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PETROCHEMICAL EMPIRE

The Geo-Politics of Fossil-Fuelled Production

THE LAST TWO decades have witnessed an extraordinary surge in radical scholarship on oil. Starting with Timothy Mitchell's path-breaking work on the transition from coal to oil and its part in the emergence of 'carbon democracy', a series of important contributions have sought to weave oil more fully into the narration of 20th-century capitalism.¹ Scholars have retold the story of oil from the perspective of anticolonial protagonists in Latin America and the Middle East, situating these against the broader backdrop of the Bandung moment.² Other work has critically interrogated the putative claims of 'oil security' and supply scarcity that have long underpinned traditional accounts of US oil expansionism.³ Alongside this historical revisionism, a rich set of ecological-Marxist accounts have sought to integrate oil more systematically into the rhythms of accumulation, profitability crises and uneven global development—an analytical shift that bears directly on the challenges of climate change and the energy transition.⁴ This literature has significantly widened the conceptual purview of oil; from debates around finance and neoliberalism to discussions of contemporary aesthetic and cultural forms, oil can now be found as a core analytical referent.⁵

Common to all this new work is the attempt to situate oil as part of the actual making of social categories and patterns of political and economic power. As such, this literature upends many of the traditional tropes that have governed thinking about it, including notions of 'peak oil', oil as geopolitical 'prize' or oil as a 'curse' that inevitably damns resource-rich countries in the South to a future of bloated and parasitic Rentierism.⁶ These longstanding certitudes served to animate oil with some sort of

determinative and semi-mystical power; in their place, attention has been refocused on the social relations in which oil is embedded and that give particular meaning to it as a commodity. There is, in other words, a strong echo of Marx's critique of commodity fetishism in contemporary writing about oil—an attempt to see oil's power as deriving not from some 'thing-like' nature, but rather arising through its co-constitution with the relations of capitalism itself.

Nonetheless, there is a palpable absence in this expansive, revisionist reworking of our thinking about oil. Almost without exception, this scholarship treats it solely as an energy source or transport fuel—disregarding completely the other aspect of oil's mid-20th century emergence as the dominant fossil fuel: the birth of a world composed of plastics and other

¹ Timothy Mitchell, *Carbon Democracy: Political Power in the Age of Oil*, London and New York 2011.

² Bernard Mommer, *Global Oil and the Nation State*, New York 2002; Christopher Dietrich, *Oil Revolution*, Cambridge 2017; Giuliano Garavini, *The Rise and Fall of OPEC in the Twentieth Century*, Oxford 2019.

³ Mazen Labban, *Space, Oil and Capital*, New York 2008; Robert Vitalis, *Oilcraft: The Myths of Scarcity and Security That Haunt US Energy Policy*, Redwood City CA 2020.

⁴ John Bellamy Foster, *The Ecological Revolution*, New York 2009; Jason Moore, *Capitalism in the Web of Life*, London and New York 2015; Andreas Malm, *The Progress of This Storm*, London and New York 2018; Geoff Mann and Joel Wainwright, *Climate Leviathan*, London and New York 2018; Roberto Ortiz, 'Oil-Fueled Accumulation in Late Capitalism: Energy, Uneven Development and Climate Crisis', *Critical Historical Studies*, vol. 7, no. 2, Fall 2020, pp. 205–40.

⁵ On the relationship between oil, financialization and neoliberalism, see Mazen Labban, 'Oil in Parallax: Scarcity, Markets and the Financialization of Accumulation', *Geoforum*, vol. 41, no. 4, July 2010, pp. 541–52; and Caleb Wellum, 'Energizing Finance: The Energy Crisis, Oil Futures and Neoliberal Narratives', *Enterprise & Society*, vol. 21, no. 1, March 2020, pp. 2–37. On oil and culture, see Ross Barrett and Daniel Worden, eds, *Oil Culture*, Minneapolis 2014; Imre Szeman, 'System Failure: Oil, Futurity and the Anticipation of Disaster', *South Atlantic Quarterly*, vol. 106, no. 4, Fall 2007, pp. 805–23; Matthew Huber, *Lifeflood: Oil, Freedom and the Forces of Capital*, Minneapolis 2013.

⁶ For an excellent critique of peak oil and notions of scarcity, see Mazen Labban's *Space, Oil and Capital* and 'Oil in Parallax'. Robert Vitalis's *Oilcraft* takes a new look at the 1970s oil crises and the US–Saudi relationship, taking aim at the idea of oil security as the main driver of US foreign policy in the Middle East. Adam Hanieh, 'Rethinking Class and State in the Gulf Cooperation Council', in Joel Beinin et al., eds, *A Critical Political Economy of the Middle East and North Africa*, Redwood City CA 2021, presents a recent critique of Rentier State Theory as applied to the Gulf States of the Middle East.

synthetic products derived from petroleum.⁷ From the 1950s onwards, a wide array of naturally derived substances—wood, glass, paper, natural rubber, natural fertilizers, soaps, cotton, wool and metals—were systematically displaced by plastics, synthetic fibres, detergents and other petroleum-based chemicals. This ‘petrochemical’ revolution enabled the *syntheticization* of what had previously been encountered and appropriated only within the domain of nature; the very substance of daily life was transformed, alchemy-like, into various derivatives of petroleum. Here is oil not as energy source, but as feedstock, the literal raw material of commodity production itself.⁸

The making of a synthetic world is a missing piece in understanding the place of oil in contemporary capitalism.⁹ It is a story that begins in the early 20th century with the growth of the chemical industry in Germany and the US, subsequently moving through the rise of fascism and two

⁷ A partial exception to this oil-as-fuel assumption is work on agriculture and the Green Revolution, which often acknowledges oil as a raw material utilized in the expansion of fertilizers and pesticides from the 1930s onwards. Jason Moore, for example, has recently emphasized the role of oil in enabling what he describes as the proliferation of ‘cheap food’. For Moore, oil’s place in agriculture turned ‘oil and natural gas into food’: ‘farming was no longer farming. It was petro-farming’: *Web of Life*, pp. 251–2. Another important exception is Matthew Huber’s *Lifeblood*, which presents a fascinating account of oil’s impact on US cultural and political practices, specifically post-war sensibilities of individuality and ‘freedom’. Huber’s work is distinctive for its wider consideration of petrochemicals, including plastics, in this process.

⁸ According to the IEA, around 15 per cent of global oil is used for purposes other than energy or transport, a proportion that has increased from around 9 per cent in 1973: IEA, *Key World Energy Statistics 2019*, pp. 46–7. There is, however, a great deal of uncertainty in these estimations due to problems with data collection and the difficulty of disaggregating the energy and raw-material uses of oil in chemical production.

⁹ There has been little critical engagement with the emergence of the petrochemical industry, although Barry Commoner’s pioneering work of the 1970s provides important clues for how such a history could be written. See in particular Commoner’s *The Closing Circle*, New York 1971, and his *Poverty of Power: Energy and the Economic Crisis*, London 1976. An important book covering some of the issues surrounding petrochemicals and environmental policy (with a foreword by Commoner) is Kenneth Geiser, *Materials Matter: Toward a Sustainable Materials Policy*, Cambridge MA 2001. Significant accounts of the development of the history of petrochemicals from an industry perspective include Keith Chapman, *The International Petrochemical Industry*, Oxford 1991; Peter Spitz, *Petrochemicals: The Rise of an Industry*, New York 1988; and Louis Galambos et al., eds, *The Global Chemical Industry in the Age of the Petrochemical Revolution*, Cambridge 2006.

