EARTH4ALL: DEEP-DIVE PAPER 19

July 2025

Circular economy: Why resources matter for economic system change

Monika Dittrich
Head of the Circular Systems Research Unit at the Wuppertal Institute

Peter Hennicke
Senior Advisor at the Wuppertal Institute and member of the Club of Rome

Till Kellerhoff
Programme Director of the Club of Rome, Director, Earth4All

Earth 4All

Contents

Introduction

Extracting and processing materials is one of the most underappreciated yet powerful forces shaping our world. According to the *Global Resources Outlook 2024*, over half of global greenhouse gas emissions and 90% of land-use related biodiversity loss stem from resource extraction and processing.[1] Yet global material use keeps growing relentlessly. Since 1970, natural resource extraction has more than tripled. Today, the total mass of human-made materials—concrete, steel, plastic and more—has surpassed the weight of all living biomass on Earth.

Today, the total mass of human-made materials—concrete, steel, plastic and more—has surpassed the weight of all living biomass on Earth.

This deep dive explores the material foundations of our economy and wellbeing—foundations that are both indispensable and increasingly destructive. It highlights how raw materials underpin everything from food and energy to digital communication, and shows how current patterns of overuse, waste, and inequality are pushing us beyond planetary boundaries. It also lays bare the growing geopolitical tensions and environmental justice issues tied to resource dependency and scarcity.

To achieve the five extraordinary turnarounds at the heart of the vision set out in *Earth for All: A Survival Guide for Humanity* —eliminating poverty, reducing inequality, empowering women, transforming food systems, and realising the energy transition—materials emerge as a unifying thread. This paper explores that connection in greater depth.

This means rethinking how we use resources, shifting from linear "take-make-waste" systems toward circular economies, and ensuring fairer access to materials essential for life and for a sustainable future.

Natural resources: the basis of our prosperity

Earth for All: A Survival Guide for Humanity pointed out the great power that lies in five extraordinary turnarounds. In industrial countries in particular, another topic is central to a successful transformation and permeates all the other turnarounds: the topic of resources. Natural resources are central to our lives: soil and water for our food, wind and sun as well as raw materials and land for our energy supply. We humans derive enormous benefits from the earth's ecosystems. The so-called ecosystem services of nature are responsible for 55% of the global gross national product.[2] Without natural resources and the services of nature, no human life, no modern economy, no social activity is conceivable: food, clothing, mobility, heat, even communication, today primarily by means of computers and mobile phones, are not possible without biotic and abiotic raw materials, water, land or soil. Not even sitting in a meadow is conceivable without raw materials, as it requires maintenance to be enjoyed. Natural resources therefore form the physical basis for prosperity.

Raw materials as the central basis on the one hand, and the environmental impacts associated with their extraction on the other, make one thing clear: sustainable economic activity requires a particularly sparing use of the resources available to us.

This point is reinforced when geopolitical aspects and the uneven geographical distribution of raw material deposits are considered, as well as how unevenly raw materials are consumed globally. Every use of raw materials is associated with a variety of environmental impacts. The specific burdens differ depending on the raw material and regional preconditions such as geological characteristics. Environmental pollution occurs in particular when raw materials are extracted from the environment - for example through landscape changes, soil compaction and mining damage - or released back into nature - for example in the form of waste, toxins and emissions. In the meantime, the various environmental burdens are accumulating so that the natural foundations of social prosperity are severely impaired, and ecosystems can no longer absorb the burdens without being permanently damaged.

Environmental burdens are accumulating so that the natural foundations of social prosperity are severely impaired, and ecosystems can no longer absorb the burdens without being permanently damaged.

Despite all the differences between raw materials and their forms of use, one simple rule still applies: the more sparingly natural resources are used, the lesser the environmental impact. There are countless examples that show that overexploitation is carried out at the expense of nature or at the expense of the local population and that damage not remedied or compensated for. Mining activities also cause damages, and this even applies to those that have long since ceased. In Germany, for example, in the Ruhr region, mining damage to roads and buildings is still occurring today as a result of decades of underground coal mining - and will do so for some time to come. It is not without reason that these burdens are also called “perpetual costs”. Groundwater bodies in areas with long-abandoned mining or industrial sites are still contaminated and soils are so depleted or poisoned that hardly any life grows in and on them - damage for which the general public will have to pay to a very large extent.

