected on the changing environment oil companies had to operate in for the coming year. The oil industry, he claimed, had long struggled with overly regulating governments, making it difficult to increase profits and make the right business decisions. Now, in the mid-1980s, however, this had

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[472] Morgan Stanley, *Purchase Recommendation: Kerr-McGee* (1981), 14, Dean McGee Papers (Lawrence, Kansas: University of Kansas – Kenneth Spencer Research Library), box 251.
[473] Tyler Priest, *The Offshore Imperative: Shell Oil's Search for Petroleum in Postwar America* (Texas A&M Press, 2007); T.D. Ross, 'The Status and Strategies of the International Oil Corporations,' Judith Rees and Peter Odell (eds), *The International Oil Industry: An Interdisciplinary Perspective* (New York: Palgrave Macmillan, 1987), 68.
[474] Ross, 'The Status and Strategies of the International Oil Corporations,' 68.
[475] Ross, 'The Status and Strategies of the International Oil Corporations,' 69.

changed. In a section, ominously called "the revenge of the market," Ortoli claimed that "after being cornered for a long time by governmental or intergovernmental interventions, especially on prices, the market has retaliated in recent months. Downstream, administrative price controls have been abolished almost everywhere, especially in France, and trade barriers (especially for petroleum product imports) have been considerably relaxed."[476]

Also, the United States increasingly deregulated oil prices from the mid-1970s to the early 1980s.[477] By liberalizing the pricing of petroleum and the increasing volatility of the price of international oil, new market mechanisms like futures trading and spot markets brought a "sensational increase of trading" to the oil market. This development benefited Western oil companies, providing the opportunity for companies, cut off from the equity oil of their concessions, to operate as buyers on the market. To be better equipped to react to very short-term market flexibility, many oil companies started a process called 'de-integration' that emphasized the autonomy and profitability of the downstream sector.[478] This new way of working, however, was less applicable to the nuclear fuel cycle where the market was less volatile and long-term contracts were dominant.

The high returns on investment in oil production, in combination with the high capital investments and uncertainty about long-term future energy developments, increasingly encouraged oil managers to prefer investments that would provide a higher return on investments in the short-term. The growing importance of increasing a company's stock value also encouraged these decisions. Many of the highly diversified companies, also called conglomerates, had often been undervalued on the stock market during the 1970s and early 1980s, leading to increasingly critical voices.[479] According to business historian Mark Mizruchi this vulnerability became apparent for many of the US based companies when the Reagan administration issued a new set of guidelines that reduced the restrictions against

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[476] Translation from French by author: "Longtemps corseté par des interventions gouvernementales ou intergouvernementales concernant en particulier les prix, le marché a pris sa revanche au cours de ces derniers mois. C'est ainsi qu'en aval, les contrôles administratifs des prix ont été supprimé un peu partout, et notamment en France, de même que les entraves aux échanges (en particulier sur les importations de produits pétroliers) étaient sensiblement desserrées". 'Réunion d'information avec les analystes financier,' 2, Francois-Xavier Ortoli Papers (Florence: EUI - Historical Archives of the European Union), folder 139.

[477] Michael Ollinger, 'The limits of growth of the multidivisional firm: a case study of the US oil industry from 1930-90,' *Strategic Management Journal* 15 (1994), 515; Francesco Petrini, 'Counter-Shocked? The Oil Majors and the Price Slump of the 1980s,' Duccio Basosi, Giuliano Garavini and Massimiliano Trentin (eds), *Counter-Shock: The Oil Counter-Revolution of the 1980s* (London: I.B. Tauris, 2018), 85.

[478] Caleb Wellum, 'Energizing Finance: The Energy Crisis, Oil Futures, and Neoliberal Narratives,' *Enterprise & Society* 21, 1, (2020); Petrini, 'Counter-Shocked? The Oil Majors and the Price Slump of the 1980s,' 84-88; Ross, 'The Status and Strategies of the International Oil Corporations,' 68.

[479] The median Fortune 500 company was typically active in three separate industry categories, all being undervalued. Gerald F. Davis, *Managed by Markets: How Finance Re-Shaped America* (New York: Oxford University Press, 2009), 84; Mizruchi, *The Fracturing of the American Corporate Elite*, 208. Reinforced by the second oil crisis of 1979, especially newspapers with a strong focus on economics started running several stories on the failure of the way corporate planning was conducted within the industry. In a 1981 series, *Fortune* made fun of the strategists at different, especially oil, companies with article titles like 'The Decline of the Experience Curve', 'Oh where, Oh Where Has My Little Dog Gone…', and 'Corporate Strategists Under Fire'. *Business Week* even ran a cover story expressing the idea that "the notion that an effective strategy can be constructed by someone in an ivory tower is totally bankrupt". Walter Kiechel III, 'New Management Strategies,' *Fortune* (5 and 19 October; 2 and 16 November 1981); 'The New Breed of Strategic Planner: Number Crunching Professionals Are Giving Way to Line Managers,' *Business Week* (17 September 1984), 62; Grayson, *Who and How in Planning for Large Companies*, 2.

horizontal and vertical mergers.[480] Also, the Federal Trade Commission appeared less willing to intervene in antitrust cases.[481] Together with new court rulings that abolished various laws regulating tender offers as unconstitutional, these developments set the stage for a takeover wave that disrupted the business landscape in the US during the 1980s and peaked between 1984 and 1989.[482]

Within this takeover wave, shareholders quickly recognized that they could buy up highly diversified companies to then divide them into parts and sell off the individual parts for more money than the total value of the combined firm.[483] This in part happened to Gulf Oil, which was one of the most diversified companies among the US oil majors, and which had to sell its nuclear subsidiaries (including General Atomic) after a hostile takeover by Chevron.[484] Given that the degree of diversification largely determined the risk for a hostile takeover, the managers of the various US based oil companies increasingly felt the need to refocus the investment strategies from long-term, higher risk, investments in projects like nuclear energy to higher return investments in short-term oil production with less risk involved.

Especially when after 1985 oil prices dropped again and oil companies had less cash available, oil companies "temporarily" abandoned their long-term diversification strategies. This also included their nuclear investments. Although managers and planners such as T.D. Ross from Shell stressed that the diversification remained the long-term agenda of the majors, many oil companies backed away from their diversification projects.[485]

Farewell to Fusion Research

For many companies, the refocus onto oil also meant the end of their support for experimental nuclear research projects. Although there never had been any expectation for that research to become profitable within the short-term, industrial support for nuclear fusion developments dwindled from the mid-1980s onward. Exxon Nuclear, for instance, had been involved since the 1970s with a new fusion research project at Princeton. Scientists from Exxon regularly joined project meetings and

[480] Mizruchi, *The Fracturing of the American Corporate Elite*, 208-209.
[481] Linda Brewster Stearns and Kenneth D. Allan, 'Economic Behavior in Institutional Environments: The Corporate Merger Wave of the 1980s,' *American Sociological Review* 61 (1996), 705; Mizruchi, *The Fracturing of the American Corporate Elite*, 209.
[482] Between 1980 and 1990, 28 percent of Fortune 500 companies received tender offers from outsiders, more than two-third hostile, and in 1990 one-third of the Fortune 500 was no longer an independent entity. Davis, *Managed by Markets: How Finance Re-Shaped America*, 84-85; Mizruchi, *The Fracturing of the American Corporate Elite*, 209-210.
[483] Mizruchi, *The Fracturing of the American Corporate Elite*, 209-210.
[484] Ritter, 'Denver Firm to Pay More than $50 Million'.
[485] Ross, 'The Status and Strategies of the International Oil Corporations,' 73.

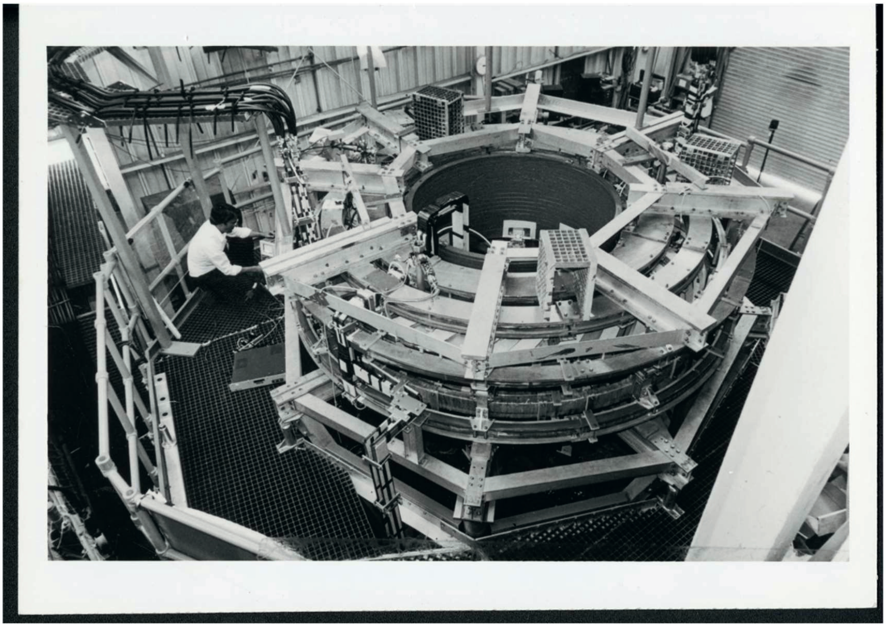

Figure 26: "The OHTE reactor concept in San Diego, California, a comparatively small and less expensive fusion concept, may put a major company in the forefront of a new energy age," (1985). Phillips Petroleum Co., Shield *4 (1983); American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History), Box 42, folder 45.*

participated in the research.[486] In 1977, Exxon even enlisted Robert Lewis Hirsch as executive. Hirsch, who was the former director of the US fusion program and assistant administrator of the US Energy Research and Development Administration, had been responsible for the long-term strategy of US fusion research.[487] However, although the three big reactor projects would come into operation at the beginning of the 1980s, and in 1985 US president Ronald Reagan struck a deal with the president of the Soviet Union, Mikhail Gorbachev, to collaborate on a reactor, called ITER, that would prove the technical feasibility of breakeven, Exxon pulled out of their commitment to fusion research at the end of the 1980s.[488]

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[486] M. Roberts and E.S. Bettis, *Oak Ridge Tokamak Experimental Power Reactor Study Reference Design* (National Technical Information Service US Department of Commerce, 1975), x-xi; Stacey, *The Quest for a Fusion Energy Reactor*, 133.

[487] Hirsch would continue to work for Exxon as executive where he became responsible for Exxon's synthetic fuel program, and shale oil production. He also worked for the Arco oil company. Later Hirsch would become famous as energy expert publishing about peak oil, being the lead author of the 2005 Hirsch report for the US Department of Energy called *Peaking of World Oil Production: Impacts, Mitigation, and Risk Management*. Robert L. Hirsch, Roger Bezdek and Robert Wendling, *Peaking of World Oil Production: Impacts, Mitigation, and Risk Management* (Science Applications International Corporation, US Department of Energy, National Energy Technology Laboratory, 2005); Thomas Heppenheimer, *The Man-Made Sun: The Quest for Fusion Power* (Little: Brown, 1984), 33—47, 193-195; Stephen O. Dean, *Search for the Ultimate Energy Source: A History of the US Fusion Energy Program* (New York: Springer, 2013), 217-218.

[488] Associated Press, 'Exxon Corp. Selling Exxon Nuclear to West German Firm,' *AP News Archive* (December 23, 1986); Dean, *Search for the Ultimate Energy Source*, 89-90.

Exxon's withdrawal from nuclear fusion research coincided with disappointing research results on the big tokamaks. Although during the 1990s both JET and the TFTR at Princeton delivered on their promises of demonstrating a nuclear fusion reaction, the research encountered many technical setbacks in the preceding years that postponed many of the expected results while the need for funding continued to grow.[489] Also various Western governments started to reverse their funding.[490] Even actors who previously had been proponents of the fusion research projects, like Hirsch, became increasingly critical of the long-term strategies employed within fusion research.[491]

Not every fusion project completely aligned with the general strategies for the big tokamak reactors, however. Other projects, often supported by industrial parties, tried to bypass research steps by working on alternative reactor models. The previous chapter already discussed how Gulf Oil, Shell and Phillips Petroleum funded new reactor designs via General Atomic. Also here, however, the oil companies pulled out of their research funding during the 1980s. Although Shell had continued their support for the long-term fusion research at General Atomic while they had already pulled out of regular nuclear fission during the 1980s, Shell's support stopped before Chevron took over Gulf Oil and the company sold its interests back to Gulf in 1982.[492]

The withdrawal from fundamental nuclear fusion research symbolically marks the temporary end of the commitment to long-term diversification strategies by the various oil companies. Even more than with the investments in regular nuclear fission, the various oil actors had been perfectly aware from the very beginning of the fundamental character and the long-term horizon for commercial applications of the research projects that they participated in. The timeline for fusion to reach its commercial potential did not fundamentally change, yet oil firms' commitment vanished, in the wake of a wider process of refocusing on short-term profits within the oil industry during the 1980s. Many of their diversification projects, including most of their nuclear investments, were divested in favor of other highly capital-intensive investments in oil production. At the beginning of the 1990s, most of the oil industry had phased out of nuclear.

