The battery paradox

How the electric vehicle boom is draining communities and the planet

Alejandro González & Esther de Haan

December 2020

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SOMO

Stichting Onderzoek Multinationale Ondernemingen
Centre for Research on Multinational Corporations

Sarphatistraat 30
1018 GL Amsterdam
The Netherlands
T: +31 (0)20 639 12 91
F: +31 (0)20 639 13 21
info@somo.nl
www.somo.nl

The Centre for Research on Multinational Corporations (SOMO) is an independent, not-for-profit research and network organisation working on social, ecological and economic issues related to sustainable development. Since 1973, the organisation investigates multinational corporations and the consequences of their activities for people and the environment around the world.

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Amsterdam, December 2020

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Acronyms

CO_2	Carbon dioxide
DRC	Democratic Republic of Congo
EBA	European Battery Alliance
EC	European Commission
EESC	European Economic and Social Committee
EIB	European Investment Bank
EU	European Union
EV	Electric vehicle
FPIC	Free, prior and informed consent
GBA	Global Battery Alliance
GWh	Gigawatt hours
NGO	Non-governmental organisation
ICE	Internal combustion engine
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRP	International Resource Panel
kWh	Kilowatt-hour
Li-ion battery	Lithium-ion battery
LCO	Lithium-cobalt oxide
LED Scenario	Low Energy Demand Scenario
LFP	Lithium iron phosphate
LMO	Lithium manganese oxide
LTO	Lithium titanate
NCA	Lithium nickel cobalt aluminium
NGO	Non-governmental organization
NMC	Lithium nickel manganese cobalt
SOMO	Centre for Research on Multinational Corporations
USGS	United States Geological Survey

Executive summary

The transport sector accounted for roughly a quarter of global CO_2 emissions in 2019, with over 70 per cent coming from road transport. It is clear that these emissions need to be curbed if the targets of the Paris Climate Agreement are to be reached and catastrophic climate change is to be avoided. But phasing out fossil fuel-powered cars in favour of electric vehicles may come at an unacceptably high social and environmental cost.

Electric vehicles are often presented as the ultimate solution to help reduce emissions from road transport. After all, they run on batteries instead of oil, eliminating the CO_2 exhaust emissions of traditional engines. This is why governments across the world are adopting policies to phase out petrol and diesel cars and stimulate massive uptake of electric vehicles. This has already led to a worldwide boom in the production and sales of electric cars, which will only pick up speed in the coming years.

At the core of this transition is the production of lithium-ion batteries. The minerals required to produce these batteries – lithium, cobalt, nickel, graphite, manganese– are extracted from the earth, just like fossil fuels, and demand for them is skyrocketing. A recent report by the World Bank estimates that demand for lithium, cobalt and graphite could grow by nearly 500 per cent by 2050.

While electric vehicles are widely embraced, the pressure of the great battery boom is increasingly being felt by communities around the world, including in Argentina, Chile and Bolivia – the so-called 'Lithium Triangle' countries that host three-quarters of the world's lithium resources – and the Democratic Republic of Congo, which produces about two-thirds of the world's cobalt. Issues reported include heavy pollution, water scarcity, exposure to toxics, non-disclosure of suficient information, lack of consultation and community consent, community conflicts and abuses, impact on indigenous rights, dangerous mining conditions and child labour. The unprecedented increase in demand for these and other raw materials thus poses serious human rights and environmental risks and begs the question how sustainable and fair a mobility transition based on the mass uptake of electric vehicles really is.

To answer this question, this report analyses the composition of the most common Li-ion batteries and reviews the whole battery value chain, from mining to production, and recycling. It looks at the composition of the batteries, the biggest players in the industry and the (expected) consequences on the ground. Apart from critically assessing the current and future social and environmental impacts of the soaring demand for minerals needed to produce batteries for electric vehicles, the report also looks at alternative, less mineral-dependent strategies to reduce emissions in the transport sector.

Key findings

- Extensive documentation shows that the social and environmental impacts associated with mining of key minerals (lithium, cobalt, nickel, graphite and manganese) for producing Li-ion batteries are destructive and widespread. The mass uptake of electric cars would result in more mining and energy consumption, increasing these impacts, which raises serious social and environmental concerns about transitioning from a dependency on oil to a dependency on minerals for mobility.

- As electric vehicles gain market share, an enormous number of the batteries that power them will reach end-of-life in the decades to come. An important concern is that battery manufacturers are currently not designing Li-ion batteries to optimise recycling. Differences in design of battery cells, modules and packs hinder recycling efficiency. Packs are not easy to disassemble and cells are not easy to separate for recycling.

- Key players pushing for the mass adoption of electric vehicles are primarily businesses, governments in the US, Europe and China, the European Commission as well as partnerships (battery alliances) with a strong corporate presence. The expected market value and potential profits of the Li-ion battery value chain is a key motivator of their efforts to scale up Li-ion battery production and the mass uptake of electric vehicles. Predictions clearly show that the expected economic benefits would be unequally distributed among the different segments of the value chain, predominantly favouring those businesses that are engaged with cell and car manufacturing.

- Corporate players and battery alliances are already heavily invested in the development of a Li-ion battery value chain, leading to a vested interest in the mass uptake of batteries. These companies are likely to support a system that locks society in a transport system where individual car ownership is central.

- Policy measures in different countries and at the EU level are playing a decisive role in incentivising the electric vehicle boom, often accompanied with public spending. In Europe, the declaration of the battery as a strategic priority by the European Commission is accompanied by an important change in industrial policy, which shifts away from open market and free competition towards a government supported Li-ion battery industry, allowing for the easing of market and state-aid rules.

- While mass adoption of electric vehicles is being promoted by industry and governments (particularly in the global north), it is not the only solution to address the impacts of passenger road transport. Scientists, civil society and communities across the world are calling for a different approach based on environmental justice and the need to reduce the demand for minerals and energy in absolute terms. Strategies proposed include ride-sharing, car-sharing and smaller vehicles. These strategies based on scientific studies have the biggest potential to reduce the impact of passenger road transport. Material efficiency strategies such as recycling and extended lifespan are also important. The effects of these combined strategies are discussed in the report.

Recommendations

The following are key recommendations based on the information provided in this report. For additional recommendations, we refer to the (forthcoming) *Principles for Businesses and Governments in the Battery Value Chain* drafted by Amnesty International and allies.

To governments

- States and the EU should prioritise reducing the mineral and energy demand of passenger road transport in absolute terms. To do so, States and the EU should support and promote strategies towards car-sharing, ride-sharing and public transport.

- States should introduce policy action and regulations that promote material efficiency strategies for the use of less materials and energy, including design of smaller Li-ion batteries and electric vehicles, reuse and recycling.

- States and the EU should require manufacturers to standardise the design of Li-ion cells, modules and packs, and include proper labelling, in order to optimise recycling.

- States and the EU should introduce rules mandating Li-ion battery producers and/or EV manufacturers to take back end-of-life Li-ion batteries, through an extended producer responsibility scheme.

- States and the EU should introduce binding regulation requiring companies to conduct mandatory human rights and environmental due diligence, including the obligation of businesses to publish their due diligence practices and findings. Due diligence requirements should cover the entire battery value chain and involve communities, workers, civil society and trade unions in its design, monitoring and implementation.

- States and the EU should facilitate a democratic public debate to discuss alternative strategies to address the impacts of passenger road transport that includes the participation and meaningful engagement of mining-affected communities, workers, environmentalists, scientists, civil society and that is based on environmental justice and respect for human rights.

To companies along the battery value chain

- All companies along the Li-ion battery value chain should map and disclose their supply chain and use their leverage with business relationships to request respect for human rights, decent working conditions and environmental protection through contractual obligations.
- All companies along the Li-ion battery value chain should carry out human rights and environmental due diligence, disclosing their findings on risks and abuses and outcomes; and prevent, address and mitigate their negative impacts.
- All companies should respect human rights and environmental laws, including the right to information, water, health; a healthy environment; communities' right to withhold consent; occupational health and safety standards; and the right of freedom of association and collective bargaining.
- All companies should provide victims of abuses occurring at any stage of the value chain with access to an effective remedy and have in place an effective grievance mechanism to receive workers' and external complaints.
- Companies should prioritise reducing mineral and energy demand in absolute terms, standardise design of Li-ion batteries and their components, which facilitate reuse and recycling. Manufacturers should ensure that Li-ion batteries and components include proper labels including battery health and safety guidelines for disassembling and recycling.

Introduction

Context and point of departure

Urgent action is needed to address the climate crisis. Phasing out fossil fuels and shifting towards more sustainable sources of energy is essential to curb global warming. Reaching the targets of the Paris Agreement and limiting global warming requires urgent and 'far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems', according to the Intergovernmental Panel on Climate Change (IPCC).[1] In 2019, the transport sector (land, air, sea and water) was responsible for 24 per cent of energy-related global CO_2 emissions.[2] Roughly, road transport accounts for more than 70 per cent of all transport emissions. Within road transport, passenger road transport accounts for roughly two thirds of emissions while commercial road transport accounts for the remaining one third.[3]

Almost all energy for transport (95 per cent) comes from burning diesel and gasoline.[4] In 2019, passenger cars burned more than 20 million barrels of oil per day, representing over 20 per cent of total global demand.[5] Therefore, reducing the environmental impacts of passenger road transport is imperative and poses a major challenge in terms of addressing the climate crisis.

Increasingly, mass uptake of electric vehicles (EVs) is presented as the solution to reduce emissions of passenger road transport. After all, EVs run on batteries instead of oil, which eliminate the CO_2 exhaust emissions of traditional internal combustion engines. Electric mobility is booming, especially in China and in the global north. The global EV fleet has gone from 17,000 units in 2010 to 7.2 million by 2019, with more than 2.1 million EV sales in 2019 alone.[6] Industry analysts estimate that global sales of EVs will reach 26 million in 2030 and 54 million in 2040.[7] Despite electrification, the global fleet of passenger cars is expected to grow from 1.2 billion in 2020 to 1.4 billion in 2030, and EVs will only account for 8 per cent of the total fleet in 2030, far from replacing internal combustion engines.[8]

Countries around the world are introducing regulations, incentives and legislation to phase out petrol and diesel cars. By 2025, in Norway only 100% electric or plug-in hybrid EVs will be sold.[9] By 2030, all new cars in the Netherlands should be emission free.[10] In the UK and France, as of 2030 and 2040, respectively, sales of petrol and diesel cars will not be allowed.[11] Policy-makers in Canada, Chile, Costa Rica, India and New Zealand are also supporting the uptake of EVs.[12]

China's objectives are ambitious. China has set a target of 7 million EV sales annually by 2025.[13] China is the world's biggest EV market, followed by the European Union (EU) and the United States (US). By 2025, China is projected to account to 54 per cent of the global passenger EV sales.[14]

Policy measures have played an important role in promoting the EV boom, including emissions regulations, fuel economy standards (EU), zero-emissions mandates (Quebec and California), subsidies (Korea, China), public procurement (EU Clean Vehicles Directive), restrictions on investment in combustion engine manufacturing (China) and reduction of purchase price for EVs (India).[15]

The Battery

Batteries are at the core of this momentous transition in passenger road transport. Batteries, as stated by the European Commission's Vice President, are 'at the heart of the on-going industrial revolution. Their development and production play a strategic role in the on-going transition to clean mobility and clean energy systems'.[16] Battery manufacturing has become a priority and a strategic goal for many regions, notably China and the EU. The latter recently adopted the Strategic Action Plan for Batteries to accelerate the building of a battery value chain in Europe (see Chapter 2.1).

While there are different types of batteries, lithium-ion batteries (Li-ion batteries) are expected to dominate the EV market at least for the next decade.[17]

But what's inside a Li-ion battery? The minerals required to produce the Li-ion batteries (i.e. lithium, cobalt, nickel, graphite, manganese) come from the earth, just like fossil fuels. Minerals are the ingredients for batteries' energy storage. And demand for them is skyrocketing. A recent report by the World Bank estimates that demand for lithium, cobalt and graphite could grow by nearly 500 per cent by 2050, driven almost entirely by demand for batteries used for EVs.[18] While governments and citizens in the global north are embracing and incentivising electric vehicles, the pressure of the great battery boom is being felt by communities in places like Argentina, Chile and Bolivia – the so-called 'Lithium Triangle' countries, which host 75 per cent of the world's lithium resources – and the Democratic Republic of Congo (DRC), which produces about two-thirds of the world's cobalt. Furthermore, energy-intensive mega-factories are rapidly being built to supply the surging need for batteries. As well as requiring soaring amounts of minerals, the manufacture of Li-ion batteries also requires energy and generates carbon emissions and waste.

The unprecedented increase in demand for raw materials to make Li-ion batteries poses serious human rights and environmental risks and calls into question how clean, sustainable and fair a mobility transition based on mass uptake of EVs and increased production of batteries really is. Furthermore, passenger EVs are predicted to become the main driver for global Li-ion battery demand, far exceeding demand resulting from commercial transport, energy storage and consumer electronics.

Mass adoption of EVs is, however, not the only solution to address the impacts of passenger road transport. Scientists, civil society and communities across the world are calling for a different approach based on environmental justice and on the need to absolutely reduce the demand for minerals and energy.

Aim and research questions

The aim of this paper is to discuss and critically assess the social and environmental implications resulting from a mass uptake of EVs as a solution to address the climate impacts of passenger road transport. In particular the aim is to assess the implications resulting from a soaring mineral demand to produce Li-ion batteries to propel EVs. Furthermore, the aim is to identify other existing strategies to address the social and environmental impacts of passenger road transport in order to broaden the debate, particularly strategies based on environmental justice and towards reducing resource and energy use.

By reviewing the Li-ion battery value chain, we also aim to support existing efforts of different groups (communities, workers, trade unions, environmentalists, activists) with increased knowledge of the key players, dynamics, latest developments and leverage points of the Li-ion battery value chain in order to support their efforts towards transparency, corporate accountability and demands to respecting human rights and environmental protection.

The objectives of this report are to:

- Provide an overview of the Li-ion battery, including its mineral composition, main components and type.
- Offer an analysis of the global Li-ion battery supply chain, including its stages, main stakeholders and location of main activities.
- Identify who are the key players pushing towards (and investing in) a transition towards the mass uptake of EVs. In particular, we will focus on Europe, where the Li-ion battery value chain is changing rapidly due to increased incentives and investments.
- Analyse the main predictions of mineral demand resulting from the mass production of Li-ion batteries for EVs.
- Identify some of the main social and environmental impacts associated with mining of minerals used to produce Li-ion batteries.
- Carry out an initial non-exhaustive identification of other strategies to address the social and environmental impacts of passenger road transport and the battery value chain.

Research methodology

This report focuses on Li-ion batteries used for passenger road EVs. We focus on passenger road transport, as it is the biggest sub-segment within the road transport sector, and is responsible for two thirds of emissions. As mentioned above, passenger EVs are also the main driver for the mass production of Li-ion batteries.

The main research method used for this report is desk-based research, further complemented by empirical information gathering. Desk research was based on primary and secondary sources. Primary sources included statistical data, company's publications, reports on the social and environmental impacts of mining and the transport sector and scientific journals. Secondary sources included media articles, books, non-governmental organisation (NGO) reports and company and industry reports. Some parts of Chapter 2, particularly on the social and environmental impacts of mining, relied on previous work by the Centre for Research on Multinational Corporations (SOMO) and other NGOs. Empirical information gathering included conversations and email exchanges with different experts as well as participation in workshops, panel discussions and seminars.

Structure of this report

Chapter 1 provides an overview of the battery, including its components and different chemical compositions, focussing on the lithium rechargeable battery. The entire battery value chain is analysed, including the main players involved and key location of activities for each stage.

In Chapter 2, we identify the key players and initiatives that are promoting the mass adoption of EVs, such as the European Battery Alliance and the Global Battery Alliance. We also review major industry players that are investing in the battery value chain as well as recent alliances and consolidation of business interests. We further zoom in on the corporations investing in developing a battery value chain in Europe, as well as the governmental support that they are receiving through public spending and incentives.

Chapter 3 focuses on analysing the soaring rise in demand for minerals resulting from mass uptake of EVs and battery production. We focus on key minerals for batteries (lithium, cobalt, manganese, graphite and nickel) including the associated social and environmental impacts resulting from mining for such minerals.

Chapter 4 focuses on carrying out a non-exhaustive identification of other strategies to address the social and environmental impacts of passenger road transport. We focus on strategies based on environmental justice, reduction of private passenger cars (in order to reduce mineral and energy demand) as well as material efficiency and recycling.

We conclude with recommendations for governments and companies along the battery value chain.

1 The Li-ion battery

1.1 Li-ion battery composition

A Li-ion battery is a group of inter-connected cells capable of charging and discharging. Common end-uses of Li-ion batteries include consumer electronics, electric vehicles and energy storage.

A Li-ion battery cell is made up of several components: a negative electrode or anode (usually made of graphite with a copper collector), a positive electrode or cathode (made from a transition metal oxide that can vary in chemical composition with an aluminium collector), a separator and an electrolyte.

The chemical composition of the cathode defines the specific Li-ion battery type. The most common Li-ion battery types used for EVs, according to their cathode composition, are:

- **Lithium nickel cobalt aluminum (NCA)**, (used by Tesla).
- **Lithium nickel manganese cobalt (NMC)**, which has a higher energy density (used by BMW, Hyundai, Volkswagen, Nissan, and Mercedes-Benz).
- **Lithium manganese oxide (LMO**) (used by Nissan first generation and BMW).
- **Lithium iron phosphate (LFP)**, (commonly used in public transportation as they are more stable).
- **Lithium titanate (LTO)**, (used in public transportation for its fast-charging properties).

Another type of battery, **Lithium-cobalt oxide (LCO)**, is mostly used by consumer electronics but is deemed unsuitable for cars because of safety reasons.

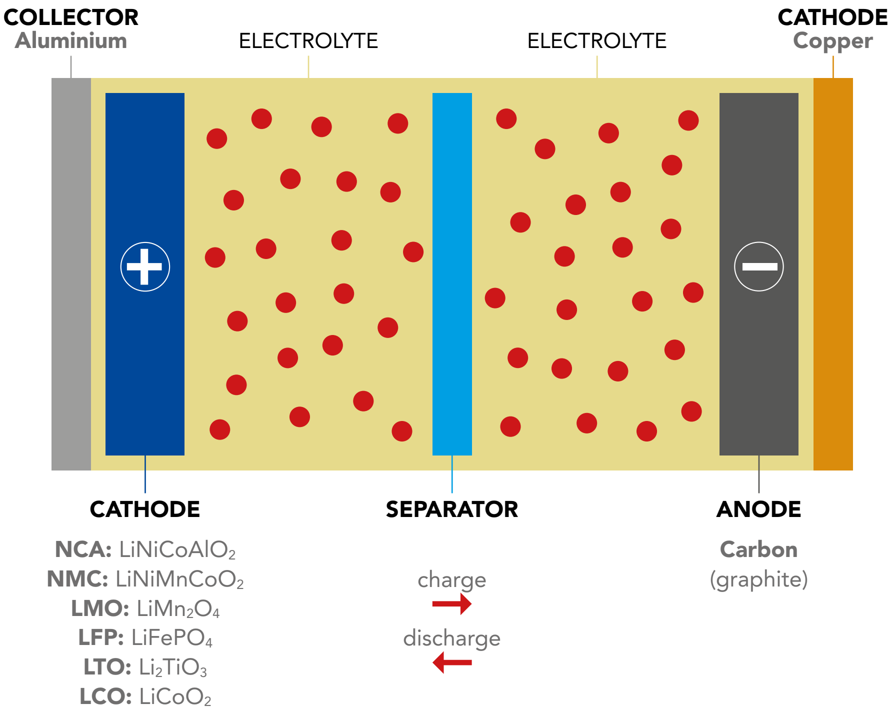
The key mineral constituents in most types of Li-ion batteries used for EVs are cobalt, lithium, graphite, manganese and nickel. Figure 1 shows a battery model, including the key materials used in the its different components.

The Li-ion battery type or composition determines its mineral demand. As an illustration, Figure 2 shows the mineral ratios for LMO, NMC 111, NMC 811 and NCA battery types.

The size of the battery (measured in power output) determines the amount of materials needed per unit. Currently the Li-ion battery size, measured in power output, ranges from 15 to100 kilowatt-hour (kWh). Compact EVs use a Li-ion battery size of 12-18 kWh, mid-size sedans use a 22-32 kWh pack, and high-end models (like Tesla) use a battery size of 60-100 kWh.[19] The bigger the size of the battery, the more minerals are required to produce them. Size plays a key role in the range of the battery. For instance, a Mitsubishi MiEV with a battery pack of 16 kWh has a range of 85 km while a Tesla S85 with a battery pack of 90 kWh reaches up to 360 km.[20]

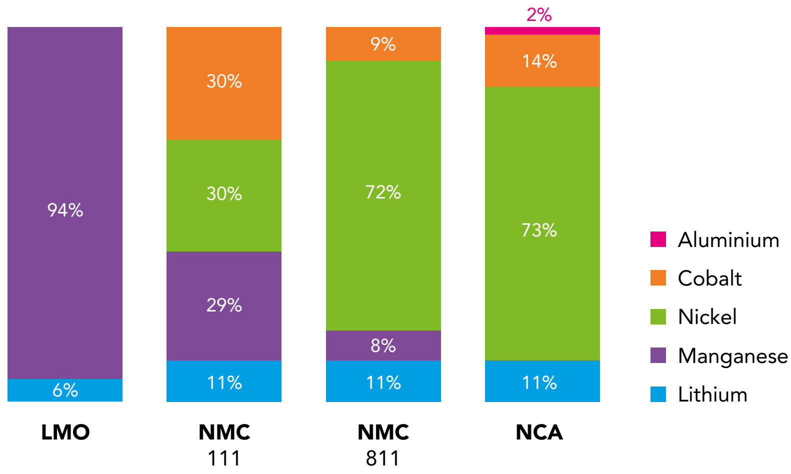
While Li-ion batteries will dominate the EV market in the next decade, according to analysts, there are other battery technologies currently being developed and tested that may become commercially viable in the near future. For instance, solid-state Li-ion batteries or zinc-air batteries could become

Figure 1 A Li-ion battery model



Source: Elaborated by SOMO.

Figure 2 Mineral ratios for the main EV Li-ion battery types



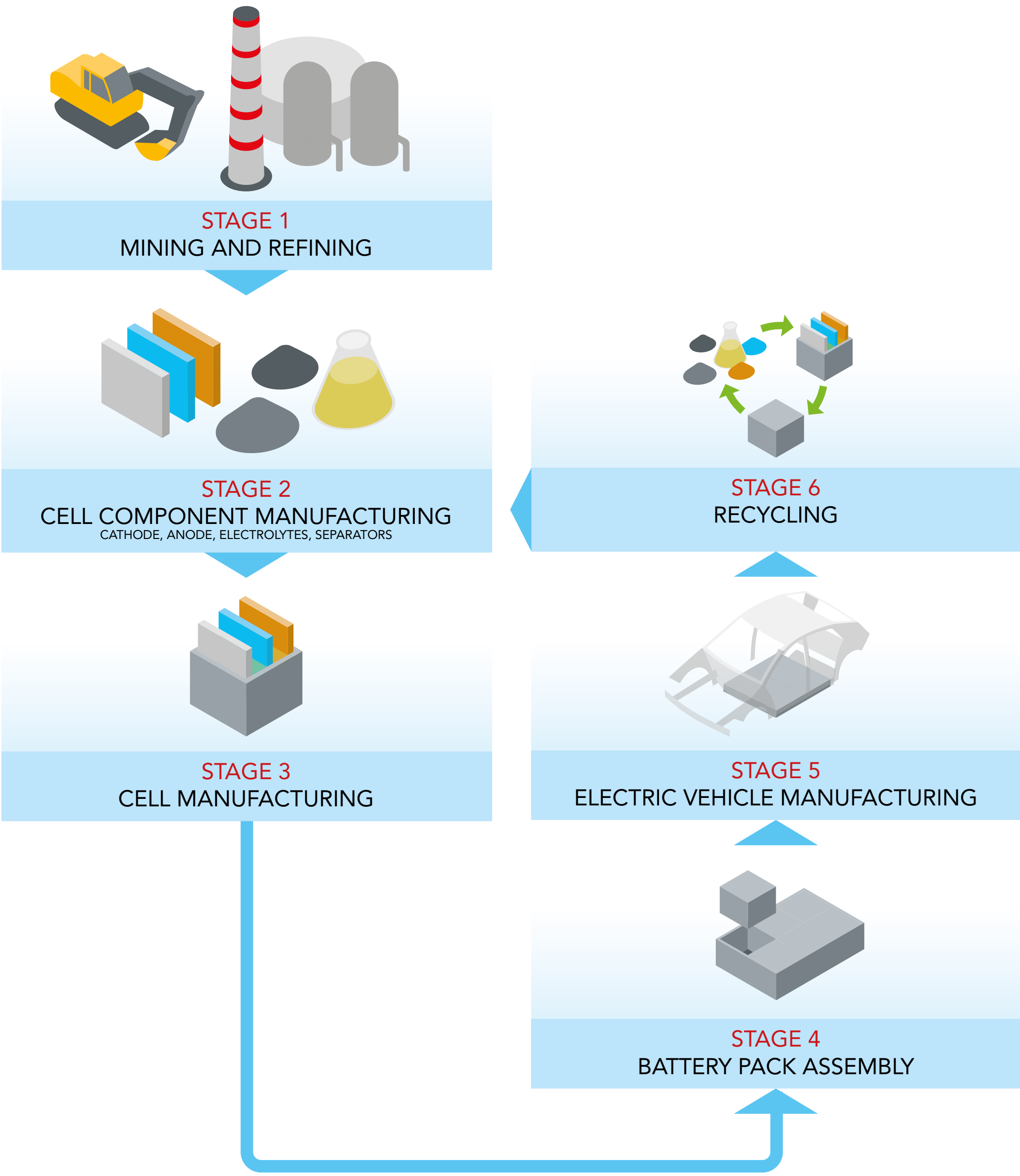
Source: BloombergNEF.

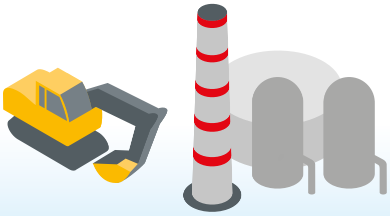
the next generation batteries for EV batteries. Solid-state Li-ion batteries use a solid electrolyte (i.e. polymer or ceramic) rather than a liquid one as used in current Li-ion batteries.
There are several options of additional minerals that could be used for the solid electrolyte (including aluminium, tin, silver and boron). Another important difference between technologies is that solid-state batteries use an anode made of lithium rather than graphite. According to some analysts and business roadmaps (e.g. Volkswagen), solid-state Li-ion batteries could be used commercially by EVs within 5 to 10 years.[21]

1.2 The Li-ion battery value chain

The Li-ion battery value chain has six key stages: mining and refining, cell component manufacturing (cathode, anode, electrolytes, separators), cell manufacturing, battery pack assembly, electric vehicle manufacturing and recycling.[22]

Figure 3 The lithium-ion battery value chain





STAGE 1 MINING AND REFINING

Sourcing of raw materials is the first stage of the battery supply chain.

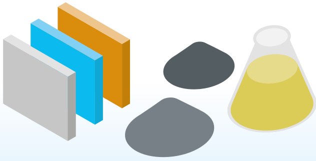
The world's mine production of several key minerals for Li-ion batteries tends to be concentrated in a few countries as observed in Table 1. In 2018, DRC produced 70 per cent of the world's cobalt; Australia produced 62 per cent of lithium (followed by Chile with 18 per cent and Argentina and China both with 7 per cent); South Africa produced 30 per cent of manganese; China produced 68 per cent of graphite.[23] Table 2 illustrates the production share, total production, location of reserves, location of resources and total estimated resources for the key minerals used to manufacture batteries.[i]

Table 1 Production, reserves and resources of key minerals

Mineral	Production share 2018	Total Production 2018	Reserves	Resources	Total estimated world resources
Lithium	Australia 62%, Chile 18%, China 7% Argentina 7%, Canada 3%, Zimbabwe 2%, Portugal 1%	95,000 tonnes	Chile 52%, Australia 17%, Argentina 10%, China 6%, Canada 2%, Zimbabwe 1%	Bolivia 26%, Argentina 21%, Chile 11%, Australia 8%, China 6%	80 million tonnes
Cobalt	DRC 70%, Russia, 4%, Australia 3%, Philippines 3%, Canada 2%, Cuba 2%	148,000 tonnes	DRC 51%, Australia 17%, Cuba 7%, Russia 4%, Philippines 4%,	Vast majority in DRC and Zambia.	25 million tonnes (terrestrial) and 120 million (oceans floor)
Manganese	South Africa 31%, Australia 18%, Gabon 12%, Ghana 7%, Brazil 7%, China 6%	18,900 tonnes	South Africa 32%, Ukraine 17%, Brazil 17%, Australia 12%	South Africa 74%, Ukraine 10%	Large and irregularly distributed.
Nickel	Indonesia 25%, Philippines 14%, Russia 14 %, New Caledonia 9%, Canada 7%	2,400,000 tonnes	Indonesia 24%, Australia 22%, Brazil 12%, Russia 8%		>117 million tonnes
Graphite (natural)	China 62%, Mozambique 9%, Brazil 8%, Madagascar 4%, Canada 3%,	1,120,000 tonnes	Turkey 30%, China 24%, Brazil 24%, Mozambique 8%		>725 million tonnes (inferred)

Source: Compiled by SOMO with data from USGS Minerals Commodity Summaries 2020.[24]

i Resources refer to the amount of the mineral in the earth's crust, while reserves refer to the amount of resources that could be economically extracted at a particular moment. 'Mineral Commodity Summaries 2020,' USGS Unnumbered Series, *Mineral Commodity Summaries 2020*, Mineral Commodity Summaries (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/mcs2020.



STAGE 2 CELL COMPONENT MANUFACTURING
CATHODE, ANODE, ELECTROLYTES, SEPARATORS

In stage 2 of the value chain, each of the different components of the Li-ion battery is manufactured, namely the cathode, anode, electrolytes and separators.

Asian companies dominate the manufacturing of cathode active materials and anodes. By 2019, 61 per cent of the cathode materials for EVs were produced by Chinese companies as well as 83 per cent of the anodes.[25]

Table 2 details the revenues and the regional production distribution of the different cell components for the Li-ion battery market in 2015 and 2019 evidencing a growing concentration by China.

Table 2 Revenues and production distribution of the different cell components

Cell components	Market Demand for Lithium batteries 2018	Revenues in US$ 2018	Production Distribution 2015	Production Distribution 2019
Cathode materials	313,000 tonnes	B$7.2	China 39%, Japan 19%, EU 13%, South Korea 7%, other 22%	China 61%
Anode materials	200,000 tonnes	B$1.8	No information	China 83%
Electrolyte	1,972,000 tonnes	B$2	China 60%, Japan 18%, Korea 7%, US 7%	No information
Separators	2500 mm^2	B$1.8	Japan 48%, China 17%, Korea 10%	No information

Source: SOMO taken from various sources.[26]

According to industry analysts the market value of cathode materials will grow significantly from US$7 billion in 2018 to $58.8 billion in 2024.[27]

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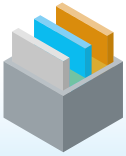


STAGE 3 CELL MANUFACTURING

A Li-ion battery cell is a single electrochemical unit composed of the electrodes, a separator and the electrolyte. In stage 3, the different cell components are assembled into a single battery cell.

Chinese companies are the undisputed leaders of Li-ion battery cell manufacturing. In 2019, Chinese players concentrated 73 per cent of cell manufacturing, followed by North Americans (10 per cent) and Europeans (6 per cent).[28]

By the end of 2020, the world's top 5 Li-ion battery cell manufacturers in terms of capacity are CATL, LG Chem, Samsung, Panasonic and BYD as shown in Table 4 (including main factories and clients).[29]

Table 3 The world's biggest cell battery manufacturers by production capacity

Company	Forecast capacity in GWh end of 2020	Key factories	Key clients
LG CHEM (Republic of Korea) including joint ventures	93	Wroclaw, Poland Holland, Michigan, US Nanjing, China Ochang, Korea	Volkswagen, General Motors, Ford, Geely (Volvo), Renault, Nissan, Hyundai, Kia, Tesla and others
CATL (China) including joint ventures	110,1	Ningde, China Thuringia, Germany (announced) Guangzhou (announced) Jiansu, China	Geely (Volvo), BMW, Daimler, Volkswagen, Toyota, Honda, Nissan, other Chinese manufacturers
BYD (China)	60	Qinghai, China Shaanxi, China (announced) Chongqing, China (announced) Shenzhen, China Huizhou, China	BYD, Toyota
Panasonic (Japan)[ii]	69	Nevada, US Various locations, Japan Dalian, China	Tesla, BMW, Toyota
Samsung (South Korea)	62	Xian, China Ulsan, South Korea Göd, Hungary	BMW

Source: SOMO based on various sources.[30]

ii Includes Tesla's Gigafactory Nevada (@37 GWh), which is operated by Panasonic, however all of the production goes to Tesla. Tesla is currently operating an 10 GWh pilot plant in Fremont, California.