World Wars that pitted Germany's coal-based chemical giants against their weaker US counterparts. By the end of the Second World War, the US emerges as the dominant global chemical power. Its dominance, however, is premised on a chemical revolution that takes place during the War itself—the shift towards the use of oil and gas as the main chemical feedstock, rather than coal. This shift was deeply synergistic with oil's rise as the world's primary fuel, and with the emergence of the US as the hegemon of the new oil-centred world order. The new petrochemical industry also carried distinctive and radical implications that fundamentally transformed the nature of post-war capitalism itself—qualitatively increasing the scale and scope of available consumer goods, cheapening the cost of industrial production and enabling huge increases in productivity through labour-saving technologies. The commodification and massification of social life, including the rapid ascendancy of industries such as TV advertising, were in good part based upon the new synthetic products derived from petroleum. All of this was inseparable from continuous scientific and technological innovation, which in turn drove the restructuring of state–business relations and far-reaching changes to industrial organization and the corporate form.

The narrative that follows focuses predominantly on these historical lineaments of our synthetic world. The weight of this history, however, sits elephant-like within the ecological crisis of the present. Petrochemicals are the means through which oil has become woven into the very fabric of our social existence, yet this ubiquity has made them almost invisible to our everyday consciousness. This fact was noted recently by the Executive Director of the International Energy Association, Fatih Birol, who described petrochemicals as 'one of the key "blind spots" of the energy system', poorly understood even by energy professionals.¹⁰ Today, petrochemicals are decisive for the future trajectory of fossil-fuel use: they will almost certainly form one of the fastest-growing sources of demand for oil over the next two decades, and there exists no viable alternative to petroleum as a material feedstock—the basic raw material—for synthetic production. In reducing the problem of oil to simply the question of finding an alternative source of energy and transport fuel, we implicitly confirm the invisibility of petrochemicals. We remake our

¹⁰ IEA, *The Future of Petrochemicals: Towards more sustainable plastics and fertilisers*, 2018, p. 14.

synthetic world as something natural. As such, foregrounding the story of petrochemicals not only opens an entirely new vista to understanding the intertwined histories of oil and capitalism, it points directly to the necessity and challenges of moving beyond both.

Roots of the chemical industry

There was little indication in the early 1900s of the sweeping transformations that would be ushered in by the petrochemical revolution just fifty years later. At the turn of the century, the chemical industry was largely focused around dye-stuffs, utilizing coal as the main precursor for chemical production. Globally, the industry was dominated by Germany's Big Three chemical companies—BASF, Bayer and Hoechst—who, in 1916, established the IG Farben (IGF) cartel in order to coordinate research and divide up European and international markets.¹¹ At that time, the German chemical industry was vastly superior to that of the US or any other European country. Germany supplied around 90 per cent of the world's synthetic dyes up until the First World War. The US dye industry consisted of only seven firms in 1913, employing a mere 528 people with a product value of \$2.4 million; in comparison, the German industry was worth \$65 million and employed 16,000 people. German dominance was backed through an aggressive policy of overseas patent protection; one 1912 survey estimated that 70 per cent of all US patents granted on synthetic organic chemicals were actually German-owned.¹²

The First World War—sometimes described as the chemists' war—would provoke significant changes to chemical production and provide a powerful impetus to the growth of the industry. In Germany, IGF played a central role in the war effort, pioneering the development of poison-gas weapons (utilizing by-products of the dye industry) and synthetic nitrates for the manufacture of explosives and fertilizers.¹³ Despite Germany's defeat and the crushing terms dictated by the Treaty of Versailles, IGF's component companies remained intact and continued to be recognized

¹¹ Peter Hayes, *Industry and Ideology: IG Farben in the Nazi Era*, New York 1987.

¹² Kathryn Steen, *The American Synthetic Organic Chemicals Industry: War and Politics, 1910–1930*, Chapel Hill NC 2014, pp. 17, 64, 55.

¹³ These synthetic nitrates allowed Germany to manufacture explosives despite the British blockade of Chile, then the world's major exporter of saltpetre, an essential ingredient in both fertilizers and explosives.

as world leaders in chemical research and production after the War. In 1925, the cartel was formally reorganized as a single entity, becoming the largest corporation in Europe and the most important chemical company in the world.¹⁴

Across the Atlantic, leading American chemical companies also profited handsomely from the War.¹⁵ In addition to increased demand for basic chemicals, a pivotal moment for the industry came with the passage of the Trading with the Enemy Act (TWEA) in October 1917 and the establishment of a new office called the Alien Property Custodian (APC). Through this office, the American state seized German-owned patents and German-owned businesses, with a particular focus on the chemical industry. Initially, this property seizure was viewed as a temporary act—after all, ‘the United States is not a pirate nation’, opined a 1917 *New York Times* editorial.¹⁶ However, less than a year later, German industrial firms were to be denounced by the APC, A. Mitchell Palmer, as ‘spy centres’ and ‘a knife at the throat of America’.¹⁷ At the end of the War, the APC held an estimated \$700 million worth of seized German assets in 30,000 trust accounts.¹⁸

For the nascent US chemical industry, the TWEA turned out to be an immensely fortunate turn of events. Just one week before the Armistice was declared on the Western Front, the Act was amended to allow the permanent confiscation of chemical patents; thousands of these patents were then sold at a pittance of their reputed value to the newly

¹⁴ Joseph Borkin, *The Crime and Punishment of IG Farben*, New York 1978, p. 37. The author of this fascinating book served on the team that prosecuted IG F for war crimes at the conclusion of WW2.

¹⁵ It has been estimated that DuPont earned \$89 million through its wartime expansion, a windfall of retained earnings that enabled the company to expand research and production significantly after the War: Chapman, *International Petrochemical Industry*, p. 65. Likewise, around 90 per cent of Dow Chemical’s production was devoted to materials such as explosives and mustard gas during the War: Jason Szilagy, ‘American Chemical Companies in the First World War’, *Proceedings of Armistice & Aftermath*, Michigan Technological University Symposium, September 2018, p. 9.

¹⁶ Benjamin Coates, ‘The Secret Life of Statutes: A Century of the Trading with the Enemy Act’, *Modern American History*, vol. 1, no. 2, July 2018, p. 158.

¹⁷ Coates, ‘Secret Life of Statutes’, p. 158.

¹⁸ Steen, *American Synthetic*, p. 23.

established Chemical Foundation, a non-profit organization that was headed by the Alien Property Custodian himself. From there, the Chemical Foundation issued non-exclusive licences to American-owned chemical firms. This mechanism for appropriating German technical knowledge was developed in conjunction with leading American companies, including DuPont, the largest chemical firm in the US at the time, which actually drew up a precise list of patents that should be targeted for seizure.¹⁹ The APC explicitly identified the TWEA and the Chemical Foundation as a means of ‘Americanizing’ the chemical industry, and in later Congress debates, one representative would describe the Act as ‘the only safeguard’ for ‘the existence of the new chemical industry in this country’.²⁰ In this manner, the law constituted a massive lever of capital accumulation for America’s burgeoning chemical sector.²¹

The establishment of the Chemical Foundation as a means of transferring patents to American firms was formally designed to prevent the monopolization of scientific techniques by a handful of firms. In actuality, however, a small number of companies emerged as leaders of the US chemical industry through the 1920s, most notably: DuPont, Union Carbide & Carbon Corporation, Dow Chemicals and Monsanto. These firms benefitted greatly from the transfer of German patents, applying new techniques to expand their output and range of basic chemicals. Of particular importance to these firms was the expanding automobile industry, which provided a steady source of demand for new chemical products at a scale that made production profitable. American chemical companies grew in lock-step with the major car manufacturers, supplying fuel additives such as the anti-knocking agent tetraethyl lead, synthetic rubber for tyres and the first synthetic plastic, Bakelite, for components such as spark plugs, batteries, steering wheels and instrument panels. Indeed, the close association between the chemical and automotive industries was expressed in joint ownership structures—DuPont, for example, owned up to 38 per cent of General Motors in the inter-war years, and when Pierre du Pont passed the presidency of

¹⁹ Steen, *American Synthetic*, p. 299.

