6

Mining Beyond National Jurisdiction

Mining, as such, is certainly no novel technological field. Prehistoric mining involved setting fire to rocks and then cooling them down with water, thereby causing fracturing and allowing the extraction of copper.[1] By smelting this copper together with tin, prehistoric societies created bronze, a hard alloy usable for tools, weapons, and other purposes. Iron-making, probably first invented in ancient China or Egypt, was more demanding due to the high temperatures required for the smelting of iron ore. Silver and gold came to be of central political importance in the Roman Empire, notably because they enabled the creation of a sophisticated currency system.[2] The silver and gold deposits of the Americas would later be at the core of European colonialism during the Age of Discovery.[3] Mining took on new significance with the Industrial Revolution, as coal began to power the economic supremacy of European countries, starting with Great Britain and Belgium. In the twentieth century, uranium mining enabled the emergence of nuclear energy, and extraction of cobalt, platinum, palladium, and other metals laid the foundation of modern computing and the information age. In parallel, for resource-rich developing countries, the extraction of metals and minerals came to be associated with economic dependence, underdevelopment, and, in some cases, endemic political violence, symbolized by the notorious 'blood diamonds' that have fuelled catastrophic civil wars in Angola, Liberia, and Sierra Leone.[4] Rare earth elements, only found in low geological concentrations and thus difficult to mine, later became central to the production of high-performance alloys, computer monitors, catalytic converters in automobiles, lasers, and many other items, making access, control, and trade questions of national security and geopolitical competition.[5]

Before we go any further, and at the risk of overgeneralization, it is important to note that the global mining industry has caused, and continuous to cause, significant adverse environmental impacts the world all over; that its business dealings are often untransparent, shady, or corrupt; and that its human rights record is abysmal.[6]

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

Giants of the commodity industry, such as Glencore and Trafigura, are shrouded in secrecy and subject to accusations that range from tax evasion to fraud to environmental crimes.[7] In May 2022, Glencore pleaded guilty to violating the US Foreign Corrupt Practices Act with what the US Department of Justice describes as a 'decade-long scheme … to make and conceal corrupt payments and bribes through intermediaries for the benefit of foreign officials across multiple countries', in addition to conceding a scheme for illegal commodity price manipulation.[8] Trafigura, in 2006, was involved in the dumping of toxic waste, so-called 'spent caustic', in the Ivory Coast, creating a public health emergency and later taking legal action against British media reporting on the case.[9] In South Africa, Chinese state-owned mining companies have been accused of systematically violating labour laws as well as health and safety regulations.[10] In Brazil, mining companies have repeatedly caused havoc when technical failures led to large-scale environmental releases of toxic by-products known as 'tailings'; the accidental release of 12 million cubic metres of tailings in the 2019 Brumadinho dam failure is considered one of the largest environmental disasters in history, with impacts on people and nature that are 'immeasurable'.[11] Here and elsewhere, there appears to be a highly problematic confluence between corporate profit-seeking to the detriment of effective risk assessment and management, weak regulatory enforcement, and corruption,[12] a feature which statistical studies suggest is prevalent across the industry.[13] Human misery is a feature of many global supply chains. In Congo, artisanal cobalt mines are 'essentially unsafe, ragged holes in the ground, with manual labour, children present, and miners so poor they dig without ladders or tools, some literally by hand'.[14] In Myanmar, a significant supplier for the Chinese market, extraction of rare earth elements has become entangled with regional power struggles in the wake of the February 2021 military coup d'état.[15]

These issues must be borne in mind when considering mining from a perspective of TNTs as well as the associated perils and, especially, 'promises'. On the face of things, it may appear absurd to analyse recent technological developments in the mining industry from a perspective of environmental and socio-ecological benefits. Yet, as I will discuss in greater detail, the mining industry plays an indispensable role in any transition towards environmental sustainability, notably including a transition to net-zero emissions in the later stages of the twenty-first century. This specific aspect is not commonly acknowledged in public and it implies potential incoherencies and trade-offs. Yet, a global sustainability transition requires raw materials that, to some extent, make the mining industry indispensable. This also forces us to engage with the prospects and scope conditions of sustainable mining, a concept that has gained political traction primarily 'thanks to mining industry sponsorship',[16] yet which simultaneously indicates the need to square the industry's outsized environmental and social footprint with the resource

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

requirements of a sustainability transition. I will return to these issues later in the chapter; for the present moment, I simply wish to stress that recognition of the central role which the mining industry is bound to play in this context does not exclude the simultaneous recognition of its disastrous legal and ethical track record.

When considering technological change, it is noteworthy that the mining industry is a sector with comparatively low R&D expenditures and limited innovation. It is an industry characterized by 'technological conservatism' where '[r]adical technical change involving a significant departure from past practice is relatively rare . . ., reflecting high capital costs, long lead times of project development, and the high risks involved in committing capital and expertise to unproven technology'.[17] This tendency has only changed since the 1990s due to increasing outsourcing from mining companies to external equipment providers that have stronger incentives to innovate.[18] Yet disruptive technological innovation is not absent but only infrequent. One notable innovation of this kind is solvent extraction and electrowinning, referred to as SX/EW, which is used to leach copper, cobalt, nickel, and other metals from their surrounding ore. This process uses sulphuric acid produced as a by-product of smelting and thus cannot be scaled independently. At the same time, the method has lower environmental impacts and energy requirements than conventional techniques, as well as a better economic performance.[19] A similar method, known as in situ recovery, leaches minerals directly from their natural surroundings, dissolving them in a carrier fluid that has been injected into a borehole or hydraulic fracture and recovering them once the fluid has been pumped up to the surface again. This method is primarily used for uranium, where it presently accounts for half of the global extraction volume. This translates into lower energy requirements and reduces surface impacts from waste material.[20] Other instances of disruptive innovation are associated with the introduction of geological computer models, high-performance smelters, and novel grinding mills, as well as new methods for geological mapping via light detection and ranging.[21] Several other technological developments could, in principle, have a transformative impact on the mining industry in the near future. One is in digitalization and artificial intelligence.[22] This includes improved geological analyses on the basis of machine learning techniques and drone-based imaging; automation and robotization of mining equipment and its coordination through the Internet of Things; and real-time, big data analytics to monitor industrial performance and geological risks.[23] Another area is biotechnology. Microbes can be used as biomarkers that facilitate the detection of metal deposits, for mineral extraction through bio-based leaching, for the management of toxic ore tailings, and for environmental remediation more broadly.[24] Together with developments in other fields, such as 3D printing and nanomaterials, this suggests an increasing, latent potential for disruptive technological change in the global mining sector.[25]

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

Against this background, there is another aspect that gives mining its specific salience, as well as its contentiousness, in the context of environmental sustainability. Technological developments both inside and outside of the mining industry, together with various political, economic, and other contextual factors, have opened up the prospect of accessing the vast deposits of metals and minerals situated in areas beyond national jurisdiction (ABNJ). These are areas which have previously been beyond the reach of industry, being remote, inaccessible, and dangerous. With declining volumes of metals and minerals that can be mined with relative ease inside territorial borders, ABNJ hold a key to vast commercial fortunes as well as to the political problem of reconciling the harmful impacts of the mining industry with the resource requirements of a global sustainability transition. Depending on technological development but also governance choices, the turn towards ABNJ might attenuate the environmental and social footprint of the mining industry and align it with a global sustainability transition. Yet it might also embed vast environmental harm in the global economy, to an extent that might well offset or overcompensate for any of its environmental benefits.

So what are these ABNJ? To start with, we should note that the term 'ABNJ' is not merely geographical in nature. Rather, ABNJ are distinct geographical regions that are subject to distinct, and somewhat idiosyncratic, legal regimes: being beyond the scope of national jurisdiction, these regions are governed exclusively through international law, with claims of national sovereignty generally being inadmissible. ABNJ are thus not simply any type of region outside of state territorial borders. Rather, they are regions beyond the scope of the territoriality principle for which states, out of concern for their common interest of common heritage, have chosen to create distinct legal regimes under international public law.

The first ABNJ which I consider in this chapter is Antarctica. Most activities related to mineral resources have been prohibited since the 1990s (see Section 6.5), which means that the possibilities for systematically assessing Antarctic mineral deposits have been extremely limited for three decades. Consequently, most studies on the subject date from the 1970s and 1980s. Due to the challenging geography of Antarctica, information about existing reserves can, for the most part, only be indirectly inferred. Parts of the Transantarctic Mountains, at the border between Eastern and Western Antarctica, may contain non-trivial reserves of copper, cobalt, gold, manganese, silver, and zinc.[26] Reserves of platinum-group metals might be located in the Dufek Intrusion, also part of the Transantarctic Mountains.[27] For any of these or other metals and minerals, extraction and logistics would be uniquely challenging due to regional climatic conditions, long distances, and the difficulties of ship-based transportation. Economic feasibility would thus require drastic increases in relevant commodity prices. That being said, there is a growing geopolitical interest in Antarctic reserves of minerals and metals. China likely

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

holds long-term interests in these and other Antarctic resources, possibly including coal and natural gas, and has been conducting in-depth scientific studies for several decades.[28] Other governments, such as Australia, India, and Russia, also hold stakes in the potential resources of Antarctica, as well as in the fragile balance of interests and claims that characterizes the Antarctic Treaty System (see later in this chapter).[29]

The second ABNJ is what is legally referred to as 'the Area' – that is, 'the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction'.[30] Interest in the Area took off during the 1970s due to a combination of expected shortfalls in the terrestrial mineral supply and an overenthusiastic belief in the abundance, and ease of extraction, of deep-sea minerals.[31] This initial interest waned in the 1980s when the technical challenges became apparent. Yet interest in deep-sea mining has recently seen a revival as advances in marine technology, robotics, and other fields are starting to bring the mineral resources of the Area into reach.[32] Three types of resources are of principal economic interest. Polymetallic (or 'manganese') nodules, containing high concentrations of various metals, are said to be situated mainly in the Clarion–Clipperton Zone of the North Pacific as well as the abyssal plains of the Atlantic, Indian, and Pacific Oceans, at depths of several kilometres. The Clarion–Clipperton Zone alone is estimated to contain polymetallic nodules with amounts of copper, manganese, nickel, thallium, and yttrium that exceed all known terrestrial reserves, at comparatively high concentrations that improve the potential economic feasibility.[33] Seafloor massive sulphides are a second resource of general interest. They occur mostly on the mid-ocean ridge, an underwater mountain chain stretching more than 60,000 km in length. Seafloor massive sulphides could be a source of high-grade copper, gold, silver, and zinc.[34] Finally, cobalt-rich ferromanganese crusts, found mainly on underwater seamounts, contain large amounts of cobalt and other metals such as nickel, platinum, and tungsten.[35] These are extremely common and may cover more than 6 million square km of ocean floor. Extracting these and other materials could involve unmanned underwater vehicles for drilling and breaking up the materials, which would then be transported to stationary platforms or vessels on the surface via pumps or vertical conveyor belts.

The third ABNJ is outer space. The moon, as well as near-Earth asteroids, may contain large volumes of diverse minerals and metals in concentrations that are so high that extraction might become economically feasible at one or the other point during this century, despite the immensity of the associated technical challenges. About one million known asteroids currently exist in our solar system. As one particularly enthusiastic observer puts it, '[i]f humans were able to get their hands on just one asteroid, it would be a game changer . . . because the value of many asteroids is measured in quintillions of dollars, telephone numbers if you will,

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

which makes the market for Earth's annual production of raw materials, at about US$660 billion per year, look paltry in comparison'.[36] The mineral and metal reserves found in asteroids and other celestial bodies could also provide raw materials for the construction of space-based infrastructure, notably in the context of the lunar bases that the United States and China are each aiming to put into operation during the 2030s. Beyond minerals and metals, water reserves, notably from ice on the lunar poles, could provide an energy carrier that facilitates further exploration of the solar system by refuelling spacecraft after they escape the Earth's gravitational pull.[37] Significant lunar helium-3 reserves, hypothetically usable in nuclear fusion, could serve the same purpose. The actual mining process could then rely on robotics and solar power, as well as on-site production of tools and other equipment via 3D printing in order to reduce the material that have to be transported from Earth. As a recent experiment on the International Space Station shows, biomining for critical metals (meaning that microbes are used to leach the materials out of the surrounding rock) would also be feasible in zero- and low-gravity environments.[38]

Between these three ABNJ, commercial mining operations have different degrees of feasibility. Deep-sea mining is presently the only form where initial commercial operations are underway and where a functional regulatory regime is gradually emerging under the auspices of the International Seabed Authority. Mining in Antarctica would presume the prior collapse of the moratorium under the Protocol on Environmental Protection to the Antarctic Treaty and thus larger geopolitical shifts in the Antarctic balance of interests. Space mining is seeing an extraordinary and increasing amount of political attention, in the wider context of the emerging new space race,[39] although the estimates of its technical and economic feasibility vary widely. While mining in ABNJ could make important contributions to a global sustainability transition, it may cause diverse and adverse environmental impacts itself. For both Antarctica and the deep sea, immense environmental risks exist for marine biodiversity, both from regular extractive operations and from large-scale technical disasters which the spatial context would likely make difficult to manage.[40] In space, environmental risks are more indirect, yet mining operations could contribute to a further escalation of the problem of orbital debris, increasingly interfering with space travel and satellite operations, and create fat-tail risks from the atmospheric entry of spacecraft shipping their mineral and metal cargo back to Earth.

Mining in ABNJ is thus potentially transformative: on the side of technological promises, it can fuel a global sustainability transition and contribute to the better management of human impacts on the global environment. At the same time, such mining operations might reduce the economic need to maintain conventional mining operations, possibly contributing to greater global justice as the social and

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

environmental footprint of the extractive industries is reduced accordingly. On the side of technological perils, mining in ABNJ poses a significant risk of environmental harm. In addition, it raises novel justice-related challenges, as Antarctica, the deep sea, and outer space are, in different ways and to different extents, subject to legal norms that assert collective rights that sit uneasily with unfettered commercial resource exploitation. The specific normative natures of ABNJ, in other words, introduce additional layers of complexity and raise the question of how to prevent potential resource exploitation from conflicting with equity norms that have deep roots in international law.[41]

Before turning to the responses of international institutions to the emerging prospects of mining in ABNJ, I first delve a little more deeply into the role of minerals and metals in the world economy. Afterwards, I elaborate on the role of minerals and metals for a global transition to environmental sustainability. As in Chapters 4 and 5, I conclude with a description and explanation of institutional responses in theoretical terms, while also offering some pointers as to which hypothetical institutional designs might provide robust leverage for realizing the promises of mining in ABNJ while simultaneously keeping its perils in check.