Four out of five of the largest Li-ion battery factories are located in China. The biggest factory is Tesla Gigafactory 1 in Nevada. Table 4 shows the world's biggest battery factories by production.

Table 4 The world's biggest battery factories by production capacity, 2019

Owner	Location	Country	Capacity in GWh
Tesla	Gigafactory 1, Nevada	US	37
LG Chem	Nanjing 1	China	28
CATL	Ningde	China	24
CATL-SAIC	Liyang	China	20
CATL	Liyang	China	15

Source: SOMO based on information from the Benchmark Minerals Intelligence.[31]

The number of factories that are planned to be constructed in the next 10 years has increased enormously spurred by the EV boom. At the end of 2019, 115 new lithium battery megafactories were planned around the world compared to 63 in December 2018.[iii32] While China, with 88 out of the 115 factories in the pipeline, is expected to continue to be the leader in terms of capacity for the next 10 years, Europe has the highest growth rate with 14 megafactories in the pipeline and an estimated capacity of 348 Gwh by 2029. The EU is investing significantly in developing a whole Li-ion battery value chain within its territory (see Chapter 2.2).

iii Battery megafactories is a term coined by Benchmark Mineral Intelligence and refers to factories with an annual capacity of more than 1 GWH. It is equivalent to the term gigafactory used by Tesla.

STAGE 4 BATTERY PACK ASSEMBLY

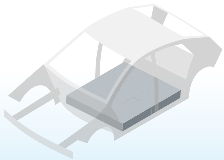
A battery pack is a set of interconnected cells. The battery pack includes wirings, sensors and the housing. The battery of an EV is expected to reach 40 to 50 per cent of the total cost of an EV.[33] Almost all car manufacturers (a notable exemption is General Motors) keep the design and assembly of the battery pack in-house. In some cases, the assembly of battery pack is done by a joint venture or a company whereby the car manufacturer has a stake. Table 5 shows the type of battery pack assembly (i.e. in-house, outsourced or joint venture) for different car manufacturers, as well as some of their key suppliers of cells.

Table 5 Battery pack manufacturing

Car manufacturer	Battery pack manufacturing	Supplier of cells
Tesla	In-house	Panasonic
GM	Outsourcing	LG Chem
BYD	In-house	BYD
BMW	In-house	Samsung SDI
Mitsubishi	In-house (through a joint venture named Lithium Energy Japan)	Not available
Nissan	In-house	Envision AESC
Renault	In-house (in collaboration with LG Chem)	LG Chem
Daimler AG	In-house	Buys cells in the global market
Volkswagen	In-house and joint venture with Northvolt AB (production planned for 2023)	LG Chem, Samsung SDI, CATL
Hyundai	Outsourcing	LG Chem and SK Innovation
Toyota	In-house for hybrids Joint ventures with CATL, BYD and Panasonic	CATL, BYD, Panasonic

Source: compiled by SOMO from various sources.[34]

Other battery pack manufacturers based in Europe include: Kriesel Electric GmbH (AT), Johnson Matthey Battery systems (UK), Continental (DE), BMZ (DE), Dow Kokam (FR) and Samsung SDI.[35]



STAGE 5 ELECTRIC VEHICLE MANUFACTURING

In this stage, the Li-ion battery pack is mounted into the vehicle. Major auto manufacturers are significantly increasing their investments to develop their EV portfolio and increase EV market penetration. By early 2019, automakers had announced more than $300 billion in investments in the EV environment. These investments were led by Volkswagen ($91 billion) followed by Daimler ($42 billion).[36] The main car manufacturers in terms of EV (unit) sales are shown in Table 6.

Table 6 Top 10 EV Car manufacturers' sales

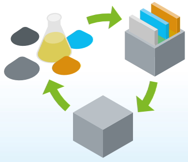
Car manufacturer	Sales in units, Jan-Nov 2019
Tesla (US)	304,841
BYD (China)	208,526
BAIC (China)	124,011
SAIC (China)	122,812
BMW (Germany)	117,932
Nissan (Japan)	74,940
Geely (China)	73,699
Volkswagen (Germany)	71,002
Hyundai (South Korea)	65,193
Toyota (Japan)	51,259
Total	**1,162,956**

Source: InsideEVs[37]

EV production and sales have boomed in the last few years. In 2019, more than 2.1 million electric vehicles were sold.[38] [iv] This is a small fraction of the total 92.8 million vehicles produced in the same year.[39] However, EV sales grew 40 per cent in 2019 alone. EV sales are predicted to reach 26 million units in 2030 and 54 million by 2040.[40]

With 1.06 million units sold in 2019, China remains the biggest EV market, followed by Europe (561,000 units) and the US (327,000 units).[41]

iv Sales data is used as a proxy of production as no publicly available data of the latter could be found.



STAGE 6 RECYCLING

Recycling of batteries is still limited due to a series of factors including recycling costs, limited volumes of batteries, recycling efficiency limitations, differences in battery design, types and chemistries, low collection rates and lack of recycling infrastructure. Furthermore, some recycling techniques do not recover all of the metals and the recycling itself may present social and environmental impacts such as chemical hazards, intense energy use and greenhouse emissions.

Until recently recycling of lithium batteries has focused on recovering cobalt due to its high value and favouring recycling techniques that fail to recover aluminium, lithium and manganese. There are no official statistics of global recycling volumes of lithium batteries. However, studies indicate that currently fewer than 5 per cent of end-of-life batteries are recycled.[42]

2 Key developments in the battery value chain

In this chapter we identify the key players and initiatives that are pushing for the mass adoption of EVs. We begin by examining the European Battery Alliance and the Global Battery Alliance, two of the most important public-private partnerships at European and global level, respectively. After that, we identify the key corporate players investing in the European battery value chain as well as the type of projects in which they are investing. We also highlight examples of public funding being used to support the development of the European value chain. Finally, we discuss recent trends in the battery value chain whereby corporate players from different segments of the value chain are strengthening ties among themselves, for instance in the form of long-term supply agreements, joint ventures or alliances between mining companies and car manufacturers or battery manufacturers.

2.1 Public-private initiatives supporting the development of the battery value chain

European Battery Alliance

The European Commission (EC) has identified the battery value chain as strategic due to its market value potential, its importance for a competitive industry and its role in the clean energy transition.[43] Since batteries account for a high proportion of cost of an EV (40 to 50 per cent), Europe aims to retain as much as possible of such added-value within its territory and protect its manufacturers from shortages and dependency on battery cell imports.[44]

The European Battery Alliance is an industry-led cooperative platform launched in October 2017 by the EC. The platform brings together the EC, EU countries, the European Investment Bank (EIB) and industrial and innovation actors with the goal of creating 'a competitive manufacturing value chain in Europe with sustainable battery cells at its core'.[45]

This is an ambitious project, considering that currently Europe has no industrial capacity to mass produce battery cells nor sufficient access to the essential raw materials.[46] In 2019, the European share of global battery cell manufacturing was only 6 per cent, which reflects the extent to which European car manufacturers are outsourcing their battery cell manufacturing to Asian battery powers in China, Japan and South Korea.[47]

In 2018, within the framework of the European Battery Alliance, the EC (working closely with industry and Member States) developed a Strategic Action Plan on Batteries.[48] The Strategic Action Plan states that the 'EU should therefore secure access to raw materials from resource-rich countries outside the EU, while boosting primary and secondary production from European source'.[49] According to the plan, the EU will use trade policy instruments to guarantee 'access to raw materials in third countries and promote socially responsible mining'.[50]

The support that the EC (including through the European Battery Alliance) is giving to the developing of a Li-ion battery value chain in Europe signals at least two important changes in European industrial policy. First, a change from open market to direct government support to industry or state targeted industrial policies.[51] Second, a change from a 'sectoral approach of industry' to a 'value chain focus'.[52]

Declaring the Li-ion battery as 'strategic' opens the door to justify exceptions to existing market rules, for instance permitting exemption for state-aid (see, for example, the Important Projects of Common European Interest Framework in section 2.2). A more permissive approach to state aid for businesses in the battery value chain is precisely what the European Economic and Social Committee (EESC) is recommending to the EC in the 2019 progress report of the Strategic Action Plan. In this progress report, the EESC calls the EC to 'adopt a flexible and supple approach to the investment aid that Member States grant to businesses in these chains'.[53] Such changes in policy can also be understood as a reaction to 'America First' protectionist policies (or its European equivalent) and to counteract Chinese geopolitical rivalry.

European policies toward Li-ion battery self-sufficiency have already succeeded in attracting public and private investments for the expansion of production in the region. EBA 250 was created as the industrial development programme of the EBA and it is led by EIT InnoEnergy. More than 260 industrial and innovator actors have joined EBA250 from all segments of the battery value chain, announcing consolidated private investments of up to €100 billion.[54]

Global Battery Alliance

In 2017, the Global Battery Alliance (GBA) was launched under the auspices of the World Economic Forum.[55] The Global Battery Alliance is a public-private partnership composed mostly of businesses (from the mining, chemical, battery and car industries) and to a much lower extent of public and international organisations and civil society groups.

The Global Battery Alliance has done research and modelling on the economic value that could be created by scaling up the development of the Li-ion battery value chain.[56] According to their base case scenario (described as a 'scenario of unguided value chain growth'), the Li-ion battery value chain is estimated to generate more than US$300 billion of revenues by 2030, compared to US$39 billion in 2018.[57] Interestingly, the lion's share of such revenues are captured by cell manufacturing ($137 billion or 46 per cent), followed by refining (25 per cent), battery pack manufacturers (16 per cent), cell component manufacturing (active materials) (8 per cent), reuse and recycling (4 per cent) and finally mining (3 per cent). The amount of revenues that would go to workers, local governments and communities is not mentioned.

The Global Battery Alliance also presents a target case, which – through a series of interventions – aims to increase the demand of Li-ion batteries by 35 per cent (as compared to the base case), driven by further reducing Li-ion battery costs by 20 per cent. According to their predictions, the target case would represent an increase of economic value of the Li-ion battery value chain of $130-185 billion.[58] Under the target case, $110-130 billion (representing 70-84 per cent of the total Li-ion battery value chain economic value) would be captured by only one segment of the value chain: application use and service.

Table 7 shows the estimated earnings (in billion US) per value chain stage for both the GBA base case and target case.

Table 7 Battery Value chain economic value in 2030 (Global Battery Alliance)

	Stage of the value chain	Base Case US$ billion earnings	Target case US$ billion earnings
Mining	Stage 1	2-3	3-4
Refining	Stage 1	5-8	6-11
Cell component manufacturing (active materials)	Stage 2	1-2	2-3
Cell manufacturing	Stage 3	9-16	12-20
Battery pack assembly	Stage 4	3-5	4-7
Application use and service	(Equivalent in part to) Stage 5	50-65	110-130
Recycling	Stage 6	~1	~1

Source: Developed by SOMO based on the Global Battery Alliance report A Vision for a Sustainable Battery Value Chain in 2030.[59]

In both cases, clearly the main recipients of the economic benefits are upstream multinational companies focused on mass producing Li-ion battery cells and EVs. In contrast, the earnings of recycling companies would be less than US$1 billion. Such scenarios also show that there would be an unequal distribution of economic benefits along the Li-ion battery value chain. Finally, the economic benefits for workers, communities or resource-rich countries are not even estimated.

The Global Battery Alliance is also developing a Battery Passport, which they propose will serve as a quality seal of batteries which will share relevant information about its sustainability including 'all applicable environmental, social, governance and lifecycle requirements based on a comprehensive definition of a "sustainable" battery'.[60]

2.2 Increased investments in the European battery value chain

To compete with China's grip on the value chain and to reduce dependency, Europe wants to move fast and invest hard in developing a European battery value chain. Supported by the EC and by industry players, major projects are currently underway, including plants for producing cell components and battery cells. European, Asian and North American players are investing in Europe, including giants such as LG Chem, Samsung, BASF, CATL, Daimler, VW and Tesla, among others. For this section, we will focus on cell component manufacturing and battery cell manufacturing, segments with the largest investments in Europe along the battery supply chain.

SOMO

Cell component manufacturing

Within the European battery value chain, it is relevant to highlight two companies for the production of cathodes: German company BASF and Belgian company Umicore. Given the expanding market, both companies are investing in production capacity: BASF in Finland and Germany, and Umicore in Finland and Poland.[61]

Umicore's cathode materials are primarily developed for NMC batteries, but are also used in NCA batteries.[62] Umicore has signed long-term supply agreement with LG Chem and Samsung SDI to supply NMC cathodes materials.[63]

BASF produces both NMC and NCA cathode active materials.[64]

Battery cell manufacturers

In the EV value chain, the distance between the production of battery cells and packs, and battery and car assembly plants, is important due to transportation costs and greater certainty of the supply chain. For this reason, and the size and growth of the battery market, top international battery manufacturers are committing big investments in Europe. Forecasts estimate that Europe will reach a battery capacity of 207 Gwh by 2023, which will likely be insufficient to cover regional EVs' batteries demand, expected to be around 400 Ghw by 2028.[65]

CATL is building one of Europe's largest battery cell production plant in Germany with an initial capacity of 14 GWh by 2020 and with possibility to expand to 24 GwH in the future.[66]

BYD is already producing batteries for electric buses in Hungary and France.

South Korean companies are also investing in Europe. **LG Chem** plans to increase their battery cell production in Poland from 15 GWh to 65 GWh by 2022.[67] **Samsung SDI** has been investing in increasing its battery production in Hungary since 2017. **SK Innovation** has announced significant investments to expand its battery production capacity for the EV market. It supplies Volkswagen (VW) with Li-ion battery cells in the US and it is constructing two factories in Hungary to compete in the European battery market.[68] SK Group controls SK Innovation Co., Ltd., which in turn is the second largest shareholder of Lingbao Wason, a top Chinese copper producer. Lingbao Wason also has a long-term supply contract with global EV manufacturers, including CATL.[69]

Tesla is currently building a gigafactory in Berlin calling it 'the most advanced high-volume electric vehicle production plant in the world' and with production expected for 2021.[70]

SAFT (owned by Total) and PSA Group are planning to construct two battery factories in Germany and France. Each factory would have an initial production capacity of 8 GWh, expandable to 24 GWh.[71]

In focus: Northvolt

Swedish company Northvolt, has declared two ambitious goals: 'develop the world's greenest battery cell and establish one of Europe's largest battery factories'.[72]

Northvolt is currently constructing a big plant named Northvolt Ett (meaning 'one' in Swedish) in Skellefteå close to the Arctic Circle whereby active materials will be produced, cells assembled and recycling will take place. The plant aims to be operational by 2021 producing 8 GWh per year and expanding to 32 GWh by 2024.[73] Northvolt already has a battery assembly facility located in Gdansk, Poland.

In 2019, Northvolt and Volkswagen entered a joint venture to construct a second battery factory in Germany with a capacity of 16 GwH and expected start of operation by end of 2023.[74]

By mid-2019, Northvolt had obtained $ 1 billion in equity capital to construct the plant including investments by Volkswagen and BMW.[75] Northvolt has already sold a substantial part of their expected production to car manufacturers.

Northvolt's production strategy is vertically integrated by bringing most of the value chain in-house including production of active materials, electrode manufacturing, cell assembly, module assembly (pack) and recycling. Procurement of raw materials remains to be outsourced.[76]

Summary of key players along the battery value chain investing in Europe

Confidence in the expansion of the European battery value chain has attracted manufacturers from across the globe, as summarised in Table 8 on the next page.

EIB loans, EU budget and state aid supporting the development of the European battery value chain

The European Investment Bank (EIB) is playing an important role in financing the development of the European battery industry through loans. From 2010 to 2020, the EIB financed battery projects worth €950 million and offered support of €4.7 billion of overall project costs. In 2020 alone, the EIB committed to further finance more than €1 billion euros for battery projects. Considering all the projects that have been approved or are currently being appraised, the EIB is financing a total battery production capacity of approximately 51 GWh.[77] Table 9 on page 29 shows some examples of key projects financed by the EIB.

Table 8 **Summary of Investments in the European EV Battery value chain**

Company	Location	Plant type	Production start	(Planned) Annual capacity. Different units used.
BASF	Finland	NMC precursors for cathodes	2022	For 300,000 EVs
	Germany	Cathode active materials	2022	(For 400,000 EVs)
Umicore	Finland	NMC precursors for cathodes	2020	Not available
	Poland	Cathodes	2020	
Guotai-Huarong Poland	Poland	Li-ion Electrolyte	2020	For 1 million EVs
Terrafame	Finland	NMC precursors for cathodes	2021	Not available
LG Chem	Poland	Battery cells	2018	15 GWh (expandable to 65 GWh by 2022)
Samsung SDI	Hungary	Battery cells	2018	1.2 to 4.8 million cells
		Battery cells	2030	(216 million cells)
SK Innovation	Hungary	Battery cells	2019	7.5 GWh
		Battery cells	2022	(9.8 - 16 GWh)
CATL	Germany	Battery cells	2022	14 Gwh (expandable to 24 GWh)
SAFT	France	Battery cells	2023	8 GWh (expandable to 24 GWh)
	Germany	Battery cells	2024	8 GWh (expandable to 24 GWh)
Northvolt (Ett Factory)	Sweden	Battery cells, including cathodes, electrodes, plus battery packs assembly	2021	8 GWh
			2024	(32 GWh)
Northvolt (Zwei factory) and VW joint venture	Germany	Battery cells	2024	(16 GWh)
Blackstone Resources AG	Germany	Battery cells, refinery and R&D for 3D-printing battery manufacturing.	2025	(3 GwH)
Daimler	Germany	Battery pack assembly (2 operational)	2012 - 2020	500,000 packs
		3 Battery pack assembly (3 planned)		Not available
	Poland	Battery pack assembly		Not available
Jaguar / Land Rover	United Kingdom	Battery pack assembly	2020	150,000 packs
Tesla	Germany	Battery cells, battery pack assembly and EV production	2021	(500,000 EVs)

Source: SOMO, compiled from various sources.[78]

Figure 4 Companies (planning) investing in the European EV Li-ion Battery value chain

Table 9 **Key battery projects financed by the European Investment Bank**

Date	Grantee	Amount	Project description
November 2017	Northvolt AB	€52.5 million	Construction and operation of a facility producing battery cells in Sweden
June 2020	Umicore	€125 million	Construction of facility producing cathodes in Poland
March 2020	LG Chem	€480 million	Construction of facility producing cells and batteries in Poland
July 2020	Northvolt	€350 million	Construction of a battery gigafactory in Sweden

Source: SOMO based on data from the European Investment Bank.[79]

EU budget is also being used to fund research and innovation battery projects. For example, the EU Research and Innovation programme Horizon 2020 granted €1.34 billion to projects related to energy storage and for low-carbon mobility from 2014 to 2020. In 2019, Horizon 2020 launched a further call of €114 million to fund research and innovation battery projects, which was followed by an additional call in 2020 of €132 millions.[80]

Finally, state aid is also being used to support battery-related projects in Europe. In a recent example, the EC approved €3.2 billion of state aid in seven countries to support battery projects along the entire battery value chain based on the Important Projects of Common European Interest (IPCEI) framework. Large corporations will be the recipients of such state aid, including BASF, Umicore, BMW, Varta and Enel, among others.[81] In another example, in 2020 SAFT (owned by Total) and PSA requested €1.3 billion in public funding from France, Germany and the European Union.[82]

As mentioned in Section 2.1, when it comes to supporting the battery value chain (for instance through the European Battery Alliance, EIB loans, allocation of EU budget for R&D and State-aid), the EC (and some members such as France and Germany) are shifting from an industrial policy based on open market and direct competition to a policy allowing for much greater intervention of government in supporting business investments. As state aid involves taxpayers' money, it is important that the general public is not only aware but also supportive of the allocation of these funds. In order to make an informed decision, the general public requires transparency and enough information about the incumbent projects and their implications for human rights and the environment across the entire value chain.

2.3 Strengthening of corporate alliances in the battery value chain

Increasingly, the players along the Li-ion battery value chain are forming alliances and business partnerships to guarantee long-term supply and to collaborate on research, production and sales of batteries and EVs. Car and battery manufacturers are signing long-term contracts among them and with mining companies. The following are a few key examples:

The Renault Nissan Mitsubishi alliance, dating back to 1999, collaborates in many areas including electrification and mobility services. While this alliance doesn't include battery manufacturers, they have invested jointly in emerging companies developing battery technologies.[83]

In 2018, **Geely formed a joint venture with CATL** (CATL Geely Power Battery) for 'research and development, production, and sales of batteries, battery modules, and battery packs'.[84] The following year Geely partnered with LG Chem to produce and sell batteries in China.[85]

In June 2019, **Volkswagen partnered with Northvolt** in a 50/50 joint venture in order to build a lithium battery factory in Germany with planned production for the end of 2023. In return for its investment, VW acquired 20 per cent of the shares of Northvolt and secured a spot in the Supervisory Board, evidencing the tightening of power relations among the battery value chain players.[86]

In July 2019, **Toyota and CATL** announced a 'comprehensive partnership' to collaborate beyond the supply of lithium batteries and into development of new battery technologies in addition to reuse and recycling.[87] In February 2020, Toyota and Panasonic announced a joint venture (Prime Planet Energy & Solutions, Inc.) to further develop and sell prismatic batteries for cars (not only for Toyota).[88] A month later, Toyota and BYD formed a joint venture (BYD Toyota EV Technology) to focus on research and development of EVs.[89]

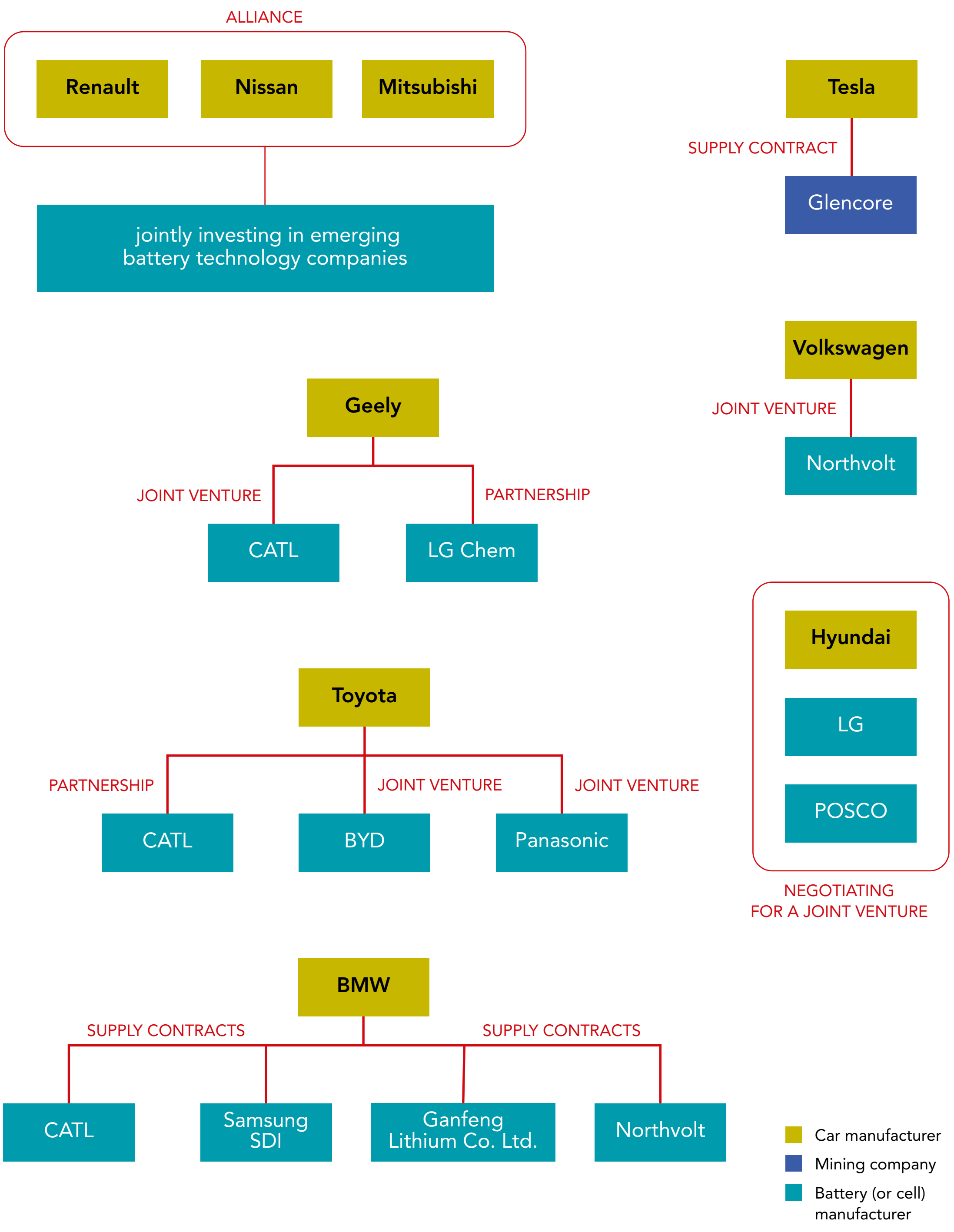
In November 2019, **BMW signed long-term supply contracts with both CATL and Samsung SDI.** BMW also announced that it will source cobalt and lithium directly from mining companies in Australia and Morocco and provide it to CATL and Samsung SDI.[90] Connected with this, BMW signed a long-term supply agreement with Ganfeng Lithium Co., Ltd. for the supply of lithium from Australia.[91] Finally, in June 2020, BMW and Northvolt signed a €2 billion long-term supply contract.[92]

In June 2020, **Tesla signed a deal with Glencore** to source cobalt for its batteries.[93] According to recent media reports, **Hyundai, LG and chemical producer POSCO** are negotiating an EV manufacturing joint venture.[94]

In early 2020, recycling company **Fortum**, **chemical producer BASF**, and the mining and refining company **Nornickel** have signed in a letter of intent to collaborate in developing a recycling facilities in Finland.[95]

Such partnerships signal that downstream companies (such as Lithium-ion battery and EV manufacturers) could set up human rights and environmental standards for suppliers in binding contractual agreements or even make their sourcing conditional on complying with such standards.

Figure 5 **Corporate alliances in the battery value chain**



3 Soaring mineral demand increases social and environmental impacts

3.1 Mineral demand predictions

There are many different predictions calculating mineral demand resulting from mass production of EV batteries. Below and in Table 11 we include predictions by the International Energy Agency, the Battery Alliance and Benchmark Mineral Intelligence that focus on forecasted mineral demand driven exclusively by batteries (and not by other technologies such as solar and wind) and within the next 10 years (which is important due to rapid technology developments).[v]

The International Energy Agency (IEA) has analysed two scenarios of predicted mineral demand for EV batteries. The IEA's *Stated Policies Scenario* is based on existing and announced policies and regulations and the IEA's *Stated Policies Scenario* is based on campaign goals whereby EV sales reach 30 per cent by 2030.[96]

According to the IEA's *Stated Policies Scenario*, demand for minerals for EVs batteries will grow as follows (2018 vs 2030): 19,000 tonnes to 180,000 tonnes for cobalt; 17,000 tonnes to 185,000 tonnes for lithium; 22,000 tonnes to 177,000 tonnes for manganese and 65,000 tonnes to 925,000 tonnes for class 1 nickel.[97]

The Global Battery Alliance also analyses two scenarios of mineral demand for EV batteries: a *base case*, based on 'unguided value chain growth', and a *target case* which aims to scale up battery production even more.[vi] Under the *base case,* from 2018 to 2030 demand for cobalt grows 2.1-fold reaching 274,000 tonnes; demand for lithium grows 6.4-fold reaching 275,972 tonnes;[vii] demand for nickel Class 1 demand grows 24-fold reaching 1,061,000 tonnes and demand for manganese grows 1.2-fold reaching 22,600 tonnes.[98]

Under the Global Battery Alliance *target case,* the demand for minerals grows 5 to 40 times more than in the base case. For the Battery Alliance, the target case represents an 'opportunity' whereby 'the mining industry needs to extract a volume equivalent to >300 Great Pyramids of Giza per year in 2030' and 'a weight equivalent to >110K Boeing 787s (Dreamliners) is refined per year'.[99]

According to Benchmark Minerals Intelligence, demand for minerals for the production of Li-ion batteries (for all applications and assuming operations at full capacity) will reach the following

v The World Bank takes a different approach and calculates mineral demand for a cluster of low-carbon technologies (solar panels, wind turbines and batteries) for 2050. However, when it comes to lithium and graphite, battery storage accounts for the entire demand in the World Bank's report. The World Bank further notes that these projections may be conservative. Kirsten Hund et al., 'Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition,' The World Bank, 2020, 112.

vi By a factor of 19 as compared to the base case.

vii 1,469,000 tonnes of lithium carbonate equivalent (LCE) equals 275,972 tonnes of lithium metal equivalent. Conversion formula: 1 kg lithium metal equivalent (LME) = 5.323 kg lithium carbonate equivalent (LCE).

quantities by 2029: 466,000 tonnes of cobalt; 484,313 tonnes of lithium[viii]; 1,849,000 tonnes of nickel and 3,591,000 tonnes of graphite.[100]

Table 10 shows a summary of the mineral demand predictions discussed above as well as the latest available production data.

Table 10 Mineral demand predictions and recent production (in tonnes)

Mineral	**Production** 2018	**IEA Stated Policies Scenario** EV batteries demand in 2030	**Global Battery Alliance** Demand for batteries in transport, energy storage and consumer electronics in 2030	**Benchmark Minerals** Demand for Li-ion batteries for all applications in 2029
Lithium	95,000	185,000	275,972	484,313
Cobalt	148,000	180,000	274,000	466,000
Manganese	18,900	177,000	22,600	379,000
Nickel	2,400,000 (all nickel)	925,000 (class I)	1,061,000 (class 1 nickel)	1,849,000
Graphite	1,120,000	–	–	3,591,000

Source: SOMO, compiled from various sources.[101]

While the above predictions differ, they all show that the mass production of EV batteries would result in a staggering rise in demand for lithium, cobalt, manganese, nickel and graphite far exceeding current production levels. This also confirms analysts' views that, over the next decade, mineral production shortages are likely to arise meaning there is not enough mineral production to satisfy forecast demand of the Li-ion battery value chain.[102] Furthermore, the price of these minerals will have a significant impact on the production costs of Li-ion cells and thus on businesses and policy ambitions pushing for mass uptake of EVs. This is particularly the case considering that the production costs of Li-ion battery cells have dropped significantly in the last decades, reaching a point whereby the price of the raw materials constitute a significant portion of its production costs.[103]

It is also important to mention that other minerals are also required to produce Li-ion batteries, such as aluminium and copper. BloombergNEF estimates that Li-ion battery demand in 2030 will result in a 10-fold increase in demand for copper and a 14-fold increase for aluminium as compared to 2019.[104]

The manufacturing of the rest of the EV, as well as the networks of charging infrastructure, will also require vast amounts of minerals. While such minerals are out of the scope of this report, copper offers an interesting example. While an internal combustion engine vehicle contains an average of 23 kg of copper, a plug-in hybrid electric vehicle contains 60 kg, a battery electric vehicle contains 83 kg, and an electric bus contains up to 369 kgs. A fast battery charger can contain up to 8 kg of copper. The Copper Alliance estimated that the EV market will increase copper demand from 185,000 tonnes in 2017 to almost 1.74 million tonnes in 2027.[105]

viii 2,578,000 tonnes of lithium carbonate equivalent (LCE) equals 484,313 tonnes of lithium metal.

These predictions exclude the amount of water and energy that is required for this tremendous amount of mining or the waste and emissions that will be generated. In the next section we will focus on the social and environmental impacts that are associated with mining of key battery minerals.

3.2 Social and environmental impacts

As discussed in the previous section, the surge of battery production leads to a substantial increase in demand for minerals. Predictions vary but they all anticipate a soaring rise in demand, which would inevitably require more mining.

It is widely documented, that mining goes hand in hand with severe and widespread social and environmental impacts.[106]

For example, the Business and Human Rights Resource Centre's Minerals tracker reports 167 allegations against 37 companies mining lithium, cobalt, copper, manganese and nickel for the transition to low-carbon technologies.[ix] The main number of allegations refer to (in descending order): environmental impacts, access to water, health impacts, indigenous peoples' rights, tax avoidance, labour rights, deaths, free, prior and informed consent (FPIC), land rights and corruption.[107]

Photo: Calma cine

ix Of those allegations, 12 are related to lithium, 50 to cobalt, 26 to nickel and six to manganese

In addition, the Environmental Justice Atlas documents hundreds of conflicts related to environmental issues of extractive projects, including cases related to lithium (14), cobalt (22), manganese (29) and nickel (54), among other minerals.[108]

The mining sector is also linked to the highest number of attacks to human rights defenders. In 2019, 25 per cent of the attacks on human rights defenders documented by the Business & Human Rights Resource Centre were related to mining.[109] From 2002 to 2019, Global Witness documented 1,939 killings of land and environmental defenders. Of the total number of killings, 367 were related to mining projects, making this sector the deadliest.[110] According to Global Witness, the root cause of such killings is often 'the imposition of damaging projects on communities without their free, prior and informed consent' and such violence is being fuelled by development banks and other investors that are 'financing abusive projects and sectors, and failing to support threatened activists.'[111]

Such extensive documentation of human rights abuses and environmental impacts related to mining raises serious concerns signalling that a mineral boom due to the mass uptake of EVs will drive an increase of such violations. Furthermore, such impacts are often being overlooked or ignored by proponents of the mass uptake of EVs. A recent systematic review of 88 peer-reviewed journal articles analysing the future demand of critical minerals found that 'little attention has been given to the social and environmental consequences that would almost certainly accompany a growth in metal demand. Most of the studies focus solely on predicting long-term demand, resulting in a lack of knowledge regarding the question, 'What are the socio-environmental implications of demand growth?' This leads to a neglect of the various risk factors that are likely to be worsened in parallel with rising metal demand.'[112]

Below we present a non-exhaustive overview of social and environmental impacts related to the key minerals needed to produce Li-ion batteries. This section relies on previous research by SOMO and other civil society organisations and experts.