²⁰ Coates, ‘Secret Life of Statutes’, p. 159.

²¹ The Trading with the Enemy Act was retained as a permanent mechanism of US foreign policy, later put to use for economic sanctions. See Coates, ‘Secret Life of Statutes’ for a discussion.

the company to his brother in 1919, he went on to become chairman of General Motors.²²

American conquest

The 1920s and 1930s were important decades in basic chemical research, focused particularly on polymers, large molecules made up of repeated chains of smaller molecular units, called monomers. The German scientist Hermann Staudinger first discovered this basic structure of polymers in 1920.²³ His ideas initially met with scepticism but soon found practical application in the development of new synthetic compounds. Through the inter-war years, numerous polymers were discovered (mostly accidentally) in the labs of the largest chemical companies, including plasticized polyvinyl chloride or PVC (1926), neoprene synthetic rubber (1930), polyethylene (1933), nylon (1935) and Teflon (1938).²⁴ However, with the exception of nylon—developed by DuPont scientists over an eleven-year period—these polymers generally lacked significant commercial application. Most importantly, coal remained the key feedstock utilized in the production of these new polymers and the wider chemical industry.

The Second World War, however, drove three major changes to the chemical industry: first, an immense increase in the diversity, output and commercialization of polymers; second, a shift towards the use of petroleum rather than coal as the basic feedstock for polymer production; and third, the emergence of the US as the dominant global chemical power, and the concomitant decline of the German chemical industry. These changes were closely related, implicitly pitting the German and American chemical industries against one another through the mediation of war. In both Germany and the US, there was an intimate connection between the development of industrial chemical techniques, the rapid growth of the leading chemical firms, and the initiative and material support of the state.

²² Steen, *American Synthetic*, p. 443.

²³ Staudinger was later employed as a consultant by IGF during the inter-war years: Chapman, *International Petrochemical Industry*, p. 45. He was nonetheless sympathetic to pacifist ideas, and his first wife Dorothea was an active socialist.

²⁴ The leading developers of these polymers were IGF, DuPont, the British firm ICI and Dow.

In the years preceding the War, IGF continued to be the clear leader in the world chemical industry, despite the increased prominence of American firms like DuPont and Dow Chemicals. IGF was central to Nazi war preparations, with the company's efforts focused particularly on the use of coal to produce synthetic fuels and artificial rubber. Hitler had identified these materials as essential to the success of Germany's future expansion. Lacking the direct colonies of other European powers, and facing the certainty of naval blockade on rubber supplies from Malaysia, Nazi planners placed enormous priority on the development of synthetic alternatives that could ensure German self-sufficiency. By 1937, IGF had become 'completely Nazified': 'almost all of the members of the IG managing board who did not already belong now joined' the Nazis, and 'all Jewish officials of IG were removed, including a third of the supervisory board'. The company was essentially transformed into the industrial arm of Germany's military, producing almost all the country's synthetic gasoline (derived from coal) as well as 'synthetic rubber, poison gases, magnesium, lubricating oil, explosives, methanol, sera, plasticizers, dyestuffs, nickel and thousands of other items necessary for the German war machine.'²⁵

Prior to its entrance into the War in December 1941, the US similarly sought to develop synthetic polymers as potential replacements for metals, natural rubber, wood and cotton.²⁶ Due to the looming shortage

²⁵ Borkin, *Crime and Punishment*, pp. 58, 60. This relationship with the Nazi war machine was enormously profitable for IGF. With each successful German conquest, the chemical company took over factories and looted assets of rival European firms: a step-wise expansion that was to encompass Austria, Czechoslovakia, Poland, Norway and France. IGF also benefitted enormously from the seizure of Jewish property and the use of forced labour in Hitler's concentration camps. The firm built a huge industrial complex in Auschwitz for the production of synthetic rubber and oil that was run by an 'almost limitless reservoir of death camp labour' and 'used as much electricity as did the entire city of Berlin': p. 7. The company's profits between 1941 and 1943 were nearly five times those of 1935, and huge amounts were invested in the expansion of new plants such as those at Auschwitz. For documentation and further discussion, see 'IG Farben at the End of the Second World War', Wollheim Memorial website.

²⁶ With the entry of the US in December 1941, the old Trading With the Enemy Act was once again employed to confiscate German patents, which were made available to any member of the public willing to pay \$15; Arnold Krammer, 'Technology Transfer as War Booty: The US Technical Oil Mission to Europe, 1945', *Technology and Culture*, vol. 22, no. 1, January 1981, p. 75.

of basic raw commodities, these new materials would find widespread use in aircraft, submarines, tanks, tents, parachutes and other essential military items—a US army order even mandated that the rubber combs carried by soldiers be replaced by a plastic version.²⁷ Over the course of the War, production of vinyl resins such as PVC increased nearly fifty-fold, acrylic polymers such as plexiglass increased by a factor of ten and overall production of plastics nearly quadrupled.²⁸ Even the development of radar technology and the atomic bomb was dependent upon two newly invented polymers, polyethylene and Teflon. Given the importance of these new synthetic materials to the Second World War, it would be little exaggeration to term this later conflict the polymers war.

As with Germany, American production of the new polymers initially utilized pre-war technologies based upon the conversion of coal and other organic materials. Over the course of the War, however, a radical transformation occurred in manufacturing techniques. Driven by escalating military demands, production shifted decisively towards the use of oil and gas as the primary feedstocks for synthetic manufacture. This transition was enabled by innovations in petroleum ‘cracking’, a technique that oil companies had been experimenting with through the 1920s and 1930s as part of efforts to increase the quantities of gasoline produced in their refineries.²⁹ In addition to improving gasoline output, cracking also generated significant quantities of other highly reactive hydrocarbons known as olefins and aromatics, which could be utilized as building blocks for synthetic polymers. In the minds of US government planners, this new ‘petrochemical’ industry was viewed as crucial to guaranteeing the supply of essential military materials, including various plastics, aviation fuels and chemicals such as toluene, an aromatic hydrocarbon that was necessary to the manufacture of explosives.³⁰

²⁷ Susan Freinkel, ‘A Brief History of Plastic’s Conquest of the World’, *Scientific American*, 29 May 2011.

²⁸ John Kenly Smith, ‘The American Chemical Industry Since the Petrochemical Revolution’, in Galambos et al., *Global Chemical Industry*, p. 175.

²⁹ Prior to WW2, this largely involved thermal cracking, the use of very high temperatures and pressures to achieve greater control over the yield of refinery products. In the early years of the War, however, this technique was displaced by catalytic cracking—the use of a catalyst to achieve the same results but in easier operating conditions.

³⁰ Toluene production had traditionally derived from coal. By 1944, however, 81 per cent of the toluene supply in the US was made from petroleum: Chapman, *International Petrochemical Industry*, p. 74.