The use and distribution of resources depends on the way in which production structures and consumption patterns are organised in our society. We must therefore fundamentally reorganise production and consumption and should always keep in mind that the meaning and purpose of economic activity should be the creation of wellbeing and social development. The economy is not an end in itself. In order for us to achieve our goal - an “Earth for all” - our economic system, production and consumption structures must be designed in such a way that there is enough for everyone – and within the planetary boundaries.

The demand for raw materials is increasing

Back in the early 1990s, the Wuppertal Institute initiated discussions on how we can reduce our energy and material consumption and thus achieve dematerialisation. Visionary books and reports such as *Factor Four: Doubling Wealth, Halving Resource Use* by Ernst Ulrich von Weizsäcker, Amory Lovins and Hunter Lovins to the Club of Rome or *Factor 10* by Friedrich Schmidt-Bleek contained ambitious targets for energy and resource consumption. They raised the fundamental question of whether and how the consumption of natural resources can be decoupled from economic development (measured in terms of gross domestic product) in absolute terms.

The global distribution issue between low- and high-income countries is directly linked to this. Figures have long pointed to the problem of inequality in resource consumption: while people in low-income countries had an average annual material footprint of 4 tonnes in 2020, it was 24 tonnes in high-income countries. The average material footprint in middle-income countries, including populous countries such as China, has also risen to 19 tonnes, as a middle class with significant resource consumption has also emerged in these countries.[3] This shows that the question of resources cannot be answered separately from the question of distribution. And this applies both within and between countries. Such massive inequality can jeopardise social cohesion in countries and globally, as shown in *Earth for All*.

A key difference between energy and raw materials should be pointed out: energy supply can be converted in such a way that it causes almost no greenhouse gas emissions. In principle, unavoidable residual greenhouse gas emissions can be absorbed by natural sinks (reforestation of forests) and technical sinks (CO_2 capture and storage). We now know that coal, oil, natural gas and even uranium can be completely replaced by renewable energies. At the international level it has been shown that the Paris Agreement can be achieved with pathways towards full decarbonisation as well.[4] However, it must be emphasised that raw materials play a central role in this. This is because the production of solar cells, wind energy generators, batteries or electrolysers for hydrogen production and the like requires raw materials, especially those whose deposits are limited.

Raw materials are different to fossil-based energy: primary raw materials will always be needed to a certain extent for life in the future. Nevertheless, many raw materials can in principle be used repeatedly, i.e. in a cycle. However, it is not possible to completely replace them with renewable raw materials, as is the case with energy: people need a minimum amount of raw materials for their basic needs (such as food, clothing, housing, communication) and to be able to lead a good and dignified life. What belongs to the minimum and what can be described as excess is a normative question; it cannot be clearly determined for all time and must ultimately be decided through a social negotiation process.

When populous emerging countries such as China began to increasingly import raw materials for their development at the turn of the millennium, prices rose line with demand. During their industrialisation phase, countries such as Germany or Japan were used to being able to buy raw materials cheaply or simply acquire them at any time. Today, they are constantly confronted with price fluctuations and rising costs. Before 2000, this mainly affected fossil raw materials, for example during the oil price crises of the 1970s. After that, the same thing increasingly happened with metals. More efficient use was no longer only required for energy or energy raw materials, but increasingly for all raw materials. More efficient use was also required not only for ecological reasons, but also for economic reasons, to maintain and promote competitiveness and security of supply.

The EU and many countries therefore launched programs to increase resource efficiency. They should ensure that the economy generates the greatest possible benefit with the lowest possible use of raw materials. In the EU, the Roadmap to a Resource Efficient Europe came into force in 2011, replaced by the European Green Deal's Circular Economy Action Plan in 2020. In fact, the productivity of raw material use in the European Union increased. While both GDP and domestic

material consumption (DMC) increased at a similar rate between 2000 and 2008, DMC has increased more slowly than GDP since then with some European countries even showing an absolute decoupling.[5]

The data shows that although we use raw materials more efficiently today, the efficiency gains have obviously not led to a reduction in the overall use of raw materials. The production of additional goods has more than compensated for the savings effect. This does not argue against the further promotion of resource efficiency at home and abroad, quite the opposite. But it shows that the current political approach is far from sufficient and must be supplemented by further approaches in order to actually achieve a noticeable reduction in environmental impact and a life within planetary boundaries.