Lithium

Li-ion batteries are the key driver for lithium demand, accounting for an estimated 65 per cent of the global end-use market.[113] Currently lithium is being extracted either from hard-rock minerals or from salt brines. Salt brine mining has lower costs but takes a longer time to process (8 to 18 months) compared to hard-rock mining (less than a month).[114]

Salt brine deposits are bodies of saline groundwater rich in dissolved lithium and other minerals. Brine is pumped out to the surface and then evaporated in a series of ponds resulting in lithium carbonate. Only highly concentrated brines are economically viable for mining, such as the ones in Chile and Argentina, which are the world's major producers of lithium from salt brines.

Spodumene is a mineral that contains lithium and is formed as crystals hosted by igneous rocks (pegmatites). The hard-rock ore containing lithium is extracted from underground or open-pit mines through conventional mining operations and then crushed and separated to produce a lithium concentrate. Such lithium concentrate is then converted into lithium-based chemicals through a process that involves acid leaching. Australia is the world's major producer of lithium concentrates from spodumene.

Since 2017, hard-rock production exceeded brine production as Australia tripled its production. Australia became the world's biggest producer, displacing Chile and Argentina to second and third place respectively.[115]

Chemical processing companies convert lithium carbonate, either from salt brines or from spodumene, into lithium hydroxide, which is used to produce cathodes for batteries.[x] Lithium production is highly concentrated by a few companies, the biggest of which (by market capitalisation) are Jianxi Ganfeng Lithium, Tianqi Lithium, Allbemarle, SQM and Livent.[116]

In 2018, most of world's lithium production came from six hard-rock mines in Australia; four brine operations in the lithium triangle (two in Argentina and two in Chile) and one hard rock and one mineral mine in China (see Table 2).[117]

Impacts

Lithium extraction in South America has been linked to negative impacts on water, indigenous rights and local communities' traditional livelihoods. While salt brines are located in water-scarce areas, lithium mining requires vast amounts of water being pumped out. Impacts to the water balance of the basin and salinisation of freshwater are major concerns.

In Argentina, research by **Fundación Ambiente y Recursos Naturales** (FARN) showed that communities were poorly informed about the potential impacts and haven't been meaningfully engaged during consultations. Furthermore, according to the study, the State has been absent during company-led consultations and has failed to provide sufficient information to local communities. Often the only information available is that produced by the mining companies, which have a vested interest in obtaining the social licence to operate. There is also a lack of understanding of cumulative impacts, a serious concern considering the large number of projects under development.[118]

In Chile, lithium mining operations have affected the rights and livelihoods of indigenous communities (including the Lickanantay people) with violations to self-determination, FPIC, land and water rights. The high intensity of water use has affected the water basins and the availability of the resource for human consumption.

According to a recent report, for the production of lithium in Chile, Albemarle extracts brine at a rate of 442 liters per second and freshwater at 23 liters per second. While SQM extracts brine at 1700 litres per second and freshwater at 450 litres per second. Those two lithium mining companies together with 2 copper mining companies (Minera Escondida owned by BHP Billiton and Compañía Minera Zaldívar) extract together 4,230 litres of fresh water per second, resulting in a hydrological stress for the Atacama salt flats. The report also highlights that, in 2016, Chilean authorities warned that 70 per cent of the country's water was used for mining operations and 17 per cent for the agricultural sector, leaving only 13 per cent for human consumption.[119]

x Both lithium carbonate and lithium hydroxide are used for batteries.

In the spotlight: Olaroz – Cauchari, Argentina (Research conducted by FARN)
Lithium: Argentina – Right to Water, Community rights violations

Context: 21 per cent of the world's lithium resources are located in Argentina, which accounted for 7 per cent of global production in 2018.[120] In Argentina there are more than 40 projects in different phases. Government officials have welcomed the lithium boom with little attention to the social and environmental impacts.

In 2019, FARN published a study on two of the most advanced lithium projects in Argentina located in Olaroz-Cauchari salt flat (4,300 metres above sea level) – a fragile ecosystem, home to 10 indigenous Atacama communities since ancestral times. It is a place with a lack of fresh water resources to meet local demand. The study found serious concerns of local communities with regard to lithium mining in connection with FPIC rights, water and environmental risks, and power asymmetries.

FPIC and meaningful engagement: The study found that community members did not know the mining project details or their implications, and that communications from the company tend to be one-sided and difficult to understand. The good faith of companies is questioned by respondents as company representatives only present positive impacts and deny any risks to water or the environment. Information about risk factors and environmental impacts is not disclosed. Information has not been presented in a suitable timeframe and in a way that is understandable to the local communities. In contrast, it tends to be lengthy and technical.

According to the interviews conducted in the study:

- 83 per cent expressed that the information provided by the companies was too technical or too lengthy.
- 85 per cent were not consulted about how they wanted to receive information.
- 30 per cent did not received information from the mining companies.

Water and environmental concerns: Communities are highly concerned about the impact of mining on water resources and the lack of feasible risk studies. Some community members have reported lower water levels. Experts agree that there are crucial information gaps to properly assess the impacts of lithium mining in the area. Experts warn of the potential salinisation of fresh water of the aquifers. There is a total lack of cumulative impact assessments analysing the different mining operations, a serious concern considering that water basins may have subterranean links. The study found a serious lack of available hydrological studies for authorities to assess the environmental impacts of lithium mining in Argentina.

FARN cites a member of the National Ombudsman's Office who stated that 'neither provincial nor national authorities have conducted hydrological studies, or carried out superficial or underground water monitoring. In addition, they have not identified areas in which salt and fresh water co-exist, nor have they calculated the hydrological balance of the watersheds in the area. The only information available is that provided by companies and there is no baseline that can be used as a reference to identify eventual modifications in the environment.'[121]

Power asymmetries: While it is a State responsibility to implement the FPIC process and protect communities' participation rights, both the provincial and the national authorities have been absent during the whole engagement process. This has generated power asymmetries whereby the companies can negotiate directly with communities using their economic power and their privately generated information.

Source: FARN, 2019, 'Lithium extraction in Argentina: a case study on the social and environmental impacts.'[122]

Cobalt

Cobalt is used to manufacture many different products. However, more than 60 per cent of cobalt is used for producing lithium batteries.[123] Even though some manufacturers are exploring battery chemistries with less cobalt content, demand is still predicted to rise sharply in the upcoming years. See the projections in Chapter 3.1.

Approximately 70 per cent of the global cobalt production is now mined in DRC, where half of the world's resources are located. The largest cobalt producers in terms of both market capitalisation and production volume are: Glencore, China Molybdenum, Vale and Gecamines.[124]

Impacts
Both large-scale mining and artisanal mining of cobalt in DRC has been extensively linked to widespread, grave and systematic human rights violations and environmental impacts. Large-scale mining leads to recurrent violations including pollution, exposure of workers and communities to toxics, sub-standard health and safety conditions, contributing to community conflicts and abuses by security personnel. Artisanal mining in turn, which accounts for 20 to 30 per cent of production, often involves working under dangerous and unhealthy conditions, child labour and unfair compensation.[125]

Miners and local communities face exposure to toxic metals and pollution derived from cobalt mining. Research has documented the pollution of rivers due to mine discharges as well as community exposure to noise, water and air pollution.[126] In a forthcoming report of African Resources Watch (Afrewatch) and PremiCongo, information is provided on soil and water contamination caused by cobalt mining, on the basis of analyses of water and soil samples.[127] Exposure to dust containing cobalt particles is a cause of a severe lung disease (hard metal lung disease). Although cobalt is a normal part of a person's intake (vitamin B12) and occurs naturally in the environment, too much intake may affect the heart and the thyroid, cause asthma and skin issues. A recent medical study published in the *Lancet* has linked birth defects to toxic pollution in Southern Katanga.[128]

Child labour in cobalt mining has been extensively documented. When mining is carried out by children, it is considered one of the worst forms of child labour. Amnesty International and Afrewatch documented children as young as seven working up to 12 hours, with no protective equipment at all and carrying heavy loads in a research report in 2016.[129] Children are further exploited financially and physically abused, including beatings and other forms of violence. A recent class action by International Rights Advocates claims that children mining cobalt have died and been maimed while multinationals (Apple, Google, Dell, Microsoft and Tesla) have allegedly aided, abetted and benefitted from the situation.[130]

Eviction of communities and loss of livelihoods have been documented as a consequence of the vast amounts of land and water used by mining operations. In some cases, communities are resettled to areas without arable land or without water.[131]

Communities and artisanal miners report cases of excessive use of force by the DRC army and by public and private security guards. For example, in June 2019 armed groups evicted artisanal miners from the Tenke Fungurume Mine, property of China Molybdenum Company Limited (CMOC). Amnesty's press release on the issue state that 'According to African Resources Watch (Afrewatch) and media reports, local residents said that soldiers destroyed housing and shelters in two villages, which could amount to forced evictions contrary to international law. Afrewatch also reported that soldiers had fired shots to disperse artisanal miners, and said it had received reports of casualties.'[132]

Poor health and safety conditions is a serious issue in cobalt mining and includes a lack of basic protective equipment (facemasks, gloves, clothes), poor ventilation at mines and dangerous structures that lead to health incidents and accidents. Local media has reported many fatal accidents at unregulated artisanal mines resulting from poor construction or dangerous mining practices.[133] For instance, in June 2019 in Kolwezi at least 47 miners were killed due to the collapse of a tunnel at a mine operated by Glencore.[134] Furthermore, with no real bargaining power and a lack of sufficient information, miners receive unfair compensation for their work and are not able to negotiate for proper pay with traders.

As the government and large-scale operators have failed to create enough safe and regulated Artisanal Mining Zones, some artisanal miners are compelled to trespass on industrial sites or work on unsafe and unregulated areas with no safety measures.[135]

More than two thirds of the population in DRC earns less than US$1.90 a day, making it one of the poorest countries in the world – in stark contrast with the multinationals producing batteries, electronics and automobiles.[136] In 2017, Amnesty International concluded that such companies have failed to take adequate steps to mitigate human rights abuses and remediate harm in their cobalt supply chain.[137]

Nickel

Nickel is a key metal for two of the most popular EV battery chemistries: NCA and NMC. Nickel is likely to become even more important in the future as chemistries move away from cobalt.

Nickel 'is a naturally occurring, lustrous, silvery-white metallic element. It is the fifth most common element on earth and occurs extensively in the earth's crust, although most nickel is inaccessible in the core of the earth. Nickel does not occur in nature by itself but it is associated with cobalt or as an alloy with copper, zinc, iron or arsenic. It occurs in nature principally as oxides (laterites), sulphides and silicates.'[138] Nickel is predominantly mined in Indonesia (25 per cent), Philippines (14 per cent), Russia (14 per cent), New Caledonia (9 per cent), Canada (7 per cent), (see Table 2).[139]

The top nickel producers in 2019 were Tsingshan Group, Norilsk Nickel (Nornickel), Vale, Glencore, Delong and Jinchuan.[140]

Impacts
Nickel mining is having enormous social and environmental impacts. The impacts of open-pit nickel mining include: water pollution, damage to forests, land erosion (which further increases the risk of floods) and biodiversity loss.

Nickel mining is also affecting the health of workers and communities around the world. According to Greenpeace Research Laboratories, 'the mining of nickel-rich ores themselves, combined with their crushing and transportation by conveyor belt, truck or train, can generate high loadings of dust in the air, dust that itself contains high concentrations of potentially toxic metals, including nickel itself, copper, cobalt and chromium.'[141]

Nickel 'at high concentrations poses a respiratory health hazard likely to cause cancer and is also known to cause asthma, lung diseases, dermatitis and sensitivity in some people.'[142] Nickel sub-sulphide and oxidic nickel are the particular compounds related to respiratory cancer.

Indonesia has become the global leader in nickel production, including high grade nickel for EV batteries. The boom of nickel mining in Indonesia is exacerbating conflict and violence. The root of such conflict is related, in many cases, to concerns from local fisherfolk and farmers about environmental impacts affecting their life, health and livelihoods.[143]

A recent ban on exports of raw ores by the Indonesian government has resulted in a further concentration of economic power on a few mining companies with enough capital to either own or invest in local smelters as well as in an increase in foreign direct investment (mainly Chinese).[144] The Indonesia Morowali Industrial Park (IMIP) in Sulawesi has become the central hub of nickel processing and smelting. However, nickel is also mined in other locations and provinces. The IMIP project is owned by a Chinese-Indonesia joint venture between Shangai Decent Investment Group Co, Ltd. (part of the Tsingshan Group) and Indonesia PT Bintangdelapan Group and received financing from the China Development Bank and the Export Import Bank.[145] A recent report reviewing working conditions at the IMIP industrial complex identified serious labour issues including a lack of collective labour agreements, coerced resignations, insufficient wages to satisfy basic needs and serious health and safety concerns and accidents that have resulted in deaths, fatigue and anxiety.[146]

In Wawonii, Sulawesi farmers and fisherfolk are protesting due to the impacts of nickel mining on the forest and the sea affecting their daily subsistence and traditional livelihoods. In Obi, Makalu fisherfolk and farmers claim that the coastal waters have been polluted by nickel mining.[147]

It is also important to note that production of Nickel is energy intensive, generates high greenhouse gas emissions and produces large amounts of toxic waste.[148] The smelting of nickel in Indonesia, powered by coal plants, causes air pollution, which increase the risks of respiratory infections and pulmonary tuberculosis, among other diseases.[149]

Recently, mining companies in Indonesia asked for permission to dump their waste into the sea, in one of the most biodiverse areas of the world.[150] Such practices of dumping nickel mining waste into the sea is done in neighbouring Papua New Guinea. In 2019, a spill by Metallurgical Corporation of China turned a bay red, affecting marine life.[151]

The devastating impacts of nickel pollution can be seen in other countries as well. Norilsk, in northern Siberia, has been rated as one of the world's most polluted cities.[152] Norilsk's locals have been exposed to air pollution containing heavy metals, sulphur dioxide and other particles due to nickel and copper mining. This exposure has caused respiratory diseases as well as lung and digestive system cancers. The soil too has been heavily polluted with copper and nickel.

The company Norilsk Mining has been heavily criticised for damaging the Artic by its mining, oil and gas operations. In May 2020, the company was responsible for a major environmental disaster whereby 21,000 tonnes of diesel spilled into a river in Siberia, threatening the Artic environment.[153] Despite Norilsk Nickel's operations in the Arctic and causing a serious environmental disaster, major investors such as ING and ABP have continued investing in the company. As a result, they have been subjected to a campaign by Fair Finance Guide Netherlands 'calling for an end to all investments in companies that exploit raw materials in the Arctic, especially mining, oil and gas companies, and for Norilsk Nickel to repair all the environmental damage caused by the oil spill'.[154]

In the Philippines, in the province of Zambales, nickel mining operations have resulted in water pollution. Nickel laterite – a nickel oxide – has contaminated water sources and spilled up to 30-nautical miles offshore. Land, river channels and coastal waters have been polluted by nickel laterite, affecting rice paddies, rivers and fishponds.[155] The commune has been losing millions of dollars in income due to the impact of nickel mining on agriculture (i.e. mango and rice) and fishing. Large areas of land have become infertile.

In another region, on the island of Palawan, acid drainage has polluted soil and water, resulting in biodiversity loss, including a reduction of fish consumed by the communities. Nickel mining there has also affected the health of workers and communities and led to displacement of communities.[156]

Graphite

Graphite is used for producing the negative electrodes in Li-ion batteries. According to analysts, lithium batteries account for around 25 per cent of global demand for natural flake graphite.[157] Significant quantities of graphite are required in EV batteries, much more than any of the other minerals. According to several sources, an EV lithium battery uses between 1 and 1.2 kg of graphite per GWH.[158] Both natural and artificial graphite can be used to produce batteries. However, manufacturers natural graphite has been preferred by manufacturers due to lower costs.[159]

Natural graphite production is dominated by China, with more than 60 per cent, followed by Mozambique with 9 per cent and Brazil with 8 per cent (see also Table 2).[160] In the past, the low cost of Chinese graphite has discouraged mining elsewhere. However, with demand soaring, new graphite mining projects are being developed in countries including Mozambique, Madagascar and Namibia.

In Cabo Delgado province in Mozambique, which hosts high-grade deposits, Australian mining companies Triton Minerals, Mustang Resources, Battery Minerals and Syrah Resources all have investment plans or ongoing projects.[161] As an example, Triton Minerals has formed a strategic partnership with the Chinese state-owned enterprise Jinan Hi-Tech group to begin construction of the Ancuabe Graphite Project in 2020.[162]

Impacts
There is little information available on the impact of graphite mining in different parts of the world. In 2016, the *Washington Post* visited mining sites at five towns in China. Graphite mining in China has led to severe pollution affecting air, water and the crops of local communities. Polluted air affects workers and communities who are suffering an increase in respiratory problems and their water has become undrinkable.[163] Exposure to graphite dust can cause serious diseases such as lung fibrosis, occupational pneumoconiosis and heart failure.[164]

Manganese

The primary use of manganese is in steel production (which accounts for about 90 per cent of annual manganese demand), aluminium production and copper production.[165]

In the field of rechargeable Li-ion batteries, the use of manganese is increasing due to its high-energy capacity, low costs and increasing stability. In rechargeable lithium batteries. manganese can be used either as an oxide or as a sulphate, depending on the battery's chemistry.

For batteries, manganese is increasingly used in the form of manganese sulphate monohydrate (MSM). High purity MSM (HPMSM) can be made from manganese ore or from high-purity electrolytic manganese metal (EMM).

As NMC batteries dominate the market of EVs, demand for high-purity manganese metal and high-purity manganese sulphate is expected to increase substantially.[166]

Most of the world's manganese is produced by just a few countries: South Africa (31 per cent), Australia (18 per cent), Gabon (12 per cent) (see also Table 2)[167]

Impacts
Manganese is the 12th most abundant element on earth and occurs naturally in rocks, soil, water and foods. Exposure to manganese, an essential nutrient in small doses, occurs via water, air, soil and food.

Mining activities and production of steel are the main sources of anthropogenic manganese pollution. Mining and processing manganese ores pose occupational risks, such as chronic manganese poisoning.[168] 'The high toxicity of manganese has been well documented from numerous studies performed on workers in the mining, welding, and ferroalloy industries, and in other occupational settings with a high level of manganese exposure'.[169]

The most common occupational illnesses due to manganese exposure 'involve the nervous system. These health effects include behavioral changes and other nervous system effects, which include movements that may become slow and clumsy. This combination of symptoms when sufficiently severe is referred to as "manganism".'[170]

Other health impacts resulting from chronic manganese exposure include impaired motor skills (such as slowed hand movements), deficient cognitive performance, lung irritation (leading to pneumonia in some cases) and loss of sex drive.[171]

Studies focused on children living in areas with high manganese exposure have found impacts on brain development, behavioural change and cognitive deficits.[172] A study conducted in Ukraine found significantly higher levels of impaired growth and skeletal deformities in children living in manganese mining regions.[173]

In South Africa, mining-affected communities have associated manganese mining with air pollution, environmental damage and health issues. Furthermore, women in South Africa reported experiencing gender-based violence in connection with the development of mines as well as not benefiting from the projects.[174] One of the main concerns of the Maremane community in South Africa was the dust resulting from mining operations, which in turn results in health impacts. Other claims by the local communities included the lack of consultation, environmental damage, access to safe water, pollution of water, noise and health issues.[175]

Manganese toxicity can also significantly affect the growth of crops on certain types of soils.
It is clear from the above examples that mining for all of the key minerals required for batteries has been previously associated with serious and widespread social and environmental impacts.
A mobility transition based on increased mining raises serious concerns regarding the risk of increasing and exacerbating such impacts.

4 Strategies to address the social and environmental impacts of EVs and the battery value chain

In the previous chapters, it has become clear that – when it comes to passenger road transport – the main proposed solution addressing the climate emergency focuses on mass adoption of EVs powered by batteries. This solution is particularly supported by industry along the battery value chain as well as by governments from the global north. Initiatives such as the Global Battery Alliance are pushing to further scale up the production and consumption of EVs. Governments in the EU, the US and China are incentivising the mass adoption of EVs, often backed with public money in the form of subsidies, tax incentives and public loans. These initiatives portray EVs as a per se green technology that will contribute to saving us from environmental collapse.

However, and as discussed in Chapter 2, the mass uptake of EVs as currently forecast by the International Energy Agency (IEA), the Battery Alliance and expert analysts will result in an unprecedented and dramatic increase in raw material extraction. This raises serious concerns, particularly for mining-affected communities and the rural areas where mining often takes place. Concerns are based on copious evidence, such as that discussed in Chapter 3, documenting that mining is one of the deadliest and most polluting industries in the world and is often associated with severe and widespread social and environmental impacts.

Besides requiring soaring amounts of minerals, the Li-ion battery value chain (from mining to manufacturing to recycling) also requires vast amounts of water and energy and generates carbon emissions and waste. Existing life-cycle impact analysis of Li-ion battery production have a myopic focus on CO_2 emissions, neglecting impacts on other important factors such as water, land and biodiversity. A recent study by the International Resource Panel found that '90 per cent of biodiversity loss and water stress are caused by resource extraction and processing'.[176]

Furthermore, despite electrification, the total number of vehicles on the road is predicted to continue growing. BloombergNEF predicts that the total vehicle fleet will grow from 1.2 billion units in 2020 to 1.4 billion in 2030 and reach 1.6 billion in 2040. From the predicted fleet of 1.6 billion units in 2040, still around 1.1 billion units are internal combustion (ICE) passenger vehicles, which is the same number of ICE units as in 2015.[177] That would mean that, after more than 25 years, the total amount of polluting ICE cars will not be reduced.

Mass adoption of EVs is, however, not the only solution when it comes to addressing the climate emergency resulting from passenger road transport. A growing body of scientific evidence shows that mitigating environmental impacts and reaching sustainability goals cannot be achieved without reducing the total amount of raw materials and energy (throughput) that go into production and consumption.[178]

In this chapter we focus on identifying other existing strategies to address the social and environmental impacts of passenger road transport besides the mass uptake of EVs. The identification of alternative strategies and perspectives is not exhaustive but rather exploratory with the aim of informing public debate about the existence of different views and interests that needs to be considered in policy and political discussions.

The strategies discussed pertain to reduction of private passenger cars, material efficiency (including design, recycling and product lifetime extension) and environmental justice.

4.1 Reducing mineral and energy demand by having fewer cars on the road

The production of Li-ion batteries requires minerals, water and energy and generates greenhouse gas emissions. The more the material and energy throughput (driven by the amount and size of Li-ion batteries), the larger the generated waste and emissions. Hence the importance of reducing the amount (and size) of Li-ion batteries and cars on the road.

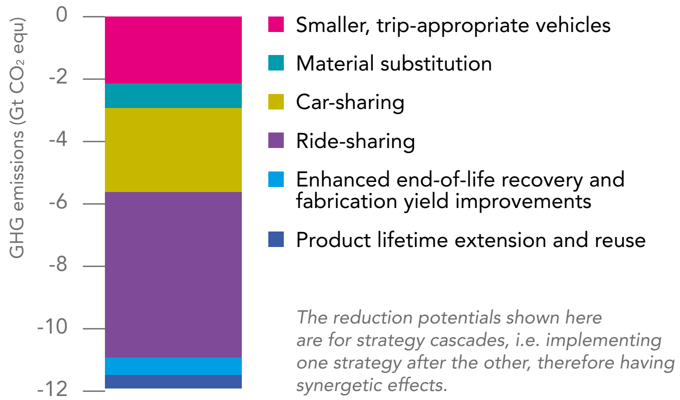
In 2018, IPCC scientists released the report *A Low Energy Demand Scenario for Meeting the 1.5°C Target and Sustainable Development Goals without Negative Emission Technologies*. The Low Energy Demand Scenario (LED scenario), besides looking at increasing the use of goods and material efficiency in general, specifically analyses the mobility sector, proposing a move from private ownership towards 'usership' and car sharing. According to the LED scenario analysis, 'Increasing vehicle occupancy by 25% and vehicle usage per day by 75% delivers the same intra-urban mobility with 50% of the vehicle fleet.'[179] This would allow the halving of the total number of light duty vehicles by 2050 to approximately 850 million. Furthermore, under the LED scenario, end-use energy demand is reduced by 40 per cent by 2050 through a series of measures including industry reducing its material outputs by 20 per cent.[xi]

Using fewer cars to provide the same service would require fewer batteries and thus reduce the minerals and energy demand and their related negative environmental impacts such as carbon emissions and mining-related pollution.

Furthermore, in a recent report, the International Resource Panel (IRP) concluded that ride-sharing, car-sharing and using smaller vehicles contribute the most to reducing life-cycle emissions of passenger cars, as can be seen in Figure 3.[180] Importantly, such strategies reduce both material and energy demand for passenger cars.

xi The scenario aptly differentiates between the global north, which would need to reduce the production of material goods by 42 per cent, and the south, by 12 per cent. A novelty of the LED scenario is that it shows that the ambitious 1.5°C target could be achieved by reducing the material throughput that goes into the economy without assuming future 'negative emissions technologies', which are controversial and speculative in terms of viability, scale and CO_2 storage capacity.

Figure 3 **Material efficiency strategies to reduce GHG emissions**



Source: IRP (2020). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future.

Finally, degrowth theory that calls for a profound transformation of society and the economy puts emphasis on a planned scaling down of the energy and material throughput of the economy (production and consumption), especially of especially of high-income countries and consumers, with the goal of increasing well-being and enhancing ecological conditions.[181]

4.2 Material efficiency strategies (design, recycling and product lifetime extension)

In the above-mentioned report on resource efficiency and climate, the IRP assess the potential of material efficiency strategies to reduce the greenhouse gas emissions of passenger cars. As used by the IRP, material efficiency refers to using fewer materials to obtain the same level of well-being for society. Material efficiency is measured by the 'amount of service obtained per unit of material use'.[182]

The IRP analysed the following material efficiency strategies: using less material by design (designing smaller vehicles), material substitution, fabrication yield improvements and more intensive use of material (including ride-sharing and car-sharing), enhanced end-of life recovery and recycling and product lifetime extension.

Designing smaller vehicles and batteries results in a straightforward strategy to reduce minerals and energy consumption. In this vein, the IRP report concluded that, besides a shift from private ownership to ride- and car- share, the design of vehicles is a 'key point of leverage' because it 'determines how much material they use, the energy used in their manufacturing and operations, their durability, and their ease of reuse and recycling'.[183]

The design of the Li-ion battery is very important for recycling. In particular the design of the cells and the battery pack can influence the ease of recycling as well as determining the most suitable recycling strategy. For example, if a battery module is difficult to disassemble and open then the cells can't be easily accessed and the only option is to use a pyrometallurgy recycling process, which requires high energy and is expensive and not efficient in recovering all active materials.[184]

Therefore, it is important that Li-ion batteries' design is adapted towards easy dismantling as 'the design of current battery packs is not optimized for easy disassembly… Many of the challenges this presents to remanufacture, re-use and recycling could be addressed if considered early in the design process.'[185]

Manufacturers use different technical specifications to produce their batteries. The current wide array of cathode chemistries (i.e. NCA, LFO, NMC), forms of battery cells (i.e. cylindrical, prismatic, pouch), fixings and the ways cells are clustered in modules makes it very difficult to standardise recycling processes and improve recycling efficiency.[186]

Another constraint limiting recycling is the lack of proper labelling of the different chemistries of all battery components, including the anode, cathode and electrolyte. Without proper labelling recyclers are unable to determine the battery health, its components and the safety guidelines for disassembling and recycling.

From the above, it follows that the standardisation of cells, modules and packs would facilitate and increase recycling rates and efficiency. For example, the standardisation of lead-acid batteries has resulted in simple recycling and disassembling processes, which reduces cost and increases recycling rates and recovery.[187] Rules mandating manufacturers to take back end-of-life Li-ion batteries, through an extended producer responsibility scheme, could also incentivise them to standardise battery design.[188]

In addition, more attention is required for improving collection and recycling rates as well as the recovery rates of minerals. According to an IISD report 'less than 5 per cent of Li-ion end-of-life batteries are recycled today' while 'approximately 99 per cent of lead-based car batteries are collected and recycled in North America and Europe, making them the most recycled of any major consumer product'.[189]

Recycling of minerals is a strategy with important potential to reduce primary demand for the production of batteries. A report prepared by the Institute for Sustainable Futures analysed the role of material efficiency, substitution and recycling in reducing primary demand for EVs and battery storage. The report concluded that 'Recycling of metals from end-of-life batteries was found to have the greatest opportunity to reduce primary demand for battery metals, including cobalt, lithium, nickel and manganese.'[190]

It is important to notice, however, that while recycling can reduce primary demand of minerals, it will not be enough to satisfy predicted demand and there will be a delay in recycled minerals becoming available.

Finally, developing more efficient recycling processes is essential to reduce the impacts of recycling itself. According to life-cycle studies, 'the application of current recycling processes to the present generation of electric-vehicle LIBs may not in all cases result in reductions in greenhouse gas emissions compared to primary production.'[191] Another scientific peer-reviewed study found that the recycling of lithium from batteries with the current technology could result in up to 45 per cent more energy consumption and 16-20 per cent higher emissions than primary production.[192]

Also longer battery life results in less battery consumption and thus less energy and mineral demand. It is important that policy-makers introduce binding rules mandating extended producer responsibility for battery and car manufacturers. Such rules need to be clear in assigning financial and material responsibility to the producers, including for cases of repurposing of batteries for second use and that regulate for cases of future bankruptcy of producers. Legal requirements, establishing high collection rates for batteries as well as high recovery rates, are important to accelerate recycling. In the EU, the Battery Directive only requires the recycling of 50 per cent of the weight of a Li-ion battery without distinguishing which raw materials are recovered or the resulting implications of recycling on the environment.[193] An improvement to the EU Battery Directive could set up higher recycling rates and introduce material-specific targets.[194]

4.3 Environmental justice perspectives

There is a different vision around how to address the social and environmental impacts of passenger road transportation from organisations in both the south and north. Communities, activists, civil society, researchers and environmental organisations offer different views on the impacts that would result from mass uptake of EVs and present alternative solutions to address the climate emergency. Such visions are based on different conceptual frameworks such as environmental justice, the right to say no to mining, democratic decision-making and democratic-owned energy systems, human rights, buen vivir.[xii]

In the lithium triangle, the Plurinational Observatory of Andean Salt Flats brings together indigenous communities, environmental experts, academics and civil society organisations from Argentina, Chile and Bolivia with the goal of protecting the salt flats, and its ecosystems and local communities, from the lithium mining that is rocketing due to battery demand.[195] They are very critical about the EV 'green transition', which in their view is having profound negative impacts on local communities and peasants and is creating environmental 'sacrifice zones'. The Observatory calls for a public debate to discuss alternatives to tackling the climate crisis based on principles of environmental justice, democratic decision-making, buen vivir and human rights.[196] In the words of one of the Observatory's

wxii There is no single definition for buen vivir. The term offers a platform for alternative visions of development having its roots in indigenous traditions in Latin America. Buen vivir focuses on achieving a good life in community, including nature. Eduardo Gudynas, 'Buen Vivir: Today's Tomorrow,' *Development* 54 (December 1, 2011), https://doi.org/10.1057/dev.2011.86.

founders, 'this vision would allow us to value communities and ecosystems, not as sources of mineral resources, but rather for the wealth of their communal knowledge and biodiversity, thinking of the regeneration of our relationship with water and nature as the starting point for a different transition.'[197]

The Eco Social Pact, which has been signed by more than 60 organisations from different Latin American countries and many individuals, is calling for a socio-ecological transition to an orderly phase out not only of oil and gas but also of mining and supports a shift to 'energy systems that are decentralized, de-commodified and democratic, as well as collective, safe and good quality transportation models'.[198]

In the US, the Climate Justice Alliance encompassing more than 70 rural and community based organisations from the climate movement, including a few international organisations, have developed a set of just transition principles to 'shift from an extractive economy to a regenerative economy'.[199] According to the Climate Justice Alliance, a just transition involves a 'set of principles, processes, and practices that build economic and political power to shift from an extractive economy to a regenerative economy. This means approaching production and consumption cycles holistically and waste-free. The transition itself must be just and equitable; redressing past harms and creating new relationships of power for the future through reparations.'[200] Their principles are based on environmental justice perspectives such as buen vivir, regenerative ecological economics, self-determination, equitable redistribution of resources and power, to name a few.