6.1 Metals in the World Economy

Between 1970 and 2019, global extraction of metal ores increased from 265 million to 9.7 billion tonnes per year.[42] The world presently produces more than 1.8 billion tonnes of steel, 26 million tonnes of copper, 170,000 tonnes of cobalt, and 100,000 tonnes of lithium every year.[43] Personal computers contain aluminium, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, gallium, gold, iron, lead, manganese, mercury, palladium, platinum, selenium, silver, and zinc.[44] Contemporary cars contain dozens of minerals, including an average of 25 kg of copper for electrical wiring, with catalytic converters containing diverse platinum-group metals and rare earth elements.[45] In a 2008 analysis by the US National Academies of Sciences, Engineering and Medicine, the annual US consumption of metals and (non-metallic, non-fuel) minerals exceeded 11 metric tonnes per capita.[46] In other words: metals – from base and light metals to steel and ferroalloys to precious metals and rare earth elements – are central to virtually every aspect of the contemporary world economy.

To start with, metals play a significant role in the manufacturing of different types of steel, including chromium, cobalt, manganese, molybdenum, nickel, silicon, and tungsten. Such alloy steels differ in their performance characteristics and find application in a wide variety of contexts, from construction to industry to engines. Aluminium and titanium are indispensable light metals in transportation and construction. Among the base metals, copper, with annual production levels of

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

about 20 million tonnes, is used for wiring and various engines, among other purposes. Other base metals are lead, zinc, and tin, used, for instance, in batteries and other electric devices. Technology metals, finally, include relatively rare and expensive elements with niche applications in specific high-tech sectors. This includes cadmium, together with nickel forming the basis of rechargeable nickel–cadmium batteries; caesium for cell phones and navigation systems; gallium in semiconductors; and lithium for batteries that have better performance and lower environmental impacts, but also higher costs than their nickel–cadmium counterparts.[47] The latter category also contains the seventeen infamous rare earth elements: cerium, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lutetium, neodymium, praseodymium, promethium, samarium, scandium, terbium, thulium, ytterbium, and yttrium. These elements differ in economic importance and, contrary to their designation, are not 'rare' but rather occur in very low concentrations so that extraction is challenging and, accordingly, costly. Yet compared to bulk metals such as copper, rare earth elements are usually required in very small quantities.[48] With the exception of promethium and scandium, rare earth elements are used in a variety of high-tech applications, including power generators, nickel–metal hydride batteries, catalytic converters, lasers, optical sensors, magnetic resonance imaging, nuclear reactors, fibre optics, light-emitting diodes, and capacitors, but also in construction materials and as fuel additives.[49] Outside of these three categories, one noteworthy addition is the platinum-group metals: iridium, osmium, palladium, platinum, rhodium, and ruthenium. Palladium, platinum, and rhodium are primarily used in the car industry, for catalytic converters that control harmful vehicle emissions. Iridium and ruthenium find use in energy, digital, and medical technologies. Osmium is principally used in alloys.[50] Another addition is uranium, used in nuclear power generation and for military purposes, including the nuclear bomb.

This brief overview shows how central different types of metal are to the contemporary world economy in its entirety; the next section will show their criticality for sectoral sustainability from transportation to energy to infrastructure development. For now, let us consider some longer historical trends. Metal prices typically track economic growth but exhibit much larger short-term variability than other commodity prices.[51] Disregarding the boom-and-bust cycles of metal commodity markets over the short term, real prices for all types of metals trend markedly upwards. Between 1990 and 2021, the real prices for most base metals as well as uranium have increased between three- and four-fold. These increases have been somewhat larger for gold and silver, and particularly large for some platinum-group metals, with real palladium prices increasing by a factor of twenty-seven.[52] The historical data that is available for rare earth elements tends to be somewhat spotty. Between 2017 and 2021, some have seen declining prices (e.g.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

europium and scandium) whereas others underwent strong growth (e.g. gadolinium, praseodymium, and terbium).[53] A major factor influencing long-term price development in global metals markets has been demand from newly emerging economies. Since the turn of the millennium, Brazil, China, India, Indonesia, Mexico, Russia, and Turkey jointly made up 92 per cent of the global increase in metals consumption.[54] At the beginning of the new millennium, industrialized countries accounted for between half and two-thirds of the global consumption of metals and non-metallic minerals; two decades later, emerging economies accounted for three-quarters of global consumption, with concomitant changes in the structure of the mining industry.[55] Some emerging economies have, simultaneously, become major suppliers as well. For rare earth elements, China has gradually acquired a virtual monopoly on global supply.[56] China is also a major producer of aluminium, cadmium, gold, lithium, molybdenum, tin, and tungsten, in addition to producing just over half of the world's steel. Indonesia and Russia are major producers of nickel, just as Brazil is for niobium and tantalum and Mexico is for silver.

These historical transformations in supply and demand have given metals a sharp geopolitical edge. In 2009 and 2012, Chinese export restrictions on rare earth elements led to dispute settlement proceedings under the WTO, with the United States and others accusing China of violating the non-discrimination principle by giving preferential treatment to its domestic consumers.[57] The European Commission set up its first Raw Materials Initiative in 2008 (revised in 2011) and, in 2020, followed up with the Critical Raw Materials Action Plan. Today, both the European Union and its member states are providing significant financial support for research, development, and innovation for enhancing supply security as well as for improving resource efficiency.[58] The United States set up a Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals in 2017[59] and spearheaded the creation of the Minerals Security Partnership, established in June 2022 as a coalition of several industrialized countries committed to mutually ensuring each other's supply security in what the news media have termed a 'metallic NATO'.[60] Other countries that have adopted national strategies and policy frameworks for addressing questions of supply security for critical metals and non-metallic minerals include Canada, Japan, and the United Kingdom.[61] For these and other countries of the Global North, improvements to resource efficiency as well as the onshoring of extraction are central elements of their resource security strategies, with the principal aim of reducing their dependencies on exports from China.[62]

Aside from such questions of supply security in the context of broader geopolitical rivalries, another issue is the finiteness of global metals reserves. The notion that resource exhaustion stands in the way of continuous and increasing resource

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

consumption is old, dating back to the writings of Thomas Malthus in the late eighteenth century and being at the core of the 1972 Club of Rome report on Limits to Growth, the impact of which on the emergence of the sustainability paradigm during the 1980s and 1990s cannot be overstated. In the same vein, the idea of 'peak oil', first proposed in 1956, entails that crude oil production over time approximates a bell curve (here also named a Hubbert curve, after its inventor), with maximum extraction levels (and subsequent decline) having been predicted for various time points in the second half of the twentieth century and the beginning of the twenty-first.[63] This model was later extended to other natural resources, including metals. One study estimates that bismuth, indium, lithium, manganese, molybdenum, nickel, and tantalum may reach their respective production peaks at various points in the coming two decades, with the production of antimony and gold already having peaked in 2012 and 2014, respectively.[64] Another study that estimates the Hubbert curve for copper predicts a production peak as early as 2029.[65]

The central assumption behind the Hubbert curve is that production volumes are primarily determined by resource stocks. While the overall usefulness of the Hubbert curve is widely accepted, there is substantial debate on its exclusion of market mechanisms. An alternative way of thinking about resource depletion is to conceptualize production levels as a function of prices and thus supply and demand. As one observer puts it: 'We will never physically run out of oil or other mineral commodities. If depletion threatens their long-run availability, it will do so by pushing production costs and prices ever higher.'[66] Another issue to consider is that production constraints can result from factors other than resource stocks and market prices. A study on the Australian mining industry suggests that environmental and social constraints can affect the timing of production peaks as well. Specifically, this means that the mining industry causes negative environmental and social externalities – costs, for instance from pollution, that are not reflected in prices. By internalizing these negative externalities, and thus making market prices account for the 'true' costs of mining, production peaks will be reached earlier than they would otherwise.[67] Without significant reductions in the social and environmental footprint of the mining industry, sustainability constraints will severely affect future metal supply.

6.2 Metals and Sustainability Transitions

There is thus a curious ambiguity in the role of metals from a sustainability perspective: on the one hand, sustainability implies hard limits to the extraction, processing, and refining of metals, whether these are base and light metals, ferroalloys, precious metals, or rare earth elements. The adverse impacts which the mining industry causes to the environment, as well as at the nature–society interface, means that it

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

cannot be scaled beyond certain thresholds. However, as will be discussed in this section, the availability of metals (in particular precious metals and rare earth elements) shapes the feasibility of a global transition towards environmental sustainability. This leads to the conundrum that a sustainability transition depends on the up-scaling of extractive activities that are blatantly unsustainable at present.

I have previously discussed how 'safe' levels of global warming require a transition towards net-zero greenhouse gas emissions by the second half of the twenty-first century (see Chapter 5). Under a 1.5℃ temperature target, global anthropogenic carbon dioxide emissions must decline by about 45 per cent by 2030 relative to their 2010 levels and reach net zero by around 2050. For a 2℃ target, 2030 emissions must decline by approximately 25 per cent and reach net zero by around 2070. This requires significant and historically unprecedented social, economic, and technological restructuration, including in transportation and energy systems – two sectors that are critically dependent on metals for their respective net-zero transitions.

Let us start with transportation, currently the source of a quarter of global carbon dioxide emissions. Long-term decarbonization strategies are typically organized around the conceptual hierarchy of avoid-shift-improve: avoiding the need for travel as far as practical (for instance, through appropriate urban planning), shifting to sustainable modes of transportation (including public transportation and bikes), and improving technology in order to reduce carbon dioxide emissions.[68] Electric vehicles are not the universal solution to the challenge of decarbonizing the global transport sector, although they are a significant and indispensable component of a larger solution package. Yet the production of electric vehicles is heavily dependent on metals – significantly more so than is the case for conventional vehicles running on internal combustion engines. This is chiefly due to their batteries. Current high-performance batteries for electric vehicles contain different combinations of cobalt, lithium, manganese, and nickel. An electric passenger car will typically contain between 8 and 17 kg of lithium, whereas heavier commercial vehicles can contain up to 51 kg.[69] Electric vehicles, particularly those running on nickel–metal hydride batteries, also contain larger amounts of rare earth elements than conventional vehicles.[70]

The International Energy Agency estimates that 16.5 million electric passenger vehicles are in service as of 2021.[71] A 2℃ temperature target is estimated to require an increase to between 1.2 and 1.6 billion vehicles by mid-century.[72] This is not necessarily realistic. A study of the US transport sector finds that '[electric vehicle] deployment consistent with a 2℃ target under current policies would be even higher than the most optimistic deployment targets'.[73] Yet for the case that states fully implement their national climate targets (under the nationally determined contributions of the 2015 Paris Agreement), the International Energy Agency

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

estimates that the corresponding expansion in the global electric vehicle fleet would lead to an increase in battery demand that requires, by 2030, fifty new mines for lithium, sixty for nickel, and seventeen for cobalt, as compared to 2021. Battery manufacturing would also require a total of ninety additional gigafactories to be constructed in that time span, with dozens of additional manufacturing plants cathodes and anodes, as well as the electric vehicles themselves.[74] With long lead times until such mines, plants, and factories can become operational, the emergence of bottlenecks that constrain decarbonization efforts in the transport sector seems likely. Another study that assesses the expansion of the electric vehicle fleet until 2050 under a 2℃ temperature target estimates a cumulative demand over the 2015–50 period for 10 million tonnes of cobalt, 182 million tonnes of copper, 0.1 million tonnes of dysprosium, 11 million tonnes of lithium, 20 million tonnes of manganese, and 68 million tonnes of nickel.[75] For some metals, these quantities are wildly out of sync with contemporary production levels: cumulative demand up to 2050 exceeds the 2021 production levels by factors of 50 for cobalt, 100 for lithium, and 25 for nickel[76] – all metals that are likely to concurrently see substantial increases in demand from sources other than the car industry. The challenge is further compounded by the long lead times required for the scaling-up of metal production as well as the uneven distribution of cumulative demand over time, which is projected to peak during the 2030s.[77] Finally, many of the existing studies on decarbonization in the transport sector derive pathways and scenarios under a 2℃ temperature target. The resource requirements for a 'safe' 1.5℃ target would accordingly be substantially more stringent than those discussed here.

Decarbonization prospects in the energy sector are considerably brighter than in transportation, yet, here as well, there is substantial dependence on metal inputs. Rare earth elements arguably matter less for energy than for transportation. A notable exception are the magnets used in modern wind turbines, particularly for offshore sites, which require rare earth elements such as dysprosium.[78] Large-scale battery storage is a crucial element for offsetting the intermittency problem in an energy system dominated by renewables, particularly solar and wind. The same resource requirements apply here as they do in the transportation context discussed earlier. Silver is widely used in solar cells and has led to bottlenecks in the past, although copper offers a potential substitute.[79] Metal dependencies are arguably more pronounced beyond the dominant silicon-based design in solar photovoltaics. Indium and tellurium, for instance, are used in thin-film solar cells. Platinum and ruthenium are used in dye-sensitized cells, part of a third generation of solar cells that are, at least in theory, extraordinarily efficient in converting sunlight into electricity.[80] Beyond solar, the decentralized nature of most types of renewable energy production, together with their geographical siting constraints, translates into more elaborate requirements for transmission and distribution than is the case

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

for fossil-based energy systems. This increases the demand for copper. Similarly, in contrast to fossil systems, renewable energies require comparatively large amounts of steel, particularly for wind power. One analysis of a net-zero energy systems transition for a 2℃ temperature, based on renewables and residual consumption of natural gas in combination with NETs or CCS, highlights how cumulative resource requirements until 2100 exceed the currently known reserves for some critical metals, including cobalt, indium, tellurium, and selenium.[81] As with transportation, the decarbonization of the global energy system presumes resource inputs that cannot easily be scaled up without causing detrimental environmental and social spin-off effects. This is particularly the case for platinum and cobalt, where a recent study identifies particularly large environmental, social, and governance risks while also noting that '[t]he social and environmental implications of the anticipated rise in [energy transition metals] extraction are rarely acknowledged in energy transition scenarios'.[82]

Little evidence suggests that the increasing demand for metals (both within and outside the transport sector) might pose a threat of proper geological resource depletion. Yet the net-zero transition presupposes that a workable system for the international trade in critical metals remains in place over the coming decades.[83] The corollary is that geopolitical rivalries hold a latent potential for supply disruption and thus create systemic risks for the net-zero transition. Another issue is that the wider effects of production increases in critical metals need to be assessed over the entire life cycle – for instance, in terms of additional energy consumption for extraction and logistics, but also in terms of additional pollutant loads. Lithium production, for example, causes an extraordinary large water footprint through its life cycle.[84] With current production processes, it is not clear how global lithium production could be scaled-up in a manner consistent with the resource requirements for decarbonization in the transport sector without, at the same time, causing severe water crises in major producer countries. Questions regarding the timescale of geological depletion are thus somewhat beside the point: without radical transformations in the mining industry and the associated supply chains, substantial shares of the existing geological reserves cannot be recovered without causing unacceptable levels of environmental harm. This situation is comparable to fossil fuels, where significant amounts of existing reserves cannot be combusted without blowing through the remaining carbon budget for 1.5 or 2℃ of global warming. Yet while sustainability transitions, particularly in the energy sector, have in recent years become an area of intense academic interest and even hype,[85] there is only limited discussion of the environmental and social implications of the associated material flows and supply chain issues. Possibly, in the brave new world of net-zero emissions, the 'on the ground' consequences of sourcing cobalt from the Democratic Republic of the Congo or lithium from water-starved Chile do not

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

matter that much at all, because the problem of metal supply chains might come to form part of a dark side of net-zero that is inconsistent with the manichean framing that has come to characterize the debate.