5

The end of a cohort

Replacing prima donnas with business students

Where the preceding decades had been the stage of a ubiquitous, and often growing, influence on nuclear developments of an oil industry that was steered by a cohort of scientist-engineers versed in both industries, the 1980s saw the end of most of these spillovers. The second chapter of this dissertation discussed how many of the scientists and engineers that would shape nuclear developments from the start of the Second World War onward were introduced to the oil industry during the late 1920s to the early 1940s in the wake of a growing focus on academically trained (geo)physicists and engineers within that industry. During the 1950s and 1960s, this cohort spilled over to the postwar nuclear developments and/or steered even the major oil companies into nuclear

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489 Braams and Stott, *Nuclear Fusion*, 217-221.
490 Dean, *Search for the Ultimate Energy Source*, 104.
491 Robert L. Hirsch, 'A Fusion Failure,' Stephen O. Dean, *Search for the Ultimate Energy Source: A History of the US Fusion Energy Program* (New York: Springer, 2013), 217-218.
492 Bill Ritter, 'Denver Firm to Pay More Than $50 Million: Energy Company to Buy GA Technologies,' *Los Angeles Times* (August 14, 1986); Sluyterman, *Concurreren in turbulente markten*, 106-109.

diversification projects. During the 1970s and 1980s however, many of these involved oil-nuclear actors reached the age of retirement. Some earlier than others – especially at Shell employees faced mandatory retirement by age sixty – but at the end of the 1980s almost none of the actors discussed in the earlier chapters still worked within either the nuclear or oil industry.

This retirement of the oil-nuclear cohort opened pathways for a new kind of manager within the oil industry. During the second half of the twentieth century the corporate structure of big Fortune 500 companies had remarkably changed, both in the US and Western Europe. Big companies had increasingly grown, encompassing an ever-growing number of projects and people, and therefore became steadily more difficult to manage.[493] This development meant that more, and different, qualities were expected from managers within these companies. As chapter 3 already showed, many of these new positions were granted to the members of the cohort of scientist-engineers during the 1950s and 1960s to prevent them from leaving the oil industry for new jobs in the aerospace and nuclear industries. Not everyone in the oil industry always applauded this development, however. Already during the 1960s critical arguments were voiced. These voices expressed concerns about the course taken by many of these scientist-engineers, and complained about – the suggested lack of – their skills to manage the ever-growing complexity of the oil companies. According to the scientist-engineers showed a limited focus on technical solutions as the only answer to the problems the oil industry faced. While reflecting on the position of engineers within the oil industry already in 1966, Halbert Halbert Jr. an engineer working in a fellowship for Gulf Oil, and D.A. Woolf, assistant professor at the University of Oklahoma, noted that some of the more common accusations about engineers were that they were "too factual", "have a peculiar type of mind", have "limited perspective", and "are intolerant of non-engineering problems", stating that "one is led to believe that industry has acquired a group of prima donnas who could quite conceivably be more of a problem than an asset."[494]

Although this kind of criticism was scarce at the end of the 1960s, this changed during the 1970s. Oil companies increasingly faced problems with high inflation and economic recession. Also, some of the flagship diversification projects that were introduced as part of the solution to the loss of access to cheap oil production in the Global South, including many of the nuclear projects, encountered more problems and delays. Especially among shareholders – a group that rapidly became more influential at the beginning of the 1980s – a new view of the role of managers became prevalent as Mark Mizruchi argues. This view no longer regarded managers as "professionals with a highly developed set of specialized knowledge who were uniquely capable of efficiency administering its operation," but rather as "mere agent[s] of shareholders… who had no specific claim to their status beyond what ownership had decided, however temporarily, to grant them."[495] Therefore the main task of a manager was no longer the maximization of profits for the company, but rather to increase the company's stock price, or what later would be called "shareholder value".[496]

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[493] Mizruchi, *The Fracturing of the American Corporate Elite*, 10; Keetie E. Sluyterman, *Dutch Enterprise in the Twentieth century: Business strategies in a small open economy* (London: Taylor & Francis, 2005), 126-182.
[494] Halbert Jr. and Woolf, 'Engineers Managing Engineers,' 288-292.
[495] Mizruchi, *The Fracturing of the American Corporate Elite*, 207.
[496] Mizruchi, *The Fracturing of the American Corporate Elite*, 206-208; Edward J. Zajac and James D. Westphal, 'The Social Construction of Market Value: Institutionalization and Learning Perspectives on Stock Market Reactions,' *American Sociological Review* 69 (2004), 435-437; Rakesh Khuruna, *From Higer Aims to Hired Hands: The Social Transformation of American Business Schools and the Unfulfilled Promise of Management as a Profession* (Princeton: Princeton University Press, 2002); Michael Useem, *Executive Defense: Shareholder Power and Corporate Reorganization* (Cambridge, MA: Harvard University Press, 1993), 11.

As an answer, slowly but steadily, a new kind of manager took over the managerial seats and board positions in both industrial and semi-governmental organizations, deemed more fit to face the encountered problems and generate more shareholder value. Multiple historians have recently showed that within sectors like the pharmaceutical industry, and even the International Atomic Energy Authority (IAEA), a background in finance or management was increasingly valued over experience in science or engineering during the 1980s.[497] One important indicator of this development here is the number of college students in business. In the US, this number had already begun to increase during the 1970s, but almost doubled at the beginning of the 1980s. By 1983, the proportion of undergraduates majoring in business had nearly doubled from ten years earlier, and the number of master's degrees nearly doubled between 1975 and 1984.[498]

This also happened within the oil industry. Like the introduction of François Ortoli at CFP-Total, these new managers often had an academic background in economics, finance, and management studies. For example, between 1973 and 1979 corporate planning at the Exxon oil company was managed by Norton Belknap, a chemical engineer known for arguing that all available energy sources should be developed, while his successors were Charles Sitter (1979-1981), trained in foreign affairs before working as a financial analyst at Exxon, and Richard John Kruizenga (1981-1992), an M.I.T. graduate in economics with a long career in Exxon's economics department.[499]

Gerrit Abram Wagner

The development of the thinking and public remarks of Gerrit Abram Wager illustrates the influence of the rise and decline of the scientist-engineering cohort in the oil industry on diversification policies well. In a way, Wagner is a counter-intuitive example in this chapter since he already became group director at Shell in 1972 and led Shell during its diversification efforts into nuclear energy before becoming an outspoken proponent of neoliberalism in the Netherlands and opponent of private companies' involvement in nuclear power. Still, or even because, of his 'out of time'-character, he offers a helpful window to show the impact of cohort change.

After finishing his law studies in Leiden during the Second World War, Wagner worked for the Dutch bank *Mees en Zonen* before joining Shell shortly after the War. Within the Shell Group, he became part of a new generation of young managers, not belonging to the cohort of academically trained

[497] Nils Kessel, 'Étudier les marches du médicament: les entreprises pharmaceutiques et la transformation du marketing en Allemagne de l'Ouest (1960-1980),' Bruno Valat (eds), *Les marches de la santé en France et en Europe (XIXe-XXe siècle)* (Presses universitaires du Midi, 2021), 175-199; Elisabeth Roehrlich, *Inspectors for Peace: A History of the International Atomic Energy Agency* (Baltimore: John Hopkins University Press, 2022), 176-178.

[498] Specifically, in corporate planning the development to incorporate more business students was noticeable. From the mid-1970s onward more business students went into planning. The placement records of the Colgate Darden Graduate Business School, one of the top American graduate business schools at the time, show that an increasing share of their school's MBAs went into planning. David Vogel, *Fluctuating Fortunes: The Political Power of Business in America* (New York: Basic Books, 1989), 274; Mizruchi, *The Fracturing of the American Corporate Elite*, 202; Grayson, *Who and How in Planning for Large Companies*, 2.

[499] Pratt and Hale, *Exxon*, 588; 'Charles Sitter Obituary,' *Dallas Morning News* (30 July 2008); 'Richard John Kruizenga: energy company executive' (version 2021), https://prabook.com/web/richard_john.kruizenga/1382680 (Accessed 23, 2023); 'Norton Belknap Obituary,' *New York Times* (September 16, 2020); Norton Belknap, *World Energy Situation* (Exxon Research Corporation, 1977).

(geo)physicists and chemical engineers that had joined Shell already before the War, but rather embarking on a career path that later became the golden standard within Shell's board rooms during the 1970s. First, Wagner started as a manager at the refinery on Curaçao, before becoming the manager in charge of Shell's enterprise in Venezuela during the 1960s and later Indonesia. In both Venezuela and Indonesia, he had to deal with an ongoing and increasing push for nationalization of the oil industry, showing him the limits of Shell's power and the increasing threat of losing access to cheap oil concessions in the Global South.[500] As Wagner later recalled during a live radio interview in 1990: "I'm from that generation that has experienced our position of power being broken down each time. If I see one predominant motive in my career, it is: over the course of thirty years, retreating from acquired positions, falling back to new positions, and still continuing to do the work from there. All illustrations of the limits of our power."[501]

When Wagner entered office of CEO of Shell in 1972, scientist-engineers lobbying for more investments in diversification projects like nuclear energy dominated Shell management positions, arguing that Shell had the opportunity to develop the nuclear industry into a competitive market. Chemical engineer Han Hoog, described by Wagner's biographer as a "close friend" to Wagner, was still holding his position as manager of Shell's Dutch investments in uranium enrichment and was known for his positive internal, and public, statements on the future development of nuclear energy.[502] Also E.J.G. Toxopeus, research director at Shell with a background in engineering at Delft University, lobbied intensively for more nuclear investments and research; and fellow board member, the chemical engineer Karel Swart, had just chaired an internal commission that had called for more diversification including investments in nuclear energy.[503]

Chapter 4 already showed that this lobbying would be successful. In 1973, Shell's decision to join forces with Gulf Oil in General Atomic marked a new step in the company's nuclear diversification. As the leading CEO, Wagner expressed in his contribution to the 1973 annual report: "During 1973 the roots for future growth in two new ventures- nuclear energy and coal- were firmly planted."[504] Wagner publicly, and internally, explained this diversification strategy by pointing toward the shared responsibility by both government and industry to develop this new source of energy to prepare society for future scarcity of fossil fuels. Already a year before officially announcing that Shell would join with Gulf Oil in General Atomic, Wagner expressed during the annual shareholder meeting of 1972 that the development of other energy sources, "first and foremost nuclear energy", was urgently needed. This required cooperation from government and industry.[505]

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[500] Van Seumeren, *Gerrit A. Wagner*, 18-72; Metze, *Hoog Spel*, 266, 276, 294-297.
[501] Translation from Dutch by author: "Ik ben van die generatie die heeft meegemaakt dat onze machtspositie telkens is afgebroken. Al ik één overheersend motief zie in mijn carrière, dan is dat: in de loop van dertig jaar terugtreden uit verworven posities, terugvallen op nieuwe stellingen, en van daaruit toch het werk blijven doen. Allemaal illustraties van de begrenzingen van onze macht." 'Marathon Interview G.A. Wagner,' VPRO Marathon Interview (Hilversum: VPRO July 12, 1990) https://www.vpro.nl/programmas/marathoninterview/luister/overzicht/w/ga-wagner.html (Accessed October 24, 2023).
[502] Van Seumeren, *Gerrit A. Wagner*, 75; 'Dr.ir. Hoog van Shell research: Na 1980 kleiner aandeel van aardgas in energieverbruik,' *Leeuwarder Courant: Hoofdblad van Friesland* (March 29, 1972), 25.
[503] 'Shell in toekomst als kernenergiehandelaar,' *Het Vrije Volk: democratisch-socialistisch dagblad* (March 19, 1971), 25; 'Shell via Gulf op kernenergiemarkt,' *Tubantia* (June 5, 1973), 9; Metze, *Hoog Spel*, 379.
[504] Gerrit A. Wagner, 'The President's foreword,' Royal Dutch Shell, *Royal Dutch Shell: Annual Report 1973* (The Hague: Royal Dutch Shell, 1974), 2-3.
[505] 'Wagner (Shell): andere bronnen energie aanboren,' *NRC Handelsblad* (April 20, 1972), 10.

In the next four to six years, however, the discourse used by Wagner would change drastically. Wagner, who was later regarded as one of the main proponents of neoliberalism in the Netherlands, afterwards reflected on Shell's investments in nuclear energy as "the biggest mistake of his career".[506] Already in 1976 Wagner complained that "nuclear energy was capital intensive", and Shell would probably decide to abandon their nuclear investments within two years. In this reaction he did not focus anymore on nuclear energy as a potential solution for future scarcity, but focused solely on the economics of the nuclear investments and stated that it became harder to make profits compared to oil with increasing governmental regulations regarding nuclear projects.[507]

This shift in focus took place in a context of increasing costs of Shell's nuclear investments in General Atomic, as well as the exodus of many of the company's remaining scientist-engineer managers.[508] Hoog left Shell in 1971 to fully concentrate on developing policies at the Dutch nuclear industrial, governmental and scientific nexus RCN before retiring in 1979. Toxopeus stepped down from his position as director of research in 1975. Also, Karel Swart would retire from Shell later in 1979. Many of their successors who would divest Shell's nuclear projects and refocus onto oil trading and production, like Dirk de Bruyne who was one of the successors of Wagner as CEO of Shell at the beginning of the 1980s, were trained in economics and finance.[509]

The cohort is dead! Long live the cohort?