Also in Europe, where more mining is also being promoted as part of the continent's strategy on raw materials, environmentalist groups and affected communities are opposing and raising concerns.[201] The European Environmental Bureau (EEB), a network of European environmental organisations, has warned that the EC's raw material strategy is a 'double-edged sword' and calls for properly assessing its social and environmental impacts. The EEB argues that Europe's raw materials strategy should rather focus on 'reducing the use of limited resources and avoiding environmental disasters often linked to mining such as deadly pollution, water shortages and the displacement of people'.[202]

Recently, in reaction to the EC Critical Raw Materials strategy, more than 230 civil society organisations and academics expressed their deep concern to the EC raw materials strategy and called to 'make absolute EU Resource use reduction a priority', 'Respect EU communities' Right to Say No to mining projects' and 'End exploitation of third countries, particularly in the Global South, and effectively protect human rights' and 'Protection of "new frontiers"' (such as deep sea mining).[203]

The previous examples were discussed in order to show that different groups and movements are uniting across borders and calling for profound transformations to address the climate emergency – transformations that go beyond a mere change of vehicle technology. Such proposals call for a profound social and ecological transformation involving consumption, production, business models and people's relationship with natural resources. Such examples are by no means comprehensive but rather are mentioned to highlight the need for a more inclusive and profound debate on the available solutions to address the impacts of passenger road transportation, which includes the perspectives of those most affected by mining. Further research and debate is needed to assess the impacts, influence, potential and viability of such proposals.

5 Conclusions and recommendations

The aim of this paper was to discuss the social and environmental implications resulting from a mass uptake of EVs. Extensive documentation shows that the social and environmental impacts associated with the mining of key minerals (lithium, cobalt, nickel, graphite and manganese) for producing Li-ion batteries are severe and widespread. The mass uptake of EVs would result in more mining and would thus increase such impacts, which raises serious social and environmental concerns of transitioning from a dependency on oil to a dependency on minerals for mobility.

These impacts are already affecting regions and communities where mining is increasing. It is important to note that mining for such key minerals tends to be concentrated in a few countries and regions. For instance, DRC, Australia and China each produce more than 60 per cent of cobalt, lithium and graphite, respectively. A third of manganese is produced in South Africa while a quarter of nickel comes from Indonesia.

In reviewing the battery value chain, we found that Asian players dominate the manufacturing of both cell components and battery cells, whereby Chinese companies in particular are the undisputed leaders. Chinese companies produce more than 60 per cent of the cathodes, more than 80 per cent of the anodes and more than 70 per cent of battery cells. Furthermore, four of the five largest Li-ion battery factories are located in China. Looking into the future, more than 110 new battery mega factories are planned around the world, mostly in China but also a considerable number in Europe.

At the final stage of the value chain, recycling of batteries remains severely limited due to several factors such as costs, differences in battery types, Li-ion battery design, lack of stock of end-of-life EV Li-ion batteries and limited recycling infrastructure, among other reasons.

As EVs gain market penetration, a significant number of Li-ion batteries will reach end-of-life in the decades to come. An important concern is that battery manufacturers are currently not designing Li-ion batteries to optimise recycling. Current differences in the design of Li-ion battery's cells, modules and packs hinder recycling efficiency. Packs are not easy to disassemble, and cells are not easy to separate for recycling. Standardisation of cell design and chemistry would facilitate recycling and also enable a more efficient, ample and higher purity recovery of raw materials. Proper labelling of Li-ion battery components and improvements towards easy module disassembly and cell separation are also beneficial towards improving recycling.

Policy and regulations aiming to reduce the social and environmental impacts of mining, and fostering a circular economy, should put greater emphasis on mandating the standardisation and proper labelling of Li-ion batteries and their components. Regulations requiring manufacturers to take back end-of-life Li-ion batteries could incentivise manufacturers towards standardising and push them to design Li-ion batteries with recycling as a priority and thus relieve pressure for primary demand of minerals.

The review of the Li-ion battery value chain shows that the key players pushing for the mass adoption of EVs are primarily businesses, governments in the US, Europe and China, the ECs as well as partnerships with a strong corporate presence. The European Battery Alliance and the Global Battery Alliance are the two most important public-private partnerships at European and global level, respectively, striving towards an EV boom. For both alliances, the expected market value (and potential profits) of the Li-ion battery value chain is a key motivator of their efforts to scale up Li-ion battery production and the mass uptake of EVs. The GBA predictions of the Li-ion value chain economic value shows clearly that the expected economic benefits would be unequally distributed among the different segments of the value chain favouring upstream companies, predominantly favouring those businesses engaged with application use (i.e. EV manufacturers) and cell manufacturing.

Corporate players pushing for mass uptake of EVs, as well as the battery alliances, omit to explore other solutions to address the impacts of passenger road transport that reduce the total number of vehicles on the roads and thus require less minerals and energy. Multinationals are investing heavily in Europe to develop a Li-ion battery value chain, which leads to a now vested interest in the mass uptake of EV passenger cars These companies are likely to support a system that locks society in a transport system where individual car ownership is central.

Policy measures in different countries and at the EU level are playing a decisive role in incentivising the EV boom, often accompanied with public spending. In Europe, the declaration of the battery as strategic by the EC is accompanied by an important change in industrial policy, which shifts away from open market and free competition towards a government supported Li-ion battery industry that allows the easing of market and state-aid rules.

To answer the **main research question**: to critically assess if mass adoption of EVs is a solution to significantly reduce the environmental impacts of passenger road transport, Chapter 4 looked at different strategies besides the mass uptake of EVs.

All forecasts predict an unprecedented and soaring growth on mineral demand with all predictions based on the assumption of a growing number of vehicles on the road. For example, industry analysts estimate 1.6 billion vehicles will be on the road by 2040 (compared with 1.2 billion in 2020).[204] Of the predicted 1.6 billion fleet in 2040, still 1.1 billion units would be ICE cars, just as in 2015. Therefore, despite the enormous investments in developing a global Li-ion battery value chain and the resulting soaring mineral production, battery and EV manufacturing (and related social and environmental impacts), we would not be really reducing the absolute amount of carbon emitting ICE vehicles, as compared to present levels.

While mass adoption of EVs is being promoted by industry and governments (particularly in the global north) it is not the only solution in terms of addressing the impacts of passenger road transport. Scientists, civil society and communities across the world are calling for a different approach based on environmental justice and on the need to absolutely reduce the demand of minerals and energy. Strategies proposed include ride-sharing, car-sharing and smaller vehicles, which have the greatest potential to reduce the life-cycle impacts of passenger road transport. Material efficiency strategies such as recycling, smaller design and extended end of life is also important.

For instance, the Low Energy Demand Scenario developed by scientists from the IPCC shows that, by increasing vehicle occupancy and usage (for instance by car sharing), the same amount of intra-urban mobility could be achieved with half of the car fleet. According to such a scenario, the fleet of light duty vehicles could be reduced to 850 million by 2050. The IRP also recently concluded that car-sharing, ride sharing and smaller vehicles are the strategies that contribute the most to reducing life-cycle emissions of passenger cars. These solutions would also significantly reduce the amount of required energy, water and minerals.

Different organisations, including environmentalist groups, activists, affected communities and citizens from around the world, propose a different mobility transition. A transition based on communities' rights to say no to mining, an absolute need to reduce resource use, democratic decision-making, human rights, recognising and addressing past abuses and buen vivir, among other conceptual frameworks.

Furthermore, in SOMO's view, mandatory human rights due diligence should be an essential element of the mobility transition. All businesses along the Li-ion battery value chain should be required to conduct comprehensive mandatory human rights and environmental due diligence, should be transparent about their findings and should prevent, address and avoid negative impacts. Workers, communities and their representatives need to be part of the design and implementation of such due diligence processes. When violations occur, an effective remedy mechanism needs to be available for victims and to hold companies into account. Without mandatory human rights and environmental due diligence, there is no guarantee of a just mobility transition.

The following are key recommendations based on the information provided in this report. For additional recommendations, we refer to the (forthcoming) *Principles for Businesses and Governments in the Battery Value Chain* drafted by Amnesty International and allies.

To governments:

- States and the EU should prioritise reducing the mineral and energy demand of passenger road transport in absolute terms. To do so, States and the EU should support and promote strategies towards car-sharing, ride-sharing and public transport.

- States should introduce policy action and regulations that promote material efficiency strategies for the use of less materials and energy, including design of smaller Li-ion batteries and EVs, reuse and recycling.

- States and the EU should require manufacturers to standardise the design of Li-ion cells, modules and packs, and include proper labelling, in order to optimise recycling.

- States and the EU should introduce rules mandating Li-ion battery producers and/or EV manufacturers to take back end-of-life Li-ion batteries, through an extended producer responsibility scheme.

- States and the EU should introduce binding regulation requiring companies to conduct mandatory human rights and environmental due diligence, including the obligation of businesses to publish their due diligence practices and findings. Due diligence requirements should cover the entire battery value chain and involve communities, workers, civil society and trade unions in its design, monitoring and implementation.

- States and the EU should facilitate a democratic public debate to discuss alternative strategies to address the impacts of passenger road transport that includes the participation and meaningful engagement of mining-affected communities, workers, environmentalists, scientists, civil society and that is based on environmental justice and respect for human rights.

To companies along the battery value chain:

- All companies along the Li-ion battery value chain should map and disclose their supply chain and use their leverage with business relationships to request respect for human rights, decent working conditions and environmental protection through contractual obligations.

- All companies along the Li-ion battery value chain should carry out human rights and environmental due diligence, disclosing their findings on risks and abuses and outcomes; and prevent, address and mitigate their negative impacts.

- All companies should respect human rights and environmental laws, including the right to information, water, health; a healthy environment; communities' right to withhold consent; occupational health and safety standards; and the right of freedom of association and collective bargaining.

- All companies should provide victims of abuses occurring at any stage of the value chain with access to an effective remedy and have in place an effective grievance mechanism to receive workers' and external complaints.

- Companies should prioritise reducing mineral and energy demand in absolute terms, standardise design of Li-ion batteries and their components, which facilitate reuse and recycling. Manufacturers should ensure that Li-ion batteries and components include proper labels including battery health and safety guidelines for disassembling and recycling.

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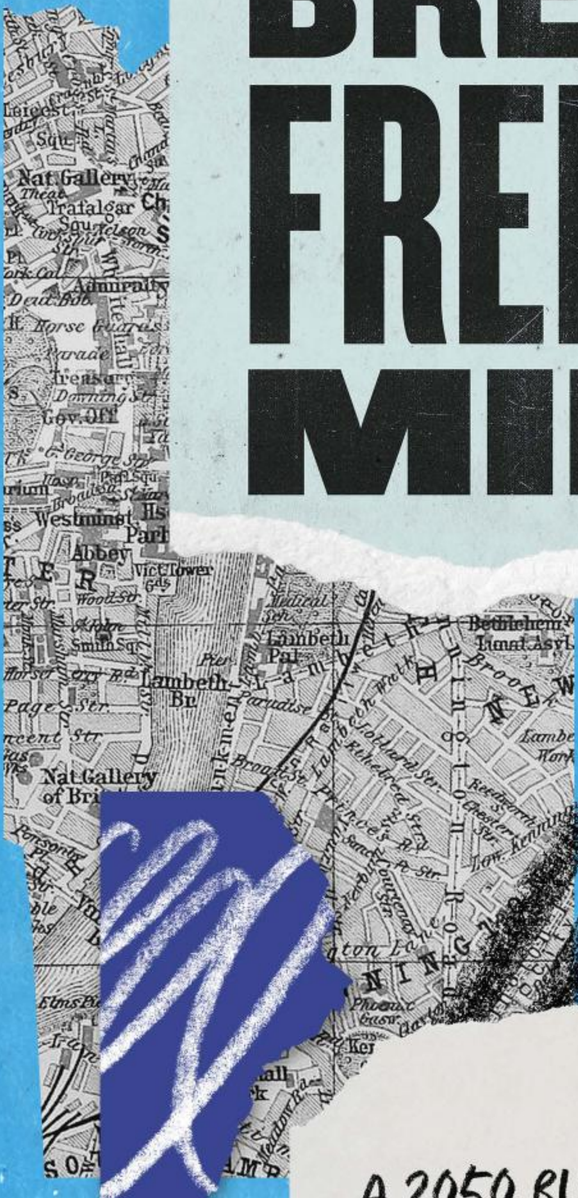
BREAKING FREE FROM MINING



A 2050 BLUEPRINT FOR A WORLD WITHOUT MINING — ON LAND AND IN THE DEEP SEA.

SEAS AT RISK

Project management and contact:
Ann Dom, adom@seas-at-risk.org

Authors: Joám Evans Pim and Ann Dom, with contributions by Nick Meynen, Diego Francesco Marin and Piotr Barczak (European Environmental Bureau) and Leida Rijnhout (LeapFrog2SD).

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1

SETTING THE SCENE

"We stand now where two roads diverge. But unlike the roads in Robert Frost's familiar poem, they are not equally fair. The road we have long been travelling is deceptively easy, a smooth superhighway on which we progress with great speed, but at its end lies disaster. The other fork of the road — the one less traveled by — offers our last, our only chance to reach a destination that assures the preservation of the earth."

– Rachel Carson,
Silent Spring, 1962

METALS – THE FOSSIL FUELS OF THE 21ST CENTURY

The transition to a carbon-neutral society is heavily focused on technology and innovation fixes, such as the large-scale shift to renewable energy, the replacement of 1.4 billion petrol and diesel cars with electric vehicles, and the digitalisation of our societies and economies. However, the underpinning economic model remains largely unchanged: extract, consume, throw away – a model that privileges continued relentless overconsumption in the Global North and pursues eternal economic growth at nature's expense.

These so-called green technologies and infrastructure fixes come with a substantial – and familiar – catch: they all require vast amounts of metals and minerals. This means opening more and more mines, exacerbating the longstanding environmental and social consequences of extractivism. Metals have become the fossil fuel of the 21st century.

Each year mining moves into new frontiers and encroaches further into nature and communities all over the world. On land, exploration goes deeper underground and eats into our remaining wilderness. For example, rather than serve as a warning, the rapid melting of Arctic ice sheets has encouraged mining, with previously unreachable sites now seen as economically viable.

World-renowned marine biologist Sylvia Earle has called deep-sea mining 'the biggest land-grab in the history of humankind' and indeed the deep sea has become the final frontier for mining on Earth. Already, more than 1.3 million square kilometres of ocean have been set aside for mineral exploration. Despite scientists warning of irreversible, large-scale biodiversity loss, some countries and companies intend to start mining in international waters as soon as 2023.

Several existential questions arise from this relentless push towards extraction. Can humanity really afford to lose large swathes of nature, on land and in the deep sea, to fuel a 'green growth' economy that will benefit a few in the Global North? Do extractive economies still have a place in the 21st century? Can we envisage a society that can counter climate and nature collapse, while simultaneously breaking free from resource extraction?

OBJECTIVE OF THIS PAPER: RETHINKING METALS AND MINING

Recent reports by the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) have awakened the world to the damning human impacts on nature and climate. The solution is difficult yet clear: transformative change.

This paper sets out some possible pathways to transformative change. It describes a science and fact-based vision of a world in which terrestrial mining has become obsolete and the deep sea is safeguarded from invasive digging. It offers an alternative to the business-as-usual approach applied by most global scenarios for future metals demand (World Bank[2], International Resource Panel[3], International Energy Agency[4], Organisation for Economic Co-operation and Development (OECD)[5]), which presume continued growth of consumption and production, expressed as Gross Domestic Product (GDP). Typically, these growth scenarios predict at least a doubling or quadrupling in the demand for metals by 2050 or 2060. Breaking away from business-as-usual and envisioning a different future is key to shaping effective policy measures that can prevent the expected mining boom.

* TRANSFORMATIVE CHANGE MEANS DOING THINGS DIFFERENTLY— NOT JUST A LITTLE MORE OR LESS OF SOMETHING WE'RE ALREADY DOING.[1]

1 Chan, K. (2019), "What Is Transformative Change, and How Do We Achieve It?: Think Globally Act Locally," IPBES blog. https://ipbes.net/news/what-transformative-change-how-do-we-achieve-it

2 World Bank (2020), Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action

3 International Resource Panel, United Nations Environment Programme (2019), Global Resources Outlook 2019: Natural resources for the future we want. https://www.resourcepanel.org/reports/global-resources-outlook

4 International Energy Agency (2021), Role of Critical Minerals in Clean Energy Transitions. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

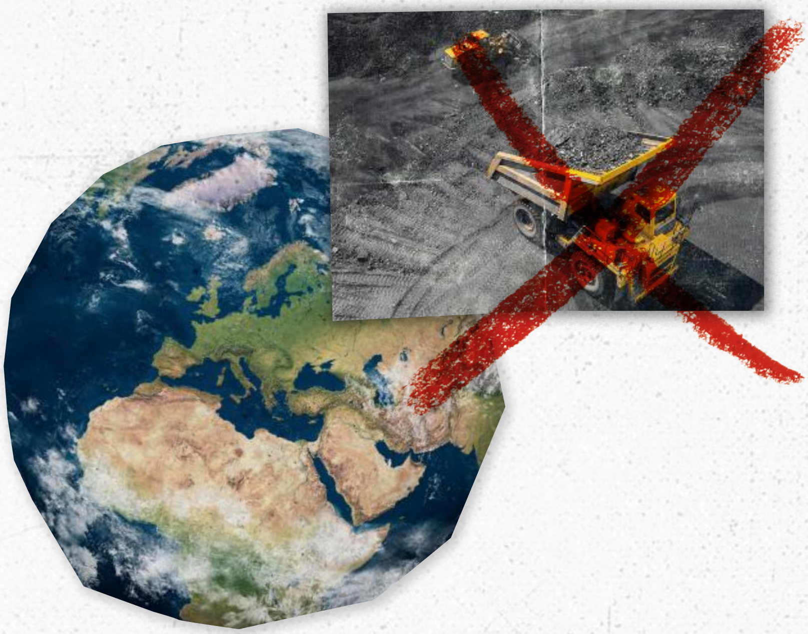
5 Organisation for Economic Co-operation and Development (2019), Global Material Resources Outlook to 2060. https://www.oecd.org/environment/global-material-resources-outlook-to-2060-9789264307452-en.htm

The paper takes 2050 as its viewpoint. This temporal displacement enables reader-participants to grasp the enormous transition to a far less resource-intensive society, a society equipped to deal with the impacts of climate change, reverse the biodiversity loss of the preceding century, and break free from resource extraction.

The paper is structured as follows:

- **2050: a post-mining world** brings us into an alternative vision of the future;
- **2020: the tipping point for mining** explains some of the ongoing trends in 2020, helping readers understand the shift to come;
- **Seeds of change** highlights the many changes and new ways of doing that were already present in 2020 and that allowed the transformation to take place;
- **A compass for the future** provides insights on on the paradigm shift away from mining in the 2020s;
- **Imagining a world without mining workshop** presents a workshop concept to co-envisage the paths to post-mining futures, encouraging readers to adopt their own paths of action.

Let's start by **projecting ourselves to 2050**, a world in which mining has become a thing of the past, and look at how we got here, by visiting the seeds of change already sprouting in 2020.



2 STORY OF A 2050 POST-MINING WORLD AND HOW WE GOT HERE

"THERE IS NOTHING LIKE A DREAM TO CREATE THE FUTURE."

— VICTOR HUGO, LES MISÉRABLES

WE ARE IN 2050, NOVEMBER 23RD – CHUQUICAMATA, CHILE.

A crowd gathers for the opening of the Global Extractivism Museum (GEM). It is a sober memorial to an era of relentless extractivism and mining that came to an end this year, when Chuquicamata, Chile's biggest copper mine and the last mine on Earth, closed. The massive scar of the mining pit forms a dramatic backdrop to the museum.

Visitors – and the millions of people across the globe who experience the GEM virtually – marvel at the mining machines on display. It is sobering to see how over time the greed for metals created irreparable injustices across the planet. The lives it destroyed, the ecological disasters it led to, the wars it ignited. The most terrifying machines are those designed for deep-sea mining – massive, automated machines designed to dig up the deep seabed, working as far as six kilometres under water. They were used only in a few tests in the 2020s and then, when by deep-sea mining's certain devastation of the place where life originated could no longer be ignored or accepted, put on hold forever.

By then it was already clear that mining was a hopelessly outdated concept: new ventures such as deep-sea mining or moon and asteroid mining were not only untenable – they weren't even needed. In the 2040s mining could no longer compete with the supply of secondary metals and substitute materials that were progressively taking over the market, supported by a circular-economy approach pioneered in the 2020s. The 2030s and 2040s were hard times for the few companies that survived the burst of the mining "bubble" and continued extracting copper, nickel, lithium or cobalt. More successful companies shifted towards urban and landfill mining, recovering metals from e-waste, landfills and other secondary sources.

It wasn't just changes in materials use that drove mine closures. Growing concern led citizens across the world to challenge extractive economies that threatened life by driving climate change. Accountability to future generations became the compass for strict circular-economy policies that included caps on global resource use and a general shift in consumer behaviour: the Great Transition. The Transition was also about deeper change, with more and more countries letting go of the tired GDP-growth paradigm and replacing it with economies focusing on wellbeing for both planet and people.

NEW VENTURES SUCH AS DEEP-SEA MINING OR MOON AND ASTEROID MINING WERE NOT ONLY UNTENABLE – THEY WEREN'T EVEN NEEDED.

2020 – THE TIPPING POINT FOR MINING

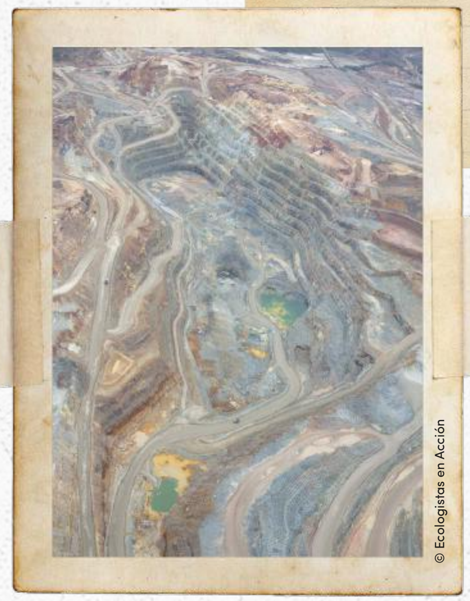
The destructive lifestyles and economies of much of the 20th century and first two decades of the 21st were deeply shaken in the Global North by the 2020 COVID pandemic. Called the "lost year" because of the deep crisis sparked by the pandemic, 2020 was later acknowledged as a positive year of change. Years of climate campaigning together with COVID-related measures such as lockdowns, travel restrictions and a return to public spaces brought on by less car use made society think about its relationship to nature. The evidence that extractivism and other assaults on nature triggered the emergence of new diseases through zoonosis contributed to a growing sense that something was fundamentally wrong with the "old normal".

In the Global North, and particularly in Europe, plans to securitise supply chains of raw materials through insourcing of mining production encouraged communities and civil society to mobilise in opposition to resource exploitation, empowered by similar social movements from the Global South, already well versed in the dangers and effects of the mining industry. Resistance came in the form of declarations, protests, petitions and rising awareness. The environmental crimes and corruption associated with mining were pursued through the courts and in the streets. New narratives such as Ubuntu, Buen Vivir and degrowth challenged traditional modes of development, and were discussed and debated amongst those who viewed "business-as-usual" as a direct threat to societal wellbeing. As people noticed how their lifestyles had been affected by COVID, new narratives of a post-gowth, post-development, post-extractive and post-mining future began to take shape.

The expansion of mining to new frontiers, such as the deep sea, stood in stark contrast to global commitment to reversing biodiversity loss. Under increasing pressure from citizens, civil society organisations and thousands of scientists, decision-makers were forced to turn their backs on extractive lobbies and listen carefully to calls for the transformational change needed to preserve life on the planet – including human life.

While many had already known that several planetary boundaries (the planet's "safe operating space for humanity") had been transgressed, this fact and its consequences were generally ignored – by individuals as much as by governments – despite the growing social and political movements promoting alternatives, despite the overwhelming scientific knowledge about the potential impacts of deep-sea mining and ongoing extraction on land. The increasing gap between the 1% extremely rich and the remaining 99%, between the over-developed and under- or de-developed areas of the world, the social exclusion and growing economic inequality which converted some countries into "sacrifice zones" for mining and other forms of extractivism to benefit others: these were ignored, too.

Looking back, it's hard to imagine how so many people put up with it. Polluted cities caused nine million deaths each year and created generations of asthmatics.[6] Toxic stress caused by working and living conditions led to a massive increase in depression and other mental health illnesses all over the world. Heavy metals at sea forced restrictions in fish consumption. Acid drainage from mining reached the seas and polluted coastal areas. The long-term health impacts of the endocrine disruptors in synthetic chemicals were just beginning to be understood. Ever-increasing extraction and processing of natural resources (metals, minerals, biomass, fossil fuels, water and land) was destroying biodiversity and driving gross human-rights violations.


© Ecologistas en Acción

6 Le Page, M. (2019). "Does air pollution really kill nearly 9 million people each year?", *New Scientist*, March 12. At: https://www.newscientist.com/article/2196238-does-air-pollution-really-kill-nearly-9-million-people-each-year/

Promises to end child labour and deadly conditions in and around mines were not kept. The exploitation of people and human rights violations by the mining industry grew with each new mine. Mining and processing kept destroying biodiversity, led to increasing water stress impacts, and about 10% of global greenhouse gas emissions.[7] Even the most unenlightened began to see: this could not go on.

Options were very limited anyway. By 2020, even the most fervent proponents of the electric vehicle (EV) transition within a GDP-growth scenario knew global reserves of metals such as copper, lithium or manganese would be depleted before 2050, even with an exponential increase in recycling rates. Predicted lithium consumption for EVs alone would have completely depleted world reserves in just two decades, while increased mining and continuous growth would have actually increased greenhouse emissions in absolute terms, making decarbonisation policies utterly useless.[8]

Deep-sea mining - still promoted by some - threatened to worsen biodiversity loss and climate conditions by reducing the ocean's carbon dioxide absorption capacity and disrupting open-ocean ecosystems on a global scale. The fact that genetic material from threatened deep-sea vents made it possible to develop tests and vaccines for COVID and other diseases[9] lead to strict protection measures under a newly mandated International Seabed Protection Agency following a global ban on deep sea mining.

PROMISES TO END CHILD LABOUR AND DEADLY CONDITIONS IN AND AROUND MINES WERE NOT KEPT. THE EXPLOITATION OF PEOPLE AND HUMAN RIGHTS VIOLATIONS BY THE MINING INDUSTRY GREW WITH EACH NEW MINE.

7 IPBES (2019). *Global Assessment Report on Biodiversity and Ecosystem Services*. Bonn: IPBES. At: https://ipbes.net/global-assessment ; IRP (2019). *Global Resources Outlook* 2019. Nairobi: UNEP. At: https://www.resourcepanel.org/reports/global-resources-outlook ; Azadi, M., et al. (2020). *"Transparency on greenhouse gas emissions from mining to enable climate change mitigation," Nature Geoscience*, 13: 100–104. At: https://www.nature.com/articles/s41561-020-0531-3

8 Blas, Ignacio de, et al. (2020). "The limits of transport decarbonization under the current growth paradigm," *Energy Strategy Reviews*, 32: 100543. At: https://www.sciencedirect.com/science/article/pii/S2211467X20300961

9 UNESCO (2020). "COVID-19: the ocean, an ally against the virus". At: https://en.unesco.org/news/covid-19-ocean-ally-against-virus

THE GREAT TRANSITION: FROM EFFICIENCY TO SUFFICIENCY

Thus 2020 became the beginning of a Great Transition toward the post-mining world of today. Many started to ask themselves what it was that people needed to thrive and have a good life and how these needs could be met within the limits of our planet. Building on early thinkers such as Mahatma Gandhi and J. C. Kumarappa and works such as *The Limits to Growth* (1972)[10] or Small Is Beautiful (1973), the community of degrowth, post-growth and ecological economics advocates brought the message to the mainstream that the paradigm needed to change, the system needed to change. Groundbreaking works like Tim Jackson's 2017 *Prosperity Without Growth*[11] and Kate Raworth's *Doughnut Economy*[12] inspired governments, companies and citizens alike. Millions of youth clamored in the streets for *system change instead of climate change*. While frightening, the 2020 crisis not only made people realise that change was needed, it showed them that it was possible.

At the political level, the notion that societies needed economic growth (i.e., growth in consumption and production, expressed as GDP growth) was starting to crack. The European Environment Agency openly challenged this idea,[13] outlining ideas for "growth without economic growth", joining the voices of indigenous peoples, local communities, social movements and scientists from across the world. In Europe, the first-ever EU binding targets to reduce over-consumption were established with the goal of reducing resource use by 2030, which would bring EU consumption within planetary boundaries by 2050. The stage was set for further developments towards a more sustainable future.

MILLIONS OF YOUTH CLAMORED IN THE STREETS FOR SYSTEM CHANGE INSTEAD OF CLIMATE CHANGE.

10 In fact, the business as usual scenario projected in the 1970s compares very well with real developments 40 years later. See: Turner, G.; Alexander, C. (2014). "Limits to Growth was right. New research shows we're nearing collapse," *The Guardian*, Sep. 2. At: https://www.theguardian.com/commentisfree/2014/sep/02/limits-to-growth-was-right-new-research-shows-were-nearing-collapse

11 Jackson, T. (2017). *Prosperity Without Growth: Foundations for the Economy of Tomorrow*. London: Routledge.

12 Raworth, K. (2018). *Doughnut Economics, Seven Ways to Think Like a 21st-Century Economist.* New York: Random House.

13 Strand, R., et al. (2021). "Growth without economic growth," EEA Briefing no. 28/2020. At: http://doi.org/10.2800/781165

Cities reinvented their mobility plans, banning private cars altogether in many places and revolutionng transport infrastructure, while rational use of work-from-home helped reduce commuting and traffic. In the Global North car sales plummeted and a drastic reduction of privately own cars followed. Reduced work weeks and workdays facilitated a return to the countryside, the return of self- and community-grown foodstuffs, and more available time for social, cultural and political engagement. Social pressure forced governments and international bodies to establish binding commitments and new regulatory frameworks.

This affected everyday patterns of consumption and behaviour: i.e., planned obsolescence of mobile phones, laptops and other electronics was banned and enforced, while strict guidelines for advertisement curbed perceived obsolescence and conspicuous consumption; new regulations ensured long-durability guarantees for all metal-containing devices as well as design and traceability standards that guaranteed reparability, reuse and full recovery of all components. No longer were hundreds of millions of old mobile phones hoarded in drawers, shipped to the Global South or dumped. Most electronic devices became a valuable part of leasing or cooperative schemes where items were fixed during their lifespan and recuperated at end-of-life as part of their producer's expanded responsibility. In the over-developed Global North, the widespread adoption of simple living[14] became a cultural trend, redefining appropriate technologies on the basis of actual needs rather than growth. Reducing overconsumption and superfluous travel was critical for de-carbonising energy and transport systems.

New institutional arrangements were made to ensure that remaining raw materials were used sensibly for the benefit of the whole of humanity while considering the possible needs of future generations. Individual countries started to ban metal mining altogether and deep-sea mining was banned globally. The International Resource Panel gave way to a new global mechanism for raw-materials governance. Mining ceased to be ruled by market mechanisms and speculative finance and came under the steering capacity of an international body and publicly owned enterprises which supervised the phasing out of new metals mining. Mining for luxury goods such as gold and diamonds was the first to be banned; rising prices led to more targeted use of minerals, extended value retention, less waste and more reuse and recycling.[15] Social needs and planetary boundaries superseded profit-making as a driver for steering enterprises, securing a "justice transition" away from mining.[16]

14 Or, as the 1987 UN World Commission on Environment and Development ("Brundtland") Commission report had stated, that *"those who are more affluent adopt life-styles within the planet's ecological means"*. See: "Report of the World Commission on Environment and Development: Our Common Future". At: http://www.un-documents.net/wced-ocf.htm

15 See: Meynen, N. (2019). *Frontlines: Stories of Global Environmental Justice*. Alresford: Zero Books, p. 142.

16 See: Hitchcock, B. (2019). *A just(ice) transition is a post-extractive transition*. London: War on Want and London Mining Network. At: https://londonminingnetwork.org/wp-content/uploads/2019/09/Post-Extractivist-Transition-report-2MB.pdf

2050, THE SYMBIOCENE

The geological scars of pollution and exploitation left by the Anthropocene – a term proudly adopted by the scientific community in the 2010s based on the new stratum of radiation, soot and plastics on the planet's surface – as well as the social and environmental scars of the Capitalocene – a historical epoch characterised by the apparently endless accumulation of capital – slowly started to heal, moving away from an apparently irreversible path toward self-annihilation and mass extinction. A new geosocial era emerged: the *Symbiocene*.[17]

How did this transition to a global society that walks lightly upon Earth come about? How did we become equipped to deal with the effects of climate change and reverse the biodiversity loss of the previous century? How did mining become obsolete, restoring life to mountains and rivers and safeguarding the seabed from an invasion of digging machines? How could bold visions for the future have empowered people, communities and countries to act? Read on to find out…

17 Albrecht, G. (2019). "After the Anthropocene," *Ecologist*, February, 27. At: https://theecologist.org/2019/feb/27/after-anthropocene

3

2020: THE TIPPING POINT FOR MINING

"THE GLOBAL RESOURCES OUTLOOK SHOWS THAT WE ARE PLOUGHING THROUGH THIS PLANET'S FINITE RESOURCES AS IF THERE IS NO TOMORROW, CAUSING CLIMATE CHANGE AND BIODIVERSITY LOSS ALONG THE WAY. FRANKLY, THERE WILL BE NO TOMORROW FOR MANY PEOPLE UNLESS WE STOP."
— JOYCE MSUYA, ACTING EXECUTIVE DIRECTOR OF UN ENVIRONMENT.