Russia's invasion of Ukraine made supply bottlenecks even more visible and measures to reduce the associated vulnerability of the economy even more urgent.

While the commodity markets had calmed down somewhat by 2019, the coronavirus pandemic made it clear just how fragile supply chains are. For an industrialised region such as Europe, stable and reliable trade relations are essential. Europe imports raw materials and preliminary products and exports them as processed goods - such as cars, machines, or chemicals. These trade relations are crucial not only for the functioning of the economy, but also for the country's prosperity. They support the creation of well-paid, high-quality jobs and promote innovation through research and development. Even the supply of essential goods such as medicines suddenly no longer seemed secure during the pandemic. The certainty that all goods would always be immediately available disappeared. Russia's invasion of Ukraine made supply bottlenecks even more visible and measures to reduce the associated vulnerability of the economy even more urgent. This affected not only energy markets, but also commodities that are not always at the centre of attention but whose economic importance is immense, such as iron, technology metals or precious gases.

The energy transition and climate action also need raw materials

The energy transition is changing the demand for raw materials. Fossil fuels must be kept in the ground - but more raw materials are needed for the production of power lines, electrolysers, and photovoltaic and wind power plants. Above all, more of the rare so-called "technology metals" such as lithium or cobalt are needed in absolute terms[6], although the demand for raw materials for the energy system may fall in future as fewer raw materials will be needed for renewable energy plants than for combustion in the current energy system. In addition, these raw materials can in principle be made available again after use through recycling, even if the recycling rates for many technology metals are currently still below one percent.[7] However, climate change is a global issue. As nearly all countries worldwide are striving for an energy transition without fossil and nuclear energy, the global demand for these metals and minerals is correspondingly huge. The sharp increase in demand is being exacerbated by the digitalisation that is taking place at the same time.

Furthermore, adapting to climate change also requires resources. Be it water retention basins, rainwater channels with a larger diameter, higher dams, drainage along roads and railroad lines or new road surfaces - we must adapt infrastructures to changing environmental conditions. And the more the environmental conditions change, the more difficult and complex the adaptation becomes. These measures require additional natural resources and further increase the pressure on ecosystems; thus, we find ourselves in a spiral of increasing repair and reparation, which itself leads to increasing resource consumption.

Today, the European Commission also emphasises that in the “old” fossil world, the focus was on ensuring the security of supply for coal, oil and natural gas. Now, as we intentionally shift away from fossil fuels toward a climate-neutral future, new dependencies are coming into focus – particularly on strategic raw materials (e.g. rare earths) and the direct import of clean energy technologies.

For example, the EU imports more than 90% of its rare earths from China. With the Net-Zero Industry Act adopted in 2024, the EU is attempting to take countermeasures and ensure that at least a proportion of the production of key technologies takes place in the EU itself.

The EU has maintained a list of critical raw materials since 2014. These are raw materials whose supply is uncertain, which are essential for the functioning of important economic sectors and can hardly or not at all be replaced, unless their functions are replaced by new innovations and other metals. Critical raw materials include phosphorus, lithium and rare earths. Phosphorus is an essential component in fertilisers and is therefore of high importance for the agricultural industry. Lithium is needed for emission-free vehicle batteries, and rare earths are indispensable in electronic components, for example in wind turbine generators. The EU list currently contains 34 raw materials or groups of raw materials. Furthermore, the EU has also defined a list of 17 strategic raw materials that are currently important for the energy transition and for future technologies such as digitalisation, including copper and aluminium.[8] The International Energy Agency[9] has stated that more than 300 new ore mines are needed for the planned energy transition (excluding digitalisation).