This is where we close the circle and return to the issue of ABNJ. Whether we like it or not, the feasibility of a global sustainability transition hinges on resources that can only be provided in sufficient volumes, via conventional means, if we accept as an inevitable by-product the significant associated environmental and social costs.[86] The issue is not whether mining in Antarctica, the deep seas, or outer space is a good idea – because, as such, it is not. Yet the deep seas, certain asteroids, and potentially even Antarctica may contain metal resources in concentrations large enough to substitute for larger numbers of mining projects elsewhere. A single platinum deposit in an asteroid, for instance, might be enough to substitute for terrestrial platinum mining in all of South Africa, where the industry has a particularly odious history.[87] Similarly, rather than meeting expanding copper demand from a renewable energy transition through the intensification of terrestrial mining with corresponding environmental impacts,[88] a limited number of deep-sea extraction operations from polymetallic nodules or seafloor massive sulphides might suffice.

The confluence of technological developments that is increasingly bringing mining in ABNJ within reach, albeit at different speeds, thus promises to contribute to impact management: by providing critical raw materials for a global sustainability transition while, at the same time, offering a potential substitute for terrestrial mining, reducing the social and environmental harm which the latter causes by shifting and concentrating mining operations elsewhere. To stress this once more: the question is not whether mining in ABNJ is a 'good idea'; the question is whether it results in degrees and types of harm that are lower, or socially more acceptable, than harm caused by conventional, terrestrial operations. In addition to the peril of environmental harm, mining in ABNJ also raises challenges related to justice: who would appropriate the (likely considerable) commercial profits from mining in ABNJ? How would existing norms on benefit-sharing, common interests, or common heritage, to be discussed in greater detail, be enacted? How would the interests of countries that lack suitable technological and financial capacities to engage in mining in ABNJ be safeguarded? And, as a final aspect, how can one ensure the provision of knowledge and information, from accompanying scientific research in ABNJ, as a global public good?

International institutions have responded to these issues in a variety of ways yet, as the following discussion will show, the prevalence of institutional drift highlights that, for the most part, international institutions have not been up to the task in providing adequate answers to the emergence of mining in ABNJ as a transformative technological field. As before, I return to the question of hypothetical institutional designs in the conclusions to this chapter.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

6.3 The Outer Space Treaty

The Outer Space Treaty, formally known as the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, was signed in 1967 amidst the tensions of East–West superpower confrontation, the threat of nuclear war, and concerns regarding the potential militarization of outer space.[89] This was a mere decade after the Soviet Union accomplished the first orbital launch in human history, leading to the 'Sputnik shock' as Western governments realized the potential of this technology for the long-range delivery of nuclear warheads. The United States had followed suit in 1958 with the launch of *Explorer 1*, to be joined by France in 1965, with China, Japan, the United Kingdom, and the European Space Agency following suite in the 1970s.[90]

The Outer Space Treaty aspired to transcend the geopolitical rifts that characterized the early history of spaceflight. In its preambular text, parties recognize 'the common interest of all mankind in the progress of the exploration and use of outer space for peaceful purposes' and state their belief 'that the exploration and use of outer space should be carried on for the benefit of all peoples irrespective of the degree of their economic or scientific development, and shall be the province of all mankind'.[91] In its operational parts, the treaty holds that '[t]he exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind' and that '[o]uter space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means'.[92] A central normative commitment that is at the core of the treaty is thus the recognition that differences in socio-economic development, particularly between industrialized and developing countries, require corrective measures in order to prevent asymmetrical distributions of technological capacities from leading to outcomes that are manifestly unjust, and that outer space constitutes a domain that is either the common heritage of humanity or, at the least, a common interest.

I briefly discussed the concept of a common heritage of humanity in Chapter 4,[93] where it was the central norm behind the International Undertaking on Plant Genetic Resources and later appeared, in attenuated form, in the Seed Treaty. The concept is also central to the deep-sea regime under UNCLOS part XI, which I discuss later in the present chapter. Its status under the Outer Space Treaty is somewhat ambiguous. This is not least because the text does not include a specific reference to the concept as such. However, the terms 'province of all mankind' and 'common interest of all mankind', as well as the national non-appropriation clause

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

in Article 2, broadly indicate the existence of collective rights held by 'countries' or by 'humanity' as such. Depending on interpretation, this could imply the existence of collective property rights or stewardship duties, as collective decision-making on the rules governing the exploration and exploitation of space resources, or as an obligation to devise corrective measures for unjust outcomes that result from differences in socio-economic development and technological capacities.[94]

Another international agreement, yet one that, for better or worse, is relegated to political insignificance, makes the point more forcefully. The 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies ('Moon Agreement') was negotiated in the decade after the conclusion of the Outer Space Treaty. Unlike the latter, the Moon Agreement explicitly calls for a regime of common heritage for the moon as well as other celestial bodies of our solar system, with the exception of Earth. While the agreement echoes the Outer Space Treaty's non-appropriation clause, the agreement goes on to explicitly prohibit property claims by states, international organizations, national organizations, non-governmental entities, and natural persons.[95] Moreover, the parties to the Moon Agreement commit to creating an international regime to regulate the extraction of resources from the moon and other celestial bodies except Earth, one aim of which would be the 'equitable sharing by all States Parties in the benefits derived from those resources, whereby the interests and needs of the developing countries, as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the moon, shall be given special consideration'.[96] While the Moon Agreement builds upon the Outer Space Treaty and its concept of the province of all humanity, only eighteen states are presently party to the agreement, practically relegating it to the status of a footnote in the history of space law. Yet the Moon Agreement also highlights how, at the very least, the Outer Space Treaty is compatible with a legal interpretation that regulates resource appropriation from a perspective of larger considerations of global justice, particularly regarding the difference between industrialized and developing countries.

Getting back to the Outer Space Treaty, it is probably safe to say that common heritage, in one way or another, constitutes a fundamental norm, yet its precise status, meaning, and implications for the exploration and exploitation of space resources continues to be a matter of dispute.[97] In 2000, this led to one of the more curious disputes in international law. An unmanned NASA spacecraft, the Near Earth Asteroid Rendezvous Shoemaker, had entered the orbit of the asteroid 433 Eros and was to land on its surface the following year, a first in the history of spaceflight. Back on Earth, Gregory Nemitz, a self-described 'space activist' from Idaho, asserted 433 Eros as his private property and issued NASA a parking bill for US$ 20. In response, NASA held that, with the United States being party to the

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

Outer Space Treaty, the Article 2 non-appropriation clause 'would seem to preclude' property claims to 433 Eros by US nationals. The agency accordingly 'respectfully decline[d] to make the requested payment at this time'.[98] The manifest absurdity of this episode reflects deeply problematic tensions in international space law regarding the implications that the partial and ambiguous common heritage elements of the Outer Space Treaty have for private property rights. In particular, the question of how Article 2 applies not to states but to natural and legal persons under their respective jurisdiction acquired major significance in later years, as I will discuss later in the context of the Artemis Accords.

As such, the implications of the Outer Space Treaty for asteroid mining, particularly by private entities, are unclear. Some scholars argue that the treaty does not interfere with the commercial extraction of minerals by private operators.[99] I previously argued that, at the very least, the treaty is open to an operationalization based on common heritage and the sharing of (commercial and other) benefits.[100] It may thus be compatible with both a free-market model with unfettered private property rights and commercial profits that are fully appropriated by operators with suitable technical and financial capacities, and a regulated model where private mining companies would, in one way or another, be obliged to make direct and tangible contributions to the furtherance of broader collective interests and notions of fairness and equity.

As with other core treaties of international space law, the Outer Space Treaty is overseen by the UN Committee on the Peaceful Uses of Outer Space (COPUOS). This body was set up by the UN General Assembly in 1959 in order to review matters of space-related international cooperation and to 'study practical and feasible means for giving effect to programmes in the peaceful uses of outer space'.[101] Initially composed of 24 member states, COPUOS membership increased over the decades, reaching 100 in 2021, as more and more non-spacefaring countries sought to obtain some measure of political influence over the emerging technological and economic benefits of the space economy.[102] COPUOS has only recently begun to engage with the issue of space resources more closely. In 2016, its legal subcommittee decided for the first time to include as a future agenda item the '[g]eneral exchange of views on potential legal models for activities in exploration, exploitation and utilization of space resources' in order to 'provide an opportunity for a constructive, multilateral exchange of views on such activities, including their economic aspects'.[103]

In the years since then, discussions in COPUOS started coalescing around two distinct and largely incompatible ideas. On the one hand, several industrialized countries, spearheaded by the United States, argue that the Outer Space Treaty guarantees 'the freedom of exploration and use of outer space and, in that regard, [does] not prohibit the utilization and exploitation of resources contained in

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

celestial bodies'; thus, 'as a matter of international law there [is] no legal need to develop detailed implementation guidelines regarding lawful activities'.[104] On the other hand, China, Russia, and various developing countries started to argue in favour of a multilateral approach that places the exploration and exploitation of space resources under the jurisdiction of the international community and ensures that the benefits of the new space race do not solely accrue to the technologically advanced countries. At the 2022 meeting of COPUOS, the G77/China held that, '[i] n light of the increasing participation and the evolving potential of the private sector in space activities, the negotiation of an international legally binding instrument that clearly defines and guides commercial activities in outer space could play an important role in expanding the use of outer space and stimulate space activities for the benefit of humanity', further asserting that 'the developing countries shall not be excluded from the benefits of space exploration and their rights shall be considered in the discussion'.[105]

These discussions were, and continue to be, strongly influenced by legal developments outside of the United Nations system, which I shall briefly summarize. To start with, since 2016, a high-level stakeholder forum, the Hague Space Resources Governance Working Group, has been analysing the need for, and modalities of, a potential international framework to regulate exploration and exploitation. In 2019, the working group adopted its so-called Building Blocks, a series of core recommendations to inform international deliberations and potential negotiations.[106] The Building Blocks are slanted towards the interests of the space industry and leading spacefaring nations, with an emphasis on private property rights and 'priority rights' that would grant operators exclusivity to explore and exploit space resources in a defined area for a limited period of time, while containing only weak elements for benefit-sharing and no references to common heritage. This broader approach mirrors the ideas behind the Artemis Accords, a series of bilateral agreements that the US government has concluded with (currently twenty-one) other governments since 2020.[107] The Artemis Accords are geared towards the free, safe, and sustainable exploration and exploitation of space resources. Notably, its signatories 'affirm that the extraction of space resources does not inherently constitute national appropriation under Article II of the Outer Space Treaty'.[108] Legally, while the Accords cannot change the existing rights and obligations which its signatories have in parallel under the Outer Space Treaty, they offer a specific interpretation of the ambiguous non-appropriation clause under Article II of that treaty. The Accords also commit its signatories to openly sharing scientific data which they have gathered from their cooperative activities in outer space, yet explicitly exempt 'private sector operations' from this provision.[109] To some extent, this is an unavoidable consequence of prioritizing commercial interests over the rights of the public and the international community,

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

yet it arguably also narrows down the scope for scientific cooperation and development foreseen under the Outer Space Treaty. Finally, the international developments discussed in this paragraph also mirror changes in domestic legislation. The 2015 US Commercial Space Launch Competitiveness Act holds that US citizens that are 'engaged in commercial recovery of an asteroid resource or a space resource . . . shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States'.[110] This, of course, stands diametrically opposed to what NASA's legal division found fifteen years earlier when refusing to pay the requested fee for 'parking' on the asteroid claimed by Gregory Nemitz: namely, that the non-appropriation clause of the Outer Space Treaty 'would seem to preclude' appropriation by US citizens.[111]

The situation under the Outer Space Treaty thus remains inconclusive. In 2021, COPUOS members decided to form a Working Group on Legal Aspects of Space Resource Activities for the development of further analyses and recommendations.[112] However, this decision appears to attempt to push down to the technical level what is inherently a political problem in need of a negotiated solution. As the exploration and exploitation of space resources, possibly including asteroids, appears to be gaining in feasibility, multilateral space governance under the auspices of the UN is being displaced by a club of advanced economies that is led by the United States and gives priority to commercial interests and private appropriation over the global equity norms encapsulated in international space law. Meanwhile, China and Russia have emerged as the champions of the multilateral, UN-centric order for reasons that likely go beyond principled moral commitment. While the Outer Space Treaty remains the central framework for the future exploration and exploitation of space resources, the Artemis Accords and the Building Blocks of the Hague Space Resources Governance Working Group, as well as domestic legislative changes in the United States and elsewhere, all seek to reinforce a partisan interpretation of the non-appropriation clause that does not follow from the text of the treaty by default. Rather, it imputes a precise meaning to a legal provision that was designed for ambiguity in order to bridge diverging political preferences during the original negotiations on the Outer Space Treaty. These divergences originate from global asymmetries in spaceflight capacities and, in one or another form, still persist more than five decades later. In other words, the legal claim that the non-appropriation clause somehow does not apply to commercial actors does not resolve the political problem of global inequality in the emerging space industry along, very roughly, North–South lines. The failure to address this political problem seems to be at the core of the non-responsiveness to the emergence of asteroid mining that we can observe in the context of the Outer Space Treaty.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

6.4 The United Nations Convention on the Law of the Sea

The United Nations Convention on the Law of the Sea (UNCLOS) is the central international agreement setting out legally binding rules for virtually every aspect related to the seas. Legally, its nature is complex. UNCLOS in its contemporary form emerged through a series of UN conferences that started in the 1950s, initially resulting in a set of formally distinct international agreements that were integrated into a single instrument between 1973 and 1982. Rules on deep-sea mining, contained in part XI of that agreement, proved unpalatable to the United States and other industrialized countries, which considered it contrary to their economic interests.[113] This led to a so-called implementation agreement, concluded in 1994, which modified and superseded part XI, assuaging the concerns of industrialized countries and enabling their full participation in the law of the sea regime. Without a doubt, UNCLOS part XI contains the clearest definition and most elaborate operationalization of the common heritage principle in all of international law. This part applies to the so-called Area, which is 'the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction'.[114] The Area, as well as the 'solid, liquid or gaseous mineral resources' which it contains, 'are the common heritage of mankind'.[115] They are outside the scope of national sovereignty and under the collective jurisdiction of humanity as such.[116] The rights of humanity in the area and its resources are represented by the International Seabed Authority, an intergovernmental agency under the control of UNCLOS contracting parties, which is mandated to create and implement operational rules to ensure the 'equitable sharing of financial and other economic benefits derived from activities in the Area'.[117]