5

In his study of the French oil industry in the twentieth century, Douglas Yates clearly distinguishes the new cohort from the preceding cohort of polytechnicians that had dominated the French oil industry during the first decades after the Second World War. The member of the new cohort was an *inspecteur de finances*. He studied administrative law and economics before entering the *grands corps* of finance inspectors in the French Ministry of Finances instead of beginning as a member of the *Corps des Mines*. Yates introduces François-Xavier Ortoli (Total), Albin Chalandon (ELF), and Philippe Jaffré (ELF) as archetypes of this cohort, often battling the traditional and self-centered mining corps at the companies they presided over and leading their companies into strategies that were more focused on short-term profit making in the oil market.[510]

Outside France, the educational background of the members of this new cohort was in mathematics or economics followed by an MBA at a business school like Harvard, Stanford, Wharton, Sloan, Chicago, or Columbia. There, the members trained in economics, finance, and business administration before entering the oil industry during the 1950s and 1960s or first entered the oil industry to then go back to school for an MBA. Within the oil industry, these actors started their careers within the newly established planning departments of their companies. According to management scholar and former oil executive, Leslie Grayson, the planning departments were established during the 1950s and 1960s

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[506] 'Marathon Interview G.A. Wagner,' VPRO Marathon Interview (Hilversum: VPRO July 12, 1990) https://www.vpro.nl/programmas/marathoninterview/luister/overzicht/w/ga-wagner.html (Accessed October 24, 2023).
[507] 'Shell draait goed: kernenergie wordt te duur,' *Algemeen Dagblad* (April 15, 1976), 23; 'Olie- en gasreserves Noordzee nu geschat op 50-60 mld. vaten,' *NRC handelsblad* (April 15, 1977), 12.
[508] See for losses General Atomic Company: Royal Dutch Shell, *Royal Dutch Shell: Annual Report 1979* (The Hague: Royal Dutch Shell, 1980), 18.
[509] Sluyterman, *Concurreren in turbulente markten,* 104; Metze, *Hoog Spel*, 379-380.
[510] Yates, *The French oil industry*, 4.

to accommodate the interests of a couple of particular managers. These managers regularly also had a background in business management, like John G. McLean at Conoco and Robert W. Haigh at Sohio, and they attracted a new generation of recently graduated business students to the oil sector. Examples include Samuel Schwartz, Howard Blauvelt and Aivars Krats (all Conoco), Lawerence E. Appley at Sohio, and Bennett E. Bidwell, Richard C. Buterbaugh and James K. Dobson at Kerr-McGee. These actors were hired at an early age and spent several years as planners, before continuing their careers in the operating divisions of the oil companies, and finally becoming managers during the 1980s.[511]

In some ways, the emergence of this new cohort resembles the development of the cohort of scientist-engineers that had shaped the post-war nuclear developments and the diversification of the oil industry into nuclear energy. The second chapter of this dissertation told the story of Paul Darwin Foote, the already established atomic scientist, who started at Gulf Oil in 1927 by setting up a geophysics division before becoming an executive at Gulf. The career of Foote, who after the Second World War transferred to the US AEC, nicely illustrated the increasing focus within the Western oil industry on hiring academically trained personnel with a background in engineering and geosciences. Almost two decades later, someone like John McLean would fulfill a similar role within Conoco for the new cohort, establishing a planning department focused on bringing in business students.[512] Also, in both instances the rise of both cohorts to the management levels within the oil industry coincided with major disruptions within the oil industry (i.e., losing access to cheap oil concessions in the Middle East at the end of the 1960s and the restructuring of markets during the 1980s).

The replacement of the oil-nuclear cohort that had shaped the nuclear diversification projects within the oil industry by new oil managers with a background in economics and business was no smooth transition from one cohort to another, however. Chemists, geoscientists, or engineers did not disappear from the boards rooms of the oil industry completely. A big share of the executive seats would continue to be filled by “technologists” (to use the apt term used by Leslie Grayson) to this day.[513] Also Yates recalls the rivalry between the engineers and financial inspectors that shaped the story of the French oil industry during the 1980s and 1990s.[514] Still, many of the remaining chemical

[511] McLean was already an established professor at the Harvard Business School before he was hired to head Conoco’s planning department in 1953. Samuel Schwartz also had a background at Harvard Business School, and he became Executive Vice-President of Planning at Conoco mid-1985. Blauvelt and Krasts were from Colombia and Chicago before joining Conoco. Krasts would become the planning vice-president in 1985. At Sohio, Appley and Haigh graduated from Harvard Business School. At Kerr-McGee: Bennett Bidwell (graduated in 152 in business administration at Babson College) became member of the board of directors at the end of the 1980s, Richard Buterbaugh had a career at Chevron after obtaining a bachelor degree in accounting and economics and before becoming the vice president of investor relations at Kerr-McGee, and Dobson studied mathematics and finance before joining Kerr-McGee as financial analyst and becoming manager of economics and financial analysis. Grayson, *Who and How in Planning for Large Companies*, 62; ‘Biography – Bennett E. Bidwell,’ (June 1995), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 1, folder 23; ‘Biography – Richard C. Buterbaugh,’ (October 2000), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 1, folder 23; ‘Biography – James K. Dobson,’ (August 1994), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 1, folder 40.
[512] Grayson, *Who and How in Planning for Large Companies*, 62.
[513] Ibidem, 64.
[514] Yates, *The French oil industry*, 4, 215-232.

engineers and geoscientists in the management of several oil companies, for example within Kerr-McGee, increasingly had obtained degrees in management or finance later during their careers.[515]

The new "cohort" also was less cohesive than its predecessor. Where the preceding chapters have discussed the cohort of scientist-engineers as a network of actors moving in between the oil and nuclear industries, and various governmental organizations, while staying in contact with each other, this new "cohort" was less interconnected. Although there definitely were points of contact between members of this cohort, often grounded in a shared educational background, the cooperation was often less explicit than before when in the US geophysicists like Wallace E. Pratt, Marion King Hubbert and Everette DeGolyer served in the same AEC committees and regularly corresponded, and in the Netherlands many former Shell engineers and geoscientists collaborated in the Dutch nuclear industry.[516]

This difference between the two cohorts studied in this thesis coincides with a development that Mark Mizruchi called the fracturing of the American corporate elite. In historical studies of the ruling business elites of the postwar United States, Mizruchi argues that at the end of the 1970s and during the 1980s American business leaders became increasingly confrontational with labor and government when facing inflation, foreign competition and growing public criticism. Mizruchi shows how during the first postwar decades business leaders often held chairs on the boards of a wide variety of banks, governmental organizations and companies, encouraging a self-proclaimed "ethic of civic responsibility and enlightened self-interest by steering a course of moderation and pragmatism" where governmental efforts were sometimes joined to investments in infrastructure and health care. During the 1980s however, business leaders became more self-focused under pressure to focus on shareholder value and short-term profits rather than long-term problems facing their country. During this process, the corporate elite undermined their ability to work together, as also the number of interlocking boards declined and hostility between company leaders grew during the takeover battles.[517]

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[515] Examples include F. Benjamin Henry Jr. – VP of Planning for Kerr-McGee's Refinery Corp. 1981-1997 – who got a master's degree in administration after a BA in chemistry, George Hennigan – Senior VP for Kerr-McGee and President of Kerr-McGee Chemical 1981-1997 – who held a BA in engineering and master's degree in business administration and system management, Robert Henderson – VP 1982-1991 – who did a BA in engineering 1953 and later in 1969 got a jurist doctorate at Loyale University, and John O. Bodman – VP of marketing and planning 1981-1985 – who got his master's degree in business at Harvard after a BA in chemical engineering. 'Biography John O. Bodman' (1985), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 1, folder 16; 'Biography F. Benjamin Henry Jr.' (1994), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 2, folder 38; 'Biography George Hennigan,' (1997), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 2, folder 37; 'Biography Robert Henderson,' (1991), Kerr-McGee Corporation (Oklahoma City: Oklahoma Historical Society), box 2, folder 36.

[516] For example, John McLean (later Conoco) and Robert Haigh (later Sohio) collaborated in writing the book *The Growth of International Oil Companies* (1954) when they were both at Harvard Business School. In this book they argued that to be able to sustain growth at times of abundant oil, US oil companies should make more international investments in oil production, a point that McLean regularly repeated while working for Conoco. This in contrast to the strategy of another medium-sized US oil company, Kerr-McGee, that under the influence of its manager, geologist Dean McGee, heavily invested in uranium mining to sustain growth (see chapter 3). John G. McLean and Robert W. Haigh, *The Growth of International Oil Companies* (Boston: Harvard University Press, 1954); John G. McLean, 'The Transition from Domestic to International Oil Operations,' *Journal of Petroleum Technology* 20, 12 (1968), 1339-1343; Grayson, *Who and How in Planning for Large Companies*, 62.

[517] Mizruchi, *The Fracturing of the American Corporate Elite*. Also, specifically interlocks between companies that were active in the nuclear industry and the banks funding those companies declined during the early 1980s as

Therefore, it is hard to say that a new cohort of economists and business administrators directly replaced the cohort of scientist-engineers that had steered the oil industry into their nuclear diversification projects and had shaped the development of nuclear energy until the late 1970s. The emergence of a new type of managers that increasingly rose to power within the oil industry during the 1980s did not so much constitute a new and coherent cohort on its own, but rather signaled the end of a generation of oil managers that had dominated the board rooms before. This shift serves as a clear indicator of the developments that brought companies within the oil industry to withdraw from their nuclear investments and their long-term commitment to the development of atomic energy production.

Phasing out oil's nuclear commitment: concluding observations

In a response to a question if he was convinced of the virtues of long-term planning as chairman of a big French oil company, Ortoli answered by quoting Paul Claudel's play *Le soulier de satin* (*The Satin Slipper*): "Le mat écoute la vergue et apprend d'elle que le vent va changer."[518] According to Ortoli, everyone had their own, "more or less sophisticated", way of "écouter la vergue", but the important thing was to remain attentive and open to how the winds are changing. Although states and companies used to ground their strategies in long-term forecasts, this was not the way Ortoli managed his company.

The entrance of Ortoli at CFP-Total indeed introduced a new way of listening to the wind. After Ortoli's new assessment of concurrent market developments, the French oil company changed from one of the most diversified companies, with multiple investments in nuclear energy projects, to a strategy refocusing on short-term profits in oil production in less than a decade. This chapter argued that the 1980s marked a clear turning point for the nuclear diversification strategies of many Western oil companies. Over the span of a decade, oil firms divested the nuclear projects that they had committed to during the 1960s and 1970s. Although oil and nuclear actors presented a variety of reasons to explain why the promise of atomic energy seemed to dissipate and thus why they stopped investing in nuclear energy, ranging from environmentalism to increasing costs for nuclear developments, this chapter showed that the most important reasons for this shift were actually based in developments within financial markets and the oil industry itself.

During the 1980s, these developments entailed increasing investment costs for both oil and nuclear, while Western oil companies needed more capital to fend off hostile take-overs and trade as buyers on increasly volatile oil markets. When increasingly powerful shareholders pressured oil companies to create higher return on investments, the firms refocused toward short-term investment strategies within the oil sector and abandoned long-term nuclear diversification projects.

This shift was possible because a new kind of manager emerged within the oil industry. With his background at the French elite school in management studies, Ortoli becoming *president* of CFP-Total

Mark Hertsgaard shows in his study to the industrial leaders in the nuclear sector. Although there is no smoking gun showing that this directly influenced the funding decisions of nuclear projects perse, the banking loans to these companies dwindled around the same time. Hertsgaard, *Nuclear Inc.*, 273-276, 292-300.

[518] "The mast listens to the yardarm and learns from it that the wind is about to change" (translation by author). 'Entretien avec Francois-Xavier Ortoli (Propos recueillis par Bernard Cazes),' Francois-Xavier Ortoli Papers (Florence: EUI - Historical Archives of the European Union), folder 140.

symbolized the rise of a new cohort of managers trained in economics, finance, and business administration. Over the span of a decade, this manager replaced the cohort of scientist-engineers of which many members, who embarked their oil firms on nuclear diversification projects, were about to retire. Now more focused on creating profits for shareholders, the new cohort of managers steered their companies away from long-term projects that were only modestly profitable and which held uncertainties for the future.

CHAPTER 6

6

6. A century of oil-nuclear spillovers

Concluding observations

"As oil majors diversify their portfolios and invest in promising technologies like fusion energy, it becomes evident that the energy landscape is undergoing a transformative shift. Through sustained investments and collaborative efforts, the fusion industry could usher in a new era of clean and abundant energy, paving the way for a more sustainable future."