By shifting to petroleum as a basic feedstock, the abundance of US oil and natural-gas supplies would enable these materials to be produced cheaply and at large scale.³¹

Significant levels of US government funding were thus directed into petrochemical research and refinery construction during the War, and manufacturing volumes for basic petrochemicals grew at an unprecedented pace. Between 1940 and 1946, the production of ethyl benzene (used in synthetic rubber) rose from 500 to 135,000 tons, ethylene dichloride (for PVC) from 9,000 to 27,000 tons, ethyl chloride (anti-knocking gasoline additive) from 3,000 to 28,500 tons and ethylene oxide (an antifreeze and fumigation agent) from 41,500 to 78,000 tons.³² These products were not only utilized by the American military but were essential to supporting other Allied powers—Standard Oil's (now ExxonMobil) Baton Rouge refinery, for example, was the largest source of aviation fuel for the Allies during the War and was said to have 'saved England in the Battle of Britain'.³³

Arguably the most important petroleum-based industry that emerged in the US during the War was that of synthetic rubber. Before 1939, 90 per cent of the world's natural rubber originated from just three countries—Ceylon, India and Malaysia—but with Japan's conquest of Asia, American access to these supplies disappeared.³⁴ The US government took various initiatives to conserve rubber—including mandating the first-ever national speed limit in May 1942—but these measures could not satisfy the tremendous demand for rubber coming from all branches of the military.³⁵ Indeed, just six months after the US entered the War,

³¹ Geiser, *Materials Matter*, p. 43.

³² Peter Spitz, *Primed for Success: The Story of Scientific Design Company*, Cham, Switzerland 2019, p. 40.

³³ Spitz, *Primed for Success*, p. 32. More than half of total capital expenditure on Baton Rouge came from the US government: Chapman, *International Petrochemical Industry*, p. 74. In 2010, ExxonMobil used this support to sue the US government for reimbursement on environmental damages it had been required to pay at this refinery. In 2020, the US government lost the case and was ordered to pay \$20 million and partially foot the bill for future clean-up costs.

³⁴ Paul Samuelson, 'The US Government Synthetic Rubber Program 1941–1955: An Examination in Search of Lessons for Current Energy Technology Commercialization Projects', Working Paper MIT-EL 76-027WP, MIT, Cambridge MA, November 1976, p. 4.

³⁵ The so-called 'Victory Speed Limit' of 35 MPH lasted from May 1942 until the end of the War in August 1945.

Ferdinand Eberstadt—then chair of the Army and Navy Munitions Board, and destined to be an instrumental figure in the creation of the National Security Council—claimed that the US would have ‘no alternative but to call the whole thing off’ unless synthetic rubber could be produced in large enough quantities.³⁶ Driven by these fears, the US government embarked on a massive programme to build synthetic rubber plants that could produce rubber derived from petroleum.³⁷ These plants would be government-owned, but operated by private firms on a ‘cost plus management fee’ basis. By the end of the War, over 2 million tons of synthetic rubber had been produced by more than fifty plants.³⁸ This huge expansion permanently altered the nature of American rubber production: in 1941, almost 99 per cent of all US domestic rubber consumption was natural; by 1945, this figure had fallen to 15 per cent.³⁹ Perhaps most remarkably, the US emerged from the War as the world’s largest exporter of rubber; prior to 1939, it had been the world’s largest importer.

With the end of the War, the US government sought to divest ownership of this immense network of rubber plants to the private sector. Plans were initially delayed by the beginning of the Korean War in 1950, but just ten days after the end of that conflict the US Congress passed the Rubber Producing Facilities Disposal Act of 1953. Much like the seizure of German patents in the wake of the First World War, this Act represented another major transfer of wealth to the US chemical industry, with plants worth a total of \$700 million sold for a mere \$260 million. During Congressional hearings in 1954, one opponent protested that the sale should properly be ‘labelled a giveaway’ and accurately predicted that it would ‘bring about complete domination of the industry by a few mammoth corporations’.⁴⁰ Indeed, the ultimate beneficiaries of the sale were a handful of oil, rubber and chemical firms including Standard Oil, Shell, Goodyear, Firestone and Dow Chemicals. By 1958, just six firms

³⁶ Cited in William Tuttle Jr, ‘The Birth of an Industry: The Synthetic Rubber “Mess” in World War II’, *Technology and Culture*, vol. 22, no. 1, January 1981, p. 38.

³⁷ Initially there was an inter-industry dispute over whether synthetic rubber should be produced from alcohol (derived from grain) or from petroleum. In the end, oil companies won out. See Tuttle, ‘Birth of an Industry’ and Chapman, *International Petrochemical Industry*, pp. 69–72, for an account of these disputes.

³⁸ Kenly Smith, ‘American Chemical Industry’, p. 175.

³⁹ Tuttle, ‘Birth of an Industry’, p. 65.

⁴⁰ James Patton, President of the National Farmers Union, ‘Rubber Facilities Disposal’, Hearings before a Subcommittee of the Committee on Banking and Currency, US Senate, 84th Congress, 1st Session, on S. 691, 4a, 1955.

controlled 79 per cent of all US plant capacity for the main type of synthetic rubber production.⁴¹

The story of rubber illustrates the extraordinary impact that the petrochemical revolution would have on American capitalism. At the beginning of the War, a commercial petrochemical industry did not exist in the US. By 1950, half of the American output of organic chemicals would be made from petrochemicals. By the end of the 1950s, this figure would reach just under 90 per cent.⁴² This transformation of synthetic production was not simply a result of technological innovation or the contingent choices of American war planners. Crucially, the petrochemical revolution embodied a more fundamental shift towards oil as the fulcrum of the world's energy regime, a process that had begun in the early 20th century but that was fully consummated by the War itself.⁴³ The expansion of the oil industry massively increased the availability of basic feedstocks for chemical production; this considerably cheapened the cost of material manufacture because the inevitable by-products of fuel production were transformed into a profitable input for petrochemicals. What was essentially 'waste' had suddenly become an indispensable component of circulating constant capital. In short, at the heart of the petrochemical revolution was a radical change to the wider reproduction of capital: the production of commodities had become derivative—or a by-product—of the production of energy.

Moreover, and no less significantly, all this occurred in the context of a global oil industry that was largely dominated by US firms. By the time of the Second World War, the US was the world's largest producer of oil and gas and held over 70 per cent of global refining capacity, compared to

⁴¹ Stanley Boyle, 'Government Promotion of Monopoly Power: An Examination of the Sale of the Synthetic Rubber Industry', *Journal of Industrial Economics*, vol. 9, no. 2, April 1961, p. 158.

⁴² Kenly Smith, 'American Chemical Industry', p. 178.

⁴³ Lord Curzon famously observed of WWI that the winning side had floated to victory on a sea of oil—all the more so in WW2. Petroleum energy sources were more efficient than coal and easier to transport; they were also cheaper and more plentiful. Naval ships, aircraft and military vehicles all depended upon ready supplies of liquid petroleum fuels. The emergence of a post-war oil-centred world order was also closely connected to the development of the automobile industry (Huber, *Lifeblood*) and the rise of industrial farming (Moore, *Web of Life*). In this sense, the petrochemical revolution can be seen as another core element of oil's consolidation at the centre of the world's energy regime.

only 7 per cent in Western Europe. Five of the famed Seven Sisters—the seven oil companies that controlled 85 per cent of the world's petroleum reserves—were American-owned. At the end of the War, almost all the world's production capacity for ethylene—the fundamental building block of petrochemical production and today frequently described as the 'world's most important chemical'—was located in the US.⁴⁴ There was thus a mutually reinforcing relationship between the rise of American hegemony, the shift to an oil-centred global energy regime and the revolution in commodity production inaugurated by petrochemicals.