At the time of writing, the precise manner in which common heritage and benefit-sharing will be operationalized is still a matter of political debate. Unlike for benefit-sharing regimes such as the CBD or the Seed Treaty (see Chapter 4), the possibilities for, and modalities of, benefit-sharing under UNCLOS are fairly complex.[118] One potential avenue is the sharing of commercial profits derived from the exploitation of deep-sea minerals: as soon as commercial mining starts, operators would pay fees or royalties to the International Seabed Authority, who would then disburse them on behalf of humanity as such. Another option is in a particularly noteworthy feature of the deep-sea mining regime called the Enterprise: a mining operator under the authority of the International Seabed Authority that would 'carry out activities in the Area directly … as well as the transporting, processing and marketing of minerals recovered from the Area'.[119] The Enterprise is typically understood as a supranational mining company, or a 'global parastatal entity … to implement the redistributionist intentions' of the common heritage principle.[120] The 1994 Agreement on Implementation

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

constrained the role originally foreseen for the Enterprise under UNCLOS in important ways, including by requiring it to operate under commercial principles rather than with mandatory financial support from the contracting parties to UNCLOS.[121] The Enterprise would become operational once the International Seabed Authority grants an exploitation contract to an entity other than the Enterprise, or to a joint venture between such an entity and the Enterprise itself.[122] Another option for benefit-sharing is via the reserve area system: in principle, applications for exploitation contracts must specify two largely equivalent sites for potential mining operations – in the case that International Seabed Authority grants the contract, one of these sites becomes reserved for future exploitation by the Enterprise or by a developing country. This system has been slightly adjusted for some types of minerals (sulphides and cobalt crusts), where applicants may alternatively opt for a profit-sharing arrangement with the Enterprise.[123] Finally, UNCLOS also allows for the sharing of benefits from marine scientific research in the Area, which 'shall be carried out exclusively for peaceful purposes and for the benefit of mankind as a whole'.[124]

To this day, the modalities of benefit-sharing in the context of deep-sea mining remain unresolved, although over the past two decades the International Seabed Authority has taken important steps towards an operational regime for future commercial operations. That being said, the role of the Authority remains a matter of dispute. Allegations of undue industry influence and conflicts of interest abound, as exemplified by the appearance of the Authority's Secretary-General in a 2018 promotional video for DeepGreen Metals, a Canadian mining company now known as The Metals Company.[125] Yet these problems are partially by design: 'There is no other precedent of an international intergovernmental treaty body (with 168 members, each with their own political priorities and interests) attempting to act as a minerals licensing, environmental permitting, monitoring and enforcement, and revenue collection agency', and '[w]hen the Enterprise comes into existence, the [International Seabed Authority] will be required to issue exploration or mining contracts to, and regulate, itself'.[126] These challenges notwithstanding, the International Seabed Authority has made major contributions to the evolution of the deep-sea mining regime, most importantly with the development of the Mining Code.

The Mining Code is a set of regulations and guidelines which the International Seabed Authority has developed in accordance with its mandate as set out under UNCLOS. Of central importance is the distinction between exploration and exploitation. The International Seabed Authority defines exploration as the 'searching for deposits [of cobalt crusts, polymetallic sulphides or polymetallic nodules] in the Area with exclusive rights, the analysis of such deposits, the use and testing of recovery systems and equipment, processing facilities and transportation systems

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

and the carrying out of studies of the environmental, technical, economic, commercial and other appropriate factors that must be taken into account in exploitation.'

Conversely, it defines exploitation as 'the recovery for commercial purposes of [of cobalt crusts, polymetallic sulphides or polymetallic nodules] in the Area and the extraction of minerals therefrom, including the construction and operation of mining, processing and transportation systems, for the production and marketing of metals'.[127] The Mining Code contains three different regulations dealing, respectively, with the exploration of polymetallic nodules, sulphides, and cobalt crusts, in addition to guidelines and recommendations for contractors regarding reporting standards or environmental impact assessments. For exploitation, the Mining Code is less well developed, with draft standards and guidelines still pending formal adoption. The International Seabed Authority had originally intended to finalize the exploitation regulations in 2020 yet, like many other international organizations, had to cope with the disruptions of the COVID-19 pandemic. More fundamentally, the exploitation regulations will need to nail down the precise ways in which commercial mining operations must align with the common heritage principle and the benefit-sharing requirement, while simultaneously ensuring a high level of environmental integrity.[128] Since 2018, the Finance Committee of the International Seabed Authority has made some progress in its discussions on monetary and non-monetary benefit-sharing. The most prominent option under consideration is a system based on *ad valorem* royalties (i.e. a levy that is a percentage of the total value of the minerals that a contractor has extracted) that would be distributed between UNCLOS contracting parties and would also go towards financing the International Seabed Authority itself. Many technical details remain unclear at the time of writing, the most important of which is arguably the *rate* of these royalty payments. An alternative proposal is to bundle benefit-sharing streams in a Seabed Sustainability Fund, which would then invest in projects for the conservation and sustainable use of the Area, in a manner comparable to the FAO Seed Treaty discussed in Chapter 4.[129] Besides these unresolved financial questions, the challenge of reconciling commercial mining with adequate protection of the marine environment has over time increased in urgency in the political discussions under the International Seabed Authority.[130]

While progress on the exploitation regulations remains slow, more and more of the fifteen-year exploration contracts which the International Seabed Authority has granted to a total of twenty-nine different operators (as of 2022) are lapsing and thus require formal extension – otherwise, the exploration regulations would have required contractors to either apply for an exploitation contract for the area in question (which would require the International Seabed Authority to have concluded its work on the exploitation regulations) or to relinquish their rights in that

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

area. Adding to the political pressure is a decision by Nauru, in June 2021, to use an obscure rule contained in the annex to the 1994 Agreement on Implementation. Under this rule, a state may notify the International Seabed Authority of the intent to apply for an exploitation contract; if, within two years' of the date of notification (i.e. by June 2023) the International Seabed Authority has *not* finalized the relevant rules, regulations, and procedures, it must nevertheless consider this application for approval.[131] This rule has been described as a 'nuclear option',[132] although its precise legal meaning remains somewhat unclear. While this does *not* mean that the International Seabed Authority must finalize its exploitation regulations by June 2023 or the first commercial mining programme in history will go ahead no matter what, it certainly increases the pressure on the Authority to conclude its deliberations. The decision by Nauru is based on its sponsorship of Nauru Ocean Resources Inc., a subsidiary of the previously mentioned The Metals Company, which has held an exploration contract for polymetallic nodules in the Clarion–Clipperton Zone since 2011. As such, the government of Nauru likely expects to reap financial and economic benefits from commercial mining under its sponsorship.

Aside from the Mining Code, the International Seabed Authority has also taken some steps towards operationalizing the provisions on marine scientific research entailed in UNCLOS parts XI and XIII. The DeepData platform is a recent initiative for hosting data generated by contractors in the course of mineral exploration and making it, in parts, available to the public. The International Seabed Authority has also adopted an action plan in the context of the UN Decade of Ocean Science for Sustainable Development, a framework that operates across the UN system and aims to leverage the marine sciences for the sustainable development goals during the 2021–30 period.[133] The Authority also engages in partnerships and strategic alliances with other international agencies, notably the Intergovernmental Oceanographic Commission, for data-sharing from marine scientific research.[134] The Sustainable Seabed Knowledge Initiative, launched in June 2022, is a partnership with several public institutions and scientific programmes working on issues related to deep-sea biodiversity. This initiative is about the collection, processing, and analysis of genetic data from deep-sea organisms and the development of corresponding digital platforms, similar to the International Nucleotide Sequence Database Collaboration and other bioinformatic tools discussed in Chapter 4. The Sustainable Seabed Knowledge Initiative links to a much larger and politically explosive debate that goes well beyond the scope of this chapter and shall thus be addressed only briefly. Marine genetic resources, including from the Area, are increasingly used in the development of a range of commercial products.[135] In the context of the wider international debate on benefit-sharing that I touched upon in Chapter 4, the question of how (or whether) to develop a benefit-sharing regime for marine genetic

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

resources, including for those originating from beyond national borders, is a matter of intense political scrutiny and scientific interest. The legal status of marine genetic resources under UNCLOS is rather complex and, while they would generally not fall under the common heritage principle and benefit-sharing obligations of part XI, the provisions on marine scientific research of both parts XI and XIII are broadly applicable. It is in this context that activities of the International Seabed Authority, such as the Sustainable Seabed Knowledge Initiative, need to be considered. UNCLOS obliges the Authority to 'promote and encourage the conduct of marine scientific research in the Area' and to 'coordinate and disseminate the results of such research and analysis when available'. This generally applies to research on marine genetic resources,[136] regardless of the fact that they do not strictly fall within the scope of the definition of common heritage of UNCLOS part XI. Given the provisions of part XI, it is also clear that the International Seabed Authority has specific obligations regarding marine scientific research *in the Area* that go beyond its general obligations regarding marine scientific research *on the high seas*. At the same time, marine genetic resources pose a regulatory challenge that is disparate to the International Seabed Authority's primary function, which is to manage the exploration and potential exploitation of deep-sea minerals.

All in all, the International Seabed Authority has operationalized some major elements of the UNCLOS deep-sea mining regime while others continue to be work in progress. At the time of writing, it appears unlikely that the Authority will finalize its exploitation regulations before the expiration of Nauru's two-year deadline in 2023 – just as it appears unlikely that Nauru Ocean Resources Inc. – or any other contractor, for that matter – will be both willing and able to commence the first commercial deep-sea mining operations in history nevertheless. The decision by the Nauruan government to trigger the deadline, a step that is virtually to have been coordinated with Nauru Ocean Resources Inc. in advance, is emblematic of the increasing commercial interest in the exploitation of deep-sea minerals. At the same time, there are many open questions regarding the role of the International Seabed Authority itself, especially how it appears to be beholden to the interests of the mining industry while being less invested in either the common heritage of humanity or the comprehensive protection of the deep-sea environment. Perhaps similar to the asteroids and other space resources, a threat in the debate is the tendency to reduce the challenge of deep-sea mining to questions of technical and economic feasibility.[137] However, whether there is a profitable business case for the extraction of minerals from the ocean floor is one thing; another thing entirely is how such commercial operations would be reconciled with the challenging normative requirements of UNCLOS part XI as well as the diverse obligations both inside and outside of UNCLOS regarding the protection of the marine environment. With

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

France and several others pushing for a moratorium at the November 2023 session of the International Seabed Authority's Council, the deep-sea mining regime might well end up following a similar trajectory to the Antarctic mining regime.

6.5 The Antarctic Treaty System

We now turn towards Antarctica. This is a borderline case: for one, the role of critical metals for fuelling a global environmental sustainability transition did not matter during the negotiations on international instruments for the regulation of Antarctic mining during the 1980s and early 1990s. Rather, motives of commercial profit and resource security dominated – making this case different from even UNCLOS, where a similar framing initially existed yet, over time, gave way to the contemporary framing of deep-sea mining for providing raw materials for global decarbonization and other environmental purposes. In addition, different from deep-sea mining and asteroid mining, the technological dimensions of Antarctic mining have always remained underspecified, also owing to the fact that, to this day, there is no clear understanding of what types and quantities of mineral resources Antarctica actually contains.

As with the Outer Space Treaty, the origins of the overarching legal framework, the Antarctic Treaty System, are deeply rooted in the history of the Cold War. During the 1940s, conflicts emerged between Argentina, Chile, and the United Kingdom, all of which were making different sorts of territorial claims in Antarctica. The threat of a potential military conflict between three of its major allies led to the United States stepping in. Antarctica then got dragged into the superpower conflict, as the Soviet Union began asserting its own interests in the region. This, in turn, led to the United States pushing for an international solution that would defuse the conflicts between Argentina, Chile and the United Kingdom while simultaneously keeping Soviet influence at bay. While the East–West conflict thus played a formative role for the Antarctic Treaty System, the Eisenhower administration likely overestimated Soviet interests in the region by a significant margin – as one observer notes, 'it seems that Soviet policymakers were happy to sit back and watch the squabbles develop in the Antarctic Peninsula region among its Cold War rivals, occasionally seeking to stir up animosities with provocative statements and broadcasts'.[138]

The Antarctic Treaty was signed in 1959 and entered into force in 1961. Among its twelve original signatory states, seven made various and sometimes competing territorial claims to Antarctica. Besides Argentina, Chile, and the United Kingdom, these included Australia, France, New Zealand, and Norway. The treaty is built on a careful compromise: existing territorial claims would be maintained but neither asserted nor recognized, whereas new claims would be inadmissible.[139] On the

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

basis of this delicate balance, the Treaty prescribes that 'Antarctica shall be used for peaceful purposes only'.[140] The Treaty further mandates the freedom of scientific investigation in Antarctica; commits parties to international scientific collaboration; prohibits nuclear testing and radioactive waste proposal; and provides an overarching framework for international cooperation by mandating regular meetings among contracting parties for consultations, information exchange, and collective decision-making on matters of common interest in the region. Various additional agreements were subsequently concluded within the overall structure of this treaty. These include the 1972 Convention for the Conservation of Antarctic Seals and the 1980 Convention for the Conservation of Antarctic Marine Living Resources, as well as two mining-related agreements that I will discuss in greater detail. Together with the Antarctic Treaty, these so-called related agreements make up the Antarctic Treaty *System*, which is under the oversight of the Antarctic Treaty Consultative Meeting, composed of the representatives of (presently) fifty-four states.[141] Of these, twenty-five are 'non-consultative parties' without formal voting rights. The twenty-nine consultative parties with formal voting rights include the original twelve signatories referred to earlier, as well as seventeen others that have demonstrated their interest in Antarctica 'by conducting substantial scientific research activity there, such as the establishment of a scientific station or the despatch of a scientific expedition'.[142]

First attempts to regulate Antarctic mining commenced in the 1980s when states set out to negotiate what would become the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA). In the 1970s, a legal debate began to emerge on the status of commercial mining under the Antarctic Treaty.[143] While some observers argued that commercial mining would be allowed since the Treaty did not expressly prohibit it, others held that mining would be inconsistent with its broader purposes, as noted in the preambular provision that 'Antarctica . . . shall not become the scene or object of international discord'.[144] Since the early 1970s, momentum towards an international regime for the regulation of Antarctic mining started to develop. In 1975, the Antarctic Treaty Consultative Meeting noted its concerns 'that mineral resource exploration and exploitation could adversely affect the unique environment of the Antarctic and of other ecosystems dependent on the Antarctic environment' and its conviction 'of the need for restraint while seeking timely agreed solutions by the Consultative Parties'.[145] In other words, the consultative parties sought to forestall any possible unilateral action that might upset the fragile Antarctic balance of interests while, in the meantime, working towards an international solution. In 1977, the Antarctic Treaty Consultative Meeting spelled out the parameters for the development of a future regime for mineral exploitation: protecting the Antarctic environment and dependent ecosystems, ensuring the integrity of the Antarctic Treaty, in particular