- Perla Velasco, Journalist and industry analyst, 15 June, 2023[518]

[518] Perla Velasco, 'Oil Industry Explores Viability of Nuclear Fusion,' Mexico Business News (June 15, 2023), https://mexicobusiness.news/oilandgas/news/oil-industry-explores-viability-nuclear-fusion (Accessed May 29, 2024).

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A century of oil-nuclear spillovers

Recently, industrial analysts and journalists reported on a "new" trend of major oil companies investing in nuclear energy. Shell, Equinor, ENI and Chevron now invest in fusion technology, funding various start-ups with the goal to advance the research and potential commercialization of this energy source.[520] According to a 2020 press release from Chevron, the company invests in Zap Energy Inc., a Seattle-based start-up company that develops innovative modular nuclear fusion reactors, to "enhance the company's focus on a diverse portfolio of low-carbon energy resources with the capacity to provide communities across the globe access to, reliable, and ever-cleaner energy."[521] Other companies, like TotalEnergies (previously Total), also start investing in uranium mining, providing leaching solutions for In Situ Leaching that are "environment friendly" and have "unmatched health benefits".[522]

Not only do Western oil companies embark on nuclear projects, but non-Western oil actors are also becoming fully involved in production of nuclear energy too. Examples include Indian-Oil managing nuclear reactors in India, and the Oil and Natural Gas Corporation exploiting several uranium mining projects in Assam and the Cauvery area of Tamil Nadu (India).[523] Also in China, the China National Offshore Oil Corporation cooperates with the China General Nuclear Power Group to "push forward the organic integration of the offshore oil industry and the nuclear power industry".[524]

Nuclear energy seems to have returned as *the* new diversification project for the oil industry, making analysts and environmentalists debate the question whether these investments are sincere commitments to an environmentally friendly future or a new attempt to greenwash fossil fuels.[525]

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[520] Velasco, 'Oil Industry Explores Viability of Nuclear Fusion,'; Jason Deign, 'Why Are Oil and Gas Companies Investing in Nuclear Fusion?,' *GreenTechMedia* (September 18, 2020), https://www.greentechmedia.com/articles/read/why-are-oil-and-gas-companies-investing-in-nuclear-fusion (Accessed April 29, 2024).

[521] Chevron, 'Chevron invests in nuclear fusion start-up,' *Chevron.com* (August 12, 2020), https://www.chevron.com/newsroom/2020/q3/chevron-invests-in-nuclear-fusion-start-up (Accessed May 31, 2024).

[522] TotalEnergies, 'Metal mining with Elixore diluents,' *TotalEnergies* (February 2023), https://specialfluids.totalenergies.com/en/our-applications/metal-mining-elixore-fluids (Accessed April 29, 2024).

[523] IndianOil, 'IndianOil and Nuclear Power Corporations sign JV agreement for setting up nuclear power plants,' *iocl.com* (January 12, 2011), https://iocl.com/NewsDetails/11299 (Accessed June 18, 2024); World Nuclear Association, 'Country Profiles: Nuclear Power in India,' *World Nuclear Association* (May 8, 2024), https://world-nuclear.org/information-library/country-profiles/countries-g-n/india (Accessed June 18, 2024).

[524] CNNC, 'Our Business,' *cnnc.com* (March 2019), https://en.cnnc.com.cn/oilandgasengineering.html (Accessed June 18, 2024); World Nuclear Association, 'Country Profile: China Nuclear Power,' *World Nuclear Association* (June 3, 2024), https://world-nuclear.org/Information-Library/Country-Profiles/countries-A-F/China-Nuclear-Power (Accessed June 18, 2024).

[525] Velasco, 'Oil Industry Explores Viability of Nuclear Fusion,'; Deign, 'Why Are Oil and Gas Companies Investing in Nuclear Fusion?'; Ian Palmer, 'When Will Nuclear Fusion Put Oil and Gas Out of Business,' *Forbes* (December 18, 2022); Rad Adams, 'Gloves are off in fossil fuel fight against nuclear,' *World Nuclear News* (May 2, 2017),

These debates take place in a wider context of renewed debates about the end of oil, the frame of nuclear energy as a green alternative, and the role of the oil industry in managing the energy mix of the future.[526]

This dissertation shows that it is necessary to study the past roles of incumbent industrial actors in the development of nuclear energy to properly understand these trends. Although state actors have heavily and repeatedly influenced nuclear developments in the past – also this dissertation discussed ample examples of nuclear policies and regulations imposed by (semi)governmental organizations – historians have understudied the pivotal role of private companies. As this dissertation makes clear, especially oil actors were ubiquitous in the historical development of nuclear energy. They developed technologies, operated nuclear project, and shaped discourses, while in the process crossing the boundaries between innovative nuclear technology development, an incumbent oil regime, and governmental organizations. By doing so, the oil industry not only shaped the addition of nuclear energy to the global energy mix, but also became a crucial factor in current debates about nuclear energy.

The involvement of the oil industry in nuclear developments is grounded in a century-long history of spillovers of technologies, people, practices, and knowledge. Already from the start of the twentieth century, techniques and geoscientists combined the exploration for oil and radioactive minerals in their research and practices. This entanglement positioned the oil industry to play a pivotal role in the early industrialization of nuclear energy with the Manhattan Project, and later, often Western, nuclear industrial developments. These technologies, such as radioactive well logging, mass spectrometry, and In Situ Leaching, provided the oil industry with a gateway into nuclear energy, but also with an opportunity to frame their nuclear investments as answers to future resource scarcity and the environmental impact of regular nuclear energy production and fossil fuel combustion.

This long history shows that the diversification strategies of many major oil firms in the 1970s were no mere accident inspired by false expectation and rosy views. Oil actors used the technological expertise and experience with earlier oil-nuclear spillovers to engage with nuclear energy. Steered by a cohort of scientist-engineers that were versed in the atomic physics underpinning these technologies, the companies embarked on long-term diversification strategies to establish lasting positions throughout the nuclear fuel cycle. Only when a new management cohort – trained in economics and finance to better anticipate new market developments and increased shareholder power – succeeded this cohort did firms divest their nuclear projects and replace their long-term strategies with a focus on short-term profits from oil production.

First, this chapter discusses the main conclusions drawn from the preceding narrative about a century of oil-nuclear spillovers and how these “petroleum legacies” sometimes exceed the temporal and geographical boundaries of this dissertation’s research. While reflecting on current nuclear developments in oil exporting countries such Saudi Arabia, I argue that uranium and crude oil were,

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https://world-nuclear-news.org/Articles/Gloves-are-off-in-fossil-fuel-fight-against-nuclea (Accessed June 18, 2024).

[526] Reda Cherif, Fuad Hasanov, and Aditya Pande, ‘Riding the Energy Transition: Oil beyond 2040,’ *Asian Economic Policy Review* 16, 1 (2021), 117-137; Bassam Fattouh, Rahmatallah Poudineh and Rob West, ‘The rise of renewables and energy transition: what adaptation strategy exists for oil companies and oil-exporting countries?,’ *Original research* 3 (2019), 45-58; Paul Josephson, ‘How Green Is the Atom? The Past – and Future – of Nuclear Energy in the United States,’ *Origins: Current Events in Historical Perspective* (July 2024), https://origins.osu.edu/read/how-green-atom (Accessed August 2, 2024).

and still are, inextricably linked to each other and will continue to shape potential future diversification pathways for oil actors. This chapter then reflects on the use of cohort theory in the field of transition studies and argues that cohort theory offers new, helpful tools to analyze the individual agency of actors that moved in between the oil industry, the development of nuclear energy, and various (semi)governmental organizations shaping nuclear policies. As this dissertation showed, the succession of various generations at the management levels indicates shifts in the strategies employed by oil companies towards diversification and helps explain how the oil companies repeatedly got involved with nuclear developments.

Petroleum legacies

Frontiers of energy

This dissertation started with Gulf Oil's CEO, geophysicist E.D. Brocket, announcing the diversification plans for his company in an annual meeting of shareholders in 1967. In the same year, the company bought General Atomic to develop HTGR-reactors and launched a uranium exploration program in the US and Canada. In a celebratory book, called *Frontiers of Energy* (1971), Gulf Oil hailed its nuclear diversification program:

> To ancient civilizations and even in recent centuries, the ultimate source of all energy and life was the sun.…However, within our contemporary industrial society a complementary energy has been discovered and developed – oil. Just as our universal life-cycle would terminate with the sun's darkness; so our twentieth century existence would dwindle without the presence of oil and its multiplicity of application…...And yet our constant search for energy stretches beyond to new frontiers, to the realms of man-made energy – nuclear power.[527]

As this dissertation argues, however, this was not the beginning of the oil industry's involvement in nuclear energy. Chapter 2 showed how oil-nuclear spillovers already took place during the first decades of the twentieth century. Also for Gulf Oil, 1967 did not mark the start of the connections between the company and the development of atomic energy. This involvement dated back to the early 1920s when the firm hired the prominent atomic physicist Paul Darwin Foote to establish a geophysical division within the company, creating an environment where oil actors and technologies would continue to spill over from and to nuclear energy research and industrial developments.

As the second chapter argued, this early geophysical intertwinement built on the shared characteristics of both oil and radioactive minerals. Around the decaying biomass in the same sedimentary layers where reservoirs of oil formed, radioactive minerals also amassed. Specifically in petroleum source rock, radium and uranium grouped together in deposits that would link the petroleum industry to uranium exploration during the twentieth century.

This connection sparked the development of innovative technologies to measure, and analyze, radioactivity in the petroleum industry that proved useful to locate sedimentary layers, vaults, and minerals underground. These technologies, which would find applications in both the oil and nuclear industries, formed the basis of later oil-nuclear spillovers. Already during the Manhattan Project

[527] Gulf Oil Corporation, 'Frontiers of Energy,' (1971), Gulf Oil Corporation Records (Pittsburgh: Detre Library and Archives, Heinz History Center), box B, folder 22.

various oil actors were involved in uranium exploration programs, and after the Second World War this involvement only increased with oil firms using their technological expertise as the basis for their diversification strategies during the 1950s and 1960s. Gulf Oil too, celebrated the use of their radioactive well logging devices – technologies that were developed within the oil industry during the 1930s and 1940s – in the discovery of the huge Rabbit Lake uranium mine in Canada.[528]

These technological spillovers – including petrochemical technologies used to analyze and process gasses, fluids, and rocks – were shaped by a generation of physicists, chemists and chemical engineers that graduated from the 1920s to the early 1940s before starting their careers in the oil industry. Their shared background in their studies in early atomics physics, and later in the geosciences and engineering within the oil industry, forged a network of oil actors that during the 1940s and 1950s shaped the development of nuclear industries in Western countries such as France, the Netherlands, the UK, and the US. When the petroleum industry encountered problems enlisting new petroleum engineers and geophysicists due to the increasing popularity of the nuclear and aerospace industries during the late 1950s and 1960s, new pathways opened for members of this cohort to steer their firms into nuclear diversification projects as oil managers.

In a context where the Western oil industry increasingly lost control over oil prices and the access to cheap oil production in the Global South – especially within the OPEC member states – the scientist-engineer managers engaged in long-term commitments to nuclear energy development during the 1960s and 1970s. With investments in innovative nuclear energy research and developments, various oil companies tried to establish a presence throughout the nuclear fuel cycle. By framing these investments as answers to both future resource scarcity and the environmental impact of fossil fuel combustion and traditional nuclear fission, the oil companies both acknowledged environmental problems of both energy sources and invested (political) capital in their efforts to expand into innovative nuclear projects.

During the 1980s and early 1990s, this long-term commitment halted, however. Western oil companies temporarily stopped their nuclear investments and divested their already established nuclear projects. Due to pressure from increasingly powerful shareholders, a new generation of managers took over from the scientist-engineer cohort, members of which were nearing retirement. The new generation of managers, more often trained in finance and management, preferred the short-term profits of the oil industry and increasing shareholder value rather than the previous long-term, often more uncertain, investments in nuclear energy.