Europe subordinated

In late 1944, with Allied leaders looking in growing anticipation to the end of the War, the issue of Germany's long-standing and powerful chemical industry loomed large in the various scenarios of post-war planners. Much of the physical infrastructure of German industry lay in rubble, or was in territory conquered by the Soviet Union. There was, however, considerable scientific expertise, built upon decades of chemical experimentation, scattered through research facilities and laboratories across Germany. Cognizant of this potential treasure trove of knowledge, US oil-company executives began lobbying American officials in August 1944 for a plan to seize this research in the event of Germany's defeat. Competing interests in the US government initially failed to agree on a united approach, but by the end of the year an audacious scheme had cohered.

Two dozen leading US oil-company managers and scientists were temporarily drafted as colonels of the US army, provided with uniforms and secretly ushered into German territory to visit industrial facilities and collect documents from IGF and other German firms. Between February and August 1945, these teams gathered material that ran to over 300,000 pages; their visits continued after the War, and by 1948 a dedicated office set up by President Truman would report that 'more than 5 million microfilmed pages of technical documents, all in German, containing drawings, flow sheets, reports of chemical experiments and meetings of German technical societies' were still being processed. One later historian would describe these events as akin to 'technology transfer' through 'war booty', commenting that 'never in the history of the modern world

⁴⁴ Chapman, *International Petrochemical Industry*, pp. 60, 17.

has a sophisticated industrial nation had at its complete disposal the industrial secrets of another nation'.⁴⁵

With the conclusion of the War, the inextricable connections between German fascism and the German chemical industry were formally recognized at the Nuremberg war-crime trials. Twenty-four leading executives of IGF were indicted and tried at Nuremberg, with thirteen eventually found guilty of war crimes including slavery, mass murder and plunder.⁴⁶ However, in a pattern replicated throughout post-war German big business, those eventually sentenced to prison received extremely short sentences and early pardons and were quickly reintegrated into the top echelons of West German industry. IGF itself was broken up into its original constituent parts of Bayer, Hoechst and BASF. Heading each of these companies into the 1950s and 1960s were the IGF managers of the Nazi era, including those that had served time for war crimes.⁴⁷ Beyond the reconstitution of the Big Three under the auspices of former war criminals, other leading IGF directors were released early from prison and went on to prosperous careers with the US government and American chemical firms.⁴⁸

Alongside the diffusion of German scientific knowledge, post-war planners also sought systematically to shift Germany's chemical industries away from the use of coal-based technologies towards oil. The Potsdam Conference of 16 July 1945 went so far as to ban Germany from utilizing coal as a feedstock for fuel production—a move that forced the expansion of oil refining in order to satisfy the country's need for

⁴⁵ Krammer, 'Technology Transfer', p. 97.

⁴⁶ Borkin, *Crime and Punishment*, p. 121.

⁴⁷ IGF board member Friedrich Jähne, who had been convicted of war crimes at Nuremberg, was hired as the chairman of the Hoechst supervisory board in 1955. Fritz ter Meer, also convicted of war crimes at Nuremberg, became chair of the board of directors for Bayer in 1956. Although he was acquitted of war crimes in the Nuremberg trial, former IGF board member Carl Wurster, who became chief executive of BASF in 1952, had been a 'military economy leader' (*Wehrwirtschaftsführer*) and was awarded a Knight's Cross for War Service by the Nazis in 1943.

⁴⁸ One of these was Otto Ambros, who was found guilty of crimes against humanity—the use of slave labour—at Auschwitz and is credited with the invention of Sarin gas. Ambros was granted clemency by the US government in 1951, becoming an advisor to the US Army Chemical Corps and Dow Chemicals, among other leading US chemical firms. See the entry for 'Ambros, Otto / W. R. Grace and Company' at the Ronald Reagan Presidential Library and Museum website.

liquid fuels.⁴⁹ In 1951 this order was rescinded, but by that stage all four German coal-to-fuel plants in Western-controlled zones had either been deactivated or converted to processing oil. As oil became more available and necessary infrastructure such as pipelines were built, BASF, Hoechst and Bayer entered the petrochemical industry through partnerships with British and American oil firms. By 1961, oil and gas had overtaken coal as the primary feedstock for the German chemical industry—and by 1963, 63 per cent of all German chemical production was derived from petroleum.⁵⁰

A similar transition away from coal occurred in other West European states. Despite some initial opposition by US oil companies, who feared losing their dominant position in world oil markets, funding from the Marshall Plan supported a significant expansion of European refining capacity in the immediate post-war years.⁵¹ European refinery capacity increased five-fold between 1948 and 1955, and by 1960 Europe's share of global refining capacity stood at 16 per cent, up from 7 per cent in 1940.⁵² The increase in the output of refined-oil derivatives enabled a decisive shift towards petroleum-based production of chemicals. This was most evident in the UK, where more investment went into petrochemicals than any other branch of British industry between 1948 and 1958.⁵³ By 1962, around two-thirds of all British chemical production would be petroleum-based. In that same year, petrochemicals averaged 58 per cent of chemical production across Western Europe as a whole—a figure that had increased from negligible levels in just over a decade.⁵⁴

Crucially, however, the crude oil that fed European refineries, and thus the nascent petrochemical industry, was supplied wholly through

⁴⁹ Anthony Stranges, 'Germany's synthetic fuel industry, 1927–1945', in Lesch, ed., *The German Chemical Industry in the Twentieth Century*, Dordrecht 2000, p. 213.

⁵⁰ Ulrich Wengenroth, 'The German Chemical Industry after World War II', in Galambos et al., eds, *Global Chemical Industry*, p. 149.

⁵¹ David Painter, 'Oil and the Marshall Plan', *Business History Review*, vol. 58, no. 3, Autumn 1984, pp. 359–83.

⁵² Chapman, *International Petrochemical Industry*, p. 83.

⁵³ Wyn Grant, 'The United Kingdom', in Galambos et al., eds, *Global Chemical Industry*, p. 299.

⁵⁴ Chapman, *International Petrochemical Industry*, p. 82. The frontrunner in this transition was the UK. British scientists had participated in the secret teams that visited IGF plants between 1944 and 1945, and Britain was the first West European country to utilize petroleum feedstocks for chemical production.

imports—unlike the US, where plentiful supplies of domestic oil and gas had enabled the earlier expansion of the petrochemical industry. The bill for European oil imports was the largest dollar item for most Marshall Plan countries, striking testimony to the central importance that oil had now assumed in capitalist growth.⁵⁵ By providing this funding, the US state not only facilitated the oil-based trajectory of European industrial development, it also directly supported the international expansion of the Seven Sisters, who were the sole source of European oil imports. As vertically integrated firms that dominated each step in the exploration, production, transportation and refining of oil, these oil majors were thus embedded at the core of Europe's emerging petrochemical revolution. Shipping terminals, oil pipelines, refineries and petrochemical plants formed distinct spatial agglomerations superintended by one or other of these firms—most notably BP, Shell, Esso and Texaco. The initial extension of the petrochemical industry across Europe took place largely through joint ventures between these oil majors and local European capital.⁵⁶

The geographical origins of Europe's oil imports were no less consequential to the emergence of its petrochemical industry. Through the 1950s and 1960s, most of the oil exported to Europe came from oil fields located in the Middle East. The oil majors operated these fields through concessionary agreements with host governments and held the power to set the price of oil which was then used to calculate royalty payments.⁵⁷ These royalties and other tax expenses were thereby minimized through the oil majors' arrogation of price controls, which kept the costs of oil production in the Middle East very low compared to other oil-producing areas of the world and in relation to coal. This was extremely advantageous for the Seven Sisters, and by the mid-1950s, the profitability of foreign operations for US oil companies was double that of domestic production.⁵⁸ All of this ultimately depended upon effective Anglo-American control over territory and political authority in the Middle East, which at that time was divided principally between Britain across Kuwait, Iran, Iraq and the smaller Trucial States in the Gulf, and the US in Saudi Arabia. A direct thread thus connected the emergence of a synthetic world with

⁵⁵ Painter, 'Oil and the Marshall Plan', p. 362.