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

its provisions on territorial claims, and giving due consideration to the Antarctic interests of humanity at large.[146] Negotiations began in 1981 against the background of a complex constellation of interests, not just between industrialized and developing countries, but also between territorial claimants and non-claimants.[147]

In 1988, nineteen parties signed CRAMRA. Its purpose was to regulate all activities related to Antarctic mineral resources, meaning 'all non-living natural non-renewable resources, including fossil fuels, metallic and non-metallic minerals'.[148] The agreement possessed substantial regulatory depth, with permitting and authorization decisions based on assessments of environmental impacts and technological feasibility, a strict liability regime covering potential environmental harm caused by operators, and an inspection regime covering all relevant 'stations, installations and equipment' as well as associated ships and aircraft.[149] This inspection regime was particularly noteworthy since it would have allowed on-site inspections both by national observers designated by the governments of member states, as well as *international* observers designated by the governing body of CRAMRA, the Antarctic Mineral Resources Commission.[150] Furthermore, CRAMRA prohibited any Antarctic mineral resource activities except those taking place in accordance with its specifications which, in turn, would have depended on whether these activities comply with the agreement's environmental safety requirements. CRAMRA also incorporated, through particularly ambiguous legal phrasing, the broader interests of 'humanity' as alluded to in the preamble of the Antarctic Treaty and as mandated in the 1977 criteria set out by the Antarctic Treaty Consultative Meeting. CRAMRA did so through its convoluted article 6, which sets out that 'cooperation … shall be promoted and encouragement given to international participation in Antarctic mineral resource activities by interested Parties which are Antarctic Treaty Consultative Parties and by other interested Parties, in particular, developing countries in either category'.[151]

By the standards of international environmental law, CRAMRA was certainly intrusive.[152] Yet observers have questioned whether it would have provided sufficient protection for the Antarctic environment.[153] CRAMRA's demise came surprisingly fast. Due to mounting environmental concerns, within a year of the agreement being signed, Australia and France, two consultative parties to the Antarctic Treaty that had not signed CRAMRA, positioned themselves against the agreement and advocated for not letting it enter into force.[154] Shortly thereafter, New Zealand, which had played a pivotal diplomatic role in the international negotiations, distanced itself as well. Inside the Antarctic Treaty Council Meeting, a division emerged between countries in favour of letting CRAMRA enter into force, notably the United States and the United Kingdom, and their opponents, led by Australia and France.[155] Yet within just one year – a time span that is nothing short of extraordinary in international treaty negotiations, and

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

especially so under conditions of diverging policy preferences – the Antarctic Treaty Council Meeting negotiated an alternative instrument: the Protocol on Environmental Protection to the Antarctic Treaty, adopted in Madrid in 1991, which relegated CRAMRA to a footnote in international history.

The Madrid Protocol provides comprehensive protection for the Antarctic environment. It goes far beyond the narrow issue of mining and includes provisions on waste, pollution, and protected areas, among others. It unequivocally prohibits '[a]ny activity relating to mineral resources, other than scientific research'.[156] This prohibition is likely indefinite. The Madrid Protocol allows for a review conference to be held fifty years after its entry into force (i.e. in 2048). That review conference will be able to amend or otherwise modify any part of the treaty text by majority decision – with the exception of the mining ban, which can only be lifted in this way if 'there is in force a binding legal regime on Antarctic mineral resource activities that includes an agreed means for determining whether, and, if so, under which conditions, any such activities would be acceptable'.[157] Alternatively, parties may amend or modify any treaty provision (including the mining ban) at any time and without the fifty-year period; however, this would require a decision by consensus which, given the overwhelming opposition to mining in the Antarctic Treaty Consultative Meeting, is nothing short of implausible.[158]

6.6 Conclusions

With a broad range of technological changes inside and outside the mining industry, the extraction of metals of crucial environmental and economic importance from ABNJ is slowly coming within reach. In principle, mining in ABNJ might provide crucial raw materials for a global transition towards environmental sustainability. At the same time, the comparatively high concentrations of (some) metal deposits in ABNJ raise the possibility of substituting for conventional mining operations: while it is inconceivable that ABNJ mining would *not* cause environmental harm (asteroid mining being perhaps a partial exception), on aggregate this harm might be lower than that generated under the status quo. Mining in ABNJ might thus allow for a partial shift from extensive to intensive extractive operations. With all of this in mind, the technological changes that are bringing the exploitation of ABNJ within reach hold the (true or false) promise of contributing to impact management. A more subtle technological promise relates to justice: in different ways and to different degrees, the legal regimes for Antarctica, the deep seas, and outer space entail collective rights vested in the international community or even humanity at large. As the case of deep-sea mining illustrates, this provides a strong rationale for placing ABNJ mining operations under international oversight and for developing mechanisms that ensure the fair distribution of the resulting benefits. Shifting from

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

conventional operations to ABNJ might accordingly entail improvements in global justice. Finally, mining in ABNJ can entail substantial benefits for scientific research and thus for the knowledge and information commons more broadly. The prominent role of scientific research in the respective legal frameworks of UNCLOS, the Antarctic Treaty System, and the Outer Space Treaty testifies to the broad awareness among stakeholders that the exploration of ABNJ may offer diverse and significant opportunities for research and data-sharing.

On the flipside, the potential environmental harm from mining in ABNJ is enormous. There is particular risk of large-scale industrial disasters, which would be challenging to manage for geographical reasons. Some aspects of potential environmental harm may even be unknown or unknowable in advance. Mining risks irreversible damage to deep-sea biodiversity that is, for the largest part, still scientifically unexplored. The effects of space pollution from asteroid blasting or similar extraction techniques might have consequences for the space environment that we cannot anticipate at present. Counting everything together, it is by no means a foregone conclusion that aggregate harm from mining in ABNJ is necessarily lower than the aggregate harm from equivalent conventional mining operations. This leads to the peril of crowding out alternatives: in the present, a shift towards ABNJ mining would likely weaken the political and economic incentives for improving resource efficiency, yet, in the long run, this shift might fail to deliver the promised environmental benefits.

The institutional responses to this configuration of promises and perils show only limited diversity. The regime for regulated deep-sea mining has been emerging for more than a decade and might just be a few years away from becoming fully operational. In the case of asteroid mining, we are observing institutional drift, yet developments outside of the Outer Space Treaty signify major changes in how the rules of that treaty, notably regarding its non-appropriation clause, are being interpreted by key stakeholders. For Antarctica, states abruptly abandoned a comprehensive legal instrument for the *regulation* of mining and instead chose an instrument for its *prohibition*. Yet the institutional responses for Antarctica and the deep seas are comparable in both depth and scope. CRAMRA, the Madrid Protocol, and the rules developed under UNCLOS by the International Seabed Authority all carry high degrees of obligation and precision, in addition to being backed by a variety of compliance-related mechanisms. The three institutional responses are also comparable in scope, broadly focusing on minerals as such, notably including fossil fuels,[159] one notable distinction being the rules that the International Seabed Authority has developed for specific *types* of minerals (i.e. polymetallic nodules, sulphides, and cobalt crusts). While we find a significant difference in purpose between the Madrid Protocol on the one hand, and CRAMRA as well as UNCLOS and the International Seabed Authority on the other, their

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

similarities in scope and depth imply that it is only the Outer Space Treaty which introduces some degree of variation.

The consequences for the realization of technological promises and the avoidance of perils are complex. The deep-sea regime is arguably on course for making some, even if possibly limited, contribution to global justice by leveraging mining for common heritage. At the same time, its environmental impacts, both in terms of direct harm towards marine biodiversity and in terms of aggregate effects from the potential displacement of conventional mining operations, are presently unclear. Moreover, its contribution to the knowledge and information commons appears limited by commercial interests in data protection. Finally, as the development of the final, missing pieces of the International Seabed Authority's Mining Code has dramatically picked up in pace in recent years (especially with the triggering of the two-year deadline by Nauru in 2021), and as commercial activity is ramping up, there is a serious threat of crowding out alternatives; rushing into deep-sea mining, without a carefully calibrated regulatory structure or robust evidence on the degree to which the resulting environmental harm will lead to baseline deviation by the displacement of conventional mining, increases the risk of making irreversible political commitments in the present that turn out to be undesirable in the future. In the case of the Outer Space Treaty, institutional drift implies that there is limited, if any, international institutional support for leveraging the potential of asteroid mining for global justice. Developments outside of the Outer Space Treaty, notably with the Artemis Accords and its provisions on space debris, are bound to contribute to the avoidance of environmental harm. At the same time, the Artemis Accords appear to give a somewhat narrower scope to scientific data-sharing than the Outer Space Treaty itself, thus cutting back on the positive spin-off effects which asteroid mining might have for the knowledge and information commons. For Antarctica, finally, the Madrid Protocol constitutes a formidable instrument for the prevention of environmental harm from mining. With scientific research being exempt from the mining ban, and with the broader normative importance that the Antarctic Treaty System gives to research and data-sharing, we can also see a clear contribution to the knowledge and information commons.

How can we explain the observable variation in institutional responses in theoretical terms? The *international constellation of interests*, to start with, is remarkably similar across all three ABNJ: governments of countries with advanced technological capacities tend to prefer international solutions that would enable resource extraction subject to one or the other form of regulatory oversight. Other governments emphasize the primacy of environmental protection and, in the case of developing countries, the need for operational solutions that would ensure participation and benefit-sharing. These structural positions hold limited sway for explaining institutional outcomes: the high degree of malignancy that characterizes

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

the interest constellations for all three ABNJ cannot explain why we find deep as well as broad institutional responses in the form of CRAMRA, the Madrid Protocol, and the deep-sea regime, yet institutional drift in the case of the Outer Space Treaty. For that matter, such a structural account also fails to explain the abrupt shift from CRAMRA to the Madrid Protocol. Including questions of technical and economic feasibility in the assessment of interest constellations does not lead to significant improvements: today, asteroid mining is a concept that is not significantly more far-fetched than deep-sea mining and Antarctic mining were in the 1970s and 1980s. The uncertain feasibility of asteroid mining might cause institutional drift because states have limited stakes in an institutional response, but states nevertheless opted for comprehensive institutional responses while the feasibility of mining the deep seas and Antarctica was similarly unclear (and, in the case of Antarctica, remains so until the present day). We might, however, reconsider the conditions under which states that have sufficient technological and economic capacities to engage in mining operations in ABNJ require international solutions in the first place: at a basic level, such states do not need international institutions in order to appropriate for themselves the mineral resources that might be found in ABNJ. In the negotiations of the 1970s and early 1980s, the United States and several other industrialized countries argued that deep-sea mining was already legal as a matter of customary international law and, as noted previously, subsequently refrained from joining UNCLOS due to concerns over the mining regulations in part XI, a situation that was only resolved with the 1994 Agreement on Implementation.[160] Whether the Antarctic Treaty contains implicit restrictions for mining operations was a matter of dispute during the 1970s and 1980s up to the adoption of CRAMRA and the Madrid Protocol. In this sense, the legal gymnastics over whether the non-appropriation clause of the Outer Space Treaty applies to commercial exploration and exploitation by private actors is just one more iteration of high-capacity states arguing for their right to engage in unfettered resource extraction. This line of thought, however, would require a number of second-order considerations regarding the conditions under which these states can be made to participate in international cooperative solutions nevertheless. For UNCLOS, the role of issue linkages, whereby high-capacity states consent to some international regulation of mining because they expect to gain from other elements in a bargaining package, might be one such consideration. Yet for CRAMRA and the Madrid Protocol, the explanatory power of static interest constellations remains fuzzy one way or another.

The institutional responses to the emerging prospects of mining in ABNJ can be better explained from the vantage point of *normative fit*. UNCLOS contained an unambiguous mandate, as well as clear guiding norms and principles, on the basis of which the International Seabed Authority would subsequently develop the deep-sea mining regime. This is partially also the case for the Antarctic Treaty

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

System. The Antarctic Treaty itself addressed the issue only implicitly by mandating the Antarctic Treaty Council Meeting to formulate, consider, and recommend measures related to the 'preservation and conservation of living resources in Antarctica'.[161] This provision profoundly influenced the subsequent evolution of the Antarctic Treaty System by providing a mandate for the development of environmental protection instruments, such as the 1980 Convention on the Conservation of Antarctic Marine Living Resources.[162] The increasing institutionalization of environmental protection in the evolving Antarctic Treaty System provided a strong normative fit for the development of a mining regime from the 1970s onwards. While UNCLOS part XI approaches mining primarily from the perspective of resource extraction, the Antarctic Treaty System does so from the vantage point of environmental protection. In other words, both UNCLOS and the Antarctic Treaty System provide a *strong* normative fit that can explain the subsequent development of institutional outcomes of considerable depth and scope. In the same manner, the institutional drift that characterizes the Outer Space Treaty is explicable by the *weak* normative fit which that treaty would provide for the development of an operational asteroid mining regime. The Outer Space Treaty neither contains a mandate for the development of such a regime nor does it provide unambiguous norms and principles which this regime would merely need to operationalize. The Outer Space Treaty is consistent with a wide range of (partially incompatible) models, ranging from common heritage and benefit-sharing all the way up to largely unregulated space capitalism.[163] However, the Treaty is *indeterminate* between these models: its text is compatible with a wide range of interpretations, yet it provides limited (if any) guidance for adjudicating between them. Thus, in contrast to UNCLOS and the Antarctic Treaty System, the Outer Space Treaty does not provide fertile normative ground for the development of an operational mining regime.

A perspective of *governance object construction* can similarly shed light on the observable variation which we find in ABNJ mining. The economic and geostrategic dimension of mining, especially for critical technology metals, is a well-established political fact across all three ABNJ. Yet what sets outer space apart from both Antarctica and the deep seas is that the environmental case for an international institutional response is significantly less clear. Responses under the Antarctic Treaty System and UNCLOS were, albeit to different degrees, shaped by the understanding that mining carries vast potential for causing environmental harm. Under the former, the regulation of mining was an outgrowth of the gradual expansion of a mandate for environmental protection, as noted earlier. Under the latter, states primarily approached mining from the perspectives of resource appropriation and benefit-sharing, although the simultaneous protection of the marine environment from potential harm caused

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

by extractive operations had been recognized as a key element since the early 1970s.[164] Yet the extent to which environmental harm associated with asteroid mining would be a problem is not entirely clear. Some of this harm would be directed to the extraterrestrial environment. It is unclear what consequences this would entail for human societies and the planetary environment. More fundamentally, the question of whether harm to the space environment should be an ethical matter of concern has been largely ignored in the global environmental debate. With limited political, legal, and philosophical discussion of the space environment,[165] the environmental implications of asteroid mining do not have the same salience as was the case with the emergence of mining regulation for Antarctica and the deep seas. Asteroid mining, in other words, is presently narrowly defined in terms of resource appropriation and the potential modalities of benefit-sharing. Compared to mining in the other two ABNJ, this makes it into a political niche issue that is unable to command a similar level of political attention and concern.