WHAT WAS IT LIKE BACK IN 2020?

Earth was in crisis at the turn of the third decade of the century: climate change, the peak of the Anthropogenic extinction, water scarcity and peak extraction of oil and many metals. These interwoven crises were being approached as unconnected problems despite their common root causes. The main driver of environmental destruction, biodiversity extinction and dramatic climate events was the overconsumption fuelling an extractive throw-away economy in over-developed societies. This was based on a fantasy of perpetual growth imposed by a global minority.

Growing consumption and increasing population numbers living unsustainable lifestyles meant Earth was no longer able to deliver natural resources for an overgrown socioeconomic metabolism nor to absorb its waste, including carbon emissions. The global material footprint, i.e., the total amount of all raw materials – including metals and minerals – extracted to meet consumption demands was more than 90 billion tons in 2017, an increase of 70% from 2000. The UN had predicted that it would grow to 190 billion tons by 2060.[18] Inequalities in per capita resource consumption were extravagant: from 30 tonnes per person in high-income countries to 2 tonnes in low-income countries. In 2020, 1% of the world's population used twice as much energy as the less materially "wealthy" 50%.[19]

THE GLOBAL MATERIAL FOOTPRINT, I.E., THE TOTAL AMOUNT OF ALL RAW MATERIALS — INCLUDING METALS AND MINERALS — EXTRACTED TO MEET CONSUMPTION DEMANDS WAS MORE THAN 90 BILLION TONS IN 2017, AN INCREASE OF 70% FROM 2000. THE UN HAD PREDICTED THAT IT WOULD GROW TO 190 BILLION TONS BY 2060.

18 See: https://unstats.un.org/sdgs/report/2019/goal-12/

19 Gore, T. (2020). *Confronting carbon inequality*. Nairobi: Oxfam. At: https://www.oxfam.org/en/research/confronting-carbon-inequality

In 2020, the UN Secretary-General António Guterres denounced humanity's suicidal "war on nature", warning about the broken state of the planet: "Biodiversity is collapsing. One million species are at risk of extinction. Ecosystems are disappearing before our eyes. Deserts are spreading. Wetlands are being lost. Every year, we lose 10 million hectares of forests."[20] That same year, the Executive Director of UN Environment Inger Andersen and the economist Partha Dasgupta said COVID was an "SOS signal for the human enterprise"[21] and that contemporary economic thinking did not recognise that human wealth depends on nature's health. They stressed how the pandemic was a warning about "the need to live within the planet's 'safe operating space', and the disastrous environmental, health and economic consequences of failing to do so." Correctly, they identified the problem as a mismatch between the artificial "economic grammar" driving policy and business and "nature's syntax", which determines how the real world works.

At the beginning of the Great Transition, big corporations and their lobbies influenced public debate. They worked behind the scenes, stoking the obsession for economic growth[22] and policy-makers' fear of making bold decisions. Despite the clear evidence change was indeed possible, political will proved difficult to mobilise. Many feared the uncertainty, while others gripped firmly to their profits and lifestyles even as everything threatened to collapse around them.

Policy decisions that appeared to be solutions or improvements were in fact only temporary measures, problems postponed in the short term only to deepen them further. It was no longer possible to solve existing problems using the same kind of thinking that created them – but alternatives were often dismissed as utopian or unrealistic.

River at the San Finx mine, Spain

20 See: https://www.un.org/press/en/2020/sgsm20467.doc.htm

21 Carrington, D. (2020). "Coronavirus is an 'SOS signal for the human enterprise'," *The Guardian*, June 5. At: https://www.theguardian.com/world/2020/jun/05/coronavirus-is-an-sos-signal-for-the-human-enterprise

22 Richters, O.; Siemoneit, A. (2019). "Growth imperatives: Substantiating a contested concept," *Structural Change and Economic Dynamics*, 51: 126-137. At: https://doi.org/10.1016/j.strueco.2019.07.012

MINING OUR WAY INTO TROUBLE

The pathological focus on economic growth in the decades leading up to the 2020s had set humankind on a course to the abyss. Deep-sea mining was a sign of increasing desperation. Societies in over-developed countries became trapped by the belief that only owning more could make people happy. On the other hand, under- and de-developed areas with easily extractable mineral ores often became trapped by the resource curse (the poverty paradox). A 2020 scientific study published in Nature concluded that, "Based on the current resource consumption rates and best estimate of technological rate growth our study shows that we have very low probability, less than 10% in most optimistic estimate, to survive without facing a catastrophic collapse."[23] The study concluded that there were only "a few decades left before an irreversible collapse of our civilisation."

At the eleventh hour for reducing carbon emissions policy-makers and society finally acknowledged the need to turn away from fossil fuels, but with the delusional idea that all could remain the same, and only energy production would have to use renewable sources, even if these came at a huge cost in minerals, energy and infrastructure.

As over-developed countries tried to *mine their way out* of the problems they had created, most people seemed to ignore how this in fact meant digging humanity deeper into trouble. As a senior geologist at the Geological Survey of Finland put it in 2020, most policy-makers had been led to believe that, through mining, they could simply replace an industrial civilisation built on cheap oil with a green version of the same model.[24]

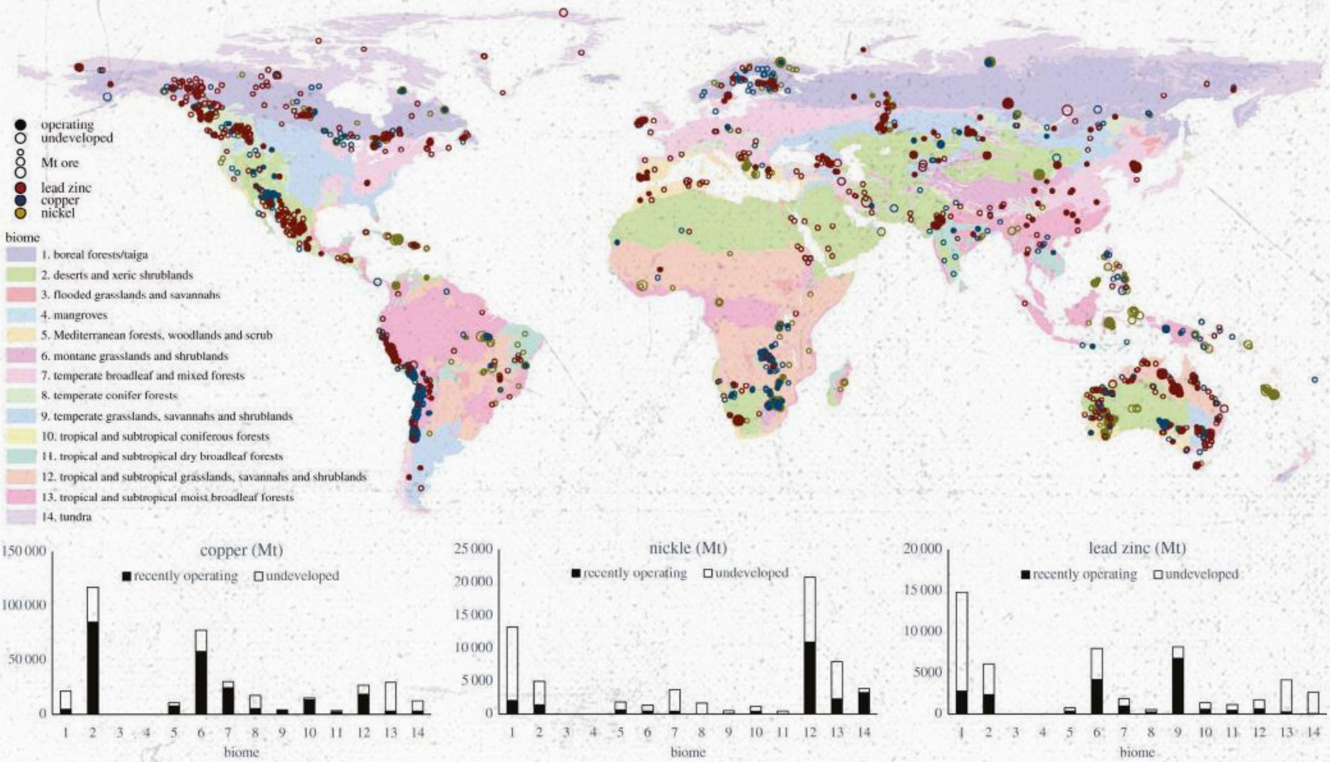
A 2020 SCIENTIFIC STUDY PUBLISHED IN NATURE CONCLUDED THAT, "BASED ON THE CURRENT RESOURCE CONSUMPTION RATES AND BEST ESTIMATE OF TECHNOLOGICAL RATE GROWTH OUR STUDY SHOWS THAT WE HAVE VERY LOW PROBABILITY, LESS THAN 10% IN MOST OPTIMISTIC ESTIMATE, TO SURVIVE WITHOUT FACING A CATASTROPHIC COLLAPSE." THE STUDY CONCLUDED THAT THERE WERE ONLY "A FEW DECADES LEFT BEFORE AN IRREVERSIBLE COLLAPSE OF OUR CIVILISATION."

23 Bologna, M.; Aquino, G. (2020). "Deforestation and world population sustainability: a quantitative analysis," *Scientific Reports*, 10: 7631. At: https://www.nature.com/articles/s41598-020-63657-6

24 Michaux, S. (2020). "The Raw Material Challenges Facing the Energy Transition from Oil to Minerals" [presentation]. At: https://www.gtk.fi/en/presentation-the-raw-material-challenges-facing-the-energy-transition-from-oil-to-minerals/

The resulting demand for renewable energy and power storage, EVs, digitisation and urbanisation, as well as an overall rise in resource consumption, pushed the demand for raw materials and mining many times beyond planetary limits, while the drive for increased *low-cost* mining led to larger and more disastrous failures in mine tailings facilities. Mining and processing kept destroying biodiversity, led to increasing water stress impacts, and about 10% of global greenhouse gas emissions.[25] Exponential growth in metal mining meant that even at what was then considered a moderate growth rate of 3%, mining production was to double every 25 years.[26]

Figure 1: Distribution of operating metal mines and prospecting projects among Earth's terrestrial biomes.



Source: Sonter et al. (2018).[27] Note: Mine symbol colour distinguishes between metals (lead/zinc, copper, nickel) and symbol size depicts reserve size (Mt). The three bar graphs represent each metal tonnage per biome and the biome numbers are found in the key.

25 IPBES (2019). *Global Assessment Report on Biodiversity and Ecosystem Services*. Bonn: IPBES. At: https://ipbes.net/global-assessment ; IRP (2019). *Global Resources Outlook 2019*. Nairobi: UNEP. At: https://www.resourcepanel.org/reports/global-resources-outlook ; Azadi, M., et al. (2020). "Transparency on greenhouse gas emissions from mining to enable climate change mitigation," *Nature Geoscience*, 13: 100–104. At: https://www.nature.com/articles/s41561-020-0531-3

26 Exter, Pieter van, et al. (2018). *Metal demand for renewable electricity generation in The Netherlands*. Amsterdam: Metabolic. At: https://www.metabolic.nl/publications/metal-demand-for-renewable-electricity-generation-in-the-netherlands-pdf/

27 Sonter, L.J., et al. (2018). "Mining and biodiversity: key issues and research needs in conservation science," *Proceedings of the Royal Society B*, 285(1892). At: https://royalsocietypublishing.org/doi/10.1098/rspb.2018.1926

Meanwhile, metals were wasted on a large scale – lost in incineration, downcycled, buried in landfills or dumped in the Global South? instead of being reused or recycled. In Europe alone, 160 million mobile phones were discarded every year. Each device, typically weighing less than 150 grams, was packed with valuable resources.[28] The "circular economy" had been a popular policy narrative for years, even supported by industry – arguably because it focused on efficiency while maintaining the economic-growth paradigm. The need for rich countries to tackle the root-cause of planetary crises – i.e., overconsumption and obsession with growth – remained largely unaddressed, even though the science was clear: humanity would not be able to recycle or mine itself out of the mess.

28 See: http://www.ellenmacarthurfoundation.org/news/in-depth-mobile-phones

RENEWABLE ENERGY PRODUCTION AND POWER STORAGE

After a century in which fossil fuels were the life-blood of global economies, the planet had been brought to the brink of climate chaos. Under great social pressure, fossil-fired power plants started to be replaced by energy production from renewables. Further electrification in all sectors would ensure the phase-out of fossil fuel. This heralded a time of techno-optimism, during which over-developed societies tried to hold onto the economic-growth model of the past century under the illusion that efficiency and innovation could turn the tide on global warming and biodiversity collapse. While the transition to renewable energies was an important component to mitigate global warming, the initial business-as-usual approach compromised carbon reduction gains, while mechanical stress and climatological impacts made wind and solar renewable energy infrastructure's lifespan short – i.e., 25 years.[29]

The transition to renewable energy meant phasing out internal combustion vehicles and ships, replacing fossil-fuel power generation and converting industrial energy systems and residential heating systems to electricity. If patterns of consumption had continued, this would have involved quadrupling the non-fossil-fuel power-generation capacity of 2020 – which included nuclear and waste incineration, in addition to metal-intensive renewables.

Under a business-as-usual projection, this would have meant building almost:

900 NEW NUCLEAR POWER STATIONS – still seen as viable by some at the time

more than 13,000 LARGE HYDROELECTRIC DAMS

some 70,000 NEW WIND FARMS and OVER 74,000 SOLAR FARMS GLOBALLY,[30]

in addition to hugely extended and material-intensive power-distribution infrastructure.[31]

29 See: http://www.ewea.org/wind-energy-basics/faq/ (wind); https://news.energysage.com/how-long-do-solar-panels-last/ (solar)

30 Based on Michaux, S. (2020), op cit.

31 Bumby, S. et al. (2010). "Life Cycle Assessment of Overhead and Underground Primary Power Distribution," *Environ. Sci. Technol.*, 44: 5587-5593. At: https://doi.org/10.1021/es9037879

Metals in a 84 MW solar power plant (tonnes)

13650	Iron
1344	Aluminium
184.8	Copper
168	Steel
46.2	Chromium
42	Manganese
38.9	Tin
19.7	Nickel
13.6	Zinc
4.5	Magnesium
4.2	Molybdenum
3.9	Silver
1.7	Lead
0.5	Titanium
0.5	Cadmium
0.4	Tellurium
0.4	Indium
0.04	Vanadium
0.03	Gallium

Massive large-scale solar-energy projects (so-called sun farms) then being built required huge quantities of minerals for solar panels, cabling, motors, inverters, transmission lines and energy-storage facilities, which in turn required extraction.[32] In fact, photovoltaic plants were one of the renewable energies with the highest raw-material demands – only beaten by offshore wind power. In the second decade of the 21st century, large-scale solar-energy projects had caused a surge in demand for certain metals, consuming 18% of the world's silver production every year and leading to aggressive extraction in increasingly marginal deposits. Some projections contemplated more than 8,000 GW of installed photovoltaic energy in 2050, up from 480 GW in 2018.[33]

While onshore wind-power infrastructures were less dependent on scarce minerals than their solar counterparts,[34] the huge scale of projects being built drove a surge in demand, including for rare-earth minerals. Demand for neodymium and dysprosium increased by 700% and 2,600% respectively.[35] The ocean was more and more seen as a vast new energy plant, with the EU alone planning a twenty-five-fold increase of offshore wind farms by 2050 (some 300 GW), which would correspond to about 80,000 wind turbines in European seas alone.[36] Globally, estimates targeted 1,400 GW of offshore facilities by the same year. [37]

32 An average sun farm in the late 2010s demanded for every MW of production capacity 162.5 tonnes of iron, 16 tonnes of aluminium, 2.2 tonnes of copper, 2 tonnes of steel, 0,55 tonnes of chromium, 0,5 tonnes of manganese, 0,46 tonnes of tin, 0,23 tonnes of nickel and 0,16 tonnes of zinc, among a much longer list of minerals. An average 84 MW farm required massive amounts of all these metals plus large quantities of other raw materials, including 4.2 tonnes of molybdenum; 3.92 tonnes of silver; 1.78 tonnes of lead, 530 kg of titanium, 390 kg of tellurium, etc. De Castro, C.; Capellán-Pérez, I. (2020). "Standard, Point of Use, and Extended Energy Return on Energy Invested (EROI) from Comprehensive Material Requirements of Present Global Wind, Solar, and Hydro Power Technologies," *Energies*, 13: 3036. At: https://doi.org/10.3390/en13123036

33 IRENA (2019). *Future of solar photovoltaic*. Abu Dhabi: International Renewable Energy Agency. At: https://www.irena.org/publications/2019/Nov/Future-of-Solar-Photovoltaic

34 Every MW of installed wind power still required 22 tonnes of iron, 2 tonnes of aluminium, 2.7 tonnes of copper, 126 tonnes of steel, 0.1 tonnes of nickel, 0.1 tonnes of neodymium and smaller amounts of dysprosium. Capellán-Péreza, Í.; de Castro, C. (2020), op. cit.

35 Alonso, E. et al. (2012). "Evaluating Rare Earth Element Availability: A Case with Revolutionary Demand from Clean Technologies," *Environ. Sci. Technol.*, 46(6):3406-3414. At: https://pubs.acs.org/doi/10.1021/es203518d

36 OREAC (2020). *The Power of our Ocean*. Brussels: Global Wind Energy Council.

37 COM(2020) 741 final. At: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:741:FIN

The shift to renewables also involved developing immense power-storage capacity to manage intermittent supply fluctuations. Some projections envisioned the installation of approximately 6 million 100MW storage stations that would require 48.7 million tonnes of lithium-ion batteries just to secure a 4-week period of limited wind and solar availability during winter.

BY 2020, THE LARGEST OF SUCH STATIONS WAS THE HORNSDALE POWER RESERVE IN AUSTRALIA, INTENDED TO SERVE AS A MODEL FOR REPLICATION ACROSS THE WORLD. SUCH BATTERY STORAGE CAPACITY, HOWEVER, WOULD HAVE REQUIRED EXTRACTING 8 MILLION TONNES OF COPPER, 4 MILLION TONNES OF ALUMINIUM, 7.4 MILLION TONNES OF NICKEL, 1.3 MILLION TONNES OF COBALT, 1 MILLION TONNES OF LITHIUM AND 10.7 MILLION TONNES OF GRAPHITE.[38]

Almost no one seemed to care back in 2020 that this disaster was built on a system of wasted energy. Energy losses in transmission and distribution grids were an average 10% (up to 50% in some countries).[39] Another 10% of the total annual household electricity consumption was due to standby losses (those little red lights) causing 1% of global carbon emissions.[40] Air conditioning accounted for another 10% of all global electricity consumption in 2018.[41] AC to DC conversion losses were around 20% for computers, rechargeable electronics and lighting. How could massive mineral extraction be justified in the context of massive waste?

38 Michaux, S. (2020), op. cit.

39 Jordaan, S.M.; Surana, K. (2019). "We calculated emissions due to electricity loss on the power grid – globally, it's a lot," *The Conversation*. At: https://theconversation.com/we-calculated-emissions-due-to-electricity-loss-on-the-power-grid-globally-its-a-lot-128296

40 See: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/selina_consumer_guide_en.pdf

41 IEA (2018). *The Future of Cooling*. Paris: International Energy Agency. At: https://www.iea.org/futureofcooling/

ELECTRIC VEHICLES

In 2009 Fatih Birol, Chief Economist of the International Energy Agency, warned "we have to leave oil before oil leaves us".[42] Even as oil was eventually left behind, the environmental consequences of burning fossil fuels did not leave us. As global warming threatened humanity, bringing a sense of urgency to move away from oil, the early choice in the 2020s was to phase out internal-combustion vehicles and replace them with EVs. For cars and trucks alone, this meant replacing 1.4 billion vehicles.

Shifting these 1.4 billion vehicles to electric motors would have required 339 million tonnes of lithium-ion batteries while electrifying maritime shipping – some 100,000 vessels – would have required another 451 million tonnes of Li-ion batteries. In Europe alone, substituting over 260 million internal-combustion vehicles with EVs would have required over 65 million tonnes of Li-ion batteries.[43] Despite a lack of alternatives to fossil-fuel-based aviation in the 2010s, passenger numbers doubled between 2009 and 2019 (partially thanks to heavy subsidies) before finally collapsing in 2020 in the context of the COVID pandemic.

The projected amount of batteries required – 790 MILLION TONNES OF LI-ION BATTERIES – for cars, trucks and marine vessels alone (excluding trains and aeroplanes, as well as power storage) would require 134.3 MILLION TONNES OF COPPER, 63.2 MILLION TONNES OF ALUMINIUM, 120 MILLION TONNES OF NICKEL, 22 MILLION TONNES OF COBALT, 17.1 MILLION TONNES OF LITHIUM and 173.8 MILLION TONNES OF GRAPHITE.[44]

These impossible figures refer exclusively to first-use EV batteries themselves, excluding the minerals necessary to build the vehicles or vessels, the minerals required to build the renewable-energy installations, the power-storage facilities to charge the batteries,[45] the subsequent battery replacements – as battery life is usually shorter than vehicle life – and all other lithium-ion batteries used for other electrical devices.

42 Connor, S. (2009). "Warning: Oil supplies are running out fast," *Independent*, August 3. At: https://www.independent.co.uk/news/science/warning-oil-supplies-are-running-out-fast-1766585.html

43 Michaux, S. (2020), op. cit.

44 Michaux, S. (2020), op- cit.

45 Lucas, A.; Silva, C.; Neto, R. (2012). "Life cycle analysis of energy supply infrastructure for conventional and electric vehicles," *Energy Policy*, 41: 537-547. At: https://doi.org/10.1016/j.enpol.2011.11.015

By 2020, on-surface copper stock (copper that had already been mined) was 50% of all known ore reserves. Projections contemplated mining in the remaining 50% over the following 30 years – i.e., mining more copper in three decades than during the previous 7,000 years.[46] In the case of other metals, such as silver and gold, the on-surface stock was 70%.[47] Although the projected mineral demand for batteries to be used in EVs alone by far exceeded known global reserves of nickel (90 million tonnes of reserves vs 120 million tonnes required) and cobalt (3.6 million tonnes vs 22 million tonnes) and would fully deplete known global lithium reserves, the assumption was that reserves would continue to expand through more exploration – particularly in the deep seas – and that mining could simply continue indefinitely.

The old English proverb says, "there are none so blind as those who will not see." Changing mobility without changing our habits was not going to solve our environmental problems, but rather aggravate them.[48] Like previous internal-combustion vehicles, proposed EVs still wasted most of their power to carry around 1 or 2 tonnes of materials that made up the vehicle itself, a hugely energy-inefficient manner to transport one or two people.[49] While it took time to admit that transport could never again be what it had become in the over-developed world at the turn of the 21st century, EVs momentarily became a revolutionary creed for those who wished for everything to remain the same. But soon it became clear that it was the whole mobility system that needed overhauling. Like other private cars, EVs spent 95% of the time parked, representing a huge waste of materials. The introduction of the EV car did not change the fact that the road transport system was coming to a grinding halt: the economic cost of traffic congestion was between 2% and 5% of GDP every year[50] and people often spent hours in motorway stand-stills.

46 Pitron, G.; Pérez, J.-L. (2019). *Le vert n'est pas vert!* [film]. Paris: Arte France.

47 Galos, K.; Szamałek, K. (2016). "Metals in Spent Mobile Phones (SMP) – a new challenge for mineral resources management," *Mineral Resources Management*, 32(4):45-48. At: http://journals.pan.pl/dlibra/publication/121561/edition/105936/

48 Pulido-Sánchez, D., et al. (2021). "Analysis of the material requirements of global electrical mobility," *Dyna*, 96(2). At: https://doi.org/10.6036/9893

49 Marqués, R. (2016). "The future of electric mobility (I) Electro-gas stations or electrostables?" At: http://active-mobility.blogspot.com.es/2016/11/

50 See: https://www.adb.org/sectors/transport/key-priorities/urban-transport (Asia); https://ec.europa.eu/transport/themes/urban/urban_mobility_en (Europe)

DIGITALISATION

The beginning of the 21st century came with a frenzy of semiconductor-rich devices, particularly portable electronics such as phones, laptops or tablets and a variety of previously unseen (and mostly rather useless) home appliances and gadgets. In 2020, there were about 15 billion phones, more than double the world's population at the time, in addition to some 2 billion computers. It was estimated that e-waste production would reach 120 million tonnes per year by 2050, while in 2017 global annual production of electronic and electrical waste was already at 44 million tons – the equivalent of 4,500 Eiffel Towers.[51]

An average smartphone included 50 different metals, including almost every existent rare-earth element. In the mid-2010s approximately 5% of global gold, silver and copper production and 20% of cobalt and palladium production went to mobile phones alone, while if adding up all other electric and electronic equipment, these devices hoarded over 40% of the global mining production of copper, tin, antimony, indium, ruthenium and rare-earth elements.[52]

Metal contents of an average smartphone

(Source: University of Plymouth[53])

Iron	33 G	**Molybdenum**	0.07 G
Chrome	7 G	**Gold**	0.036 G
Copper	6 G	**Praseodymium**	0.03 G
Nickel	2.7 G	**Tantalum**	0.02 G
Aluminium	2.5 G	**Niobium**	0.01 G
Tungsten	0.9 G	**Antimony**	0.007 G
Tin	0.7 G	**Gadolinium**	0.005 G
Neodymium	0.16 G	**Germanium**	0.002 G
Silver	0.09 G	**Dysprosium**	0.002 G
Cobalt	0.07 G	**Indium**	0.002 G

51 WEF (2019). *A New Circular Vision for Electronics*. Geneva: World Economic Forum. At: http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf

52 Hagelüken, C. (2013). "Recycling of technology metals from electronics". At: http://www.p-plus.nl/resources/articlefiles/ClosingtheLoopNL2013-10Hagelueken.pdf

53 Williams, A. (2019). "Scientists use a blender to reveal what's in our smartphones". At: https://www.plymouth.ac.uk/news/scientists-use-a-blender-to-reveal-whats-in-our-smartphones%20
Also see: https://youtu.be/bhuWmcDT05Q

Although concentration-wise a mobile phone had 100 times more gold and 10 times more tungsten than a high-grade mineral deposit,[54] nine out of ten discarded phones – with an average lifespan of little more than two years in 2020 – were incinerated or buried in landfills[55] when over 80% of their total metal value could be recycled with the technology then available.[56] Poor product design made recycling costly and ineffective, while neither producers nor consumers were made liable for recovery. In fact, many people kept stacks of fully operative but out-of-fashion phones in their drawers for no apparent reason.[57] In the EU alone, there were more than 500 million shelved phones in 2020, worth 1.3 billion euros of recoverable gold, silver, platinum, palladium and copper.[58] As a society, we were mining in the wrong places: we should have been mining our drawers and landfills.

The IoT, which involved flooding our homes, towns, cities, workplaces and almost every aspect of life with sensors, apps and other digital technologies, further increased metal demand as sensors needed tin, tungsten, tantalum and platinum; radio frequency identification-tags – such as those used at the time to avoid people stealing items in shops – used silver, copper and aluminium stolen from poor countries around the world; touchscreens relied on indium, silver and copper; and microchips required gallium.[59] The IoT also involved extensive and overlapping wireless networks – as analogue technology led to 2G, 3G, 4G and 5G. Increasing frequency spectrum meant expanding the number of base stations and orbital satellites to support massive volumes of data, with the growing demand for minerals for infrastructure.

* 1.3 BILLION EUROS OF RECOVERABLE GOLD, SILVER, PLATINUM, PALLADIUM AND COPPER

54 Galos, K.; Szamałek, K. (2016). See previous reference.

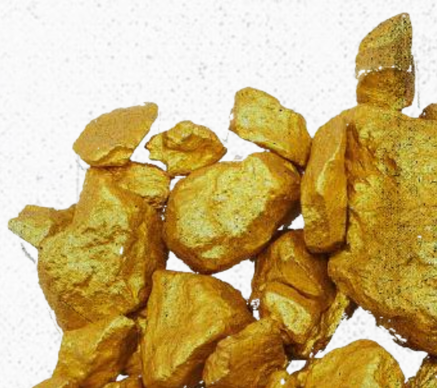
55 Gornall, J. (2016). "Here's the fix: planned obsolescence and the rise of a global repair movement," *The National*, October 10. At: https://www.thenationalnews.com/arts-culture/here-s-the-fix-planned-obsolescence-and-the-rise-of-a-global-repair-movement-1.161013

56 Bookhagenab, B., et al. (2020). "Metallic resources in smartphones," *Resources Policy*, 68: 101750. At: https://doi.org/10.1016/j.resourpol.2020.101750

57 Unwin, T. (2020). "Digital Technologies Are Part of the Climate Change Problem," *ICTworks*, February 20. At: https://www.ictworks.org/digital-technologies-climate-change-problem/

58 reBuy (2020). 2020 Mobile Phone E-Waste Index. At: https://www.rebuy.de/s/mobile-ewaste-index-en

59 Pilgrim, H. (2017). *The Dark Side of Digitalization*. Berlin: PowerShift. At: http://ak-rohstoffe.de/wp-content/uploads/2020/07/PS_FS_Digitalization.pdf



ICT networks used up 10% of the world's electrical production in 2020, while some estimates calculated up to 50% use of world electric production by 2030.[60] In 2020, the digital sector was responsible for almost 4% of global greenhouse emissions (double those from aviation) while 80% of data traffic was video (mostly entertainment).[61] Instead of using the potentials of digital technologies wisely for solving already existing problems – like mobility issues – it was used to "create" new needs and generate massive data flows and technologies to meet them.

COVID accelerated digitalisation trends like never before, leading to an exponential increase in online education, online shopping and online working and meeting. It made some ICT companies dream about making this the norm for the future. In a stark warning, also reminiscent of *The Machine Stops*, Naomi Klein wrote:

This is a future in which, for the privileged, almost everything is home delivered, either virtually via streaming and cloud technology, or physically via driverless vehicle or drone, then screen "shared" on a mediated platform. It's a future that employs far fewer teachers, doctors and drivers. It accepts no cash or credit cards (under guise of virus control), and has skeletal mass transit and far less live art. It's a future that claims to be run on "artificial intelligence", but is actually held together by tens of millions of anonymous workers tucked away in warehouses, data centres, content-moderation mills, electronic sweatshops, lithium mines, industrial farms, meat-processing plants and prisons, where they are left unprotected from disease and hyper-exploitation. It's a future in which our every move, our every word, our every relationship is trackable, traceable and data-mineable by unprecedented collaborations between government and tech giants.[62]

* COVID ACCELERATED DIGITALISATION TRENDS LIKE NEVER BEFORE

60 See: https://ictfootprint.eu/en/news/decreasing-ict-energy-consumption-%E2%80%93-power-data-centres-and-people%E2%80%99s-will-ictfootprinteu-webinar

61 Efoui-Hess, M. (2019). *Climate crisis: The unsustainable use of online video*. Paris: The Shift Project. At: https://theshiftproject.org/en/article/unsustainable-use-online-video/

62 Klein, N. (2020). "How big tech plans to profit from the pandemic," *The Guardian*, May 13. At: https://www.theguardian.com/news/2020/may/13/naomi-klein-how-big-tech-plans-to-profit-from-coronavirus-pandemic

URBANISATION – CITIES GOBBLING UP MATERIALS

At the end of the 2010s, more than half of the world population lived in cities; some projections estimated that by 2050 the urban population would represent 90% of humanity. In 2020, the UN still claimed that "Urbanisation will continue to be the driving force for global growth".[63] If the infrastructure technology of the 2010s was going to be maintained, material consumption would probably need to rise from 40 billion tonnes in 2010 to approximately 90 billion tonnes in 2050.[64] As a 2018 report by the UN International Resource Panel acknowledged, the material requirements, including huge quantities of metals such as copper, iron, titanium or steel, was "more than the planet can sustainably provide".

As an example of this trend, in just three years (2011–2013) China used more cement – 6.6 gigatonnes – than the United States had used during the whole previous century (1901–2000).[65] Growing urban infrastructure inevitably meant more mining in increasingly depopulated rural areas, while smart cities required greater quantities of rarer metals. Self-indulgent efficient and eco-cities seemed to ignore where and how the resources needed for so-called green urbanisation were extracted and at what colossal environmental costs. A vast and increasingly depopulated global hinterland – often due to forced displacement and evictions – continued to feed urban growth and build up waste, including construction residues.