⁵⁶ See Galambos et al., eds, *Global Chemical Industry*, for a survey of different European countries.

⁵⁷ Francisco Parra, *Oil Politics: A Modern History of Petroleum*, London 2004.

⁵⁸ Commoner, *Poverty of Power*, p. 55.

patterns of colonial domination: the rise of petrochemicals in Europe was as much an American and Middle Eastern story as a European one.

Chemical century

The post-war petrochemical revolution inaugurated a far-reaching transformation in patterns of industrial production and consumption. The ubiquitous spread of synthetic materials derived from petroleum rapidly colonized all aspects of everyday life, not only driving the emergence of new industries such as plastics and packaging, but also reshaping cultural practices and the set of material products associated with the 'good life' and the American Dream.⁵⁹ Business historians have subsequently described this period as the 'chemicalization' of industry, with virtually all forms of commodity production linked to petrochemicals in some manner. In the US, the chemical industry moved to the centre of capitalist development through the 1950s and 1960s, experiencing growth rates double that of GDP and profit rates at least 25 per cent higher than those found in other manufacturing industries.⁶⁰ With the chemical industry 'unmatched by any other' in growth, earnings and potential, normally circumspect pundits of the post-war era foresaw a future in which 'most industries will be absorbed into the chemical industry'. This was the beginning—proclaimed a *Fortune* magazine headline in 1950—of the 'Chemical Century'.⁶¹

One important consequence of this petrochemical revolution was its impact on science. With chemistry research located ever more centrally within the circuits of commodity production, the 'chemicalization' of industry was associated with a parallel phenomenon, more broadly described by Harry Braverman as the 'transformation of science itself into capital'.⁶² In the US, this was expressed through the growing collaboration between industry and university chemistry departments, as well as the increasing prominence of chemical engineering as a distinct branch of academic research.⁶³ Chemical engineering itself became organized largely around the notion of 'unit operations', a kind of theoretical Taylorism that approached chemistry through a small number

⁵⁹ See Huber, *Lifeblood*, Chapter 3.

⁶⁰ Kenly Smith, 'American Chemical Industry', p. 169.

⁶¹ 'The Chemical Century', *Fortune*, March 1950, p. 70.

⁶² Harry Braverman, *Labour and Monopoly Capital*, New York 1974, p. 167.

⁶³ Spitz, *Primed for Success*, pp. 20–1.

of generic processes—separation, crystallization, distillation—easily transferable across the development of new synthetic products. Large firms became major donors of chemistry departments, often mandating the prioritization of research connected to product development. At the same time, chemical engineers gained increasing prominence as managers and executives of chemical firms, coming to identify ‘the scientific transformation of America and the corporate transformation of America [as] one and the same’.⁶⁴

With science increasingly an appurtenance of business calculus, the internal organization of firms in the chemical industry was also transformed. Historians of the industry frequently point out that the major challenge presented by petrochemicals for business was not the act of discovering new chemical products—this was relatively straightforward, given the basic structure of polymers—but inventing a *use* for these new chemicals. As a result, chemical firms increasingly prioritized activities such as marketing and product commercialization. In turn, companies began to structure themselves around individual product lines rather than generic activities. Associated with this internal reorganization were innovations in accounting; DuPont, for example, pioneered the introduction of Return on Investment (ROI) as an accounting measure, a means to capture the costs of invention, marketing and revenue for discrete products.⁶⁵ And because this enabled individual units to be easily valued and then offered for sale by their parent companies, this form of organization propelled repeated waves of consolidation in the chemical industry. Consequently, a small number of very large companies emerged around specific product specializations.⁶⁶

At the same time, a handful of basic petrochemical products such as ethylene, propylene, benzene and toluene formed the core inputs for

⁶⁴ David Noble, *America by Design: Science, Technology and the Rise of Corporate Capitalism*, New York 1977, p. 19.

⁶⁵ Alfred Chandler Jr, ‘The Competitive Performance of US Industrial Enterprises since the Second World War’, *Business History Review*, vol. 68, no. 1, Spring 1994, pp. 11–12.

⁶⁶ By the 1960s, it was estimated that just 15 companies controlled most US petrochemical production: Geiser, *Material Matters*, p. 49. This concentration and centralization of capital is a long-standing feature of the chemical industry. Indeed, the 1925 formation of IGF occurred because the German chemical giant BASF could not alone afford the commercialization of a newly discovered means of producing synthetic fuels: Borkin, *Crime and Punishment*, p. 39.

more complex derivative chemicals. The production of these essential precursors was increasingly associated with huge increases in the size of petrochemical plants, as producers sought to achieve economies of scale. One industry expert in 1979 described the proliferation of ‘massive, integrated industrial complexes’ where basic petrochemical production was connected to the manufacture of more complex derivative products through a spaghetti-like maze of pipes, tubes and specialized storage hubs. Between 1950 and 1970, the size of such plants in the US increased by a factor of ten, and they could take up to 42 months to construct, with some components so large that they required on-site manufacture.⁶⁷ These massive fixed-capital costs typically exceeded the capacity of individual firms and thus drove further industry consolidation through mergers, exclusive-partnership agreements and joint ventures.⁶⁸

While the basic costs of materials, fuel and machinery in the petrochemical industry were very high, the proportion of labour costs was extremely low—indeed, considerably less than other industrial sectors. In this respect, petrochemicals were one of the first branches of industry to exhibit what Ernest Mandel described as the ‘third technological revolution’: almost full automation, where plants were designed around ‘automated flow systems’, integrated networks of machinery, vessels and pipes that ran continuously with only a few workers monitoring the process.⁶⁹ Indeed, the cost of labour for the petrochemical industry in the early 1970s was calculated at significantly less than 1 per cent of total production expenses.⁷⁰ As the size of petrochemical complexes increased,

⁶⁷ Mark Cantley, ‘The Scale of Ethylene Plants’, International Institute of Applied Systems Analysis Working Paper, 1979, pp. 17, 12.

⁶⁸ Another structural change associated with this process was the emergence of specialized chemical engineering firms that developed petrochemical processes and innovations in plant designs and would then license these technologies to manufacturers, rather than proprietary engineering knowledge remaining exclusively in the hands of individual chemical firms. This innovation helped encourage the post-war diffusion of petrochemical plants through Europe and Japan. The leading engineering firm in this respect was the Scientific Design Company (see Spitz, *Primed*, for a history), which, after numerous acquisitions, is today owned by a joint venture of Saudi Arabia’s SABIC (see below) and the Swiss multinational, Clariant. Many of the world’s largest engineering firms such as KBR have their origins in these activities.

⁶⁹ Ernest Mandel, *Late Capitalism*, London and New York 1998, pp. 184–223.