In concluding this chapter, I wish to consider some elements for the potential design of international institutional frameworks that might be superior to those considered herein in terms of the realization of promises and the avoidance of perils. To hark back to the beginning of this chapter, I have discussed how mining in ABNJ might reduce aggregate anthropogenic impacts on the global environment and thus also mitigate negative environmental feedback for human societies. I have noted how the respective legal regimes for Antarctica, the deep seas, and outer space possess distinct characteristics that may allow resource extraction to have positive effects on global justice. At the same time, I have also indicated that the aggregate environmental harm from ABNJ mining might be of a comparable magnitude to the aggregate harm caused by the conventional mining operations which it displaces: the environmental balance sheet from a global shift towards ABNJ mining might well turn out to be negative, and this raises a further problem of crowding out alternatives: an incorrect belief in the future promises of ABNJ mining may reduce ambitions for the pursuit of alternatives in the present. Recycling technology is one way of reducing the dependencies of human societies on the extraction of metals, although the problem of irreversible commitments applies there as well: failure to develop the raw material supply due to the expectation of high recycling rates becoming economically and technologically feasible in the future amounts to the same type of gamble. In any case, with the scaling-up of demand, it is clear that improvements in recycling rates can only play a complementary role – albeit an important one. However, it is possibly not primarily the technological side which poses the largest challenges. High recycling rates for rare earth elements and other critical metals are only economically feasible if raw material prices are high enough, which is presently not generally the case.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

The corollary is that high recycling rates require market interventions.[166] Recycling, in other words, does not offer an easy way out of the problem of supplying the expanding demand for critical metals. The history of plastic recycling, moreover, offers a cautionary tale regarding the feasibility of recycling critical technology metals in order to achieve circularity and contribute to environmental sustainability.[167]

Approaching the problem of institutional design for the promises and perils associated with mining beyond ABNJ, a first criterion is that relevant projects should require international authorization based on a comparison of expected environmental harm against the baseline of conventional mining projects. Mining, whether in national jurisdictions or beyond, inevitably causes environmental harm, and pretending otherwise does not benefit the debate. Yet for mining projects in ABNJ to be granted international authorization, there needs to be a clear case that the ratio between economic benefits and environmental harm is more favourable than it is for conventional projects within national jurisdictions. Calculating some common measure of aggregate harm is of course challenging, especially when comparing geographical regions and ecosystems with vastly different characteristics. Yet in more abstract terms, institutional design for mining in ABNJ must be based on a normative commitment to choosing the lesser (environmental) evil. To reiterate once more, this is because the central question is not whether mining in the deep seas or other ABNJ is a particularly attractive idea (because it is clearly not). The question is, rather, whether a specific, proposed mining project in a given ABNJ can reasonably be expected to reduce environmental harm in comparison to the baseline. There is no convincing reason to extract metals from the deep seas if the extraction of equivalent volumes through conventional operations inside of national jurisdictions would likely lead to better environmental outcomes. Similarly, there is no convincing reason to ban mining projects in ABNJ on the grounds of their potential environmental harm if the consequence is that metals will instead be sourced from conventional mining operations that are even more damaging for the environment. As such, the biodiversity of Antarctica or the deep seas does not have an intrinsically greater value than, say, the biodiversity of Katanga Province in the Democratic Republic of Congo (a major global copper source) or the biodiversity in the Northern Myanmarese 'sacrifice zone' of rare earth extraction.[168] In operational terms, this requires the development of robust methodological guidelines and indicators for estimating the expected deviation of a proposed mining project in ABNJ from the historical baseline for conventional mining projects inside national jurisdictions. Unequivocal evidence of net environmental benefits needs to be one necessary condition for a proposed mining project in an ABNJ to receive international authorization.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

A second consideration harks back to issues of global justice, especially in regards to the peculiar characteristics of the existing legal regimes for the deep seas, Antarctica, and outer space. Just as mining in ABNJ must have environmental net benefits, it must give effect to the different collective rights enshrined in UNCLOS, the Antarctic Treaty, and the Outer Space Treaty.[169] A variety of benefit-sharing mechanisms have been discussed in these and other contexts.[170] While mechanisms such as data-sharing, capacity-building, and training programmes provide some added value, it is hard to imagine that extractive operations in ABNJ would live up to meaningful equity criteria *without* including a substantial redistributive element. This means that benefit-sharing should entail a significant monetary component. A centralized approach, such as the Seabed Sustainability Fund that is under discussion in the International Seabed Authority, would arguably provide greater leverage for channelling financial resources into environmentally sound projects than a decentralized approach that disburses benefits between governments in accordance with specific equity criteria. Such a fund, for the Area or other ABNJ, could, for instance, provide financial firepower for improving resource efficiency in developing countries or for environmental remediation of conventional mining sites. In this context, another issue to consider from the experience with the International Seabed Authority is also that any international regulator requires careful rules to avoid conflicts of interest and perverse incentives if they are bound to receive financial benefits for themselves from mining projects that they have to assess, approve, and oversee. If regulators receive a share of commercial profits from mining projects to cover their own administrative and other costs, they may give the go-ahead to projects that are not justified in terms of relative environmental harm or in terms of justice.

Third, there is a need to assert the freedom of scientific research and a culture of data-sharing even in the face of countervailing commercial interests. This also extends to potential spin-offs that are only indirectly related to mining as such. Mineral exploration in ABNJ may, for instance, enable novel scientific insights into life: marine organisms in the deep seas, frozen microbes in Antarctica, or, hypothetically, extraterrestrial life forms. If these or others were the by-products of a commercial exploration programme, international rules would be required to ensure proper data-sharing and to prevent the assertion of exclusionary property rights. The same applies to geological data generated during commercial exploration and exploitation. While there is a case to be made that public disclosure of such data contravenes the interests of commercial operators in data privacy, the normative status of collective interests and the freedom of scientific research, as enshrined in UNCLOS, the Antarctic Treaty System, and the Outer Space Treaty, should outweigh this consideration.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

Notes

1. Timberlake, S. (2019). Archaeology of Mining in the Pre-industrial Age: The Recognition and Interpretation of Ancient Mines. In S. Berger & P. Alexander (eds.), *Making Sense of Mining History: Themes and Agendas*. London: Routledge, pp. 25–64.
2. Wilson, A. (2012). Raw Materials and Energy. In W. Scheidel (ed.), *The Cambridge Companion to the Roman Economy*. Cambridge: Cambridge University Press, pp. 133–55.
3. Brown, K. (2012). *A History of Mining in Latin America. From the Colonial Era to the Present*. Albuquerque: University of New Mexico Press.
4. For example, Ross, M. L. (1999). The Political Economy of the Resource Curse. *World Politics*, *51*(2), 297–322; Campbell, G. (2004). *Blood Diamonds: Tracing the Deadly Path of the World's Most Precious Stones*. Boulder: Westview Press; Ali, S. H., Sturman, K., & Collins, N. (eds.). (2019). *Africa's Mineral Fortune: The Science and Politics of Mining and Sustainable Development*. London: Routledge; Glaab, K., and Stuvøy, K. (2021). The Politics of Violence in Extractivism: Space, Time and Normativity. In J. Shapiro & J.-A. McNeish (eds.), *Our Extractive Age. Expressions of Violence and Resistance*. Abingdon: Routledge, pp. 31–47.
5. Kiggins, R. D. (2015). The Strategic and Security Implications of Rare Earths. In R. D. Kiggins (ed.), *The Political Economy of Rare Earth Elements: Rising Powers and Technological Change*. Basingstoke: Palgrave, pp. 1–19.
6. For example, Simons, P., and Macklin, A. (2014). *The Governance Gap: Extractive Industries, Human Rights and the Home State Advantage*. Abingdon: Routledge. However, large, multinational mining and commodity companies represent a rather small share of the overall industry, although their business practices generate high visibility and cause significant adverse human and environmental impacts. For a fascinating discussion of this issue, see Franks, D. M., Keenan, J., & Hailu, D. (2022). Mineral Security Essential to Achieving the Sustainable Development Goals. *Nature Sustainability*, online first.
7. Blas, J., & Farchy, J. (2021). *The World for Sale. Money, Power and the Traders who Barter the Earth's Resources*. New York: Oxford University Press.
8. See Glencore Entered Guilty Pleas to Foreign Bribery and Market Manipulation Schemes: www.justice.gov/opa/pr/glencore-entered-guilty-pleas-foreign-bribery-and-market-manipulation-schemes, accessed 4th August 2022.
9. Amnesty International and Greenpeace Netherlands. (2012). *The Toxic Truth: About a Company Called Trafigura, A Ship Called the Probo Koala, and the Dumping of Waste in Côte d'Ivoire*. London/Amsterdam.
10. Human Rights Watch. (2011). '*You'll be Fired if you Refuse': Labor Abuses in Zambia's Chinese State-owned Copper Mines*. New York: Human Rights Watch.
11. Vergilio, C. D. S., Lacerda, D., Oliveira, B. C. V. D., et al. (2020). Metal Concentrations and Biological Effects from One of the Largest Mining Disasters in the World (Brumadinho, Minas Gerais, Brazil). *Scientific Reports*, *10*(1), 1–12, p. 2.
12. Saes, B. M., & Muradian, R. (2021). What Misguides Environmental Risk Perceptions in Corporations? Explaining the Failure of Vale to Prevent the Two Largest Mining Disasters in Brazil. *Resources Policy*, *72*, 102022; Pastran, S. H., & Mallett, A. (2020). Unearthing Power: A Decolonial Analysis of the Samarco Mine Disaster and the Brazilian Mining Industry. *The Extractive Industries and Society*, *7*(2), 704–15.
13. Petermann, A., Guzmán, J. I., & Tilton, J. E. (2007). Mining and Corruption. *Resources Policy*, *32*(3), 91–103; Knutsen, C. H., Kotsadam, A., Olsen, E. H., & Wig, T. (2017). Mining and Local Corruption in Africa. *American Journal of Political Science*, *61*(2), 320–34.
14. Sovacool, B. K. (2019). The Precarious Political Economy of Cobalt: Balancing Prosperity, Poverty and Brutality in Artisanal and Industrial Mining in the Democratic Republic of the Congo. *The Extractive Industries and Society*, *6*(3), 915–39, p. 937.
15. Sadan, M., Yü, D. S., Lawn, D. S., and Zhou, R. (2022). *Rare Earth Elements, Global Inequalities and the 'Just Transition'*. London: The British Academy.
16. Whitmore, A. (2006). The Emperor's New Clothes: Sustainable Mining? *Journal of Cleaner Production*, *14*(3–4), 309–14, p. 309; for a critical discussion, see also Kirsch, S. (2010). Sustainable Mining. *Dialectical Anthropology*, *34*(1), 87–93.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

17. Warhurst, A., & Bridge, G. (1996). Improving Environmental Performance through Innovation: Recent Trends in the Mining Industry. *Minerals Engineering*, *9*(9), 907–21, p. 907.
18. Sánchez, F., & Hartlieb, P. (2020). Innovation in the Mining Industry: Technological Trends and a Case Study of the Challenges of Disruptive Innovation. *Mining, Metallurgy & Exploration*, *37*(5), 1385–99, p. 1388.
19. Bartos, P. J. (2002). SX-EW Copper and the Technology cycle. *Resources Policy*, *28*(3–4), 85–94.
20. Sánchez, F., & Hartlieb, P. (2020). Innovation in the Mining Industry: Technological Trends and a Case Study of the Challenges of Disruptive Innovation. *Mining, Metallurgy & Exploration*, *37*(5), 1385–99, pp. 1394–5.
21. Bartos, P. J. (2007). Is Mining a High-Tech Industry? Investigations into Innovation and Productivity Advance. *Resources Policy*, *32*(4), 149–58, pp. 151–2; Lusty, P. A. J., & Gunn, A. G. (2015). Challenges to Global Mineral Resource Security and Options for Future Supply. *Geological Society, London, Special Publications*, *393*(1), 265–76, pp. 270–1.
22. Sánchez, F., & Hartlieb, P. (2020). Innovation in the Mining Industry: Technological Trends and a Case Study of the Challenges of Disruptive Innovation. *Mining, Metallurgy & Exploration*, *37*(5), 1385–99.
23. Barnewold, L., & Lottermoser, B. G. (2020). Identification of Digital Technologies and Digitalization Trends in the Mining Industry. *International journal of mining science and technology*, *30*(6), 747–57; pp. 752–5.
24. Dunbar, W. S. (2017). Biotechnology and the Mine of Tomorrow. *Trends in Biotechnology*, *35*(1), 79–89; Aznar-Sánchez, J. A., Velasco-Muñoz, J. F., Belmonte-Ureña, L. J., & Manzano-Agugliaro, F. (2019). Innovation and Technology for Sustainable Mining Activity: A Worldwide Research Assessment. *Journal of Cleaner Production*, *221*, 38–54, p. 40; Levett, A., Gleeson, S. A., & Kallmeyer, J. (2021). From Exploration to Remediation: A Microbial Perspective for Innovation in Mining. *Earth-Science Reviews*, *216*, 103563, pp. 13–14.
25. Humphreys, D. (2020). Mining Productivity and the Fourth Industrial Revolution. *Mineral Economics*, *33*(1), 115–25.
26. Rowley, P. D., Williams, P. L., and Pride, D. E. (1983). Mineral Occurrences of Antarctica. In J. C. Behrend (ed.) (1983), *Petroleum and Mineral Resources of Antarctica*. Alexandria, VA: Geological Survey Circular 909, pp. 27–9; see also Wright, N. A., & Williams, P. L. (eds.). (1974). *Mineral Resources of Antarctica*. Geological Survey Circular 705.
27. Rowley, P. D., Williams, P. L., and Pride, D. E. (1983). Mineral Occurrences of Antarctica. In J. C. Behrend (ed.) (1983), *Petroleum and Mineral Resources of Antarctica*. Alexandria, VA: Geological Survey Circular 909, p. 40.
28. Brady, A.-M. (2017), *China as a Polar Great Power*. Cambridge: Cambridge University Press.
29. Bray, D. (2016). The Geopolitics of Antarctic Governance: Sovereignty and Strategic Denial in Australia's Antarctic policy. *Australian Journal of International Affairs*, *70*(3), 256–74.
30. United Nations Convention on the Law of the Sea, Art. 1.1.1.
31. Glasby, G. P. (2000). Lessons Learned from Deep-sea Mining. *Science*, *289*(5479), 551–3.
32. For example, Leng, D., Shao, S., Xie, Y., Wang, H., & Liu, G. (2021). A Brief Review of Recent Progress on Deep Sea Mining Vehicle. *Ocean Engineering*, *228*, 108565.
33. Hein, J. R., Koschinsky, A., & Kuhn, T. (2020). Deep-Ocean Polymetallic Nodules as a Resource for Critical Materials. *Nature Reviews Earth & Environment*, *1*(3), 158–69, p. 163.
34. Hoagland, P., Beaulieu, S., Tivey, M. A., et al. (2010). Deep-Sea Mining of Seafloor Massive Sulfides. *Marine Policy*, *34*(3), 728–32.
35. Manheim, F. T. (1986). Marine Cobalt Resources. *Science*, *232*(4750), 600–8.
36. James, T. (2018). Asteroid Mining Concepts. In T. James (ed.), *Deep Space Commodities. Exploration, Production and Trading*. Cham: Palgrave.
37. Ross, S. D. (2001). *Near-Earth Asteroid Mining. Space Industry Report*. Pasadena: California Institute of Technology.
38. Cockell, C. S., Santomartino, R., Finster, K., et al. (2020). Space Station Biomining Experiment Demonstrates Rare Earth Element Extraction in Microgravity and Mars Gravity. *Nature Communications*, *11*(1), 1–11.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