Intertwined geographies

The preceding story already indicates that, although Western oil companies halted their commitment to nuclear energy during the 1980s and 1990s, both industries would remain intertwined due to the geographical qualities of both oil and uranium and the legacies of the petroleum industry's nuclear involvement. The radioactive mineral necessary to produce nuclear electricity common to nuclear reactors in the world is still often located close to the world's petroleum reserves. Just like the companies searching for both oil and uranium on the US Colorado Plateau, also other places with

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[528] Gulf Oil Corporation, 'The Rabbit Lake Operation,' (1978), Gulf Oil Corporation Records (Pittsburgh: Detre Library and Archives, Heinz History Center), box B, folder 22.

petroleum reserves often contain uranium deposits. Because of the shared geological history of both resources, Saudi Arabia, which is already rich in oil, was able to claim to possess almost seven percent of the global uranium reserves in 2023.[529] Based on its access to both oil and uranium, the Saudi energy minister, Prince Abdulaziz bin Salman, presented the country's wish to "utilize its national uranium resources" at a mining industry conference in Riyadh.[530]

With their plans for a new domestic nuclear industry, Saudi Arabia used the oil industry as a model. Just as the French Petro-engineer and nuclear manager André Giraud proclaimed that his CEA had to become the "Shell of the atom" in 1971, the Saudis presented their state oil company, Saudi Aramco, as a model for how to develop their nuclear industry.[531] The oil company, originally called the Arabian American Oil Company, was established in 1933 by Standard Oil of California to search for oil in Saudi Arabia. In the following years, US firms Texaco, Standard Oil of New Jersy, and Standard Oil of New York Aramco joined the company and brought in capital, people, and technology to expand the oil production. During the decades following the Second World War, however, new agreements on the distribution of the oil profits increasingly improved the position of Saudi Arabia until the Kingdom completely took over the company in 1980.[532] According to Prince Abdulaziz, this development offered a model for the new Saudi nuclear industry by first inviting US nuclear companies to bring in technological expertise while using Saudi domestic uranium resources before Saudi Arabia will take over.[533]

Besides offering oil actors a model for how to manage their nuclear projects, also the oil industry developed various technologies that are still in use in today's uranium industry. The claims by Saudi Arabia about the scope of their uranium resources are partly based on the discovery of radium isotopes collected near mining projects and oil wells and refineries. By using gamma spectroscopy analysis of soil samples, and radioactive well logging techniques, specific areas rich in radioactive minerals were located over the past few decades.[534] Also in the US and Australia tools such as the prompt fission neutron tool, that are based on traditional well logging techniques, are used in contemporary projects to map uranium deposits.[535]

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[529] Jay Solomon, 'The Saudis want the US to help build a 'nuclear Aramco',' *Semafor* (June 2, 2023), https://www.semafor.com/article/06/01/2023/saudi-us-nuclear-aramco (Accessed June 18, 2024).
[530] 'Saudi Arabia plans to use domestic uranium for entire nuclear fuel cycle,' *Al Arabiya* (January 11, 2023), https://english.alarabiya.net/News/saudi-arabia/2023/01/11/Saudi-Arabia-plans-to-use-domestic-uranium-for-entire-nuclear-fuel-cycle-Minister (Accessed June 18, 2024).
[531] Solomon, 'The Saudis want the US to help build a 'nuclear Aramco''.
[532] Irvine H. Anderson, *Aramco, the United States, and Saudi Arabia: A Study of the Dynamics of Foreign Oil Policy, 1933-1950* (Princeton: Princeton University Press, 2014); Yergin, *The Prize*.
[533] Solomon, 'The Saudis want the US to help build a 'nuclear Aramco''.
[534] F.S. Al-Saleh and G.A. Al-Harsham, 'Measurements of radiation level in petroleum products and wastes in Riyadh City Refinery,' *Journal of Environmental Radioactivity* 99, 7 (2008), 1026-1031; Francesco Ameodo et all, 'Characterization of Naturally Occurring Radioactive Material (NORM) Generated from the Lower Cretaceous Carbonate Formations in the Arabian Peninsula and Gulf,' *Berg- und Hüttenmännische Monatshefte* 165, 8 (2020), 353-363; Falah Abu-Jarad, 'Application of Radiation Sources in the Oil & Gas Industry and Shortages in their Services,' *Proceedings of the International Symposium on the Peaceful Applications of Nuclear Technologies in the GCC Countries* (Jeddah, 2008); Sami Alharbi, 'Naturally occurring radioactive material (NORM) in Saudi Arabia: A Review,' *Journal of Radiation Research and Applied Sciences* 17, 3 (2024), 100981.
[535] R. Penny, C. Ames, and A. Ross, 'Determining uranium concentration in boreholes using wireline logging techniques: Comparison of gamma logging with prompt fission neutron technology (PFN),' *Applied Earth Science: Transactions of the Institutions of Mining and Metallurgy* 121, 2 (2012), 89-95.

Additionally, the technique of In Situ Leaching (ISL), that the oil industry introduced and developed during the 1970s based on waterflooding techniques, is currently applied to 57 percent of all uranium mining projects in the world. Due to its economic efficiency and the persistent frame of it being a relatively "environmentally friendly" way of mining, the technique is now dominant in the US, Kazakhstan and Uzbekistan, while it is also employed in Australia, China and Russia.[536] While several scientists already indicated that there were environmental impacts in using chemical leaching methods for uranium mining, the industry managed to keep leaching in the United States and Australia largely safe from tightened regulations that did affect other forms of uranium mining. Promotional material and lobbying efforts from the oil companies ignored or downplayed these problems. Only after some significant environmental disasters, such as in the soil poisoning around the Straz mines in the Czech Republic that came to light after 1989, did experts and environmentalists act against leaching on a larger scale, although ISL is still presented by some oil companies as an environmentally friendly way to mine uranium.[537]

The continuous presence of these oil technologies in uranium mining shows how the geographies and technologies of oil and uranium remain intertwined. Although Western oil companies halted or divested their nuclear diversification projects during the 1980s and 1990s, the story about oil and the atom did not stop there. As the example of Saudi Arabia shows, oil actors will continue to play a pivotal role in potential future nuclear developments. There is an ongoing connection in spillovers of people, technologies, and practices, that keeps establishing pathways for oil actors to move in between both industries and shape the development of the nuclear industry.

Diversification as a strategy

Not only did the legacy of the oil involvement in nuclear energy survive in technologies, returning investments, and environmental discourse, also former oil companies and subsidiaries are still in business today. For example, the British-German-Dutch enrichment company Urenco, with Shell as one of the founding parties of the Dutch branch, continues to process uranium based on the centrifugal methods originally developed by Standard Oil of New Jersey in the Manhattan Project.[538] Also General Atomics (in 1993 the company would be renamed to General Atomics instead of General Atomic), after being sold by Chevron in 1986, still participates in both experimental and applied research into nuclear fission and fusion development.[539] Even Exxon's enrichment plants, which were sold to the German company Siemens in 1986, are operating to this day.[540]

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[536] World Nuclear Association, 'In-Situ Leach Mining of Uranium,' *World Nuclear Association* (May 16, 2024), https://world-nuclear.org/information-library/Nuclear-Fuel-Cycle/Mining-of-Uranium/In-Situ-Leach-Mining-of-Uranium (Accessed June 18, 2024).

[537] Mudd, *An Environmental Critique of In Situ Leach Mining*, 75-79; TotalEnergies, 'Metal Mining with Elixore diluents'.

[538] Urenco, 'Urenco Nederland,' *urenco.com* (2023), https://www.urenco.com/global-operations/urenco-nederland (Accessed June 18, 2024).

[539] General Atomic Company, 'About: Global Progress Through Technology,' *ga.com* (2023), https://www.ga.com/about/ (Accessed June 18, 2024).

[540] In 2001 Siemens sold its reactor and enrichment projects to the French nuclear company Framatome (owned by Électricité de France (EDF) and Mitsubishi Heavy Industries) that still operates the enrichment plants. Framatome, 'Richland, Washington,' *Framatome* (date unknown),

While these nuclear companies continued finding ways to generate profits, decisions to participate in the nuclear business among oil actors varied over time – both among different oil actors at the same time and among oil companies over different times. When the oil companies in the US, France, UK, and the Netherlands were confronted with abundant oil from the Middle East during the 1950s, smaller and middle-sized companies with little access to international oil concessions started investing in uranium projects. Later, when forecasts predicted that oil concessions would become less profitable and Western oil companies' assets in the Global South would increasingly be nationalized, also major, internationally active, oil companies started diversification projects in nuclear energy by buying existing companies or establishing new subsidiaries.

Even when seemingly sparked by short-term events, the strategies to enter nuclear energy were often based on long-term prospects for future energy developments. As chapter 3 and 4 showed, oil firms framed their nuclear diversification as a long-term commitment to become full-fledged energy companies and develop the energy resource that would pose an answer to potential future resource scarcity, environmental pollution, and increasing nationalization of oil projects in the Middle East. Especially during the 1950s, there were heated debates among oil actors whether and when nuclear energy would eventually overthrow petroleum as the primary energy source. During the 1960s and 1970s too, the nuclear diversification of various oil actors always was presented as a long-term strategy where nuclear increasingly would become a more dominant factor in the global energy mix. To this end, oil actors also invested in long-term and experimental research projects like nuclear fusion.

During the 1980s, this commitment to long-term projects diminished, however. While many of the nuclear projects still were in a stage of development, and the already commercialized projects often were modestly profitable, Western oil companies withdrew from their diversification projects to refocus on short-term profits. This happened even when, as chapter 5 stated, oil firms' planners still agreed that diversification was the ultimate long-term strategy for the companies.

Based on these debates, this thesis shows that strategic decisions whether to invest in nuclear energy were deliberate choices. Although disruptions in the oil market, opportunities to obtain access to cheap oil production, and changing market regulations all played important roles in the decision-making process of the various Western oil actors, company executives made their individual investments decisions based on how they understood the world. In this way, the oil industry never functioned as a monolithic entity, but instead consisted of a wide variety of different firms where individual actors at the management level tried to steer their companies as they saw fit.

Reflections on cohorts

What is an energy addition if not oil actors persevering?

This dissertation applied cohort theory to weave together these two preceding stories. The theoretical framework offered a way to combine the technological and scientific history of spillovers between the oil and uranium industries with a business history of the nuclear strategies developed and abandoned within Western oil companies. The geochemical and geophysical technologies and geographical knowledge that linked the oil industry to uranium exploration were developed and applied by oil actors

https://www.framatome.com/en/implantations/richland/ (Accessed June 10, 2024); Andrew Teller, *The EPR Reactor: Evolution to Gen III+ based on proven technology* (Vienna: IAEA, 2010).

who would later help design the development of various early nuclear industrial projects and steer their companies into nuclear diversification projects. In this way, these actors shaped the addition of nuclear energy to the global energy mix.

In its analysis of this 'energy addition' this dissertation used concepts derived from the Multi-Level Perspective (MLP). Chapter 2 and 3 focused on oil involvement in multiple "niche" applications of nuclear energy, ranging from research into radioactive minerals to early industrial applications in the Manhattan Project. Especially in its early industrial developments, state actors (governments, but also semi-governmental organizations such as the Dutch RCN) played a big role in establishing projects, issuing policies and regulations, and protecting nuclear technology from competitive markets by subsidizing the liability costs. This involvement changed – although state actors remained important – during the 1960s and 1970s when major incumbent oil firms increasingly got involved in managing nuclear projects due to changes in "landscape" such as decolonization and losing access to cheap oil production in the Global South (chapters 3 and 4). During the 1980s, changing market regulations (where again state actors played a big role) and oil prices created a new context in which incumbent actors (temporarily) disengaged with nuclear energy projects, and the addition of nuclear energy halted (chapter 5).

Traditionally, transition frameworks, particularly the multi-level perspective, have had difficulty in representing the agency of individual actors without losing track of the overarching story of a transition (or addition) such as the addition of nuclear energy.[541] MLP by itself does not account for the many individual oil actors that moved in between the oil regime, the nuclear niche, and (semi)governmental organizations. This dissertation shows how cohort theory can offer explanations that connect structure (incumbent oil companies' strategies regarding nuclear energy) to these individual actors' agency. By focusing on the shared characteristics of the oil actors moving in between the different levels of the transition, most notably their academic background and career trajectories within the oil industry, this thesis argues that generational shifts do matter in assessing oil firms' strategies toward alternative energy sources such as nuclear energy.

As the preceding chapters argued, taking the careers of these different actors together based on their shared academic background and experience in the oil industry helps explain why specific diversification projects, like nuclear energy, were selected by oil companies, and how the networks and knowledge the oil industry profited from in these projects were developed. Because of the network of oil actors in the nuclear industries and the technological expertise, the cohort of scientist-engineers *could* make the decision to diversify their companies into nuclear energy when they rose to power within the oil industry during the 1960s. When the members of this cohort retired during the 1970s and 1980s, this *enabled* a new cohort to disengage with these long-term nuclear projects and focus on short-term profits and higher shareholder value.

By using cohort theory as a model to analyze the development of nuclear diversification projects within the Western oil industry, this thesis offers a better understanding of how individual actors shaped energy developments. During the twentieth century, nuclear energy developed from an energy source with primarily niche applications to a full-fledged energy regime delivering up to seven percent of the world-wide energy demand at its peak. Although the energy source never fulfilled the predictions

[541] Aroújo, 'The emerging field of energy transitions,' *Energy Research & Social Science*, 112-121; Geels, 'The Multi-level perspective on sustainability transitions,' 24-40.

made by oil geophysicists like Marion King Hubbert and Paul Lyons, it still became a substantial part of the global energy mix, even when the development of new reactors in the West halted during the 1980s.[542] This development was shaped by individual actors that moved in between the new nuclear industrial developments, incumbent oil companies, and (semi-)governmental organizations over the span of their careers.