⁷⁰ Charles Levinson, *Capital, Inflation and the Multinationals*, London 1971, pp. 228–9.

the need for extra labour was estimated by industry analysts as ‘not significantly different from zero’. That is, at a certain size of plant, it was theoretically possible to increase output to ‘*any level*’ by merely increasing other inputs while holding labour at a fixed level.⁷¹ For these reasons, petrochemicals have consistently had higher levels of productivity than any other branch of industry.

This higher technical composition of the petrochemical industry was a leading element within the post-war increase in the organic composition of capital, a fact that has gone largely unremarked in Marxist discussions over post-war profit rates. But the degree to which petrochemicals drove the ‘replacement of living labour by dead labour’ extends far beyond the enormous costs of constant capital (fixed and circulating) within petrochemical plants themselves. At a more elemental level, petrochemicals marked a qualitative shift in the nature of commodity production: labour-intensive naturally occurring goods—often sourced from far-flung colonial territories—were replaced by synthetic materials that had an average necessary labour content approaching zero. This was not simply an increase in the quantity or scale of production. Rather, use value itself was irrevocably detached from its long-standing association with specific exchange values: the functional attributes of wood, glass, paper, natural rubber, natural fertilizers, soaps, cotton, wool and metals, would now be served by plastics, synthetic fibres, detergents and other petroleum-based chemicals.⁷²

Moreover, the development of these synthetic materials had far-reaching implications for other industrial sectors. By the early 1950s, a new generation of materials known as thermoplastics had become widespread. These plastic polymers become mouldable when heated and hard when cooled, as opposed to thermosetting plastics that keep their initial shape permanently. With the development of injection-moulding machines through the 1950s and 1960s, thermoplastics enabled the automated fabrication of cheaply reproducible components that transformed whole branches of industrial production, including the manufacture of heavy machinery, automobiles, medicine, construction, consumer goods,

⁷¹ Cantley, ‘Scale of Ethylene’, p. 27.

⁷² This qualitative transformation in the nature of post-war commodity production—and its enormous ecological implications—was first highlighted by Barry Commoner in *The Closing Circle* and *Poverty of Power*, cited above.

packaging and so forth.⁷³ Akin to modern day alchemy, a bag of small thermoplastic pellets could be transformed into any simple commodity after the appropriate mould was set. And once a mould was in place, there was little extra cost to manufacturing each additional item; this not only further accelerated the expulsion of labour from a widening sphere of commodity production, it also encouraged enormous increases in commodity output.⁷⁴

In this manner, the petrochemical revolution was inseparable from the chronic levels of overproduction that came to mark the post-war era. As huge quantities of new and easily reproducible synthetic goods displaced natural materials during the first decades after the War, producers were faced with the obstacles of limited market size and the restricted needs of the post-war consumer. Ever-accelerating quantities of waste, inbuilt obsolescence and the ubiquitous spread of disposability became the hallmarks of capitalist production, a situation presciently narrated by Vance Packard in his 1960 classic, *The Waste Makers*. As he noted, the solution to this dilemma was closely connected to the spectacular expansion of another 'new' industry, advertising, which aimed at inculcating the mass consumer 'with plausible excuses for buying more of each product than might in earlier years have seemed rational or prudent.'⁷⁵ But all branding needs a 'skin', and here advertisers turned once again to petrochemicals for a solution. The pervasive supply of cheap and malleable petrochemicals enabled a huge expansion in packaging and labelling, which soon came to adorn all consumer goods. Packaging quickly became the largest end-use for plastics and currently makes up more than one-third of the global demand for plastics.⁷⁶

Synthetic futures

Today a small number of very large firms dominate global petrochemical production. With costs heavily dependent upon the price of crude oil

⁷³ Geiser, *Material Matters*, p. 70.

⁷⁴ As Barry Commoner pointed out in *The Closing Circle*, 'If you asked a craftsman to make you a special pair of candlesticks he would be delighted; if you asked for two million pairs he would be appalled. Yet if you asked a plastics moulder for one pair of candlesticks he would be appalled, but delighted if you asked for two million pairs.' Today, around 90 per cent of plastics are thermoplastics: Geiser, *Material Matters*, p. 70.

⁷⁵ Vance Packard, *The Waste Makers*, New York 1960, p. 23.

⁷⁶ IEA, 'Future of Petrochemicals', p. 19.

inputs and petroleum refining, production tends to be clustered around major oil producing sites, and most new petrochemical complexes are joint-ventures that involve both oil majors—ExxonMobil, Shell, Chevron and BP—and more specialized chemical firms that frequently originate in German and American militarism: Dow, DuPont and BASF. The US remains a major production zone, a position accentuated by the rise of shale oil from 2011 onwards, which gave US-based producers access to a ready supply of low-cost feedstocks. However, there has been a steady decline in the relative power of long-standing Western petrochemical companies; in 2010, 32 of the top 50 chemical producers in the world were headquartered in North America or Europe, a figure that had dropped to 28 by 2020.⁷⁷

The most significant change to affect the global petrochemical industry over the last decade has been the rise of China and the wider Asia region as core zones of petrochemical production and consumption. With China's emergence as a key centre of global manufacturing, the country's consumption of petrochemicals has skyrocketed. Petrochemical consumption underlay initial Chinese production of cheap domestic goods, furniture and clothing, thus spearheading the country's export dominance across markets in the rest of the world.⁷⁸ In 2017, chemical sales in China represented nearly 40 per cent of global chemical-industry revenues, and between 2010 and 2015, China's market grew *each year* at a rate that was equivalent to the combined chemical sales of Spain and Brazil.⁷⁹ To meet this rapidly increasing consumption, China's petrochemical production increased from 10 per cent of global petrochemical capacity in 2000 to a staggering 37 per cent in 2017; over this same period, Europe's share of global capacity fell from 20 per cent to 12 per cent, and North America's from 25 per cent to 14 per cent.⁸⁰ Nearly 30 per cent of the world's increase in petrochemical capacity over the next decade is expected to come from China, far more than for any other producer worldwide.⁸¹

⁷⁷ Alexander Tullo, 'Global Top 50', *Chemical & Engineering News*, 3 August 2009.

⁷⁸ A similar pattern of petrochemical-led development was evident in the earlier rise of East Asian 'tigers' through the 1960s and 1990s.

⁷⁹ Sheng Hong et al., 'China's Chemical Industry: New Strategies for a New Era', McKinsey & Co., 20 March 2019, p. 2.

⁸⁰ 'The GCC Petrochemical and Chemical Industry: Facts and Figures 2017', Gulf Petrochemicals & Chemicals Association (GPCA), 2018, p. 27.

⁸¹ 'China to contribute 28% of global petrochemical capacity additions by 2030', GlobalData website, 30 October 2020.

Apart from China, the region that has seen an increased share of global production over recent years is the Gulf Cooperation Council (GCC), a group of six Arab states that now holds 6 per cent of global petrochemical capacity, a figure that has doubled since 2000.⁸² Led by Saudi Arabia, the GCC is now a leading producer of several basic petrochemicals. Foremost here is ethylene, which continues to be the world's most important petrochemical and forms an essential input for the manufacture of packaging, construction materials and automobile parts.⁸³ World consumption of ethylene doubled over the last decade, and between 2008 and 2017, the Gulf's share of ethylene capacity grew from 11.5 to 19 per cent, the region rising from the world's fourth to second ranked producer, just behind North America, whose global share fell from 27 to 21 per cent.⁸⁴ The GCC added more ethylene capacity than any other region of the world over this period: indeed, since 2005, around one-third of the increase in global ethylene capacity has come from the GCC, more than China (28 per cent), the rest of Asia (22 per cent) and the US (13 per cent).⁸⁵

The rise of China and the Gulf has pushed large state-owned firms to the centre of the world petrochemical industry. Conspicuous examples are China's Sinopec and Saudi Arabia's SABIC, which now rank as the second and fourth largest petrochemical companies in the world respectively, up from fifth and seventh places in 2007.⁸⁶ The power of these firms stems, in part, from their close linkages to the upstream oil sector: Sinopec is directly involved in the ownership, exploration and production of crude oil and gas, while SABIC is 70 per cent owned by Saudi Aramco, the world's largest oil producer. These linkages further illustrate the structural evolution of the global petrochemical industry towards vertically integrated ownership of oil and gas fields,

⁸² GPCA, 'Facts and Figures 2017', p. 27.