63 UN-Habitat (2020). *World Cities Report 2020: The Value of Sustainable Urbanization*. Nairobi: UN-Habitat. At: https://unhabitat.org/World%20Cities%20Report%202020

64 IRP (2018). *The Weight of Cities*. Nairobi: UNEP. At: https://www.resourcepanel.org/reports/weight-cities

65 Smil, Vaclav (2013). Making the modern world: materials and dematerialization. Chichester: Wiley.

THE GEOPOLITICS OF DYSTOPIA: "WHERE" OR "WHETHER" TO MINE?

These accelerating trends had all the ingredients for an extractivist dystopia. Extractivism not only drained natural resources out of life-sustaining ecosystems, converting them into commodities and waste, but also drained society: it extracted cheap labour from workers without fair pay; it extracted the added value (profit) created by workers for shareholders; it extracted public money for private corporations (subsidies) to maximise profits and redeem their environmental liabilities; it extracted resources from the Global South and peripheral areas to be consumed in the Global North and wealthier cities, leaving huge environmental and social burdens behind; and it extracted data, curtailing privacy and autonomy. Globally, 150 mining companies controlled almost 90% of raw-material extraction in the world.[66]

These different forms of extraction combined into a powerful global phenomenon: extractivism, a profoundly un-ecological and anti-social economic model fuelled by the unsustainable exploitation of nature – from minerals, metals and fossil fuels to land, water and humans. This kind of economy, built upon earlier forms of colonialism, was enabled by the ideological assumption that the Earth, future generations and other, less powerful people were resources to be exploited without limit or consequence for the benefit of a global minority.

66 Ericsson, M. (2012). "Mining industry corporate actors analysis". At: https://goxi.org/sites/default/files/2019-06/Mining%20industry%20corporate%20actors%20analysis.pdf

Paradoxically, human rights violations and absence of environmental "best practices", together with international economic rivalries, were used as an excuse to justify mining pristine areas on land and the destruction of the deep seabed. The fact that certain countries prohibited foreign investors from extracting metals in their territory together with international concerns regarding security of supply was a perfect excuse to encourage mining where (and how) no one had mined before. These actions threatened to exacerbate the environmental and social consequences that extractivism had caused for centuries. At the same time, used batteries and other discarded devices bearing such "critical metals" were being shipped from the EU and US all the way to China for recycling and later repurchase.[67]

Mining was one of the world's most polluting, destructive and deadly[68] industries and a main contributor to climate change and the destruction of nature.[69] The production of seven metals (iron, aluminium, copper, zinc, lead, nickel and manganese) was responsible for 7% of total greenhouse gas emissions.[70] Growing opposition to mining was confronted in many countries with brutality and murder.[71] In 2012, 34 miners on strike were shot dead by police in South Africa.[72] In 2019, more than 200 environmental defenders were killed, mostly in conflicts involving mining.[73] In places where the assassination of opponents was not acceptable, soft counter-insurgency tactics were used to undermine or ridicule those who denounced its impacts and associated corruption.[74]

* IN 2012, 34 MINERS ON STRIKE WERE SHOT DEAD BY POLICE IN SOUTH AFRICA.[71]

67 Melin, H. (2019). *State-of-the-art in reuse and recycling of lithium-ion batteries– A research review*. Stockholm: The Swedish Energy Agency. At: http://www.energimyndigheten.se/globalassets/forskning--innovation/overgripande/state-of-the-art-in-reuse-and-recycling-of-lithium-ion-batteries-2019.pdf

68 MacDonald, A. et al. (2019). "The Hidden Deaths of Mining," *The Wall Street Journal*, December 21. At: https://www.wsj.com/articles/the-hidden-deaths-of-mining-11577825555

69 Nag, O.S. (2020). "The World's Most Polluting Industries", *World Atlas*, October 21. At: https://www.worldatlas.com/articles/the-top-10-polluting-industries-in-the-world.html

70 OECD (2018). *Global Material Resources Outlook to 2060*. Paris: OECD. At: https://doi.org/10.1787/9789264307452-en

71 See: https://www.ilo.org/ipec/areas/Miningandquarrying/lang--en/index.htm

72 See: https://marikana.mg.co.za/

73 Global Witness (2020). *Defending tomorrow*. London: Global Witness. At: https://www.globalwitness.org/en/campaigns/environmental-activists/defending-tomorrow/

74 Dunlap, A. (2020). "Wind, coal, and copper: the politics of land grabbing, counterinsurgency, and the social engineering of extraction," *Globalizations*, 17:4, 661-682. At: https://doi.org/10.1080/14747731.2019.1682789 ; Martinez Alier, J. (2020). "MIREU Backfires," *Environmental Justice*. At: http://www.envjustice.org/2020/09/mireu-backfires/

As part of what was called the Great Acceleration, mining not only continued to be critical for the armaments industry[75] but directly fuelled and prolonged wars, instigated political instability, increased the vulnerability of countries to war and undermined the quality of governance, all in order to get hold of the last minerals across the world, further expanding the consequences of what came to be called the resource curse.[76] Tensions and rivalry between states were also used as an excuse to further ease environmental regulations and silence communities in the sacrifice zones. Indigenous peoples were displaced and whole communities forcibly evicted. In India alone, mining brought about the displacement of 2.55 million people between 1950 and 1990.[77] Labour and health conditions in many mines and smelting factories were inhumane, while more than a million children were working as miners in the early 2020s. As anthropologist Stuart Kirsch put it, mining was an industry where profits were predicated on harm.[78] People had enough of it.

75 Selwyn, D. (2020). *Martial Mining*. London: London Mining Network. At: https://londonminingnetwork.org/wp-content/uploads/2020/04/Martial-Mining.pdf

76 Ross, M.L. (2004). "What Do We Know about Natural Resources and Civil War?" *Journal of Peace Research*, 41(3): 337-356. At: https://doi.org/10.1177/0022343304043773 ; Norman, C. S. (2008). "Rule of Law and the Resource Curse," *Environmental and Resource Economics*, 43 (2): 183-207. At: https://link.springer.com/article/10.1007/s10640-008-9231-y

77 Terminski, B. (2012). "Mining-Induced Displacement and Resettlement: Social Problem and Human Rights Issue," *SSRN*. At: https://www.ssrn.com/abstract=2028490

78 Kirsch, Stuart (2014). *Mining Capitalism*. Oakland: University of California Press. p. 13.

MORE EXTRACTION MEANT MORE DESTRUCTION

As the UN International Resource Panel co-chair Janez Potočnik warned, it was not resource exhaustion that was becoming the core limiting factor of development but rather the "environmental and health consequences caused by this excessive and irresponsible use of resources".[79] A 2020 tailings guidelines warned that mine tailings dams were "failing with increasing frequency and severity".[80] The surge of mining of the early 21st century meant many more and far larger tailings dams,[81] increasing chances of ever greater mining disasters. As the guidelines acknowledged, "the safest tailings facility is the one that is not built."

In 2019 the critical failure of a mine tailings dam in Brumadinho, Brazil, killed over 250 people, destroyed a whole city and released 12 million cubic meters of tailings, polluting 300 km of river ecosystems. In 2015, another tailings dam in the same region caused the Mariana disaster, which released 43.7 million cubic meters of tailings, killing 19 people and polluting 650 km of rivers with heavy metals such as arsenic, lead and mercury before reaching the Atlantic. A year before, in 2014, the tailings dam of the Mount Polley gold and copper mine in Canada failed, causing the spill of 21 million cubic meters into nearby lakes and rivers. One of the reasons for this series of disasters was the decline of ore grades since the 1980s and a subscequent "doubling the volume of mine waste tailings generated for each unit of mineral produced".

THE SURGE OF MINING OF THE EARLY 21ST CENTURY MEANT MANY MORE AND FAR LARGER TAILINGS DAMS, INCREASING CHANCES OF EVER GREATER MINING

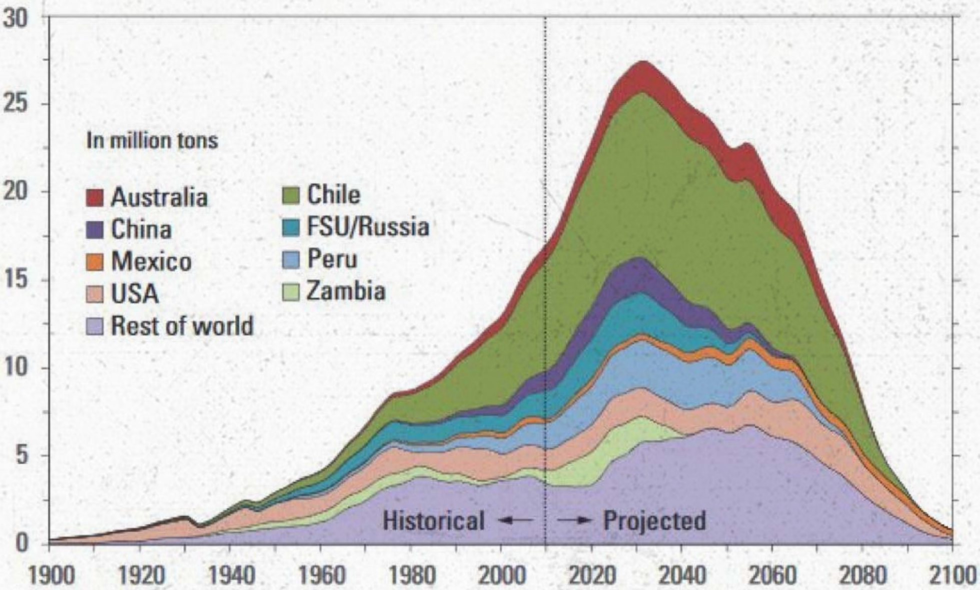
79 See: https://europa.eu/capacity4dev/file/83457/download?token=V5Ht7VEH

80 Morrill, J., et al. (2020). *Safety First: Guidelines for Responsible Mine Tailings Management.* Washington: Earthworks. At: https://www.earthworks.org/publications/safety-first-guidelines-for-responsible-mine-tailings-management/

81 Gold mines – like Mount Polley – generated about 20% of mine tailings in the world. Mudd, G.M. (2019). "Mining & Its Growing Environmental Impacts". At: https://miningwatch.ca/sites/default/files/muddpresentationmining-v-mine-waste.pdf

Grades were reduced by half for many minerals. The average concentration of copper went from 1.8% in 1930 to 0.5% in the 2010s.[82] Lower concentration of ores required mining higher volumes of materials with no commercial value to get the same amount of metals, usually in bulk operations. These demanded higher energy intake, created larger environmental impacts and long-term liabilities and were more likely to involve bigger waste facilities built under minimum low-cost safety standards. Lower ore grades and increasing metal demand was also leading to a rise in greenhouse gas emissions from mining and metal production, which already amounted to 10% of global energy-related greenhouse gas emissions in 2018. Decreasing grades in copper deposits in Chile from 2001 to 2017 led to a 130% increase in fuel consumption and a 32% increase of electricity consumption per unit of mined copper.[83] Projections estimated that by 2050 the exploitation of the last major copper deposits would drain 2.4% of global energy consumption, compared to 0.3% in 2012.[84]

Figure 2: Historical and projected copper production (in million tons).



Soure: Kerr (2014).[85]

82 Arnsperger, C.; Bourg, D. (2017). *Écologie intégrale. Pour une société permacirculaire*. Paris: Presses Universitaires de France, p. 87

83 Azadi, M. et al. (2020). "Transparency on greenhouse gas emissions from mining to enable climate change mitigation," *Nature Geoscience*, 13:100-104. At: https://www.nature.com/articles/s41561-020-0531-3

84 Elshkaki, A. et al. (2016). "Copper demand, supply, and associated energy use to 2050," *Global Environmental Change*, 39: 305-315. At: https://doi.org/10.1016/j.gloenvcha.2016.06.006

85 Kerr, R. (2014). "The coming copper peak," Science, 343: 722-724. At: https://science.sciencemag.org/content/343/6172/722

In 2011, a UN report had already acknowledged that "Today, depending on the metal concerned, about three times as much material needs to be moved for the same ore extraction as a century ago, with concomitant increases in land disruption, groundwater implications and energy use".[86] Together with increased demand this led to a vicious cycle that policymakers, pressured by mining lobbies, seemed unwilling to break:[87] "more energy [was] necessary to extract more minerals which [were] needed to build more energy infrastructure, part of which [was] needed to provide the additional energy required to extract more minerals and so on and so on."[88]

While in the early 2020s most people were roughly aware of what climate change was, very few had had any clue about acid mine drainage, although the UN had acknowledged it as the second biggest global issue after global warming.[89] A 2006 review of environmental impact statements for mining operations concluded that "nearly all the mines that developed acid drainage either underestimated or ignored the potential for acid drainage in their EISs" as well as impacts to groundwater, seeps, and surface water.[90]

86 IRP (2011). *Decoupling natural resource use and environmental impacts from economic growth*. Nairobi: UNEP. At: https://www.ourenergypolicy.org/wp-content/uploads/2014/07/decoupling.pdf

87 See, for example, the EU's 2020 "Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability". At: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0474

88 Parrique, T. et al. (2019). *Decoupling debunked: Evidence and arguments against green growth as a sole strategy for sustainability*. Brussels: European Environmental Bureau. At: https://eeb.org/library/decoupling-debunked/

89 Marchildon, J. (2017). "The UN Has Called This The Second Biggest Environmental Problem Facing Our World," *Global Citizen*, September 14. At: https://www.globalcitizen.org/en/content/acid-drainage/

90 Kuipers, J.R. et al. (2006). *Comparison of Predicted and Actual Water Quality at Hardrock Mines*. Washington: Earthworks. At: https://www.earthworks.org/publications/comparison_of_predicted_and_actual_water_quality_at_hardrock_mines/

Heavy metals were poisoning soils, rivers, underground water and the oceans. In Cerro de Pasco, Peru, 90% of all children had high levels of lead, mercury, arsenic, tungsten, and other heavy metals in their bodies.[91] Children in the Sierra Minera of Cartagena, in Spain, were suffering a similar fate.[92] The small Tinto and Odiel rivers in Spain transported 37% of the zinc and 15% of the copper contributed by all of the world's rivers to the seas and oceans.[93] This was a consequence of continued mining activity in their basin and lack of environmental control and restoration efforts, leading high heavy metal concentrations in many types of commercially important fish species and forcing restrictions among at-risk groups, particularly children.[94]

Not only were the social and ecological impacts of terrestrial mining worsening, but the drive for mining pushed destruction into previously untouched and pristine environments.[95] A 2020 article in Nature had revealed how mines targeting "materials needed for renewable energy production" had a greater overlap with protected areas and remaining wilderness than mines targeting other materials.[96]

91 See: https://pulitzercenter.org/projects/pasco-region-residents-peru-plead-poisoned-kids

92 Kuner, D. (2019). "Heavy metals are school health risk in Murcia," *EuroWeekly*, October 30. At: https://www.euroweeklynews.com/2019/10/30/heavy-metals-are-school-health-risk-in-murcia/

93 Nieto, J.M., et al. (2007). "Acid mine drainage pollution in the Tinto and Odiel rivers (Iberian Pyrite Belt, SW Spain) and bioavailability of the transported metals to the Huelva Estuary," *Environment International*, 33(4):445-455. At: https://doi.org/10.1016/j.envint.2006.11.010

94 Damiano, S. et al. (2011). "Accumulation of heavy metals to assess the health status of swordfish in a comparative analysis of Mediterranean and Atlantic areas," *Marine Pollution Bulletin*, 62(8):1920-1925. At: https://doi.org/10.1016/j.marpolbul.2011.04.028

95 Marin, D. (2021). "Greenland: Global Warming Hotspot and Environmental Frontline," META, Feb. 11. At: https://meta.eeb.org/2021/02/11/greenland-global-warming-hotspot-and-environmental-frontline/

96 Sonter, L., et al. (2020). "Renewable energy production will exacerbate mining threats to biodiversity," *Nature Communications*, 11:4174. At: https://www.nature.com/articles/s41467-020-17928-5

DEEP SEA MINING: THE BIGGEST LAND-GRAB IN HUMAN HISTORY

With advances in mining technologies, an old dream was revived: all eyes turned to the vast and largely unexplored half of the planet – the deep sea. The metals on the deep seabed, already briefly explored in the 1970s, again became the centre of attention. Driven by a technology optimism to "boldly go where no man has gone before", the push to mine the deep sea seemed unstoppable, and threatened the planet with unprecedented destruction.

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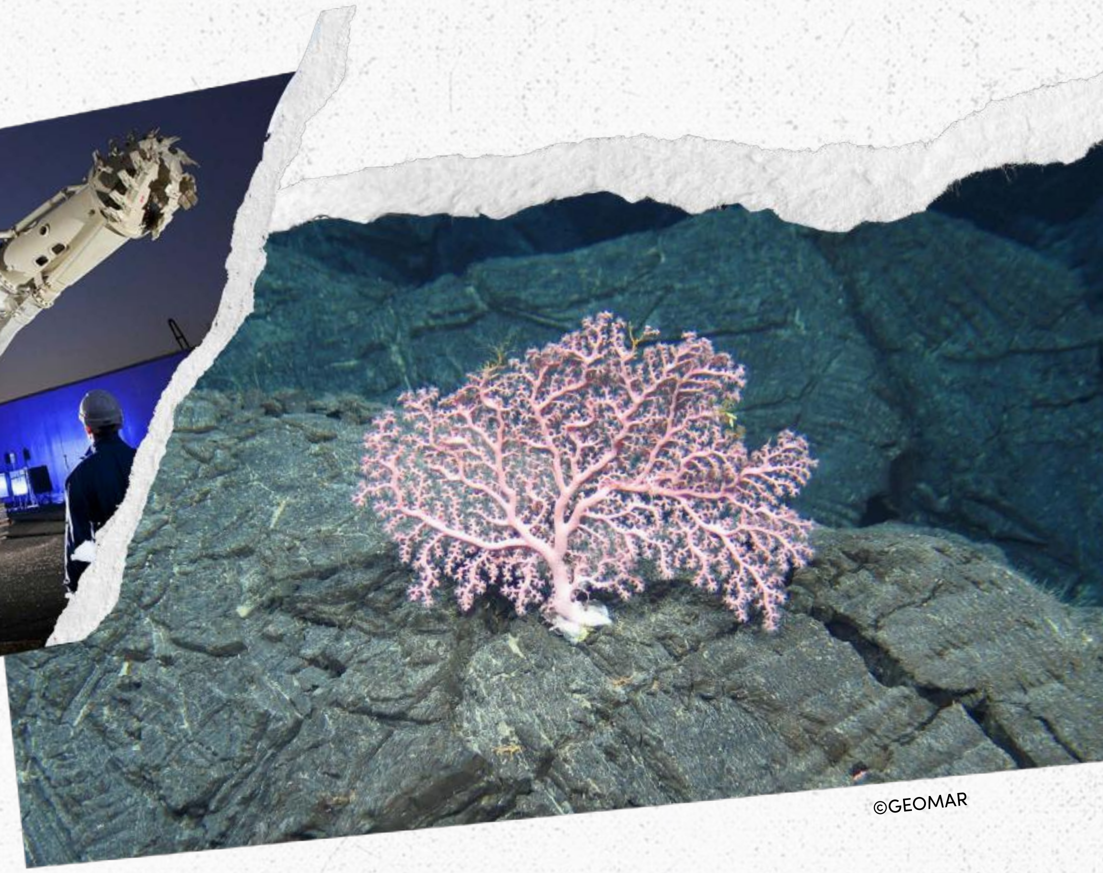

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THE DEEP SEA

The deep sea is the entire ocean below 200 meters in depth. It makes up 95% of Earth's living space. Only in recent decades have scientists been able to explore it and understand its importance.

Scientists believe that as many as 10 million species may inhabit the deep sea – a biodiversity that may be as rich as tropical rainforests. The majority of species are yet to be discovered.

All life on Earth – including human life – depends on the deep sea because it keeps the planet's systems functioning. It drives the global currents that keep temperatures and weather regulated. It regenerates nutrients. And it absorbs and stores the carbon dioxide emitted into the air by human activity.

Humans benefit from the deep sea in other ways. Deep-sea coral and sponge communities are largely untapped sources of natural products which can be used in medicines, cosmetics and other commercial products. A test being used to diagnose COVID-19 was developed using an enzyme isolated from a microbe found in deep-sea hydrothermal vents.

The deep sea is the most difficult area on Earth to access: so far, fewer humans have explored its deepest regions than have walked on the moon. But it is also extremely vulnerable.

Most deep-sea species are slow to grow and reproduce, and highly adapted to a largely unchanging environment. This makes them extremely vulnerable to overfishing and other human disturbance. This was recognised by the United Nations General Assembly, which committed nations to protect the deep sea from harmful fishing activities "recognising the immense importance and value of deep-sea ecosystems and the biodiversity they contain".

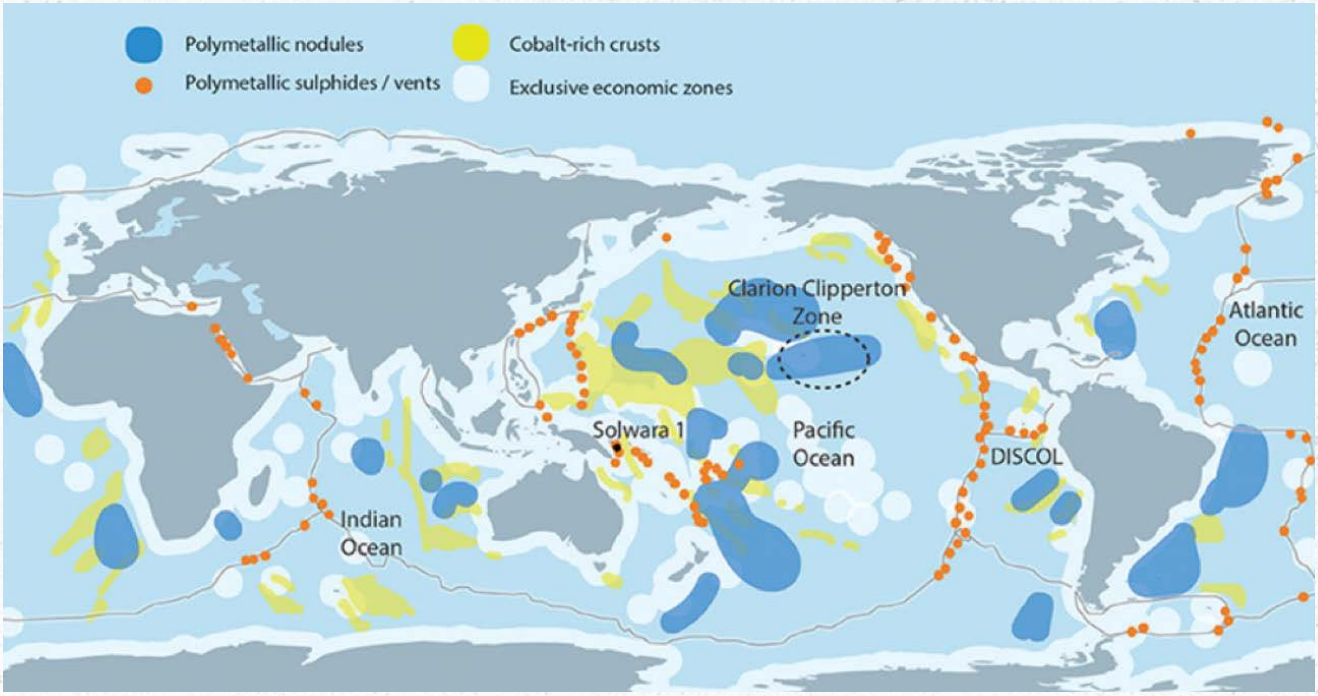
The deep sea is home to remarkably rich coral systems. Corals were once thought to inhabit only the warm waters of tropical and subtropical regions, but they have actually been thriving in deep, dark and cold waters throughout the world for millions of years. In fact, over half of all known coral species are found in the deep sea. Cold-water reefs are bustling with life, providing essential sanctuaries and nursing grounds for countless other species.

Adapted from: http://www.savethehighseas.org/about-the-deep-sea/

* ALL LIFE ON EARTH – INCLUDING HUMAN LIFE – DEPENDS ON THE DEEP SEA

In 2020, more than 1.3 million km^2 of the deep ocean was already set aside for deep-sea mining exploration, with permits overseen by the International Seabed Authority. Scientists warned of irreversible large-scale biodiversity loss, and for sediment plumes with high concentrations of heavy metals that could travel hundreds of thousands of kilometres, affecting the entire food chain through bioaccumulation and biomagnification processes.[97] Hundreds of thousands of square kilometres would be physically destroyed, including especially vulnerable areas such as seamounts that serve as a habitat and pantry for millions of species.[98] Vast areas of the seabed would be dredged for manganese nodules, rock concretions that took millions of years to grow and provided habitats for many species, which also would mean removing the top layer of the seabed in which all microbial life resides.

Figure 3: Location of the three main marine mineral deposits: polymetallic nodules (blue); polymetallic or seafloor massive sulfides (orange); and cobalt-rich ferromanganese crusts (yellow).



Source: Miller et al. (2018).

97 Hauton, C. et al. (2017). "Identifying Toxic Impacts of Metals Potentially Released during Deep-Sea Mining—A Synthesis of the Challenges to Quantifying Risk," *Front. Mar. Sci.*, 4: 368. At: https://doi.org/10.3389/fmars.2017.00368

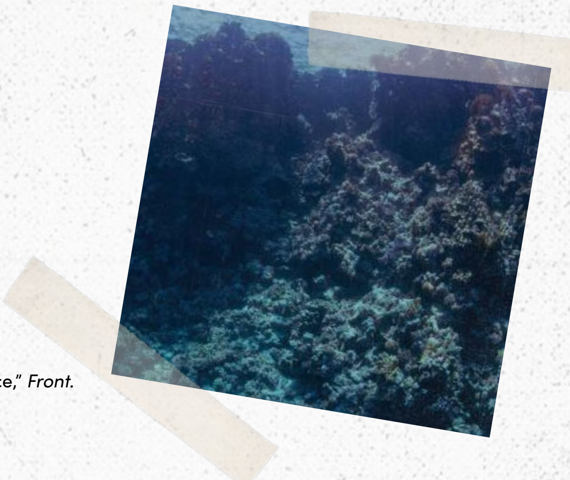
98 Miller, K.A. et al. (2018). "An Overview of Seabed Mining Including the Current State of Development, Environmental Impacts, and Knowledge Gaps," *Front. Mar. Sci.*, 4: 418. At: https://doi.org/10.3389/fmars.2017.00418; Watling, L.; Auster P.J. (2017). "Seamounts on the High Seas Should Be Managed as Vulnerable Marine Ecosystems," *Front. Mar. Sci.*, 4: 14. At: https://doi.org/10.3389/fmars.2017.00014

The disruption of the planet's main carbon sink, oceans, which captured a quarter of the CO_2 emitted by human activity,[99] would imply the release of greenhouse gases sequestered for millions of years, suppressing the capacity of carbon-fixing organisms.[100] Deep-sea mining risked the destruction or extinction of species that allowed for the discovery of new medicines, associated with life forms present only in the deep ocean, like the COVID test, developed using an enzyme isolated from a microbe found in deep-water hydrothermal vents.[101]

Calls for moratoriums or bans were issued by, among others, the United Nations Environmental Programme, the European Parliament, the European Commission, the British Parliament, the International Union for Conservation of Nature, the EU's fisheries advisory councils, Seas At Risk, WWF, Greenpeace, Fauna & Flora International and Deep Sea Conservation Coalition.[102] They went largely unheeded by the International Seabed Authority, the UN-sponsored body – with 167 countries and the EU among its members – mandated in 1994 to manage deep-sea resources for the "protection and preservation of the marine environment". In practice, the ISA mostly acted as a promotor of deep sea-mining.

In a compelling video message, world-renowned marine biologist Sylvia Earle called deep-sea mining the biggest land-grab in the history of humankind and warned it could vastly disrupt deep-sea ecosystems that provided oxygen to all life on earth and had a climate-regulating function.[103]

Legally designated as "Common Heritage of Mankind", the deep sea was being divided like a cake for the financial gains of a few countries and companies. And more and more the fundamental question was being posed: could it be that we – humankind – stood to lose far more than we would gain if the member nations of the ISA permitted deep-sea mining?[104]



99 See: https://www.earth.columbia.edu/articles/view/2586

100 Levin, L.A. et al. (2016). "Hydrothermal Vents and Methane Seeps: Rethinking the Sphere of Influence," *Front. Mar. Sci.*, 3: 72. At: https://doi.org/10.3389/fmars.2016.00072

101 See: https://en.unesco.org/news/covid-19-ocean-ally-against-virus-0

102 See: http://www.savethehighseas.org/wp-content/uploads/2020/06/DSCC_FactSheet3_DSM_moratorium_4pp_web.pdf

103 Earle, S. (2021. "Oceanographer Sylvia Earle on the Dangers of Deep-Sea Mining," *Now This News*, March 4. At: https://nowthisnews.com/videos/earth/oceanographer-sylvia-earle-on-the-dangers-of-deep-sea-mining

104 See: http://www.savethehighseas.org/wp-content/uploads/2020/07/DSCC_FactSheet6_DSM_WhoBenefits_4pp_web.pdf

4 SEEDS OF CHANGE

"TO GET OUT OF A HOLE, THE FIRST STEP IS TO STOP DIGGING."

— ENGLISH PROVERB

If we look back at 2020 and the preceding decades through today's post-extractive lens, many seeds of change that were to become pivotal in the transformational decade ahead become evident. While an increasing sense of urgency calling for the development, escalation and spread of emerging alternatives existed at the time, most were disregarded by mainstream policy-makers as utopian or unpractical exercises of wishful thinking.

Changes related to the circular economy, technology, efficiency and innovation were an important step in the right direction. But deeper social and economic change was critical. The biggest challenge and opportunity was to move away from a linear, throw-away economy focussed on consumption and GDP growth to a circular economy focussed on sufficiency, wellbeing and fair and equitable distribution.

THINKING ENERGY DIFFERENTLY

Energy consumption reduction was not only about behaviours and design – like keeping those irritating standby lights off – and upscaling simple and efficient appropriate technologies. It was first and foremost part of an overall transition to a much less energy-intensive economy. Calls were being made to end wasteful practices and energy-hoarding by electro-intensive industries while personal and family energy budget schemes such as the UK's TEQs[105] were followed by binding mechanisms for resource capping and schemes conditioning trade to mandatory metal recovery and substitution.

Wasteful use of electricity for heating and cooling was minimised through age-old ground-coupled heat exchangers – Provençal or Canadian wells – solar chimneys, circulating fans as well as solar thermal collectors and water-brake windmills. The extended use of pot skirts, pressure cookers, fireless cookers and solar cookers[106] led to huge energy savings in everyday cooking, while shared open WiFi, a movement started in 2012,[107] made 5G unnecessary and significantly cut IT energy use.

Direct hydro- and wind-power were other age-old technologies that made their comeback, not only for industrial applications[108] but even for water-powered household devices.[109] So did compressed-air energy-storage systems, which were already being deployed in the 2010s and, together with hydraulic accumulators, gravity batteries and thermal energy-storage systems, made stationary lithium-ion storage stations unnecessary. Ironically, the end of mining brought new uses for abandoned mineshafts, with the design of gravity-storage installations using 2000-tonne weights suspended from winches.[110]

105 See: https://flemingpolicycentre.org.uk/teqs/

106 De Decker, K. (2014). "If We Insulate Our Houses, Why Not Our Cooking Pots?," *Low-tech magazine*, Jul. 1. At: https://www.lowtechmagazine.com/2014/07/cooking-pot-insulation-key-to-sustainable-cooking.html

107 See: https://www.eff.org/pages/openwirelessorg

108 De Decker, K. (2013). "Back to Basics: Direct Hydropower," *Low-tech magazine*, Aug. 11. At: https://www.lowtechmagazine.com/2013/08/direct-hydropower.html

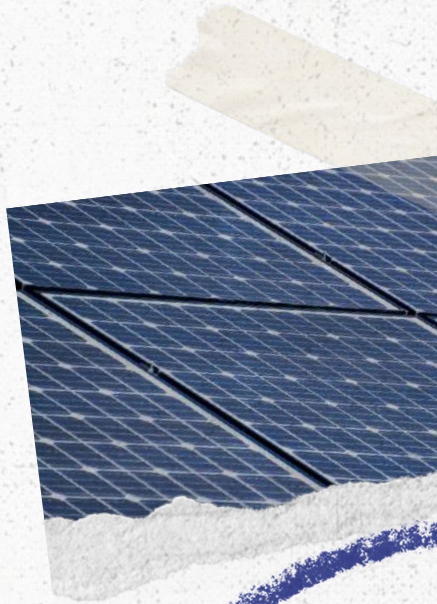
109 De Decker, K. (2013). "Power from the Tap: Water Motors," *Low-tech magazine*, Sept. 9. At: https://www.lowtechmagazine.com/2013/09/power-from-the-tap-water-motors.html

110 O'Neill, N. (2018). "Is gravity and old mineshafts the next breakthrough in energy storage?," *Imperial College London*, Apr. 23. At: https://www.imperial.ac.uk/news/185896/are-gravity-mineshafts-next-breakthrough-energy/

Losses in long-distance transport systems led to rethinking the grid as large-scale, mineral-intensive power plants became unviable. The 2020s became a decade of transition back to distributed generation, once the norm, with small, interconnected, distributed energy resources that massively reduced energy losses in transmission.[111] Decentralised models and protest grid defections[112] to counter initial resistance by electric power lobbies helped democratise energy supply beyond existing oligopolies.[113]

In 2010 the US state of Colorado passed a law requiring that by 2020 at least 3% of electricity generation came from distributed grids, while EU Directive 2019/944 acknowledged citizen energy communities,[114] helping renewable energy cooperatives and their distributed grids to thrive. Home, community and district biodigesters became a common way to address energy needs while coping with waste.[115]

Massive losses in AC to DC conversion – DC already accounted for about 50% of the energy used in buildings in 2020 – were avoided by shifting to parallel AC/DC installations at homes and offices,[116] leading to 25% energy savings.[117] Distributed energy and DC household systems allowed homes to use the power they produced through solar, wind or pico- or micro-hydro directly in low-power devices without incurring conversion losses, meaning fewer solar panels (or other technologies) for the same amount of energy. The mainstreaming of direct-DC electric appliances and efficient house design to minimise cable losses further reduced consumption and made electric products simpler, cheaper, more reliable and longer-life, extending product value over time.[118]



111 O'Neil, C. (2019). "From the Bottom Up: Designing a Decentralized Power System," *NREL*. At: https://www.nrel.gov/news/features/2019/from-the-bottom-up-designing-a-decentralized-power-system.html

112 Rocky Mountain Institute (2014). *The economics of grid defection*. Boulder: Rocky Mountain Instituite. At: https://www.homerenergy.com/pdf/RMI_Grid_Defection_Report.pdf Miniature solar panels on windows and balconies became a common sight at first, powering low-voltage direct current (DC) distribution networks for laptops, LED lighting and other small appliances.