Also, in contemporary debates on the role of oil firms in a transition toward sustainable energy sources, it is essential to include cohort shifts to be able to assess the diversification projects in "green" technologies of various companies. By connecting the structure of a past nuclear energy addition with the agency of individual actors shaping various oil-nuclear spillovers, this dissertation showed that for incumbent oil firms to commit to long-term strategies of developing alternative energy sources that will not be as profitable as oil projects in the short-term, a cohort of managers with experience and knowledge in past spillovers between both energy sources is needed.

The limits of cohort theory

Of course, cohort theory only offers one lens to focus on the twentieth century oil-nuclear spillovers. Like all models, also this theoretical framework offers an abstraction of the historical reality and encourages historians to smooth out a rough and knotted story, obscuring inconvenient complications.[543] One of the most obvious examples of these potential pitfalls is the existence of many deviations from the leading cohorts. As this dissertation showed, there were several actors working as economists within in the oil industry – such as Aramco's James Terry Duce and A. H. Chapman, and Gulf Oil's T.D. Lumpkin – who argued for diversification strategies for their companies in the 1950s and 1960s. Also, as discussed in chapter 5, during and after the 1980s still many oil executives continued to have a background in geophysics or petroleum engineering. Cohort theory assisted in uncovering general trends that helped explain overarching developments like the shifts in popularity of diversification strategies within the oil industry and the development of nuclear energy, but the theory does not offer an all-encompassing framework that captures the entirety of an industry as big and varied as the oil industry.

In addition, in this dissertation geoscientists and (chemical) engineers are grouped together in the same cohort that emerged in between the 1920s and early 1940s within the oil industry, while in academic literature there is a growing tendency to highlight the differences in working style and interests between scientists and engineers.[544] In many cases within this thesis, however, merging the two groups made sense since the members of this cohort were all part of the same networks, or even shared common educational backgrounds. Engineers like Eger Murphree operated in the same institutions, committees and boards as geophysicists like Wallace E. Pratt and Everette Degolyer. In the Netherlands too, chemical engineers like Han Hoog and Maarten Bogaardts often corresponded and collaborated with (former) Shell scientists like Hendrik Brinkman. In France, the engineers

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[542] British Petroleum, *BP Statistical Review of World Energy* (London: The Editor, 2018), 11.

[543] Alan Okros, 'Generational Theory and Cohort Analysis,' Alan Okros (eds), *Harnessing the Potential of Digital Post-Millennials in the Future Workplace: Management for Professionals* (London: Springer, 2020), 33-51.

[544] Thomas E. Pinelli, 'Distinguishing Engineers from Scientists – The Case for an Engineering Knowledge Community,' *Science & Technology Libraries* 21, 3-4 (2001), 131-163; Richelle Boone (ongoing work).

Figure 27: Scientist conducting research with an isotope ratio mass spectrometer at Continental Oil Company, 1977. American Petroleum Institute Photograph and Film Collection (Washington D.C.: National Museum of American History), Box 52, folder 69.

graduating from the *Ecole Polytechnique* also often had an extensive training in geophysics, and sometimes even in geochemistry.[545]

Still, within the cohort opinions about the future of nuclear energy and the role the petroleum industry had to play in the development of this new energy source varied. Although all these actors did play roles in various nuclear institutions and companies, the cohort members who shaped nuclear developments made different decisions whether to diversify (and to what extent) into nuclear energy based on varying expectations about the how both industries would develop. As chapter 3 described, oil geophysicists like Paul Lyons and Marion King Hubbert predicted an imminent and swift end of oil as primary energy source with nuclear energy taking over. Other geophysicists, including Everette Degolyer and Morgan Davis countered these predictions by pointing toward the abundance of the big oil fields in the Middle East, while geophysicists and engineers like Dean McGee and Pierre Guillaumat argued for the future importance of both oil and uranium. All these actors were members of the same cohort, but the cohort never consisted as a monolithic entity.

A potential blind spot of only focusing on the development of a cohort is the impact, both on health and the environment, of the technological spillovers that were shaped by this cohort. As this

[545] Göran Ahlström, *Engineers and Industrial Growth: Higher Technical Education and the Engineering Profession During the Nineteenth and Early Twentieth Centuries: France, Germany, Sweden, and England* (London: Routledge, 1982), 17-67; Antoine Picon, Bruno Belhoste, Amy Dahan-Dalmnénico. and D. Pesre, *La France des X, deux siècles d'histoire* (Economica, 1995); Antoine Picon, Bruno Belhoste, and Amy Dahan-Dalmnénico (eds), *La formation polytechnicienne, 1794-1994* (Paris: Dunod, 1994).

dissertation – especially the third, fourth and fifth chapters – showed the nuclear technologies and investments introduced by the oil industry established a uranium industry that was often based on colonial practices, and offered little protection for workers, locals and the environment. By framing new technologies like In Situ Leaching as "environmentally friendly" the oil companies also shaped a discourse where new leaching practices could become the most common uranium mining method, while repressing concerns about the poisoning of the soil and groundwater.

Focusing on a cohort of scientists and engineers becoming managers within the oil and nuclear industries also creates a potential blind spot regarding the many women and minorities working within both industries. Although almost all the management positions within the nuclear and oil industries were exclusively taken by men during the studied period, there actually were several women and people of color working as geophysicists, chemists and engineers within the oil and uranium industries, or shaping the development of both industries in other ways. In this dissertation, a few examples that played crucial roles in constituting the development of the uranium industry and the cohort as a network have been mentioned, such as Margareth C. Cobb, the geophysicist who translated and reviewed Richard Ambronn's work on measuring radioactivity in oil wells, Stella Dysart, the oil wildcatter and owner of the uranium deposits near Ambrosia Lake, and Karen Silkwood, the first female member of the bargaining committee for the union of Oil, Chemical and Atomic Workers (OCAW) at Kerr-McGee. Yet, in this thesis these references only signal that an overarching study of the role of women and minorities in this cohort is still needed, especially at levels other than upper management within both industries.

Cohort shifts and the emergence of neoliberalism

Socialist nuclear policies

Even when considering these potential blind spots, cohort theory could potentially offer new perspectives on the development of other management theories and ideas. This thesis mostly focused on the role of diversification strategies in relation to cohort changes and increasing shareholder power, but an open question remains as to how this development relates to the emerging influence of neoliberalism within the oil industry. In 1983, Richard Holwill, vice-president of energy decisions at the Heritage Foundation, published an extensive argument against some elements of Ronald Reagan's energy policies. Specifically, Holwill argued that Reagan's backing of the nuclear industry by extending nuclear subsidies contradicted his neoliberal views. According to Holwill the Reagan administration showed "the appearance of being for a free market in all things conventional, but virtually socialist on nuclear power."[546]

In the 1970s and 1980s, various neoliberal think tanks regularly expressed their views regarding energy policies, focusing on how deregulated markets would solve the energy problems faced in Western countries. In their reports and position papers, their authors argued that markets should be deregulated, governmental subsidies scaled down, and companies gain the freedom to compete. One technology became the main target of the think tanks' struggle against too heavily regulated and subsidized energy sources: the expensive production of nuclear energy.

[546] Richard N. Holwill, 'Department of Energy,' Richard N. Holwill (eds), *Agenda 83* (Washington, DC: Heritage Foundation, 1983), 138-139.

A policy paper for the Cato Institute by Barry Brownstein, associate professor of economics and director of the Bureau of Business Research at the University of Baltimore, also expressed this criticism. In his paper, Brownstein argued that while the subsidies for the nuclear industry from the Reagan administration would not necessarily establish "the nonviability of the nuclear power industry, in that it might well be that nuclear energy might not exist in the absence of government intervention." "Perhaps the most common fallacy in public policy arguments," Brownstein continued before tapping into previous discussions about resource scarcity, "is the simple failure to understand that we live in a world of pervasive scarcity."[547]

Here, Brownstein argued that the concept of scarcity encompasses the idea that "to obtain more of an item, something must be sacrificed. This is as true of energy as it is of any other scarce good. What is being sacrificed is the increased production of other goods and services that now must be foregone to obtain more nuclear energy." Where the Club of Rome and geophysicists like Hubbert King had used the concept of "scarcity" to talk about the limits to the availability of physical resources and waste production, Brownstein reframed this concept to focus solely on the money invested. According to Brownstein the money spent on subsidized nuclear power plants was money not spent on developing energy sources that would be viable without government subsidies: "Over $150 billion has been spent on the construction of nuclear power plants – $150 billion that could have been spent on other activities, including other energy alternatives."[548]

With these arguments, neoliberals positioned themselves as outspoken opponents of nuclear power. In doing so, they also denounced industrial frames of building a sustainable future with "environmentally friendly" nuclear technologies. Based on earlier classical liberal ideas, neoliberals criticized the dominant Keynesian ideas by arguing for a more liberalized market economy and a restricted growth of the reserves of the federal reserves. According to prominent neoliberal thinker Milton Friedman, business enterprises had the prime function to generate profits, with their central responsibility to their shareholders. Friedman rejected the idea that business owners should also seek to perform social tasks and argued that any company spending more on pollution controls than required by law "in order to contribute to the social objective of improving the environment", was practicing "pure and unadulterated socialism".[549]

6

Carbon neoliberalism

An interesting avenue for further research, based on the findings of this dissertation, would be to then investigate in what ways the increasing influence of the cohort of economists and business students in the oil industry after 1973 created pathways for neoliberal ideas and climate denialism to enter the top levels of the oil industry. The idea that the 1973/74 oil crisis propelled neoliberal thinking within financial markets, governments and industry is not new. Various scholars have pointed out that the crisis and the succeeding recession led prominent figures in academia, industry and the public sphere to argue that in fact not the geophysical limits of resource reserves constrained economic growth, but rather the increased volatility of the markets in combination with the inability of a strongly regulated,

[547] Brownstein, 'The Price-Anderson Act: Is It Consistent with a Sound Energy Policy'.
[548] Ibidem.
[549] Milton Friedman, 'The social responsibility of business is to increase profits,' *New York Times Magazine* (September 13, 1970); M. Marinetto, 'The Historical Development of Business Philanthropy: Social Responsibility in the New Corporate Economy,' *Business History* 41, 4 (1999), 1-20; Walker, *More Heat than Life*, 22.

and increasingly nationalized, industry to act in these markets were the main factors causing the decline of growth.[550]

These neoliberal ideas were further developed and propagated by various conservative and neoliberal think tanks and institutions. The first wave of neoliberal think tanks had already been set up between the 1940s and 1970s. In the United States these included the American Enterprise Institute (AEI), Herman Kahn's Hudson Institute, and the Foundation of Economic Education (FEE), and in the United Kingdom the Institute of Economic Affairs (IEA). The founding of these first think tanks was followed by a new wave during the 1970s. The new wave included the Centre for Policy Studies (CPS) and the Adam Smith Institute (ASI) in Britain, and the Heritage Foundation and the Cato Institute in the United States.[551]

Although several scholars pointed out that these think tanks in themselves were not always the most influential in furthering neoliberal ideas, and that instead ministers and civil servants proved to be the motors behind the emerging neoliberal ideas within governments, these institutions did provide an ideological backing and new arguments for the actors supporting neoliberal ideology.[552] Many of these institutions were funded, or even founded, with money derived from wealth earned in the oil industry. Several fossil fuel magnates, including the Mellon family, Edward Noble and the Koch brothers, founded think tanks in the mid-1970s such as the Heritage Foundation and the Cato Institute. They also sponsored other institutions and politicians in Washington D.C. that promoted "trickle-down economics" including Ronald Reagan's campaign for the presidency.[553]

Also, companies themselves started funding neoliberal think tanks, institutions and events organized by proponents of neoliberalism and monetarism. For instance, economic historian Neil Rollings has shown how Shell Oil supported the work of neoliberal think tank the IEA in the United Kingdom.[554] In the United States, Mobil Oil and other companies (including the Exxon-owned Canadian company Imperial Oil) started funding research and lobbying conducted by Herman Kahn's Hudson Institute.[555] In Western Europe, major oil companies supported the distribution of neoliberal and monetarist ideas by funding events like a debate between Swiss-American economist Karl Brunner, an adviser to British

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[550] Caleb Wellum, 'Energizing Finance,' 7-8; Jeremy Walker, *More Heat than Life: The Tangled Roots of Ecology, Energy, and Economics* (London: Palgrave MacMillan, 2020), 3-32.

[551] Daniel Stedman Jones, *The Masters of the Universe: Hayek, Friedman, and the Birth of Neoliberal Politics* (Princeton University Press, 2012), 134.

[552] Thomas Turnbull, ''No Solution to the Immediate Crisis',' 573; Ben Jackson, 'Intellectual Histories of Neoliberalism and their Limits,' Aled Davies, Ben Jackson and Florence Sutcliffe-Braithwaite (eds), *The Neoliberal Age? Britain since the 1970s* (London: UCL Press, 2021), 52; Bram Mellink and Merijn Oudenampsen, *Neoliberalisme: een Nederlandse geschiedenis* (Amsterdam: Boom, 2022).

[553] Mitchell, *Carbon Democracy*, 198; Sandy Smith-Nonini, 'The role of corporate oil and energy debt in creating the neoliberal era,' *Economic Anthropology* 3 (2016), 62-63.