39. For example, Devezas, T., de Melo, F. C. L., Gregori, M. L., et al. (2012). The Struggle for Space: Past and Future of the Space Race. *Technological Forecasting and Social Change*, *79*(5), 963–85; Pekkanen, S. M. (2019). Governing the New Space Race. *American Journal of International Law*, *113*, 92–7.
40. Cullen, R. (1994). Antarctic Minerals and Conservation. *Ecological Economics*, *10*(2), 143–55; Van Dover, C. L., Ardron, J. A., Escobar, E., et al. (2017). Biodiversity Loss from Deep-Sea Mining. *Nature Geoscience*, *10*(7), 464–5; Cormier, R., & Londsdale, J. (2020). Risk Assessment for Deep Sea Mining: An Overview of Risk. *Marine Policy*, *114*, 103485.
41. For example, Joyner, C. C. (1986). Legal Implications of the Concept of the Common Heritage of Mankind. *International & Comparative Law Quarterly*, *35*(1), 190–9.
42. United Nations Environment Programme. (2021). *Global Material Flows Database*, www .resourcepanel.org/global-material-flows-database.
43. OECD. (2021). *Steel Market Developments – Q2 2021*. Paris: Organization for Economic Co-operation and Development; US Geological Survey. (2022), *Mineral Commodity Summaries 2022*. St. Louis.
44. US Geological Survey. (2001). Obsolete Computers, 'Gold Mine', or High-Tech Trash? Resource Recovery from Recycling. USGS Fact Sheet FS-060–01. Denver.
45. National Research Council. (2008). *Minerals, Critical Minerals and the US Economy.* Washington, DC: National Academies Press, p. 8.
46. National Research Council. (2008). *Minerals, Critical Minerals and the US Economy.* Washington, DC: National Academies Press, p. 1.
47. Kesler, S. E., Simon, A. C., & Simon, A. F. (2015). *Mineral Resources, Economics and the Environment*. Cambridge: Cambridge University Press, pp. 184–250.
48. Veronese, K. (2015). *Rare: The High-stakes Race to Satisfy our Need for the Scarcest Metals on Earth*. New York: Prometheus Books.
49. Wall, F. (2014). Rare Earth Elements. In G. Gunn (ed.), *Critical Metals Handbook*. Chichester: Wiley, pp. 312–49, p. 329; Ganguli, R., & Cook, D. R. (2018). Rare Earths: A Review of the Landscape. *MRS Energy & Sustainability*, *5*; Balaram, V. (2019). Rare Earth Elements: A Review of Applications, Occurrence, Exploration, Analysis, Recycling and Environmental Impact. *Geoscience Frontiers*, *10*(4), 1285–303.
50. Gunn, G. (2014). Platinum-Group Metals. In G. Gunn (ed.), *Critical Metals Handbook*. Chichester: Wiley, pp. 284–311.
51. World Bank. (2021). *Commodity Markets Outlook: Causes and Consequences of Metal Price Shocks*. Washington, DC: World Bank.
52. International Monetary Fund. (2022), *IMF Primary Commodity Price System*, https://data .imf.org, accessed 10 August 2022.
53. International Renewable Energy Agency. (2022). *Critical Materials for the Energy Transition: Rare Earth Elements*. Technical Paper 2/2022. Abu Dhabi: International Renewable Energy Agency.
54. World Bank. (2018), *The Role of Major Emerging Markets in Global Commodity Demand*. Policy Research Working Paper 8495. Washington, DC.
55. Humphreys, D. (2019). The Mining Industry after the Boom. *Mineral Economics*, *32*(2), 145–51.
56. Ganguli, R., & Cook, D. R. (2018). Rare Earths: A Review of the Landscape. *MRS Energy & Sustainability*, *5*.
57. Mancheri, N. A. (2015). World Trade in Rare Earths, Chinese Export Restrictions and Implications. *Resources Policy*, *46*, 262–71.
58. Rech, M. (2015), Rare Earth Elements and the European Union. In R. D. Kiggins (ed.), *The Political Economy of Rare Earth Elements. Rising Powers and Technological Change*. Basingstoke: Palgrave, pp. 62–84; Løvik, A. N., Hagelüken, C., & Wäger, P. (2018). Improving Supply Security of Critical Metals: Current Developments and Research in the EU. *Sustainable Materials and Technologies*, *15*, 9–18; Theodosopoulos, V. (2020). The Geopolitics of Supply: Towards a New EU Approach to the Security of Supply of Critical Raw Materials? *Institute for European Studies Policy Brief*.
59. Executive Order 13817 of 20 December 2017.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

60. See US Forms 'Friendly' Coalition to Secure Critical Minerals: www.reuters.com/business/energy/us-forms-friendly-coalition-secure-critical-minerals-andy-home-2022-06-30/, accessed 10 August 2022.
61. Kalantzakos, S. (2020). The Race for Critical Minerals in an Era of Geopolitical Realignments. *The International Spectator*, *55*(3), 1–16.
62. Gulley, A. L., Nassar, N. T., & Xun, S. (2018). China, the United States and Competition for Resources that Enable Emerging Technologies. *Proceedings of the National Academy of Sciences*, *115*(16), 4111–15; Riofrancos, T. (2022). The Security – Sustainability Nexus: Lithium Onshoring in the Global North. *Global Environmental Politics*, *23*(1), 1–22.
63. See Bardi, U. (2009). Peak Oil: The Four Stages of a New Idea. *Energy*, *34*(3), 323–6.
64. Calvo, G., Valero, A., & Valero, A. (2017). Assessing Maximum Production Peak and Resource Availability of Non-fuel Mineral Resources: Analyzing the Influence of Extractable Global Resources. *Resources, Conservation and Recycling*, *125*, 208–17; see also May, D., Prior, T., Cordell, D., & Giurco, D. (2012). Peak Minerals: Theoretical Foundations and Practical Application. *Natural Resources Research*, *21*(1), 43–60.
65. Sverdrup, H. U., Ragnarsdottir, K. V., & Koca, D. (2014). On Modelling the Global Copper Mining Rates, Market Supply, Copper Price and the End of Copper Reserves. *Resources, Conservation and Recycling*, *87*, 158–74, p. 160.
66. Tilton, J. E. (2018). The Hubbert Peak Model and Assessing the Threat of Mineral Depletion. *Resources, Conservation and Recycling*, *139*, 280–6; see also Northey, S. A., Mudd, G. M., & Werner, T. T. (2018). Unresolved Complexity in Assessments of Mineral Resource Depletion and Availability. *Natural Resources Research*, *27*(2), 241–55.
67. Prior, T., Giurco, D., Mudd, G., Mason, L., & Behrisch, J. (2012). Resource Depletion, Peak Minerals and the Implications for Sustainable Resource Management. *Global Environmental Change*, *22*(3), 577–87.
68. Bakker, S., Zuidgeest, M., De Coninck, H., & Huizenga, C. (2014). Transport, Development and Climate Change Mitigation: Towards an Integrated Approach. *Transport Reviews*, *34*(3), 335–55.
69. Hache, E., Seck, G. S., Simoen, M., Bonnet, C., & Carcanague, S. (2019). Critical Raw Materials and Transportation Sector Electrification: A Detailed Bottom-up Analysis in World Transport. *Applied Energy*, *240*, 6–25, p. 15.
70. Alonso, E., Wallington, T., Sherman, A., et al. (2012). An Assessment of the Rare Earth Element Content of Conventional and Electric Vehicles. *SAE International Journal of Materials and Manufacturing*, *5*(2), 473–7.
71. International Energy Agency. (2022). *Global Electric Vehicle Outlook 2022. Securing Supplies for an Electric Future*. Paris: International Energy Agency.
72. Hache, E., Seck, G. S., Simoen, M., Bonnet, C., & Carcanague, S. (2019). Critical Raw Materials and Transportation Sector Electrification: A Detailed Bottom-up Analysis in World Transport. *Applied Energy*, *240*, 6–25; Habib, K., Hansdóttir, S. T., & Habib, H. (2020). Critical Metals for Electromobility: Global Demand Scenarios for Passenger Vehicles, 2015–2050. *Resources, Conservation and Recycling*, *154*, 104603.
73. Milovanoff, A., Posen, I. D., & MacLean, H. L. (2020). Electrification of Light-Duty Vehicle Fleet Alone will not Meet Mitigation Targets. *Nature Climate Change*, *10*(12), 1102–7, pp. 1103–4.
74. International Energy Agency. (2022). *Global Supply Chains of EV Batteries*. Paris: International Energy Agency.
75. Habib, K., Hansdóttir, S. T., & Habib, H. (2020). Critical Metals for Electromobility: Global Demand Scenarios for Passenger Vehicles, 2015–2050. *Resources, Conservation and Recycling*, *154*, 104603, p. 6.
76. US Geological Survey. (2022). *Mineral Commodity Summaries 2022*. St. Louis.
77. Habib, K., Hansdóttir, S. T., & Habib, H. (2020). Critical Metals for Electromobility: Global Demand Scenarios for Passenger Vehicles, 2015–2050. *Resources, Conservation and Recycling*, *154*, 104603, p. 6.
78. Hoenderdaal, S., Espinoza, L. T., Marscheider-Weidemann, F., & Graus, W. (2013). Can a Dysprosium Shortage Threaten Green Energy Technologies? *Energy*, *49*, 344–55.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

79. García-Olivares, A. (2015). Substituting Silver in Solar Photovoltaics is Feasible and Allows for Decentralization in Smart Regional Grids. *Environmental Innovation and Societal Transitions*, *17*, 15–21.
80. Gong, J., Liang, J., & Sumathy, K. (2012). Review on Dye-Sensitized Solar Cells (DSSCs): Fundamental Concepts and Novel Materials. *Renewable and Sustainable Energy Reviews*, *16*(8), 5848–60.
81. Tokimatsu, K., Wachtmeister, H., McLellan, B., et al. (2017). Energy Modeling Approach to the Global Energy-mineral Nexus: A First Look at Metal Requirements and the 2C Target. *Applied Energy*, *207*, 494–509.
82. Lèbre, É., Stringer, M., Svobodova, K., et al. (2020). The Social and Environmental Complexities of Extracting Energy Transition Metals. *Nature Communications*, *11*(1), 1–8.
83. See, for example, Simon, B., Ziemann, S., & Weil, M. (2015). Potential Metal Requirement of Active Materials in Lithium-ion Battery Cells of Electric Vehicles and its Impact on Reserves: Focus on Europe. *Resources, Conservation and Recycling*, *104*, 300–10.
84. Kelly, J. C., Wang, M., Dai, Q., & Winjobi, O. (2021). Energy, Greenhouse Gas and Water Life Cycle Analysis of Lithium Carbonate and Lithium Hydroxide Monohydrate from Brine and Ore Resources and their Use in Lithium Ion Battery Cathodes and Lithium Ion Batteries. *Resources, Conservation and Recycling*, *174*, 105762; Schomberg, A. C., Bringezu, S., & Flörke, M. (2021). Extended Life Cycle Assessment Reveals the Spatially-explicit Water Scarcity Footprint of a Lithium-ion Battery Storage. *Communications Earth & Environment*, *2*(1), 1–10.
85. Kirchherr, J. (2022). Bullshit in the Sustainability and Transitions Literature: A Provocation. *Circular Economy and Sustainability*, 1–6.
86. Sovacool, B. K., Ali, S. H., Bazilian, M., et al. (2020). Sustainable Minerals and Metals for a Low-carbon Future. *Science*, *367*(6473), 30–3.
87. For example, Capps, G. (2012). A Bourgeois Reform with Social Justice? The Contradictions of the Minerals Development Bill and Black Economic Empowerment in the South African Platinum Mining Industry. *Review of African Political Economy*, *39*(132), 315–33; Bowman, A. (2018). Financialization and the Extractive Industries: The Case of South African Platinum Mining. *Competition & Change*, *22*(4), 388–412.
88. Kuipers, K. J., van Oers, L. F., Verboon, M., & van der Voet, E. (2018). Assessing Environmental Implications Associated with Global Copper Demand and Supply Scenarios from 2010 to 2050. *Global Environmental Change*, *49*, 106–15.
89. See Lai, A. K. (2021). *The Cold War, the Space Race, and the Law of Outer Space: Space for Peace*. Abingdon: Routledge, pp. 105–36.
90. Neufeld, M. J. (2018). *Spaceflight: A Concise History*. Cambridge, MA: MIT Press.
91. Outer Space Treaty, preamble.
92. Outer Space Treaty, Articles 1 and 2.
93. As before, outside of direct quotations I will refer to ‘humanity’ instead of ‘mankind’.
94. Buxton, C. R. (2004). Property in Outer Space: The Common Heritage of Mankind Principle vs. the First in Time, First in Right, Rule of Property. *Journal of Air Law & Commerce*, *69*, 689.
95. Moon Agreement Articles 11.2 and 11.3.
96. Moon Agreement, Article 11.7.d.
97. For instance, Rana, H. S. (1994). The Common Heritage of Mankind and the Final Frontier: A Revaluation of Values Constituting the International Legal Regime for Outer Space Activities. *Rutgers Law Journal*, *26*, 225; Pop, V. (2000). Appropriation in Outer Space: The Relationship between Land Ownership and Sovereignty on the Celestial Bodies. *Space Policy*, 16(4), 275–82. For a dissenting view, see Khatwani, N. (2019). Common Heritage of Mankind for Outer Space. *Astropolitics*, *17*(2), 89–103.
98. See www.orbdev.com/010309.html, accessed 2nd August 2022. See also Pop, V. (2001). The Men Who Sold the Moon: Science Fiction or Legal Nonsense? *Space Policy*, *17*(3), 195–203.
99. Wrench, J. G. (2019). Non-Appropriation, No Problem: The Outer Space Treaty is Ready for Asteroid Mining. *Case Western Reserve Journal of International Law*, *51*, 437.
100. Butkevičienė, E., & Rabitz, F. (2022). Sharing the Benefits of Asteroid Mining. *Global Policy*, *13*(2), 247–58.
101. UN General Assembly resolution 1472 (XIV)