113 Kunze, C.; Becker, S. (2015). "Collective ownership in renewable energy and opportunities for sustainable degrowth," *Sustain Sci*, 1-13. At: https://doi.org/10.1007/s11625-015-0301-0 ; European Union (2018). *Models of Local Energy Ownership and the Role of Local Energy Communities in Energy Transition in Europe*. At: https://cor.europa.eu/en/engage/studies/Documents/local-energy-ownership.pdf

114 See: https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/energy-communities-overview-energy-and-social-innovation

115 See: https://mossy.earth/guides/energy/home-biodigester

116 Glasgo, B.; Lima Azevedo, I.; Hendrickson, C. (2016). "How much electricity can we save by using direct current circuits in homes?" *Applied Energy*, 180: 66-75. At: https://www.sciencedirect.com/science/article/pii/S0306261916309771#b0060

117 Savage, P.; Nordhaus, R. R.; Jamieson, S. P. (2010). "DC Microgrids:Benefits and Barriers," *Yale School of Forestry and Environmental Studies*, March. At: https://www.academia.edu/8050676/DC_Microgrids_Benefits_and_Barriers

118 De Decker, K. (2016). "Slow Electricity: The Return of DC Power?," *Low-tech magazine*, Apr. 27. At: https://www.lowtechmagazine.com/2016/04/slow-electricity-the-return-of-low-voltage-dc-power.html

RETHINKING MOBILITY SYSTEMS

While predictions had estimated 2 billion international travellers in 2020 (mostly using planes), travel actually collapsed, falling by 70%. While the COVID pandemic took the blame, in reality, passenger numbers had already been dropping significantly in European short-haul routes because of *flygskam* (flight shaming) instigated by climate activists[119] and preference for rail. Even in over-developed countries like the UK, at least half of the population took no flights at all in a given year, with 70% of flights taken by less than 15% of the population.[120] Commuting and other work-related travel also dropped dramatically as work-from-home schemes grew. Transport methods also changed. Earlier ongoing trends explain how this collapse became the "new normal".

Shifts in individual transportation modes and needs had increasingly made private car ownership obsolete.[121] Cities were again starting to become living spaces, often decentralised, where people could walk or cycle to and from work, meeting spaces and markets. It took almost two decades for cities like Ghent,[122] in Belgium, to become pedestrianised and car-free, but the trend expanded rapidly in the 2020s. The cycling boom intensified[123] so much that even by the 2010s, some countries had already started to remove motorways instead of building more.[124]

119 Asquith, J. (2020). "The Spread Of Flight Shame In Europe—Is Greta Thunberg The Reason Why?" *Forbes*, January 13. At: https://www.forbes.com/sites/jamesasquith/2020/01/13/the-spread-of-flight-shame-in-europe-is-greta-thunberg-the-reason-why/

120 Hopkinson, L., et al. (2019). "Radical Transport Policy Two-Pagers," *Transport for Quality of Life*. At: http://www.transportforqualityoflife.com/radicaltransportpolicytwopagers/

121 Nieuwenhuijsen, M.J.; Khreisd, H. (2016). "Car free cities: Pathway to healthy urban living," *Environment International*, 94: 251-262. At: https://www.sciencedirect.com/science/article/pii/S0160412016302161

122 Rutter, T. (2016). "Car-free Belgium: why can't Brussels match Ghent's pedestrianised vision?" *The Guardian*, November 28. At: https://www.theguardian.com/cities/2016/nov/28/car-free-belgium-why-cant-brussels-match-ghents-pedestrianised-vision

123 See: https://ecf.com/news-and-events/news/get-ready-cycling-boom-experts-predict-30-million-bicycle-sales-2030

124 See: https://bicycledutch.wordpress.com/2016/01/05/motorway-removed-to-bring-back-original-water/

COVID was a wake-up call to rethink urban mobility systems in particular. Following long standing traditions in place such as Amsterdam, Copenhagen and Bogotá,[125] voices were raised for enhanced public transport, putting in place car-sharing systems and walking and cycling infrastructures in cities. Milan – the epicentre of Italy's COVID outbreak – announced it would transform 35 km of its streets for cycling.[126] In Berlin, a campaign started to oust the car.[127] Parisian Mayor Anne Hidalgo announced that returning to a city dominated by cars post-pandemic was "out of the question"[128] and declared Paris would become a "15 minute city" (were residents can meet most of their needs within a short walk or bicycle ride from their homes). And more people started asking what needed to be asked: can we let go of car ownership?

Costs associated with car ownership and maintenance (pay-as-you-drive pricing policies, advertising bans, taxation, highway charges, parking fees, etc.) and the redesign of transport infrastructure paved the way for plain walking or a combination of public transport with the use of bikes, skates, unicycles, velomobiles and kick scooters becoming the norm. Bikes, pedelecs and scooters became part of urban infrastructure through public sharing systems and were rarely individually owned. Even as micro e-mobility developed, the types of batteries that micro e-mobility needed were less energy-intensive and required significantly less material than EV batteries, further reducing the demand for increased extraction. Alternative technologies, including metal-free protein batteries, made mining for batteries increasingly redundant.

In the 2010s bicycles were already replacing vans for cargo deliveries in many cities.[129] Even in regions where car-like vehicles could not be easily replaced – such as rural areas – private ownership dwindled with the emergence of sharing systems and capillary public transportation coverage through on-demand services, drastically reducing car numbers, raising mean passenger occupation and cutting carbon emissions.

125 Sisson, P. (2020). "Ban cars: Why cities are embracing the call for car-free streets," *City Monitor*, September 21. At: https://citymonitor.ai/transport/ban-cars-why-cities-are-embracing-the-call-for-car-free-streets

126 Perry, F. (2020). "How cities are clamping down on cars," *BBC Future Planet*, April 30. At: https://www.bbc.com/future/article/20200429-are-we-witnessing-the-death-of-the-car

127 Posaner, J. (2021). "Berlin campaigners look to oust the car," *Politico*, February 26. At: https://www.politico.eu/article/berlin-looks-to-the-post-car-city/

128 Frost, R. (2020). "Will cars be banned in Paris after lockdown?" *Euronews*, May 5. At: https://www.euronews.com/living/2020/05/15/will-cars-be-banned-in-paris-after-lockdown

129 De Decker, K. (2012). "Cargo cyclists replace truck drivers on European city streets," *Low-tech Magazine*, September 24. At: https://www.lowtechmagazine.com/2012/09/jobs-of-the-future-cargo-cyclist.html

Where needed for individual transport, car-equivalents became smaller and lighter, replaced by light electric and compressed-air (battery-free) quadricycles, velomobiles and rickshaws. Metal frames gave way to organic and light recycled materials, such as bamboo and other natural fibres, which were becoming popular not only for bikes[130] but also cars.[131] Strict battery standards on durability and reusability, as well as recycled-content requirements and supply-chain due diligence – such as the EU's 2021 Batteries regulation – helped end wasteful practices associated with non-catenary or grid-connected vehicles and appliances.

By 1999 it was already known that around 70% of households owning a car – some 700 million – would economically benefit from shifting to car sharing, with 95% of cars being idle during most of the day[132] while most driving was for short distances that could be walked or cycled.[133] Eventually, car-sharing schemes became mainstream through Transport as a Service and peer-to-peer systems, and also due to the lower costs of renting instead of owning.[134] By 2020, Moscow had a fleet of over 30,000 shared cars making some 50 million trips per year.[135]

Eventually, cars started to become a rarity in many towns and cities, as well as on the previously jammed roads connecting them. Catenary-based grid-connected systems – train, light rail, commuter rail, metro, trams, trolleybuses, guideway and elevated transport systems – became the standard land transport for both passengers and freight[136] – following insistent policy recommendations such as those by the Intergovernmental Panel on Climate Change.[137] These highly efficient, battery-free systems already moved much of the world in 2020, more than doubling the number of passenger-kilometres moving on electric trains from 1995 to 2016,[138] and reaching 3 trillion by 2020. In reality, grid-connected electric transport had already been the norm in the beginnings of mass transport systems, when "The electric streetcar [had been] the dominant mass transit vehicle".[139]

130 See: http://www.bamboobike.org/

131 Scharping, N. (2017). "A New Take on the Biodegradable Car," *Discover*, August 8. At: https://www.discovermagazine.com/technology/a-new-take-on-the-biodegradable-car

132 Prettenhaler, F.E.; Steininger, K.W. (1999). "From ownership to service use lifestyle: The potential of car sharing," *Ecol. Econ.*, 28:443-53. At: https://doi.org/10.1016/S0921-8009(98)00109-8; García-Olivares, A., et al. (2018). "Transportation in a 100% renewable energy system," *Energy Conversion and Management*, 158:266-285. At: https://doi.org/10.1016/j.enconman.2017.12.053

133 See: https://www.energy.gov/eere/vehicles/articles/fotw-1042-august-13-2018-2017-nearly-60-all-vehicle-trips-were-less-six-miles

134 Transport & Environment (2019) *Less (cars) is more: how to go from new to sustainable mobility*. Brussels: European Federation for Transport and Environment. At: https://www.transportenvironment.org/publications/less-cars-more-how-go-new-sustainable-mobility

135 Khrennikov, I. (2019). "Why do automakers fear car-sharing? Take a look at Moscow," *Chicago Tribune*, Feb. 11. At: https://www.chicagotribune.com/business/ct-biz-uber-lyft-automakers-russia-20190211-story.html

136 Wong, M. (2018). "Freight trams of Europe," *Euro Gunzel*. At: https://www.eurogunzel.com/2018/09/freight-trams-of-europe/

137 IPCC (2015). *Climate Change 2014*. Geneva: IPCC. At: https://www.ipcc.ch/report/ar5/syr/

138 IEA (2019). *The Future of Rail*. Paris: International Energy Agency. At: https://www.iea.org/reports/the-future-of-rail

139 Young, Jay (2015). "Infrastructure: Mass Transit in 19th- and 20th-Century Urban America," *Oxford Research Encyclopedia of American History*. At: https://doi.org/10.1093/acrefore/9780199329175.013.28

Wind also made its comeback in marine shipping in the 2020s. Rotor sails, wing sails and kite rigs started to be incorporated in modified conventional cargo vessels in the 2010s,[140] in conjunction with hydrogen fuel cells[141] and compressed air that used energy production peaks at ports to recharge. The first 32,000-tonne wind-powered freighter came into service in 2024[142] while a variety of smaller sailing ships started to serve trading routes transporting high-value, low-weight items.[143] Inland, grid-connected electric barges and riverboats (trolley boats and trolley ferries) thrived after catenary overhead systems were reintroduced to rivers and canals,[144] further removing hundreds of thousands of trucks from the roads.[145]

Shifting patterns of consumption, increased localised production,[146] taxation schemes based on transport externalities and emissions, carbon footprint labels on foodstuffs[147] and other measures also initiated changes in the transportation of goods, encouraging local production and rational use of long-distance freight. Changes in product design and usage behaviours and shifts away from pathological consumption made so-called just-in-time delivery unnecessary, allowing for slower but more rational, resilient, assured and energy-efficient logistics and goods storage, particularly for critical items.

Air travel declined sharply from 2020 onwards mainly due to *flygskam*, with leisure, business and cargo flights being increasingly limited with the prioritisation of other uses of high-energy dense fuels during the descent from Peak Oil. Urgent indispensable air transport was covered with lighter and more efficient models, maximising jet-stream travel. Jet streams also allowed for the reintroduction of heavy-load cargo airships circumnavigating the world from west to east wherever shipping and rail were unavailable.[148]

140 Bryce, E. (2018). “Cheap oil killed sailing ships. Now they’re back and totally tubular,” *Wired*, May 29. At: https://www.wired.co.uk/article/norsepower-flettner-rotor-sail-modern-ship-finland

141 Radowitz, B. (2020). “World’s first liquid hydrogen fuel cell cruise ship planned for Norway’s fjords,” *Recharge*, Feb. 5. At: https://www.rechargenews.com/transition/world-s-first-liquid-hydrogen-fuel-cell-cruise-ship-planned-for-norway-s-fjords/2-1-749070

142 Prisco, J. (2020). “Sweden’s new car carrier is the world’s largest wind-powered vessel,” *CNN*, Nov. 13. At: https://edition.cnn.com/travel/article/oceanbird-wind-powered-car-carrier-spc-intl/index.html

143 See: https://www.towt.eu/

144 De Decker, K. (2009). “Trolley canal boats,” *Low-tech magazine*, Dec. 15. At: https://www.lowtechmagazine.com/2009/12/trolley-canal-boats.html

145 See: https://www.electricvehiclesresearch.com/articles/16009/electric-container-barges-to-set-sail

146 Dombroski, S. (2019). “How Locally Grown Products are Disrupting F&B Manufacturing,” *QAD blog*, Dec. 3. At: https://www.qad.com/blog/2019/12/how-locally-grown-products-are-disrupting-fb-manufacturing

147 Tatum, M. (2020). “Will Carbon Labels on Our Food Turn us Into Climatarians?,” *Discover*, Nov. 4. At: https://www.discovermagazine.com/environment/will-carbon-labels-on-our-food-turn-us-into-climatarians

148 Hunt, J. D. et al. (2019). “Using the jet stream for sustainable airship and balloon transportation of cargo and hydrogen,” *Energy Conversion and Management*, X (3). At: https://www.sciencedirect.com/science/article/pii/S2590174519300145

MAKING OBSOLESCENCE OBSOLETE

The shift away from the throw-away take-make-waste consumer society involved adding Rs to the earlier Reduce-Reuse-Recycle triad, boosting Repair, Remanufacture and Recovery. The end of wasteful practices implied drastically curving obsolescence – technological, psychological and planned – guaranteeing reparability, long-life product cycles and built-in raw-material-recovery design.[149]

A number of pioneering public policies were already making steady progress in the 2010s. In 2015 France made planned obsolescence a punishable offence and by 2021 products had lifetime-index stickers based on build quality, reparability and durability.[150] Others followed after a 2020 European Parliament report calling for a "clamp down" on planned obsolescence.[151] Long-life guarantees were made compulsory while producer liability for repair, remanufacture and recovery encouraged companies to re-engineer designs into compliance. In the US, Massachusetts passed the first Right to Repair Act in 2012, requiring car manufacturers to provide the information necessary to allow anyone to repair their vehicles.[152]

149 Bachér, J. et al. (2020). *Electronic products and obsolescence in a circular economy*. Boeretang: European Topic Centre on Waste and Materials. At: https://www.eionet.europa.eu/etcs/etc-wmge/products/electronics-and-obsolescence-in-a-circular-economy

150 See: https://www.thelocal.fr/20180216/france-muses-whether-to-expose-the-true-lifespan-of-goods-and-appliances

151 See: https://oeil.secure.europarl.europa.eu/oeil/popups/ficheprocedure.do?reference=2020/2021(INI)

152 Wiens, K. (2014). "You Gotta Fight For Your Right to Repair Your Car," *The Atlantic*, Feb. 13. At: https://www.theatlantic.com/technology/archive/2014/02/you-gotta-fight-for-your-right-to-repair-your-car/283791/

Laws were not only passed but also rolled out and enforced, as illustrated by French and Italian legal actions in 2018 against Apple and Samsung for planned obsolescence.[153] In 2017 Sweden lowered VAT for repair services – from bikes to shoes and phones to washing machines – and new laws allowed citizens to claim part of the labour cost of appliance repair on their taxes.[154] Many were already proposing that tax on labour for repairs should be zero. Crucially, the 2020s saw generalised suppression of advertisements in public spaces and prohibition of advertising unsustainable products, following earlier bans of tobacco and alcohol advertising and a clamp-down on misleading claims to sustainability.[155]

Most of these policies had already been recommended in a 2017 UN report,[156] including minimum durability criteria and extended guarantees, planned obsolescence and right-to-repair legislation, product lifetime labelling and individual producer responsibility. EU ecodesign regulations passed on October 2019 and a previous July 2017 European Parliament resolution for "A longer lifetime for products" paved the way for upscaling such policies, ensuring the availability of replacement parts, establishing an independent system to test and detect built-in obsolescence in products, and changing design norms to force manufacturers to use easily replaceable materials and techniques that allow for repairs – for example, using screws rather than welding parts together.[157]

153 Kayali, L. (2020). "Apple fined €25M in France for misleading consumers about slowed-down iPhones," *Politico*, Feb. 7. At: https://www.politico.eu/article/apple-fined-e25m-in-france-for-misleading-consumers-about-slowed-down-iphones/ ; BBC (2018). "Apple and Samsung fined by Italian authorities over slow phones," *BBC*, Oct. 24. At: https://www.bbc.com/news/technology-45963943

154 Venard, L. (2017). "Get Paid To Fix Your Broken Things — New Swedish Tax Breaks Support Repair," *Medium*, Mar. 1. At: https://medium.com/@greenxeurope/getting-paid-to-fix-your-broken-things-new-swedish-tax-breaks-support-repair-ff67c016c211

155 Dean, B. (2020). "The five: ads banned for greenwashing," *The Guardian*, Feb. 9. At: https://www.theguardian.com/technology/2020/feb/09/the-five-ads-banned-for-greenwashing

156 Bakker, C. A.; Schuit, C. S. C. (2017). *The Long View: Exploring Product Lifetime Extension*. Nairobi: UNEP. At: https://www.oneplanetnetwork.org/resource/long-view-exploring-product-lifetime-extension

157 See: https://www.europarl.europa.eu/news/en/headlines/economy/20170629STO78621/meps-call-for-measures-to-ensure-products-last-longer

As in other instances, social action preceded public policies and forced states and corporations to act. A culture of repairing grew out from the maker and right-to-repair movements, not only producing self-organising manuals, workshops and repair cafés, but also challenging large companies like Apple, John Deere and AT&T to break restrictions preventing farmers,[158] health professionals[159] and IT users from repairing their own devices. The first repair café, a meeting space where people got together to repair household electrical and mechanical devices, computers, bicycles, clothing and other items, opened in 2009 and, a decade later, there were over 2,000 in 35 countries.[160] The iFixit right-to-repair platform grew from 1.3 million users in 2016 to more than 4.1 million by 2018.[161]

Changes also included new patterns of shared or collective ownership, as in transport and other areas. Washing machines are one example: while reparability regulations banned sealed drum designs that hindered repairability by making it uneconomical to replace certain parts,[162] there was a shift towards communal laundry facilities – like Swedish *tvättstuga* that had been common for decades – with robust long-life and easily repairable machines. Ownership shifted to usership, with producers' long-term liability encouraging long-life, robust, and reparable devices. The sharing economy went beyond cars and washing machines to include all sorts of items that became part of "Libraries of Things" and peer-to-peer lending that included tools, kitchen equipment, electronics, toys, clothes, etc.[163]

In the 2020s, maker culture and the open-source movement took a step further by adopting raw-material recovery and urban mining that allowed not only repairing and refurbishing but also locally self-built items using 3D printing from recovered materials. Microfactories started to produce plastic filaments for 3D printing extracted from e-waste,[164] bringing about the resurgence of people- and planet-centred technology, as theorised long before in Schumacher's *Small Is Beautiful*.[165]

158 Fitzpatrick, A. (2017). "Hand Me That Wrench: Farmers and Apple Fight Over the Toolbox," *Time*, Jun. 22. At: https://time.com/4828099/farmers-and-apple-fight-over-the-toolbox/

159 Condon, S. (2020). "Lawmakers call for 'right to repair' medical equipment during COVID-19 pandemic," *ZDNet*, Aug. 6. https://www.zdnet.com/article/lawmakers-call-for-right-to-repair-medical-equipment-during-covid-19-pandemic/

160 See: https://repaircafe.org/en/visit/

161 Lepawsky, J. (2019). "Planet of fixers? Mapping the middle grounds of independent and do-it-yourself information and communication technology maintenance and repair," *Geo*, Dec. 11. At: https://rgs-ibg.onlinelibrary.wiley.com/doi/full/10.1002/geo2.86

162 Porter, A. (2015). "Are washing machines built to fail?" *Which?*, Jun. 17. At: https://www.which.co.uk/news/2015/06/are-washing-machines-built-to-fail-406177/

163 Benedictus, L. (2019). "The library of things: could borrowing everything from drills to disco balls cut waste and save money?," *The Guardian*, Apr. 24. At: https://www.theguardian.com/society/2019/apr/24/library-of-things-borrowing-scheme-conquer-world

164 Mehta, A. (2019). "Australian university pioneers urban mining 'microfactories'," *Reuters Events*, Apr. 29. At: https://www.reutersevents.com/sustainability/australian-university-pioneers-urban-mining-microfactories

165 Schumacher, E. F. (1973). *Small Is Beautiful: A Study of Economics As If People Mattered*. London: Blond & Briggs.

CIRCULARITY AND INNOVATION – A FIRST STEP IN THE RIGHT DIRECTION

Circular economy policies in the 2010s emphasised recycling in a time where actual recycling rates for many metals were trivial while reuse, repair, remanufacture and lifetime extension were being mostly ignored. Policy and legal changes as well as public pressure reframed the "problem" of e-waste into a growing opportunity for urban mining so that effective metal upcycling and reuse of products not only became mandatory (with defined thresholds), but actually thrived, particularly when required recycled-content targets in manufacture were set and enforced.[166] In the 2010s China had already established that new products were required to contain a minimum of 20% recycled materials by 2025.[167]

Effective product and process design involved not only reparability and remanufacture, but also simpler, economical separation of components for recycling. The rise of available secondary metals through the reverse supply chain and the increasingly higher requirements for recycled metal use reduced demand for primary metal even further.

New buy-back and electronics-as-service schemes helped suppress e-waste hoarding, leading to increased metal recovery.[168] Extracting metals such as copper or gold from e-waste was actually 13 times cheaper than extracting them from conventional mines,[169] and even more so when compared to hypothetical deep-sea operations. In the late 2010s, a single recycling company in China was producing more cobalt annually than all the country's mines together.[170] Landfill mining – recovering materials from landfill deposits – promised soon to become fully operational and profitable.

166 Söderholm, P. (2020). "Metal markets and recycling policies: impacts and challenges," *Mineral Economics*, 33:257-272. At: https://link.springer.com/article/10.1007/s13563-019-00184-5

167 See: http://www.responsabilitas.com/blog/china-epr-regulation/

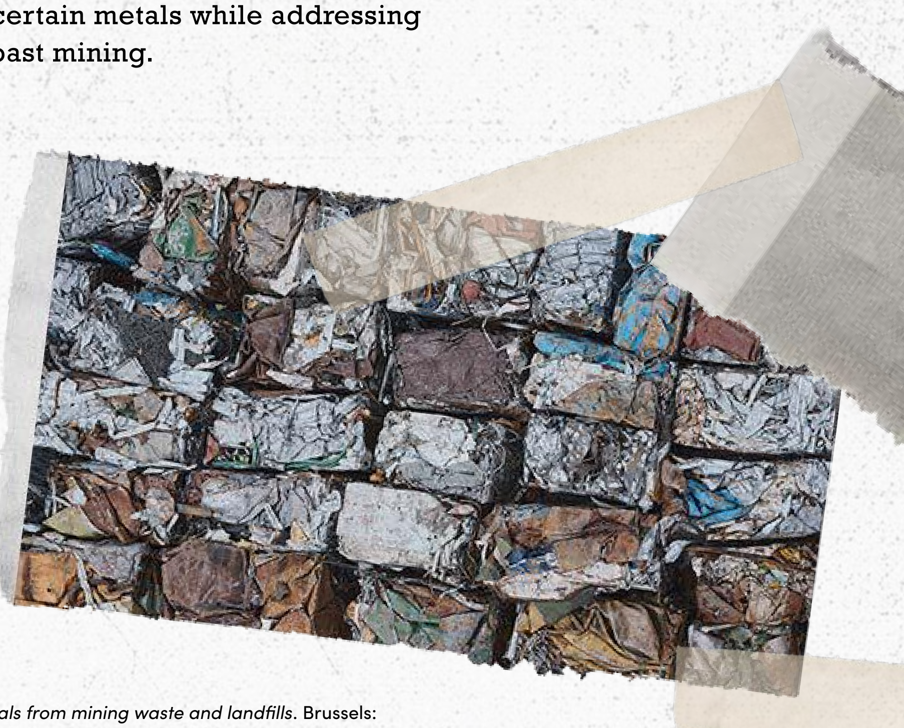
168 Johnson, R. (2018). "Fairphone-as-a-service," *Project Breakthrough*, July 26. At: http://breakthrough.unglobalcompact.org/briefs/fairphone-as-a-service/

169 Zeng, X. et al. (2018). "Urban Mining of E-Waste is Becoming More Cost-Effective Than Virgin Mining," *Environ. Sci. Technol.*, 52(8): 4835-4841. At: https://doi.org/10.1021/acs.est.7b04909

170 WEF (2019). *A New Circular Vision for Electronics*. Geneva: World Economic Forum. At: http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf

The reframing of waste policies, strategies and management solutions not only affected metal-bearing trash, but waste from mining itself: the toxic left-overs of metal mining and processing that had been dangerously building up in tailings dams, mine dumps and acid-mine drainage runoff into rivers and oceans. While addressing the unsolved environmental problems related to critical tailings infrastructure became an urgent matter, ironically, the decrease of ore-grades also made these left-behinds more attractive in terms of the prospects for recovering valuable metals. Mine tailings included relatively high recoverable concentrations of iron, copper, nickel and zinc and often smaller concentrations of gold, silver, rare-earth elements and other metals.[171]

New techniques such as phytomining or metal bioharvesting – extraction of metals in polluted soils through hyperaccumulator plants and fungi – and heavy-metal removal from polluted water started to gain traction in the 2020s. Farmers by Lake Ohrid, Albania, were selling alyssum weeds harvested in the proximities of a former nickel mine due to their high values of that metal,[172] while trials with *Pycnandra acuminate* trees showed they could produce 200kg of nickel per hectare every year for centuries (their sap contains up to 25% nickel content).[173] Research showed many other local native plant species around the world – such as *Erica andevalensis* in Iberia – could be used for decontamination and metal recovery. While some of these techniques were still energy-intensive, their wise use within post-growth societies allowed for a steady supply of certain metals while addressing continuing environmental impacts from past mining.



171 Blengini, G. (2019). *Recovery of critical and other raw materials from mining waste and landfills*. Brussels: European Union. At: https://ec.europa.eu/jrc/en/publication/recovery-critical-and-other-raw-materials-mining-waste-and-landfills

172 Schmidt, F. (2017). "When plants work as miners and cleaners," *DW*, May 18. At: https://www.dw.com/en/when-plants-work-as-miners-and-cleaners/a-38882153

173 van der Ent, A. (2019). "Heavy Metal Farming," *Australasian Science*, July-August. At: http://www.australasianscience.com.au/article/issue-may-2015/heavy-metal-farming.html

SPACE, HOUSING AND CITIES

Almost 90 years ago, in 1961's *The Death and Life of Great American Cities*,[174] Jane Jacobs had questioned the increasingly bizarre logics of urban planning and discussed the need for walkable spaces. Early adopters of pedestrianisation paved the way to *doughnut* cities and *slow* cities that rose after the 2020 COVID pandemic.[175] The localisation of neighbourhood economies and the transport revolution made cities walkable again – inaugurating the new "15-minute city" concept[176] – while the urban landscape was redesigned to accommodate urban horticulture and farming (including beekeeping), foodscaping in parks, vertical gardens and rooftop farming, community composting and biowaste-management initiatives.

From "Incredible Edible" Totnes[177] in the UK to Rosario in Argentina,[178] urban landscapes changed while rural areas flourished once again. The increasing localisation of and involvement in food production led to more diversified and resilient agricultural systems throughout the world, minimizing inequalities associated with crop monocultures, helping reduce global shipping needs, and curbing the need for chemical fertilisers – especially potash – by restoring soil productivity.

174 Jacobs, J. (1961). *The Death and Life of Great American Cities*. New York: Random House.

175 Boffey, D. (2020). "Amsterdam to embrace 'doughnut' model to mend post-coronavirus economy," *The Guardian*, Apr. 8. At: https://www.theguardian.com/world/2020/apr/08/amsterdam-doughnut-model-mend-post-coronavirus-economy

176 Sisson, P. (2020). "What is a 15-minute city?" *City Monitor*, Sept. 21. At: https://citymonitor.ai/environment/what-is-a-15-minute-city

177 See: https://www.transitiontowntotnes.org/incredible-edible/

178 See: http://www.fao.org/ag/agp/greenercities/en/ggclac/rosario.html

Ecological architecture and design in both new and updated buildings centred on maximum efficiency and reduction of raw materials through reuse (such as reclaiming lumber). From insulation schemes and passive solar building design that benefited single units in terms of daylighting, urban planning was modified to create solar envelopes in solar-oriented cities and towns.[179] The 2030 Challenge[180] was one of many initiatives that helped empower architects, planners, builders and society at large to shift their understanding of the built environment. Behavioural change included more shared housing and co-working spaces, while tax policies discouraged unused buildings and incentivised rehabilitation. Some early examples include Vancouver's "Empty Home Tax", launched in 2016,[181] or Italy's 2020 Ecobonus for renovation works targeting energy efficiency.[182]

In 1900, 85% of the world's population lived the countryside, with access to land to obtain food and dispose of waste directly. In the 2010s more than half of the world's population lived in cities, which not only demanded unprecedented levels of extraction in certain parts of the world to provide food, energy and goods, but also involved returning unprecedented levels of waste to rural areas and the seas. Separation from nature and the means of subsistence made most urban populations oblivious to the real impacts of extractivism and fostered the belief that cities could continue to grow indefinitely.[183] The Transition Movement, initiated in 2006, involved thousands of local initiatives in more than 50 countries by 2020, focussing on issues such as degrowth, energy descent, local food production and permaculture design, inspiring many other commoning communities and ecovillages that helped to make the Global North more aware of the alternatives to over-development.

179 De Decker, K. (2012). "The solar envelope: how to heat and cool cities without fossil fuels," *Low-Tech Magazine*, March. At: https://www.lowtechmagazine.com/2012/03/solar-oriented-cities-1-the-solar-envelope.html

180 See: https://architecture2030.org/2030_challenges/2030-challenge/

181 CBC (2019). "Vancouver raising empty homes tax by 25%," *CBC*, Nov. 28. At: https://www.cbc.ca/news/canada/british-columbia/vancouver-empty-homes-tax-increase-1.5376581

182 Lovells, H. (2020). "Implementing rules for Superbonus 110% have finally been issued," *JDSupra*, Aug 11. At: https://www.jdsupra.com/legalnews/implementing-rules-for-superbonus-110-40883/

183 Bradford, J. (2019). *The Future is Rural: Food System Adaptations to the Great Simplification*. Corvallis: Post Carbon Institute. At: https://www.postcarbon.org/publications/the-future-is-rural/

TIME IS...LIFE: THE TIME-USE REVOLUTION

Changes in mobility, production and transport of goods and usership were facilitated, together with many other social and economic changes – such as localised food production, increased social and political engagement, etc.– by shifts in work environments and patterns. Home working increased exponentially during COVID lockdowns, and was continued, generally on a part-time basis, when the pandemic was tamed. Working from home allowed greater flexibility, reduced commuting and allowed an inversion of urbanisation trends and rural reflourishing.