[554] Neil Rollings, 'Cracks in the Post-War Keynesian Settlement? The Role of Organised Business in Britain in the Rise of Neoliberalism before Margaret Thatcher,' *Twentieth Century British History*, 24, 4 (2014) 637–659; Turnbull, ''No Solution to the Immediate Crisis',' 573

[555] 'Corporate Environment Study,' (Corporate Planning Service, Hudson Institute, 1971), Imperial Oil Collection (Calgary: University of Calgary), IM4, box 41; Anthony J. Parisi, 'Herman Kahn Revisited,' *The New York Times* (February 26, 1978).

Prime Minister Margaret Thatcher, and the Dutch Social Democratic Party leader Joop den Uyl in Rotterdam."[556]

The increasing oil funding for neoliberalism coincided with the cohort shift within the oil industry that is described in chapter 5 of this dissertation. These coinciding developments could likely have been connected, with neoliberal thoughts entering the oil industry via the education of this cohort's members directly influencing the willingness to invest in nuclear energy specifically (many oil actors such as Gerrit Abram Wagner became fierce proponents of neoliberalism); however, such connections are hard to prove or even fully comprehend without doing extensive research into the development of neoliberalism within the oil industry.

The petro-atom: concluding observations

For now, this dissertation only offers some first thoughts on this question that set the stage for upcoming research. This dissertation focused on answering the questions why so many oil actors were involved in the development of nuclear energy throughout multiple decades, and why many oil firms divested their nuclear projects during the 1980s and early 1990s. As an answer, I positioned two cohort shifts (the emergence of the scientist-engineers as managers within the oil industry, and the shift to the successive cohort of managers trained in economics) at the center of the story of the petro-atom. This story encompassed the ubiquitous spillovers of technologies, people, practices and capital between the oil and nuclear industries that shaped the addition of nuclear energy to the global energy mix during the twentieth century.

Throughout this century, various sources of energy have had a significant impact on people's lives and the environment. Coal, biomass, hydropower and natural gas have all fueled the developments of the last decades, but none of these energy sources have been at center of energy discourse and people's imagination as much as oil and nuclear energy have. Even though they have traditionally been regarded in the historical literature as separate energy sources with clearly distinguishable traits and industries, this dissertation has made an argument that both sources were, and are, inextricably linked.

Starting with the first geoscientists and entrepreneurs finding radioactive minerals in depleted oil wells during the first decades of the twentieth century, geophysical and technological spillovers continued to shape the developments of both the petroleum and the atomic industries. Oil knowledge, actors, and capital formed a crucial basis for setting up nuclear industries, while atomic physicists and atomic technologies played an important role in establishing oil as the primary energy source during the twentieth century.

From the start of the atomic age in the West, oil actors were involved in virtually every nuclear development – an intertwining that continued through the following decades and culminated in the heydays of oil involvement in nuclear energy during the long-1970s. At that time, the oil industry dominated nuclear developments by developing new technologies, influencing the discourse on resource scarcity and environmentalism, and altering legislation in favor of continuing oil-nuclear involvement.

[556] The whole event was paid for by the American oil company Chevron. Bart Tromp, 'Van Delft naar Rotterdam,' *Het Parool* (December 4, 1982), 4; Mellink & Oudenampsen, *Neoliberalisme*, 159-160.

Although these heydays ended during the 1980s and 1990s, the oil-nuclear spillovers did not stop there. As this chapter argued, both industries are linked through shared geographies of petroleum and uranium, technologies, and actors, to this day. In a time where nuclear energy is increasingly framed as an alternative to fossil fuels, this thesis argues that also during any further addition of (or transition to) nuclear energy oil actors will persevere.

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Summary

This thesis examines the ubiquitous presence of the oil industry in the development of nuclear energy during the twentieth century. From the first decades of the previous century, oil actors were involved in the search for radioactive minerals and early technological applications of atomic physics that would become crucial for the later production of nuclear energy. Based geographical proximity and geological similarity between oil and uranium, the fast-growing oil industry was able to exert a major influence on the industrialization of nuclear energy from the beginning during World War II and the decades that followed, until today.

Building on the disciplines of STS, transition studies, business history, and the history of science, technology, and instrumentation this thesis answers the questions of why (and how) the oil industry became widely involved in almost all major nuclear projects during the twentieth century, culminating in an omnipresence in the nuclear industry the 1970s, and why many oil companies divested many of these projects during the 1980s and 1990s.

This thesis argues that the close involvement between the two industries was based primarily on shared properties of crude oil and uranium and the resulting corresponding technologies, knowledge and practices. This exchange was shaped by a cohort of geoscientists and engineers who were versed in early developments in atomic physics due to their studies during the 1920s and 1930s before starting to work in the oil industry. From these positions, they became involved in the first industrialization of nuclear power within the Manhattan Project and the subsequent quest in several Western countries to establish domestic nuclear industry. The various scientists and engineers within this cohort went on working within these new atomic industries or became executives within "their" oil company to then steer these companies in their diversification strategies into nuclear energy. As this cohort approached retirement age and, under pressure from changing market conditions and increasingly powerful shareholders, was replaced by a new cohort of managers with a background in business economics studies, the involvement of these oil companies in the development of nuclear energy also came to an (temporary) end.

In making this argument, I make use of cohort theory as developed within the social sciences. This theory allows to focus on the agency of the various individuals who shaped the development of nuclear energy without losing sight of the overarching addition of nuclear energy to the global energy mix. Combined with a toolbox of concepts from the transition studies literature, with the Multi-Level Perspective (MLP) in particular, cohort theory provides tools to study the role of individuals who hold positions within oil companies, the nuclear industry and government organizations throughout their careers within and shaped the addition of nuclear energy.

To discuss the impact of the development of the cohort, this dissertation applies a chronological approach. The second chapter (1895-1945) deals with the emergence of this cohort during the first half of the twentieth century. During these decades, the oil industry increasingly invested in developing geoscience research departments and attracting academically trained personnel with backgrounds in early quantum mechanics or as chemical engineers. These scientists and engineers brought in knowledge about, and developed, new technologies to analyze and detect oil underground based on radioactive decay. This knowledge made the oil industry a natural partner for first industrial

development of nuclear power. These developments, with the Manhattan Project in particular, thus served as a breeding ground for the Western cohort of oil scientists and engineers.

The third chapter (1945-1967) shows how this cohort contributed to the developments of the first industrial nuclear projects. The emergence of nuclear energy as a potential alternative to oil ignited debates among geophysicists, economists and executives within the oil industry. Major international oil companies, thanks to access to cheap oil from the Middle East, were able to opt for a strategy of "getting their ducks in a row" by investing in nuclear research and keeping close contact with nuclear developments without investing in nuclear energy on a large scale. Smaller oil companies, without this access, were already diversifying into uranium mining on a large scale in the 1950s based on technologies and expertise developed within the oil sector, with great impact on the health of mine workers and the environment. However, many young geophysicists and engineers increasingly chose careers in nuclear power rather than the oil industry, prompting many oil companies to make more management positions available to their scientists. From these positions, the cohort of scientists and engineers, pressured by growing fears of losing access to cheap Middle Eastern oil, were able to steer their companies into nuclear diversification projects.

The fourth chapter (1968-1979) examines the heyday of oil involvement in nuclear developments. Oil companies, based on a widely represented technological optimism, tried to gain a position in a variety of fields within the nuclear fuel chain. In the process, oil companies invested in various experimental research projects with the expectation that they would only become profitable in the (very) long term. These investments were then used by the oil companies to show that the companies were investing in environmentally friendly energy supplies and prosperity for the distant future.

Chapter 5 (1973-1993) argues that these long-term investments came to an end during the 1980s. Although various reasons were given from oil companies as to why nuclear power was less attractive, this chapter shows that hidden behind these reasonings was a shift in thinking about the role of the oil company within the oil industry. In a context of increasing shareholder power and rapidly changing markets, the cohort of scientists and engineers was slowly being replaced by a new generation of managers who were much more often trained in economic studies or business administration. These managers deliberately chose higher short-term profits in oil production to satisfy shareholders and said goodbye to the long-term strategies of their predecessors.

Finally, the last chapter reflects on the research presented there before in light of recent developments where several oil companies worldwide are once again investing in developments within nuclear energy. This thesis shows that oil and nuclear energy were linked from the beginning and will remain so for the future. To appreciate and understand the developments in the current energy transition, it is necessary to know the common past of both industries.

Samenvatting

Deze dissertatie onderzoekt de alom vertegenwoordigde aanwezigheid van de olie-industrie in de ontwikkeling van kernenergie gedurende de twintigste eeuw. Vanaf de eerste decennia van de vorige eeuw waren spelers uit de oliesector betrokken bij de zoektocht naar radioactieve mineralen en vroege technologische toepassingen van de atoomfysica die later een belangrijke rol zouden gaan spelen in de productie van nucleaire energie. Gebaseerd op geografische nabijheid en geologische overeenkomsten tussen olie en uranium, was de snelgroeiende olie-industrie vanaf het begin in staat een grote invloed uit te oefenen op de industrialisatie van nucleaire energie gedurende de Tweede Wereldoorlog en de decennia daarna, tot op heden.

Bouwend op de disciplines van bedrijfs- en wetenschapsgeschiedenis, STS en transitie studies geeft deze dissertatie antwoord op de vragen waarom (en hoe) de olie-industrie op grote schaal betrokken raakten bij bijna alle grote nucleaire projecten gedurende de twintigste eeuw met een hoogtepunt in de jaren zeventig, en waarom veel oliebedrijven gedurende de jaren tachtig en negentig veel van deze projecten afstootten.

Deze thesis beargumenteert dat de nauwe betrokkenheid tussen beide industrieën vooral is gebaseerd op gedeelde eigenschappen van ruwe olie en uranium en de daaruit voortkomende overeenkomstige technologieën, kennis en werkwijzen. Deze uitwisseling werd vormgegeven door een cohort van geowetenschappers en ingenieurs die gedurende hun studies tijdens de jaren twintig en dertig in aanraking kwamen met vroege ontwikkelingen in de atoomfysica voordat zij kwamen te werken in de olie-industrie. Vanuit deze posities raakten zij betrokken bij de eerste industrialisatie van kernenergie binnen het Manhattan Project en de daaropvolgende zoektocht in verschillende Westerse landen naar het opzetten van een eigen nationale nucleaire industrie. De verschillende wetenschappers en ingenieurs binnen dit cohort gingen vervolgens werken binnen de nieuwe atoomindustrie of werden leidinggevenden binnen "hun" oliebedrijf om vervolgens deze bedrijven te leiden in hun diversificatiestrategieën naar kernenergie. Toen dit cohort de pensioengerechtigde leeftijd naderde en, onder druk van veranderende marktomstandigheden en steeds machtiger aandeelhouders, werd vervangen door een nieuw cohort van managers met een achtergrond in bedrijfseconomische studies, kwam ook (tijdelijk) een einde aan de betrokkenheid van deze oliebedrijven bij de ontwikkeling van kernenergie.

Hierbij maak ik gebruik van de cohort theorie zoals deze is ontwikkeld binnen de sociale wetenschappen. Deze theorie neemt de zelfstandige handelingsbekwaamheid van de verschillende individuen die de ontwikkeling van kernenergie vormgaven als uitgangspunt zonder daarbij de overkoepelende toevoeging van nucleaire energie aan de wereldwijde energiemix uit het oog te verliezen. Gecombineerd met een gereedschapskist aan concepten uit de transitiestudies literatuur, met het *Multi-Level Perspective* (MLP) in bijzonder, biedt cohort theorie handvatten om de rol van individuen die gedurende hun loopbaan posities bekleden binnen oliebedrijven, de nucleaire industrie en overheidsorganisaties binnen de context van een energietransitie te bestuderen.

Om de impact van de ontwikkeling van de cohorten te bediscussiëren hanteert deze dissertatie een chronologische benadering. Het tweede hoofdstuk (1895-1945) behandelt de opkomst van dit cohort gedurende de eerste helft van de twintigste eeuw. De olie-industrie investeerde gedurende deze decennia in toenemende mate in de ontwikkeling van geowetenschappelijke onderzoeksafdelingen en het aantrekken van academisch geschoold personeel met een achtergrond in de vroege

kwantummechanica of als chemisch ingenieur. Deze wetenschappers en ingenieurs brachten kennis binnen over, en ontwikkelden zelf, nieuwe technologieën om olie te analyseren en ondergronds op te sporen op basis van radioactief verval. Deze kennis maakte de olie-industrie een natuurlijke partner voor eerste industriële ontwikkeling van kernenergie. Deze ontwikkelingen, met het Manhattan Project in het bijzonder, dienden daarmee als een kweekkamer voor het Westerse cohort van oliewetenschappers en ingenieurs.