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

102. Johnson-Freese, J. (2017). Build on the Outer Space Treaty. *Nature*, *550*(7675), 182–4.
103. Committee on the Peaceful Uses of Outer Space, Report of the Legal Subcommittee on its fifty-fifth session, held in Vienna from 4 to 15 April 2016, A /AC.105/1113, para 250.
104. Committee on the Peaceful Uses of Outer Space, Report of the Legal Subcommittee on its fifty-seventh session, held in Vienna from 9 to 20 April 2018, A /AC.105/1177, paras 238 and 239.
105. G-77 and China Statement during the Sixty-First Session of the Legal Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space. Agenda item 15. 28 March to 8 April 2022.
106. Bittencourt Neto, O. d. O., Hofmann, M., Masson-Zwaan, T., & Stefoudi, D. (eds.). (2020). *Building Blocks for the Development of an International Framework for the Governance of Space Resource Activities*. The Hague: Eleven; see also Xu, F., & Su, J. (2020). New Elements in the Hague Space Resources Governance Working Group's Building Blocks. *Space Policy*, *53*, 101386.
107. Deplano, R. (2021). The Artemis Accords: Evolution or Revolution in International Space Law? *International & Comparative Law Quarterly*, *70*(3), 799–819.
108. Artemis Accords, Section 10.2.
109. Artemis Accords, Section 8.
110. US Commercial Space Launch Competitiveness Act, Section 51303. Luxembourg has passed a similar law: see Blount, P. J. (2017). Outer Space and International Geography: Article II and the Shape of Global Order. *New England Law Review*, 52, 95.
111. See footnote 98.
112. Report of the Committee on the Peaceful Uses of Outer Space. Sixty-Fourth Session, 25 August to 3 September 2021. A/76/20, Annex III.
113. Brown, E. D. (1984). Seabed Mining: from UNCLOS to Prepcom. *Marine Policy*, 8(2), 151–64.
114. UNCLOS Article 1.1.1.
115. UNCLOS Articles 133.a and 136.
116. UNCLOS Article 137.
117. UNCLOS Article 140.2.
118. See Jaeckel, A., Ardron, J. A., & Gjerde, K. M. (2016). Sharing Benefits of the Common Heritage of Mankind – Is the Deep Seabed Mining Regime Ready? *Marine Policy*, *70*, 198–204.
119. UNCLOS Article 170.1.
120. Zalik, A. (2021). World-Making and the Deep Seabed: Mining the Area Beyond National Jurisdiction. In M. Himley, E. Havice, & G. Valdivia (eds.), *The Routledge Handbook of Critical Resource Geography.* London: Routledge, pp. 412–24, p. 414.
121. Jaeckel, A., Ardron, J. A., & Gjerde, K. M. (2016). Sharing Benefits of the Common Heritage of Mankind – Is the Deep Seabed Mining Regime Ready? *Marine Policy*, *70*, 198–204, pp. 200–1.
122. Merdekawati, A., Triatmodjo, M., Anisa Rahma, N., & Afnan Trisandi Hasibuan, I. (2022). Challenges for Operationalizing Autonomous Enterprise: What to Overcome? *Australian Journal of Maritime & Ocean Affairs*, 1–12.
123. Jaeckel, A., Ardron, J. A., & Gjerde, K. M. (2016). Sharing Benefits of the Common Heritage of Mankind – Is the Deep Seabed Mining Regime Ready? *Marine Policy*, *70*, 198–204, p. 201.
124. UNCLOS Article 143.
125. Woody, T., and Halper, E. (2022). A Gold Rush in the Deep Sea Raises Questions About the Authority Charged with Protecting It. *Los Angeles Times*, 19 April.
126. Levin, L. A., Amon, D. J., & Lily, H. (2020). Challenges to the Sustainability of Deep-seabed Mining. *Nature Sustainability*, *3*(10), 784–94, p. 789.
127. International Seabed Authority. (2012). Decision of the Assembly of the International Seabed Authority Relating to the Regulations on Prospecting and Exploration for Cobalt-rich Ferromanganese Crusts in the Area, ISBA/18/A/11. Kingston: International Seabed Authority, Regulation 1.3; International Seabed Authority. (2010). Decision of the Assembly of the International Seabed Authority Relating to the Regulations on Prospecting and Exploration for Polymetallic Sulphides in the Area, ISBA/16/A/12 Rev.1. Kingston: International Seabed Authority, Regulation 1.3; International Seabed Authority. (2013). Decision of the Council of the International Seabed Authority Relating to Amendments to the Regulations on Prospecting

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

and Exploration for Polymetallic Nodules in the Area and related matters, ISBA/19/C/17. Kingston: International Seabed Authority, Regulation 1.3.
128. Moses, J. W., & Brigham, A. M. (2021). Whose Benefit? A Comparative Perspective for the ISA. *Marine Policy*, *131*, 104550.
129. International Seabed Authority. (2022). Equitable Sharing of Financial and other Economic Benefits from Deep-Sea Mining. Policy Brief 01/2022. Kingston: International Seabed Authority.
130. Earth Negotiations Bulletin. (2020). Summary of the Twenty-Sixth Annual Session of the International Seabed Authority (First Part): 17–21 February 2020. *Earth Negotiations Bulletin* 25(224).
131. 1994 Agreement on Implementation, Annex, Section 1, paragraph 15.c.
132. Lyons, K. (2021). Deep-Sea Mining Could Start in Two Years After Pacific Nation of Nauru Gives UN Ultimatum. *The Guardian*, 30 June.
133. International Seabed Authority. (2022). Action Plan of the International Seabed Authority in Support of the United Nations Decade of Ocean Science for Sustainable Development, ISBA/26/A/4. Kingston: International Seabed Authority.
134. International Seabed Authority. (2018). Decision of the Assembly of the International Seabed Authority Relating to the Strategic Plan of the Authority for the Period 2019−2023, ISBA/24/A/10. Kingston: International Seabed Authority.
135. Blasiak, R., Jouffray, J. B., Wabnitz, C. C., Sundström, E., & Österblom, H. (2018). Corporate Control and Global Governance of Marine Genetic Resources. *Science Advances*, *4*(6), eaar5237.
136. UNCLOS Articles 143.1 and 143.2.
137. Kim, R. E. (2017). Should Deep Seabed Mining be Allowed? *Marine Policy*, *82*, 134–7.
138. Howkins, A. (2016). *Frozen Empires: An Environmental History of the Antarctic Peninsula*. New York: Oxford University Press, pp. 13–16, p. 15.
139. Antarctic Treaty, Article 4.
140. Antarctic Treaty, Article 1.
141. All of these states are parties to the Antarctic Treaty but not necessarily to the related agreements within the Antarctic Treaty System.
142. Antarctic Treaty, Article 9.2.
143. Vicuña, F. O., Vicuña, F. O., Drewry, D. J., & Walton, D. W. H. (1988). *Antarctic Mineral Exploitation: The Emerging Legal Framework*. Cambridge: Cambridge University Press, pp. 41–4.
144. Antarctic Treaty, preamble.
145. Antarctic Treaty Consultative Meeting. (1975). Recommendation VIII-14, Antarctic Mineral Resources and Environmental Impact.
146. Antarctic Treaty Consultative Meeting. (1977). Recommendation IX-1, Antarctic Mineral Resources.
147. Triggs, G. D. (1987). Negotiation of a Mineral Regime. In G. D. Triggs (ed.), *The Antarctic Treaty Regime: Law, Environment and Resources*. New York: Cambridge University Press, pp. 182–95. Andersen, R. T. (1991). Negotiating a New Regime: How CRAMRA Came into Existence. In A. Jørgensen-Dahl & W. Østreng (eds.), *The Antarctic Treaty System in World Politics*. New York: Palgrave, pp. 94–109.
148. Convention on the Regulation of Antarctic Mineral Resource Activities, Articles 1.6 and 2.1.
149. Convention on the Regulation of Antarctic Mineral Resource Activities, Articles 11 and 12.
150. Watts, A. D. (1990). The Convention on the Regulation of Antarctic Mineral Resource Activities 1988. *International & Comparative Law Quarterly*, *39*(1), 169–82, p. 172.
151. Convention on the Regulation of Antarctic Mineral Resource Activities, Article 6.
152. See Beck, P. J. (1989). Convention on the Regulation of Antarctic Mineral Resource Activities: A Major Addition to the Antarctic Treaty System. *Polar Record*, *25*(152), 19–32; Behrendt, J. C. (1989). Treaty on Antarctic Minerals and Oil – What Impact on Science and Environment? *Antarctic Science*, *1*(3), 191.
153. Visser, A. (1988). The Antarctic Minerals Regime and its Environmental Impact. *Leiden Journal of International Law*, *1*(2), 171–82; Brown, A. D. (1991). The Design of CRAMRA: How

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006

Appropriate for the Protection of the Environment? In A. Jørgensen-Dahl & W. Østreng (eds.), *The Antarctic Treaty System in World Politics*. New York: Palgrave, pp. 110–19.

154. Blay, S. K. N., & Tsamenyi, B. M. (1990). Australia and the Convention for the Regulation of Antarctic Mineral Resource Activities (CRAMRA). *Polar Record*, *26*(158), 195–202.
155. Podehl, J. G., & Rothwell, D. R. (1992). New Zealand and the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA): An Unhappy Divorce. *Victoria University of Wellington Law Review*, 22, 23.
156. Protocol on Environmental Protection to the Antarctic Treaty, Article 7.
157. Protocol on Environmental Protection to the Antarctic Treaty, Article 25.5.a.
158. Blay, S. K. (1992). New Trends in the Protection of the Antarctic Environment: The 1991 Madrid Protocol. *American Journal of International Law*, *86*(2), 377–99, pp. 395–7.
159. CRAMRA explicitly includes fossil fuels under its definition of 'mineral resources'. The Madrid Protocol bans all mineral resource activities, which implicitly includes activities related to fossil fuels. UNCLOS part XI conceives of minerals as 'all solid, liquid or gaseous mineral resources in situ in the Area at or beneath the seabed' that have been recovered from the Area (Article 133).
160. Shingleton, B. (1983). UNCLOS III and the Struggle for Law: The Elusive Customary Law of Seabed Mining. *Ocean Development & International Law*, *13*(1), 33–63.
161. Antarctic Treaty Article IX.1.(f).
162. Antarctic Treaty Consultative Meeting. (1977). Recommendation IX-2, Research on and Conservation of Antarctic Marine Living Resources; see also Edwards, D. M., & Heap, J. A. (1981). Convention on the Conservation of Antarctic Marine Living Resources: A Commentary. *Polar Record*, *20*(127), 353–62.
163. Nelson, P. L., & Block, W. E. (2018). *Space Capitalism: How Humans will Colonize Planets, Moons and Asteroids*. Cham: Palgrave; Wrench, J. G. (2019). Non-appropriation, No Problem: The Outer Space Treaty Is Ready for Asteroid Mining. *Case Western Reserve Journal of International Law*, *51*, 437; Butkevičienė, E., & Rabitz, F. (2022). Sharing the Benefits of Asteroid Mining. *Global Policy*, *13*(2), 247–58.
164. UN General Assembly (1971). Declaration of Principles Governing the Sea-Bed and the Ocean Floor, and the Subsoil Thereof, Beyond the Limits of National Jurisdiction. Adopted at the 1933rd plenary meeting, 17 Dec. 1970, para 11; see also Evriviades, E. L. (1982). The Third World's Approach to the Deep Seabed. *Ocean Development & International Law*, *11*(3–4), 201–64.
165. Notable exceptions include Friedberg, J. (2013). Bracing for the Impending Rocket Revolution: How to Regulate International Environmental Harm Caused by Commercial Space Flight. *Colorado Environmental Law Journal*, *24*, 197; Kramer, W. R. (2014). Extraterrestrial Environmental Impact Assessments – A Foreseeable Prerequisite for Wise Decisions Regarding Outer Space Exploration, Research and Development. *Space Policy*, *30*(4), 215–22; Gupta, V. (2016). Critique of the International Law on Protection of the Outer Space Environment. *Astropolitics*, *14*(1), 20–43.
166. Qiu, Y., & Suh, S. (2019). Economic Feasibility of Recycling Rare Earth Oxides from End-of-life Lighting Technologies. *Resources, Conservation and Recycling*, *150*, 104432; Binnemans, K., McGuiness, P., & Jones, P. T. (2021). Rare-Earth Recycling Needs Market Intervention. *Nature Reviews Materials*, *6*(6), 459–61.
167. Greenpeace (2022). *Circular Claims Fall Flat Again. 2022 Update*. Amsterdam: Greenpeace.
168. Sadan, M., Yü, D.S., Lawn, D.S., & Zhou, R. (2022). *Rare Earth Elements, Global Inequalities and the 'Just Transition'*. London: The British Academy.
169. Kim, R. E. (2017). Should Deep Seabed Mining be Allowed? *Marine Policy*, *82*, 134–7.
170. For example, Artuso, A. (2002). Bioprospecting, Benefit Sharing, and Biotechnological Capacity Building. *World Development*, *30*(8), 1355–68; Morgera, E., & Tsioumani, E. (2010). The Evolution of Benefit Sharing: Linking Biodiversity and Community Livelihoods. *Review of European Community & International Environmental Law*, *19*(2), 150–73; Rabitz, F. (2017). Access without Benefit-Sharing: Design, Effectiveness and Reform of the FAO Seed Treaty. *International Journal of the Commons*, *11*(2), 621–40; Laird, S., Wynberg, R., Rourke, M., et al. (2020). Rethink the Expansion of Access and Benefit Sharing. *Science*, *367*(6483), 1200–2; Butkevičienė, E., & Rabitz, F. (2022). Sharing the Benefits of Asteroid Mining. *Global Policy*, *13*(2), 247–58.

Downloaded from https://www.cambridge.org/core. UNIVERSIDAD AUTONOMA METROPOLITANA, on 17 Nov 2026 at 18:04:46, subject to the Cambridge Core terms of use, available at https://www.cambridge.org/core/terms. https://doi.org/10.1017/9781009352635.006