Four-day working weeks and six-hour workdays became the norm in the 2020s, building from early adoption experiences such as that of the Gambia in 2013[184] to extended calls a few years later, particularly during and after the COVID pandemic, in places such as Scotland[185] or Finland.[186] Strong evidence for shorter working days and weeks had been put forward by time-use researchers and led to adoption of time-use policies that promoted healthy life habits (including mental health and the physical benefits of non-motorised transport), sustainable transition towards new labour models and work-life balance between paid work, non-paid work and leisure in order to reduce inequalities.

Combined with forms of guaranteed livelihoods – such as universal basic income[187] – this allowed more time for caring, creativity, social and environmental activism and learning. Many people were increasingly able to spend more time with their families and communities and to follow their passions, which had an impact on how people viewed their environment. This slowing down of life opened up new spaces for reflection and resistance, generating more imaginative ways of recreating society through sustainable types of living.[188]

184 Williams, J. (2013). "Gambia's four day week," *Earthbound*, Feb. 7. At: https://earthbound.report/2013/02/07/gambias-four-day-week/

185 Cooney, A.F. (2020). "Scotland is ahead of the curve with four-day working week," *The National*, Jul. 23. At: https://www.thenational.scot/news/18600678.scotland-ahead-curve-four-day-working-week/

186 Claesson, A. (2020). "Finland Is Rallying Around a Six-Hour Workday — And So Should We," *Jacobin*, Sept. At: https://jacobinmag.com/2020/09/finland-six-hour-workday-working-hours-covid

187 Patel, S. B. (2021). "Universal basic income and covid-19 pandemic," *British Medical Journal*, 372: 193. At: https://doi.org/10.1136/bmj.n193

188 Jordan, J. (2017). "Artivism: Injecting Imagination into Degrowth," *Degrowth*. At: www.degrowth.info/en/catalogue-entry/blog-artivism-injecting-imagination-into-degrowth

As the New Economics Foundation had pointed out, much of our earlier resource-intensive consumption was triggered by busy-ness[189] and what sociologist Hartmut Rosa called our obsession with "increasing the volume [of activity] per unit of time":[190] traveling by plane or car rather than by public transport, bike, or on foot; throwing away items instead of trying to repair them; heating-up processed foods from afar in energy-intensive devices instead of slow-cooking locally produced or home-grown ingredients; using faster information media instead of taking time to examine issues in depth; spending free time consuming advertising and other audio-visuals instead of engaging in meaningful social, political and environmental activities. The widespread adoption of many alternatives that had been around for decades was facilitated by the social shifts stemming from time-use change and the deceleration of living.

Money systems were also reinvented, moving away from the debt-based economy of the past. Innovation in monetary, mutual- and community-credit and local-exchange trading systems included municipal and grass-root initiatives, which flourished after legal bans were lifted; in France, the Social and Solidarity Economy Law had granted legal recognition to complementary local currencies in 2013. The growth of alternative finance models – crowdfunding, peer-to-peer lending, community shares, etc. – and the crisis of traditional banking and the speculative economy allowed for greater economic resilience and a shift away from extractivist speculation, the lifeblood of mining.

189 See: https://www.foeeurope.org/eco-sufficiency-focus-on-enough-301117

190 Harmut, R. (2013). *Social Acceleration: A New Theory of Modernity*. New York: Columbia University Press.

BANS, MORATORIA AND RAW-MATERIALS GOVERNANCE

By the 2010s people had enough of mining. In 2017 El Salvador had become the first country to ban metal mining altogether, with the support of all political parties.[191] In 2010, Costa Rica's Assembly banned open-cast mining,[192] sparkling similar moves in Colombia,[193] Argentina,[194] Ecuador[195] and the Philippines.[196] In 2019 Kyrgyzstan passed a law banning mining of radioactive materials,[197] as did Spain a year later.[198] Other countries and regions passed moratoria, such as Malaysia with bauxite between 2014 and 2019, the US state of Wisconsin with its 1997 Mining Moratorium Law that was in effect for a full decade,[199] or the Uttarakhand 2017 temporary ban in India. The 1998 Protocol on Environmental Protection to the Antarctic Treaty strictly prohibiting "any activity relating to mineral resources"[200] showcased how countries could agree to put an end to the environmental damage caused by mining.

191 Mardirossian, N. (2017). "Does El Salvador's Metal Mining Ban Suggest a Global Trend?," *State of the Planet*, May 2. At: https://blogs.ei.columbia.edu/2017/05/02/does-el-salvadors-metal-mining-ban-suggest-a-global-trend/

192 Evans, M. (2013). "Costa Rica Upholds Ban On Open-Pit Mining," *The Costa Rica Star*, February 8. At: https://news.co.cr/costa-rica-upholds-ban-on-open-pit-mining/21901/

193 See: https://aida-americas.org/es/node/2081

194 Laje, D. (2019). "Argentine court upholds law banning mines," *Al Jazeera*, June 12. At: https://www.aljazeera.com/economy/2019/6/12/argentine-court-upholds-law-banning-mines

195 Jamasmie, C. (2021). "Southern Ecuador's Cuenca bans large-scale mining," *The Northern Miner*, February 19. At: https://www.mining.com/southern-ecuador-bans-large-scale-mining/

196 Sarmiento, B.S. (2020). "Philippine court upholds open-pit mining ban in Mindanao," *Mongabay*, October 19. At: https://news.mongabay.com/2020/10/philippine-court-upholds-open-pit-mining-ban-in-mindanao/

197 Fergana (2019). "Kyrgyz President signs law banning mining of uranium and thorium," *Fergana*, December 16. At: https://en.fergana.news/news/113444/

198 Hall, L. (2020). "Moves to ban uranium mining in Spain," *EuroWeekly*, October 19. At: https://www.euroweeklynews.com/2020/10/19/moves-to-ban-uranium-mining-in-spain/

199 Barrows, M. (2017). "Wisconsin Legislature Repeals Moratorium on Sulfide Mining," *Freshwater Future*, November 8. At: https://freshwaterfuture.org/watchdog/wisconsin-legislature-repeals-moratorium-on-sulfide-mining/

200 Potočnik, J. (2019). "Are we really ready to risk our own future?" Bled Strategic Forum, September 3. At: https://medium.com/bled-strategic-forum/are-we-really-ready-to-risk-our-own-future-5450c375a8fe

Mining bans worldwide.

	Country/Territory	Year	Types of mining
	**Antarctica**	1998	All mining
	**Costa Rica**	2010	Open-cast mining
	**El Salvador**	2017	All metal mining
	**Kyrgyzstan**	2019	Radioactive minerals
	**Spain**	2021	Radioactive minerals
	**Northern Territory (Australia)**	2021	Deep-sea mining
	**Cuenca (Ecuador)**	2021	All metal mining

Governments also started to turn away from the trap of investor-state dispute-settlement systems.[201] Community charters[202] and local or regional popular consultations[203] were instrumental in banning mining from the bottom up. Calls began for a global ban of the unnecessary mining of certain metals such as gold, since by 2020 there was enough gold in vaults and national reserves to meet global demand in perpetuity without extracting another ounce from the ground. More than 90% of gold was mined exclusively for luxury and financial markets, whereas less than 10% went toward industry and technology applications.[204]

201 Public Citizen (2014). Exiting the Unnecessary, Damaging Investor-State Dispute Settlement System. At: http://worldinvestmentforum.unctad.org/wp-content/uploads/2015/05/Public-Citizen-Draft.pdf

202 Rahman, M. (2018). "Community Charters," *The Conscious Lawyer*. At: https://www.theconsciouslawyer.co.uk/community-charters/

203 Dietz, K. (2018). "Referendums on mining in Colombia: the conditions in which they are held and their political meanings. The case of La Colosa," *Colombia Internacional*, 93: 93-117. At: http://dx.doi.org/10.7440/colombiaint93.2018.04

204 See: https://miningwatch.ca/blog/2019/2/5/behind-glitter-gold-facts

Concerns over the potential environmental and social impacts of deep-sea mining also led to increasing calls for a ban or a moratorium on deep-sea mining – at least untill the knowledge gaps could be closed and alternatives (like sustainable consumption and production) had been fully explored. Hundreds of NGOs and environmental and social organisations, scientists and renowned figures such as Sir David Attanborough and Sylvia Earle rallied to stop the assault on the deep sea.[205] In 2012 Australia's Northern Territory Government passed such a moratorium, extending it in 2015 and 2018 before establishing an indefinite ban in 2021.[206] In 2018 the European Parliament passed a resolution by an overwhelming majority that called for an international moratorium on deep seabed mining,[207] a move partly endorsed by the European Commission in its Biodiversity Strategy for 2030. In 2019 the Prime Ministers of Fiji, Vanuatu and Papua New Guinea made a similar call for a moratorium at least until the end of the UN Decade of Ocean Science in 2030.[208]

The UN International Resource Panel had already noted the existing governance gap in its 2020 *Mineral Resource Governance for the 21st century* report; the UN Environmental Assembly called for a new global mechanisms to oversee the use and supply of mineral resources.[209] Early UN resolutions and decisions had stressed the need for oversight. The first UN Conference on the Environment, held in Stockholm in 1972, issued an Action Plan that included recommendations for establishing a mining and mineral information system that "would indicate where certain kinds of mining should be limited, where reclamation costs would be particularly high, or where other problems would arise."[210]

©Papua New Guinea Mine Watch

205 See: http://www.savethehighseas.org/wp-content/uploads/2020/06/DSCC_FactSheet3_DSM_moratorium_4pp_web.pdf

206 See: https://newsroom.nt.gov.au/mediaRelease/34139

207 Woody, T. (2018). "European Parliament Calls for a Moratorium on Deep-Sea Mining," *News Deeply*, February 1. At: https://deeply.thenewhumanitarian.org/oceans/articles/2018/02/01/european-parliament-calls-for-a-moratorium-on-deep-sea-mining

208 Doherty, B. (2019). "Collapse of PNG deep-sea mining venture sparks calls for moratorium," *The Guardian*, September 15. At: https://www.theguardian.com/world/2019/sep/16/collapse-of-png-deep-sea-mining-venture-sparks-calls-for-moratorium

209 IRP (2020). *Mineral Resource Governance in the 21st Century*. Nairobi: UNEP. At: https://www.resourcepanel.org/reports/mineral-resource-governance-21st-century; UNEA resolution on Mineral resource governance, 9 March 2019, UNEP/EA.4/L.23. See: https://www.ecologic.eu/sites/files/publication/2020/2599-international-governance-raw-materials-ingoro.pdf

210 See: http://undocs.org/en/A/CONF.48/14/Rev.1

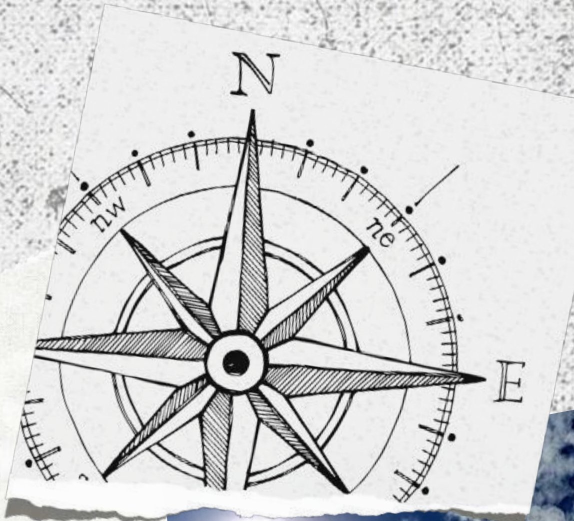
The 5th principle of the Stockholm Declaration affirmed the common conviction that: "The non-renewable resources of the earth must be employed in such a way as to guard against the danger of their future exhaustion and to ensure that benefits from such employment are shared by all mankind." Ten years later, in 1982, the UN General Assembly approved the "World Charter for Nature",[211] again establishing that "non-renewable resources which are consumed as they are used shall be exploited with restraint, taking into account their abundance, the rational possibilities of converting them for consumption, and the compatibility of their exploitation with the functioning of natural systems."

Such principles were enshrined with binding legal force in the 2021 Global Pact for the Environment,[212] an international legal framework for environmental rights, including the rights of nature and future generations, and they were consolidated after 2025, when a new set of global goals and targets to end extractivism were drawn up as a *Blueprint for 2050* without mining to succeed the 2015 UN Sustainable Development Goals in 2030.

* THE NON-RENEWABLE RESOURCES OF THE EARTH MUST BE EMPLOYED IN SUCH A WAY AS TO GUARD AGAINST THE DANGER OF THEIR FUTURE EXHAUSTION

211 See: https://digitallibrary.un.org/record/39295

212 See: https://globalpactenvironment.org/en/



5

A COMPASS FOR THE FUTURE

"YOU NEVER CHANGE THINGS BY FIGHTING THE EXISTING REALITY.

TO CHANGE SOMETHING, BUILD A NEW MODEL THAT MAKES THE EXISTING MODEL OBSOLETE."

— BUCKMINSTER FULLER

While many argued humans were destroying the Earth, it was in fact a specific social and economic system and the ideology of growth and extractivism that was driving the planet to collapse. The way many people lived, worked, produced and consumed, particularly in the Global North, was dependent on concrete decisions and on how societies were organised.

In many ways, the 2020 pandemic helped to further expose the systemically unjust and destructive nature of such systems: response packages – such as the EU's Next Generation plan – bailed out polluting corporations and stimulated the mining and energy sectors instead of supporting those who had been harder hit; local trade and production suffered strict lockdown measures while multinational online retailers made billions; streaming platforms took over the spaces for conviviality, creativity and learning.

Many among the priviledged had hoped the majority would have stood still, letting business-as-usual continue to destroy lives and the planet under pretences of sustainability and with the "miracle mining solution" of jobs for all amid the post-COVID crisis. But many decided to stand up. Faced with increasing proposals for mining projects around the world, communities mobilised to protect their lands and the deep sea. Mining companies found it more difficult to start operations due to a lack of consent from potentially affected communities. In many cases governments attempted to violently repress these resistance movements, but they were unable to convince the public at large that mining projects were an environmentally viable activity.[213]

The roots of the Great Transition can be traced back to the struggles of a myriad of frontline local and indigenous communities fighting extractivism across the world. The growing numbers of people and increased engagement could not be ignored. Earlier experiences such as Iceland's Kitchenware Revolution (2009–2011), the *Indignados* of Spain (2011), Occupy (2011–2016), the Idle No More protests in Canada (2012–), Extinction Rebellion and Fridays for Future (2018–), the *Estallido social* in Chile (2019-2020), the Climate Assemblies movement (2019–) led to new waves of global protests in the 2020s calling for a politics focused on the common good.

213 Earthworks et al. (2020). *Voices from the Ground: How the Global Mining Industry is Profiting from the COVID-19 Pandemic*. At: https://miningwatch.ca/publications/2020/6/2/voices-ground-how-global-mining-industry-profiting-covid-19-pandemic

Early examples include the acknowledgement of the Rights of Nature by the Convention on Biological Diversity (CBD) in 2021[214] and the European Economic and Social Committee's proposal for a EU Charter of the Fundamental Rights of Nature,[215] which moved away from the flawed idea of nature as a resource to be owned, used and degraded. The 2008 constitutional amendments in Ecuador, the 2010 Bolivian Law of the Rights of Mother Earth or the attribution of legal personhood through treaties to rivers, mountains or forests in New Zealand in the 2010s were obvious precedents. After Vanuatu's 2020 proposal, the Rome Statute was amended to bring the crime of ecocide under the jurisdiction of the International Criminal Court, matching previously defined crimes like genocide, crimes against humanity or war crimes.[216] The principle of "common heritage of humanity", applied in international law since the 1970s to the seabed, was extended in the 1997 *UNESCO Declaration on the Responsibilities of the Present Generations Towards Future Generations*, establishing that "Each generation inheriting the Earth temporarily should take care to use natural resources reasonably and ensure that life is not prejudiced by harmful modifications of the ecosystems."[217]

Social pressure at last transformed such declarations into binding commitments as environmental rights were further empowered through mechanisms such as the Escazú Agreement in Latin America and the Caribbean and the Aarhus Convention in Europe, Central Asia and the Caucasus. Increased public participation allowed communities and environmental defenders to more effectively resist proposed mining projects. In areas where mining projects were already present and resulting in damaged livelihoods and environments, affected people were able to hold authorities and companies to account.

The deep sea's status as common heritage of humankind – established by the 1982 United Nations Convention on the Law of the Sea – was re-evaluated in light of the 2050 Blueprint that followed the 2030 Sustainable Development Goals. Marine scientists and ocean defenders exposed the environmental and social risks of deep-sea mining. Expanding knowledge about the deep sea and efforts to improve society's ocean literacy made it clear to citizens and politicians that the life-generating role of the ocean – as provider of half of the atmosphere's oxygen, as climate regulator, as source of cultures and wellbeing – was worth more than its minerals.

* EACH GENERATION INHERITING THE EARTH TEMPORARILY SHOULD TAKE CARE TO USE NATURAL RESOURCES REASONABLY

214 See: https://www.earthlawcenter.org/elc-in-the-news/2020/9/convention-on-biodiversity-advances-the-rights-of-nature-in-proposed-post-2020-global-biodiversity-framework

215 Carducci, M., et al. (2020). *Towards an EU Charter of the Fundamental Rights of Nature*. Brussels: European Economic and Social Committee. At: https://www.eesc.europa.eu/en/our-work/publications-other-work/publications/towards-eu-charter-fundamental-rights-nature

216 Yeo, S. (2020). "Ecocide: Should killing nature be a crime?" *Future Planet*, Nov. 6. At: https://www.bbc.com/future/article/20201105-what-is-ecocide

217 See: http://portal.unesco.org/en/ev.php-URL_ID=13178&URL_DO=DO_TOPIC&URL_SECTION=201.html

The 167 member countries of the International Seabed Authority finally realised that public participation, transparency and consideration of the social and cultural impacts of activities were necessary to ensure that due regard was given to the interests of civil society, in particular in developing countries, and of future generations. The ISA's mandate to protect the deep sea eventually overcame its earlier role as "extractivism" manager.

UNCLOS AND THE COMMON HERITAGE OF HUMANKIND

The 1982 United Nations Convention on the Law of the Sea (UNCLOS) declared the Area (i.e. the seabed and ocean floor and subsoil thereof, beyond the limits of national jurisdiction) and its resources the common heritage of mankind (CHM) and vested all rights therein in "mankind as a whole". However, a consensus on the practical application of this principle had not yet been achieved in the early 2020s.

The principle of the common heritage of mankind is based on notions of stewardship and trusteeship and was created to realise a vision of solidarity and distributive justice. Critical elements of the common heritage regime outlined in UNCLOS included the preservation of the deep seabed for exclusively peaceful purposes; the principle of non-appropriation; the reservation of mineable areas for developing states in the Area; the equitable sharing of any financial or other economic benefits as well as knowledge generated through mining activities; and the protection and preservation of the marine environment.

Maltese Ambassador Arvid Pardo, one of the founders of the common heritage of humanity concept under international law, claimed that it challenged the "structural relationship between rich and poor countries" and amounted to a "revolution not merely in the law of the sea, but also in international relations". One of the main architects of the principle under international space law claimed that it is "the most important legal principle achieved by man throughout thousands of years during which law has existed as the regulating element of social exchange". This praise relates to the fact that international law in the common heritage of humanity principle sought to protect, respect and fulfil the interests of human beings independently of any politically motivated sovereign state; the concept covering all humans wherever they were living, as well as future generations.

Adapted from: The International Seabed – the Common Heritage of Mankind, IASS Policy Brief 2/2018 and https://en.wikipedia.org/wiki/Common_heritage_of_mankind

BREAKING FREE FROM THE GROWTH PARADIGM

Eighty-four years ago, in 1966, Kenneth Boulding's landmark essay, "The Economics of the Coming Spaceship Earth",[218] defined extractivism as the "cowboy economy", "the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behaviour". In contrast, Boulding called for a new "spaceman economy", considering Earth as "a single spaceship, without unlimited reservoirs of anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system".

Back in 2020, as the initial COVID disruption brought back images from the Great Depression of the 1930s, a shrinking economy initially triggered fear furthering growth-seeking responses. But many realised that the path ahead – post-growth and degrowth[219] – was very different from the unmanaged processes of economic contraction – recession, depression or collapse – that were around the corner if the over-developed world continued with business-as-usual.

The 2020 COVID pandemic and the political discussions it caused brought degrowth narratives into the spotlight,[220] facilitating a combined effort to develop many of the emergent alternatives that had been around for years or decades. Buen Vivir (good living, a concept adopted from the *Quechua Sumac Kawsay* and introduced to the Constitutions of Bolivia and Ecuador in the late 2000s) inspired new ways to achieve social and environmental justice within Spaceship Earth as a global goal, replacing GDP and a never-ending spiral of increasing commodified materials and energy use.

218 Boulding, Kenneth E. (1966). "The Economics of the Coming Spaceship Earth," In H. Jarrett (ed.) *Environmental Quality in a Growing Economy*. Baltimore: Resources for the Future/Johns Hopkins University Press, pp. 3-14.

219 Hickel, J. (2020). "What does degrowth mean? A few points of clarification," *Globalizations*. At: https://www.tandfonline.com/doi/full/10.1080/14747731.2020.1812222

220 Rathi, A (2020). "How 'Degrowth' Pushes Climate and Well-Being Over GDP," *Bloomberg Green*, September 18. At: https://www.bloomberg.com/news/articles/2020-09-18/how-degrowth-pushes-climate-and-well-being-over-gdp-quicktake

Serge Latouche summarised this shift through the "8 Rs" of the virtual circle of degrowth:[221]

- **Reassess** what matters;
- **Reframe** key notions such as wealth, poverty, value, scarcity and abundance;
- **Restructure** the productive apparatus and social relations to fit these new values;
- **Redistribute** wealth and access to natural resources between North and South and between classes, generations and individuals;
- **Relocalise** savings, financing, production and consumption;
- **Reduce** production and consumption, especially for goods and services with little use value but high environmental impact;
- **Repair** and Re-use products; and
- **Recycle** waste.

In 2013 the EU adopted its 7th Environment Action programme with the title "Living well, within the limits of our planet", a vision for 2050 that should "help guide action up to and beyond 2020", and was also reiterated in the 8th Environment Action programme:

In 2050, we live well, within the planet's ecological limits. Our prosperity and healthy environment stem from an innovative, circular economy where nothing is wasted and where natural resources are managed sustainably, and biodiversity is protected, valued and restored in ways that enhance our society's resilience. Our low-carbon growth has long been decoupled from resource use, setting the pace for a safe and sustainable global society.[222]

Green growth was based on a belief in decoupling – which held that techno-efficiency would make increasing goods and services available with negligible environmental impacts[223] – which proved to be a myth. Following the early warning of Herman Daly in his 1977 *Steady-State Economics*,[224] the profound dilemma faced by humanity at the beginning of the 2020s was clear: people could continue to dream that mounting social and environmental problems would simply solve themselves through more economic growth; or admit that the dominant social and economic system was causing irreversible environmental impacts that threatened the biosphere and human existence. Change required, first of all, a deep paradigm shift: what really needed to be decoupled were prosperity and good living from economic growth. As Daly had called for, "enough is best".

221 Latouche, S. (2010). *Farewell to Growth*. London: Polity Press,

222 See: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1493802707367&uri=CELEX:32013D1386

223 Parrique, T. et al. (2019). *Decoupling debunked: Evidence and arguments against green growth as a sole strategy for sustainability*. Brussels: European Environmental Bureau. At:https://eeb.org/library/decoupling-debunked/ ; Vadén, T. et al. (2020). "Raising the bar: on the type, size and timeline of a 'successful' decoupling," *Environmental Politics*. At: https://doi.org/10.1080/09644016.2020.1783951

224 Daly, H. E. (1977). *Steady-state economics*. San Francisco: Freeman.

SYSTEM CHANGE COMPASS

While in the 2010s many were still grappling with the unsolvable riddle of how to continually increase production and consumption without destroying the planet, in the 2020s efficiency finally gained a new (common-)sense and was paired with sufficiency.

The need to downscale economic consumption was finally addressed, the priority shifted from destructive growth to meeting people's needs without overshooting Earth's ecological ceiling, as set out in works such as Kate Raworth's Doughnut Economics.[225] A 2018 special report by the IPCC[226] warned the only viable way ahead was for rich countries to decisively cut their rates of material production and consumption. In 2020 the Club of Rome published its "System Change Compass" [227] calling for system-level change mirroring "naturally regenerative ecological systems, rather than resource-depleting systems."

"System Change Compass" (Club of Rome, 2020).

225 See: https://doughnuteconomics.org

226 IPCC (2018). *Global Warming of 1.5 ºC*. Geneva: IPCC. At: https://www.ipcc.ch/sr15/

227 Club of Rome (2020). *A System Change Compass: Implementing the European Green Deal in a time of recovery*. Winterthur: Club of Rome. At: https://clubofrome.org/publication/a-system-change-compass-implementing-the-european-green-deal-in-a-time-of-recovery/

Tim Jackson's 2017 *Prosperity Without Growth*[228] articulated many of the guiding principles for a post-growth social and economic paradigm. Focus shifted from GDP to well-being indices such as the Happy Planet Index and ideas such as Gross National Happiness and Maximum of Ecological Footprint; from smart cities to Transition Towns; and from increasing inequalities to mission-driven social enterprises and cooperatives. The "polluter pays" principle widely adopted in the first decades of the 21st century evolved into more effective Pigovian ecotaxes, higher severance taxes and "polluter restores" guarantees, particularly addressing mining.

Bold visions for the future were already being broadcast in the early 2020s. Examples included "A Societal Transformation Scenario for Staying Below 1.5°C" for countries in the Global North.[229] It suggested by 2050 there should be a 37% drop in transport demand; 81% reduction of the share of car transport in urban areas; 81% reduction of flights per person; halving of appliances per person; or a 24% reduction of calories per person (mainly through the reduction of food waste). This showed how a massive reduction in consumption was possible "by reshaping key infrastructures of societies and by regulative frameworks, economic principles and incentive structures guiding behaviour within society."

228 Jackson, T. (2017). *Prosperity Without Growth: Foundations for the Economy of Tomorrow*. London: Routledge.

229 Kuhnhenn, K. et al. (2020). *A Societal Transformation Scenario for Staying Below 1.5°C*. Berlin: Heinrich-Böll-Stiftung. At: https://eu.boell.org/en/2020/12/09/societal-transformation-scenario-staying-below-15degc

In 2021, 101 Nobel Laureates from peace, literature, medicine, physics, chemistry and economic sciences signed the "Our Planet, Our Future: An Urgent Call for Action"[230] statement, urging the adoption of "principles of recirculation and regeneration of materials" and concluding that:

Global sustainability offers the only viable path to human safety, equity, health, and progress. Humanity is waking up late to the challenges and opportunities of active planetary stewardship. But we are waking up. Long-term, scientifically based decision-making is always at a disadvantage in the contest with the needs of the present. Politicians and scientists must work together to bridge the divide between expert evidence, short-term politics, and the survival of all life on this planet in the Anthropocene epoch. The long-term potential of humanity depends upon our ability today to value our common future. Ultimately, this means valuing the resilience of societies and the resilience of Earth's biosphere.

Few of them would have imaged that global energy use in 2050 would have been reduced back to 1960 levels and that sufficiency is far more materially generous than many opponents of degrowth often assumed in the early 2020s. The social and technological solutions to bring about an end to mining and the ecological challenges of the early 21st century were already in existence; they required only an act of will to be mobilised under a common vision for the future.

And it all started when people got together to **imagine a world without mining.**

* GLOBAL SUSTAINABILITY OFFERS THE ONLY VIABLE PATH TO HUMAN SAFETY, EQUITY, HEALTH, AND PROGRESS.

230 US National Academy of Sciences (2021). "Our Planet, Our Future. An Urgent Call for Action," *National Academies*, April 29. At: https://www.nationalacademies.org/news/2021/04/nobel-prize-laureates-and-other-experts-issue-urgent-call-for-action-after-our-planet-our-future-summit

6

“IMAGINING A WORLD WITHOUT MINING” WORKSHOP

> “NEVER DOUBT THAT A SMALL GROUP OF THOUGHTFUL, COMMITTED CITIZENS CAN CHANGE THE WORLD. INDEED, IT IS THE ONLY THING THAT EVER HAS.”
>
> — MARGARET MEAD

The previous pages presented an evidence-based literary exercise to help bring about system change at the beginning of the third decade of the 21st century. Readers are invited to join the make-believe exercise by considering it a *gift from the future.*

This activity is based on an original workshop conceived in the 1980s by Elise Boulding (1920–2010) to imagine a nonviolent world. Boulding, a sociologist and peace activist, realised how many peace activists were unable to imagine a world without wars or armies, and asked, "How could we work to bring about something we cannot even see in our imaginations?"[231] Similarly, in 2021 ordinary citizens, activists in many fields and policy makers often find it hard break out of the mindset which holds that only solutions based on mining and the previously existing growth ideology could bring about change.

The workshop incorporates the views of futurist Fred Polak, who argued that positive images of the future are instrumental if movements and citizens are to guide their actions in the present toward preferred futures. This tool is of particular importance for those striving for complex social or political change, often hampered by dystopian and pessimistic views of the future.

The methodology of the workshop is detailed in the Warren Ziegler's workbook "A Mindbook for imagining/inventing a world without weapons" (1987).[232] Several adaptations of this workshop have been developed addressing a number of themes.[233] This is the first to address a world without mining. Participants may find many other existent methodologies useful to develop their action plans, such as Donella Meadows's Leverage Points[234] or *Schöne Neue Welt* by Forum Umwelt & Entwicklung.[235]

LENGTH AND SETTING: This workshop should ideally be developed at some length, preferably over a weekend and with at least two sessions of several hours each. It can be condensed to a shorter format of approximately four hours, although this is not the best option. Ideally, participants *should have read* the previous report in advance. It is highly recommended that the workshop be conducted in person and in an outdoor setting, or combine outdoors and indoors for different steps of the process.

A facilitator or group of facilitators should have prepared the workshop format in advance to guide participants through its seven steps (as described in the following box).

231 Boulding, E. (2002). "A Journey into the Future: Imagining a Nonviolent World," *Peace and Conflict Studies*, 9(1): 4. At: https://nsuworks.nova.edu/pcs/vol9/iss1/4

232 Zeigler, W. (1982). *A Mindbook of Exercises for Futures/Invention*. Denver: Futures-Invention Associates.

233 For example: http://www.globalepe.org/article_print.php?aid=43

234 See: http://donellameadows.org/archives/leverage-points-places-to-intervene-in-a-system/

235 See: https://www.snw2048.de/

WORKSHOP STEPS

1

Introduction to the activity with a brief introduction to the importance of views of the future (Fred Polak, Elise Boulding, Futures, etc.). Participants are asked to express their own personal hopes (three or four) they have for a future society 30 years from the present (in 2050) where resource consumption has been greatly reduced. These must be positive hopes.

2

Exercising imagination through memories of the past. Participants are asked to “flex their imaging muscles” by closing their eyes and, in silence, remembering a positive, personal memory from the past, one they enjoy reliving. Focus is on details such as sights, sounds, smells. These are then shared with the group. Remembering images of the past brings participants into the “imagining mode” needed to move into the future.

3

Leap into the future, 30 years ahead (2050), where/when a *world without mining* is a reality. The facilitator helps participants leap the barrier separating present-present from future-present (for example, asking them to close their eyes and drift to the future). This is an exploratory trip (20-30 minute) where participants are expected to record their observations, interview (imaginary) inhabitants, and take notes, as ethnographers or sociologists is a field study.

4

Sharing visions of the future. Participants are expected to share their observations with the group that may ask questions and seek clarification. *Present tense must be used*, as we are still 30 years into the future!

5

Consequence mapping. In small groups, participants are expected to construct a more analytical description of the society/world they have observed (i.e., institutional/social arrangements, economy, material culture, time-use, technology, etc.), negotiating contrasting or conflicting imagery that may emerge among participants. Participants are invited to draw pictures, diagrams or other representations to prepare such a description before sharing it with the larger group (materials should be prepared in advance). The group may again ask questions and seek clarifications.

6

Remembering history. Standing in the future-present society, where a post-mining world thrives, participants are asked to *remember* in the same small groups what had happened over the previous years and decades, leading to successful change. A *ladder* or Gantt chart can be used, starting from the most recent events from the *future-present* stand point to the moment the workshop was carried out 30 years ago. Participants should note key events, stepping stones, with particular focus on the use of raw materials, consumption patterns and overarching policies shifted in time. The history of change will be presented to the larger group, always using past tense to explain what "happened", and will be open to questions and debate.

7

Development of an action plan in the present. Back in the workshop's 2020 present, each individual participant (or alternatively, if the setting allows, small groups) will prepare a short-term action plan to catalyse change toward the experienced future reality based on the pictured future and remembered history. The plan should be realistic in what the individual/small group is actually ready to commit to do to bring about a world without mining. It should include concrete actions with description of how they are to be implemented, with what allies, expected results, etc. As a closing, participants should be strongly encouraged to actively engage in making such action plans reality, either individually or in collaborations.

SEAS AT RISK

Seas At Risk
Rue Rue de la Charité 22,
1210 Brussels, Belgium

Tel: +32 (0) 2 329 0124

E-mail: secretariat@seas-at-risk.org

Twitter: @SeasAtRisk

seas-at-risk.org