Vervolgens laat het derde hoofdstuk (1945-1967) zien hoe dit cohort bijdroeg aan de ontwikkelingen van de eerste industriële nucleaire projecten. De opkomst van kernenergie als potentieel alternatief voor olie deed verschillende debatten ontbranden tussen geofysici, economen en bestuurders binnen de olie-industrie. Grote, internationale, oliebedrijven konden dankzij toegang tot goedkope olie uit het Midden Oosten kiezen voor een strategie van voorsorteren waarbij wel werd geïnvesteerd in nucleair onderzoek en nauw contact werd gehouden met nucleaire ontwikkelingen zonder grootschalig te investeren in kernenergie. Kleinere oliebedrijven, zonder deze toegang, stapten in de jaren vijftig al op grote schaal in de uraniummijnbouw gebaseerd op technologieën en expertise ontwikkeld binnen de oliesector, met grote impact op de gezondheid van personeel en milieu. Veel jonge geofysici en ingenieurs kozen echter in toenemende mate voor een carrière in de kernenergie in plaats van de olie-industrie, wat veel oliebedrijven deed besluiten meer managementposities beschikbaar te maken voor hun wetenschappers. Vanuit deze posities kon het cohort van wetenschappers en ingenieurs, onder druk van toenemende angst dat de toegang tot de goedkope olie uit het Midden Oosten verloren zou gaan, hun bedrijven leiden in diversificatieprojecten in de kernenergie.

Het vierde hoofdstuk (1968-1979) gaat in op de hoogtijdagen van de oliebetrokkenheid bij de nucleaire ontwikkelingen. Oliebedrijven probeerden, gebaseerd op een alom vertegenwoordigd technologisch optimisme, een positie te verwerven op allerlei terreinen binnen de nucleaire brandstofketen. Daarbij investeerden de oliebedrijven in verschillende experimentele onderzoeksprojecten met de verwachting dat deze pas rendabel zouden worden op de (zeer) lange termijn. Deze investeringen werden vervolgens door de oliebedrijven gebruikt om te laten zien dat de bedrijven investeerden in een milieuvriendelijke energievoorziening en welvaart voor de verre toekomst.

Hoofdstuk 5 (1973-1993) beargumenteert dat een einde kwam aan deze langetermijninvesteringen gedurende de jaren tachtig. Hoewel vanuit oliebedrijven verschillende redenen werden aangedragen waarom kernenergie minder aantrekkelijk was, laat dit hoofdstuk zien dat achter deze redeneringen een omslag in het denken over de rol van het oliebedrijf binnen de olie-industrie verborgen lag. In een context van toenemende macht voor aandeelhouders en snel veranderende markten werd het cohort van wetenschappers en ingenieurs langzaam vervangen door een nieuwe generatie managers die veel vaker waren opgeleid in economische studies of bedrijfskunde. Deze managers kozen bewust voor hogere winsten op korte termijn in de productie van olie om aandeelhouders tevreden te stellen en namen afscheid van de langetermijnstrategieën van hun voorgangers.

Ten slotte reflecteert het laatste hoofdstuk op het daar voorafgaande gepresenteerde onderzoek in het licht van recente ontwikkelingen waarbij verschillende oliebedrijven wereldwijd wederom investeren in ontwikkelingen binnen de kernenergie. Deze dissertatie laat zien dat olie en kernenergie vanaf het begin verbonden waren en dit voor de toekomst ook zullen blijven. Om de ontwikkelingen in de huidige energietransitie op waarde te kunnen schatten en te kunnen begrijpen is het noodzakelijk het gemeenschappelijke verleden van beide industrieën te kennen.

Impact Paragraph

Many of the ubiquitous spillovers between the oil and nuclear industries that shaped the development of the twentieth century energy mix continue to this day. As this thesis showed, multiple oil firms still invest (or start again with investing) in nuclear energy developments, framing their investments in nuclear fission and fusion as "environmentally friendly". In current debates about the position of the oil industry in contributing to the development of alternative "green" energy sources, this thesis argues that these oil-nuclear spillovers should be understood from a longer, historical, perspective, highlighting the shared technologies and expertise. In this way, this thesis offers an example of how research to the intertwined historical developments of both energy sources offer new insights for current energy and sustainability debates.

This dissertation answered how and why many actors linked to the oil industry got involved on a large-scale in nuclear energy developments during the 1970s, and why many of these oil actors phased out their nuclear investments during the 1980s and early 1990s. As this thesis shows, oil actors became involved in uranium mining projects (with oil companies producing about forty five percent of the US domestic uranium resources in 1983), uranium enrichment, reactor manufacturing, and radioactive waste management. This ubiquitous involvement raised (sub)questions how oil actors perceived future energy developments, the role of the oil industry in developing alternative energy sources, and the role of oil-nuclear investments in debates about environmentalism and potential resource scarcity.

This thesis argues that the involvement of the oil industry in nuclear energy developments is grounded in a longer history of spillovers between both histories, dating back to early applications of quantum mechanics to explore for both oil and radioactive minerals during the first decades of the twentieth century. These spillovers of technologies, expertise, practices and people were shaped by a cohort of (geo)scientists and engineers versed in early atomic physics and who got employed in the oil industry during the 1930 and 1940s. During and after the Second World War this cohort moved in and out the oil industry, political levels, and nuclear developments, and ultimately steered even the biggest oil companies into long-term nuclear diversification projects during the 1960s and 1970s. When during the 1980s a new cohort of managers often trained in economics, finance, and business management took over within the oil industry, the long-term diversification strategies were replaced by strategies that prioritized short-term profits and increased share-holder value, in this way ending many of the nuclear investments.

In this way, this thesis shows that even when transitioning into alternative energy sources such as nuclear energy, the ubiquitous oil spillovers (including actors, practices, technologies, capital, and omnipresent nuclear frames) will continue to play a pivotal role: oil firms and states will continue to be drawn to nuclear energy having access to many of the resources and technologies needed to produce and further develop the energy source, technologies such as In Situ Leaching and radioactive well logging remain omnipresent in uranium mining, and nuclear frames of "innovations" like nuclear fusion and ISL as "environmentally friendly" linger into the future impacting both public and political debates about the future role of oil and nuclear energy in the current energy transition.

As this thesis argues, the future role from the oil industry is dependent on the strategic priorities set within the boardrooms of the various oil firms: for a successful transition out of oil and into alternative energy managers who prioritize long-term technological development over short-term profits are needed.

By making these claims this thesis targets both the academic (sub) disciplines of business, environmental, and labor historians and historians of science, technology, and instrumentation, and contributors to current societal and political, debates on sustainable energy, the energy transition, and the future role of the oil industry. To target the academic audience, I already presented parts of the argumentation presented in this thesis at business history conferences (European Business History Conference, Oslo 2023), conferences on the history of science and technology (ICOHTEC, Tallinn/Tartu, 2023; EHSH, Brussels 2022 and Barcelona 2024), energy history (Tensions of Europe online 2021 and Arhus 2022; "Black and Green?" workshop at Rachel Carson Center, 2023), Science and Technology Studies (Cornell University Science Studies Research Group 2022; WTMC, multiple occasions), and the field of transition studies/energy transitions (NOW-NERA Energy Symposium, Eindhoven 2022). Also, parts of thesis are already published (or are planned to be published) in journals such as *Historical Social Research*, *Energy Research & Social Science*, *Journal of Energy History, Nuncius*, and *Berichte zur Wissenschaftgeschichte*. In addition, the "Managing Scarcity and Sustainability" project this thesis is a product of of will continue to work on a co-authored academic monograph combining the research of Cyrus Mody, Odinn Melsted, Jelena Stankovic, and the research presented in this thesis.

This monograph is also planned to appear as a popular publication in Dutch, in this way also targeting audiences outside academia to bring in the conclusions of this thesis and the further research within the project to the current debates about the energy transitions. Regarding the conclusions of this thesis, I already presented on parts of this dissertation in interviews for *Energeia* (part of *Financieel Dagblad*) and the *Windvaan* (magazine issued by energy cooperation *De Windvogel*) about the role of oil firms in debates about climate change and energy transitions, in *De Limburger* about the storage of nuclear waste (with Vincent Lagendijk), and the American Institute of Physics' History Newsletter about the shared characteristics of oil and uranium.[557] I further developed these arguments within the public domain via various blogposts for *Over de Muur*, *Mosa Historia,* and the website of the Managing Scarcity project.[558] Also, I worked on multiple television/online items connecting my research to current debates on the energy transition and nuclear fusion developments, and published an opinion piece in the Dutch newspaper *NRC* on the current day labeling of nuclear energy (with uranium mining in particular) as "green" by the European Commission.[559]

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[557] David Duijnmeijer, 'Oliebedrijven geloofden oprecht dat zij het klimaatprobleem konden oplossen,' https://energeia.nl/energeia-artikel/40107021/oliebedrijven-geloofden-oprecht-dat-ze-het-klimaatprobleem-konden-oplossen (7 august 2023); Robin van der Kloor, 'Wordt Limburg een opslagplaats voor kernafval? 'We zijn verbaasd dat er nauwelijks discussie is',' *De Limburger* (18 June 2023); 'Interview Michiel Bron, bestuurslid Windvogel', *De Windvaan* 27, 2 (2023), 14-15; Joanna Behrman, 'Helleman Fellow Michiel Bron Explores the History of Energy,' *History Newsletter* Vol. 55, No. 1 (2023), 9-11.

[558] Michiel Bron, 'Oliebedrijven en alternatieve energie: een decennia oude combinatie?,' *Over de Muur* (October 2021), https://overdemuur.org/oliebedrijven-en-alternatieve-energie-een-decennia-oude-combinatie/; Michiel Bron, 'Archival Research in United States,' (October 2022), *Managing Scarcity* https://managingscarcity.com/blogposts/#_ftn1; Michiel Bron, 'The shared history of oil and nuclear energy,' *Mosa Historia* (March 1, 2023), https://fasos-research.nl/mosahistoria/the-shared-history-of-oil-and-nuclear-energy/#more-482.

[559] Universiteit van Nederland, 'Uitgelegd: Zo gaat kernfusie eindelijk werken,' (February 2023), https://www.universiteitvannederland.nl/college/uitgelegd-zo-gaat-kernfusie-eindelijk-werken (Accessed August 28, 2024); EditieNL, 'Aflevering 21 juni 2022,' https://www.uitzendinggemist.net/aflevering/591038/Editie_Nl.html# (Accessed August 28, 2024); Michiel Bron, 'Kies bij kernenergie ook voor de vergroening van uraniumwinning', *NRC* (18 juli 2022).

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That these fears, more than four years later, only marginally came true (even when a global pandemic prevented a lot of in person contact with colleagues, friends and family during the first one-and-a-half year) was thanks to the continuous support of the many caring, and loving, colleagues, friends and family I would like to thank here.

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Propositions

1. There is an ubiquitous and pivotal involvement of oil actors in the development of nuclear energy from its role as niche application in oil exploration to its current contribution to the global energy mix (this dissertation)
2. The involvement of oil actors in the development of nuclear energy and technologies is grounded in the shared characteristics of oil and uranium, and the subsequent geoscientific spillovers between both industries (this dissertation)
3. The spillovers between oil and nuclear energy were shaped by a cohort of scientist-engineers that moved between the oil sector, (semi) governmental organizations, and the early nuclear industry (this dissertation)
4. The nuclear investments by many Western oil companies during the 1970s were based on sincere long-term strategies to become full-fledged energy companies and guided by the cohort of scientist-engineers becoming managers within the oil firms (this dissertation)
5. The nuclear strategies within the oil industry were based on the (public) acknowledgment of the environmental impact of both fossil fuel combustion and regular nuclear fission during the 1970s among various, leading oil actors, and the presentation of oil-nuclear experimental innovations and research as “environmentally friendly” technofixes (this dissertation)
6. The divestments of the Western oil firms’ nuclear projects during the 1980s and 1990s can be attributed to an *internal* shift of focus toward short-term profit making within the top-levels of oil companies’ management (this dissertation)
7. Cohort theory offers a helpful tool for historians to address and understand individual actor agency within an energy transition framework without losing track of the overarching transition/addition (this dissertation)
8. The “greenness” often contributed to nuclear energy in current energy transition debates is based on a very limited understanding of the environmental impact of the nuclear fuel cycle
9. Current diversification projects from major oil companies will not last without a new cohort change and an internal shift of strategic priorities
10. Peter Jackson’s *The Lord of the Rings*-trilogy is an expensive rip-off of Ralph Bakshi’s 1978 film

Nuclear energy and oil are linked inseparably. From the very beginning, oil companies, technologies, scientists, and engineers have been involved in the development of atomic energy on an industrial scale. Oil was involved with the production of nuclear weapons in the Manhattan Project during the Second World War, the various uranium mining projects in the United States, Europe and the Global South, and with current day discussions about a new transition to nuclear energy. This dissertation shows that energy transitions - such as the addition of nuclear energy - can only be understood from a combined perspective of multiple energy sources and the companies that exploit these energy sources such as Exxon, Shell and TotalEnergies. This perspective learns us that the development of a new energy source occurred mainly due to the influence of already developed industries, but also depended on the backgrounds of the oil executives who devised and implemented the diversification strategies.

Michiel Bron