⁸³ Approximately 75 per cent of the global demand for ethylene comes from these three manufacturing activities: GPCA, 'Ethylene: A Litmus Test', 2019, p. 2.

⁸⁴ Experience Nduagu et al., 'Economic Impacts and Market Challenges for the Methane to Derivatives Petrochemical Sub-Sector', Canadian Energy Research Institute, March 2018, p. 2; Duane Dickson et al., 'The Future of Petrochemicals', Deloitte, 2019, p. 4.

⁸⁵ 'Rapid changes in the ethylene capacity world order', Wood Mackenzie website, 4 December 2019.

⁸⁶ Tullo, 'Global Top 50': in 2000 SABIC was ranked as the 29th-largest chemical company in the world, and Sinopec did not even make the list of the top 50.

refining and chemical production. Importantly, however, while these firms are majority state-owned, this does not mean that private capital is absent from petrochemical production in either China or the Gulf. Many privately owned firms are connected through joint ventures and strategic partnerships with Sinopec and SABIC, mostly focused on the downstream production of plastics and other synthetic polymers. In this manner, state involvement in the petrochemical sector has been a significant driver of private capital accumulation across Asia and the Middle East.⁸⁷

Despite the substantial expansion in Chinese and Gulf petrochemical production over the last decade, global demand for petrochemicals continues to outstrip increases in production capacity.⁸⁸ This inexorable growth in consumption has occurred across all types of petrochemicals, but perhaps the best illustration is the most pervasive of all petroleum products, plastics. Between 1950 and 2015, the annual global production of plastic grew nearly 200-fold, greatly eclipsing the growth of other bulk materials such as aluminium, cement and steel. This seemingly unstoppable demand is driven by the systematic displacement of natural materials by plastics across many different sectors.⁸⁹

⁸⁷ Since 2015, China has allowed full private ownership in refining and petrochemicals, including by foreign firms. Several very large privately controlled Chinese petrochemical firms are expanding into basic petrochemicals as well as upstream oil production—e.g. Hengli Petrochemical, which is now ranked as the 26th largest chemical firm in the world. For an analysis of the relationship between private and state-owned capital in the case of the Gulf's petrochemical sector, see Hanieh, *Capitalism and Class in the Gulf Arab States*, London 2011; and *Money, Markets, and Monarchies: The Gulf Cooperation Council and the Political Economy of the Contemporary Middle East*, Cambridge 2018.

⁸⁸ A widely used proxy for the petrochemical market is ethylene. Global capacity for ethylene increased 30 per cent between 2008 and 2017, while consumption doubled: Dickson, 'Future of Petrochemicals', p. 4. Nonetheless, chronic overcapacity is a recurrent feature of the global petrochemical industry, and the likelihood of supply gluts in key products has been accentuated given new production units planned in China and the Gulf. As with other industrial sectors, these cycles of overcapacity have historically been a main driver for the concentration and centralization of capital in petrochemicals.

⁸⁹ To give but one example, the production of polyester fibre recently exceeded that of all other fibres combined, including wool and cotton, and now makes up around 60 per cent of total global fibre production; IEA, 'Future of Petrochemicals', pp. 17, 20. Similar trends can be seen in the output of other high-volume plastics, including polyethylene, polypropylene and polyvinyl chloride.

The growth of plastic production is accelerating—remarkably, around half of all plastics ever made were produced in just the last twenty years. This carries far-reaching ecological implications. Plastics are by their very nature incompatible with normal biological cycles and can only be disposed of by dumping, incineration or recycling. More than 90 per cent of all plastic waste ever produced by humankind has been dumped into the ecosystem or incinerated, both routes that release toxic materials into the environment and cause long-term and cumulative damage to life itself.⁹⁰ Today, recycling rates for plastic are at best around 20 per cent, and most plastic waste in North America and Europe ends up being exported to Asia, where its ultimate fate is typically hard to determine. Indeed, alongside China’s role as a key global producer of plastics, the country for several decades became the final graveyard of the world’s plastic waste—since 1992, just under half of all global plastic waste has been exported to China.⁹¹

The continued expansion of the production of plastics and other petroleum-based synthetic materials is rapidly becoming the largest factor in the growth of demand for oil. The IEA estimates that petrochemicals will make up more than one-third of the growth in oil demand to 2030 and nearly half to 2050, an amount greater than trucks, aviation or shipping—the other components of oil demand that are difficult to replace.⁹² It is conceivable that some of the demand for oil and gas as an energy source can be reduced through alternative technologies and improved energy efficiencies—such as solar, wind or electric vehicles—but there is no way of imagining a future without oil as long as petroleum remains the fundamental material basis of commodity production.⁹³ This is a fact openly acknowledged by industry analysts and

⁹⁰ Roland Geyer et al., ‘Production, use and fate of all plastics ever made’, *Science Advances*, 19 July 2017, p. 3: ‘None of the mass-produced plastics biodegrade in any meaningful way; however, sunlight weakens the materials, causing fragmentation into particles known to reach millimeters or micro-meters in size’. ‘Research into the environmental impacts of these “microplastics” in marine and freshwater environments has accelerated in recent years, but little is known about the impacts of plastic waste in land-based ecosystems.’

⁹¹ Dickson, ‘Future of Petrochemicals’, p. 7. China banned the import of plastic waste in 2018, and most of this trade has now been diverted to other Asian countries, with Malaysia becoming the top destination in 2020.

⁹² IEA, ‘Future of Petrochemicals’, p. 11.

⁹³ Moreover, chemicals are the largest industrial consumer of energy—exceeding iron, steel and cement: IEA, *Future of Petrochemicals*, p. 27.

oil firms alike, who now speak of petrochemicals as a guarantee for ‘the future of oil’.⁹⁴

All of this points to the real problem with oil. Having become so accustomed to thinking about it as primarily an issue of energy and fuel choice, we have lost sight of how the basic materiality of our world rests upon the products of petroleum. These synthetic materials drove the post-war revolutions in productivity, labour-saving technologies and massified consumption. Birthed in war and militarism, they helped constitute an American-centred world order. Today, it is almost impossible to identify an area of life that has not been radically transformed by the presence of petrochemicals. Whether as feedstocks for manufacture and agriculture, the primary ingredients of construction materials, cleaning products and clothing or the packaging that makes transport, storage and retail possible—all aspects of our social being are bound to a seemingly unlimited supply of cheap and readily disposable petrochemicals. Synthetic materials derived from petroleum have come to define the essential condition of life itself; simultaneously, they have become normalized as natural parts of our daily existence. This paradox must be fully confronted if we are to move beyond oil.

⁹⁴ Alexander Tullo, ‘Why the future of oil is in chemicals, not fuels’, *Chemical & Engineering News*, 20 February 2019.