In view of the geopolitical changes, the EU passed the Critical Raw Materials Act in March 2024. It defines the current critical and strategic raw materials and aims to secure the supply of raw materials. One of the key objectives is to increase recycling volumes, promote domestic mining and diversify supplier countries. These policies reflect the increasing demand for raw materials in general as well as for specific raw materials. Global demand for (primary) raw materials has tripled since the 1970s and, if no countermeasures are taken, is expected to continue to double until 2060 again compared to 2017.[10] Demand in the EU has risen again slightly following a slump in the wake of the financial crisis at the end of the 2000s. There are high dependencies: 50% of all metals processed in the EU were imported in 2022. For fossil energy raw materials, the figure is as high as 70%[11] and for some metals up to 100%.[12]

At the same time, recycling is still underdeveloped: In the EU, only around 12% of all primary (extracted from nature) and secondary (extracted from waste) raw materials used were recovered through recycling in 2022. This is only a slight increase since 2010.[13] In 2023, the Resources Commission at the Federal Environment Agency published a paper on recycling indicators. In it,

it described that in principle, only around 33% of the metals from old electrical and electronic waste are recovered, despite a very high metallurgical yield. This low rate is a consequence of the collection and distribution of these valuable metals, which is based on dissipation (i.e. an increasingly small-scale dispersion).[14] This is because we do not have effective systems to collect the waste containing the metals. We need a fundamentally different, more systemic management of material flows.

Challenges of the efficient use of resources

Politicians have recognised the problem and set the target of doubling the proportion of secondary raw materials in all raw materials used by 2030 at EU level. This is the right goal, but it is hardly achievable with the current measures.[15]

Recycling is one of the very important approaches to preserving raw materials for the economy and society - not only to secure the supply of raw materials, but also to reduce the pressure on nature and environmental pollution. However, recycling is not always easy. Many types of waste cannot be easily converted back into pure raw materials or primary products. The raw materials are often “baked” like the ingredients in a cake: butter, flour, eggs and sugar cannot simply be converted back from the cake. Recycling also requires energy, sometimes even more than the production of primary raw materials. As long as primary raw materials are cheap and companies can pass on the ecological costs to the general public, many secondary raw materials cannot compete on the market. Recycled plastics, for example, must compete with plastics made from subsidized fossil raw materials - an extremely difficult undertaking. In Germany, gypsum is extracted from areas rich in biodiversity. At the same time, it ends up in landfills in the form of building rubble, although it could be recycled, as neighbouring countries show. Gravel is dredged cheaply, destroying beautiful landscapes. And this despite the fact that substitutes made from construction waste could be technically used. But these also end up in landfill sites.

Renewable raw materials are by no means always a viable solution — especially in the context of the energy transition. They too are limited, relying on land and stable, sustainable environmental conditions to grow. Yet their large-scale cultivation often involves monocultures that degrade ecosystems and reduce biodiversity, ultimately undermining the very sustainability they are meant to support. The tank-plate debate from the phase of the introduction of biofuels is arising again today in a new form: globally, a high share of wood is used for heating, cooking and power production, in 2023 around 1961 million m3 according to FAO - around half of all roundwood harvested worldwide. However, wood is used as well for construction, paper or furniture[16]. What will or should wood be used for tomorrow?

Competition for wood as a raw material is fierce. In view of climate change, wood is to be used as a substitute for greenhouse gas-intensive building materials such as cement or steel in wooden houses, while at the same time replacing fossil raw materials in (pellet) heating systems. In addition, the forest should defy climate change and absorb greenhouse gases - i.e. not be used. And all this in addition to all the common uses of wood for products, from cooking spoons to roof trusses. It is obvious this cannot all work together. Importing wood only shifts the problem to other countries. Sustainable forest management cannot develop under the pressure of demand, including for sustainable materials. Overall, we must also be careful that the demand

for sustainable products does not itself become a threat to biodiversity, water quality and soil health and thus to people, society and the economy. Economical use of the limited raw materials available and intelligent distribution is the key to this.

Green hydrogen and its derivatives, such as synthetic energy sources and raw materials for industry, could also replace fossil fuels in the future. However, they are also not unlimited. Green hydrogen is produced from water using electrolysis with electricity from renewable energies. Green hydrogen and its derivatives therefore do not cause any additional greenhouse gas emissions during operation and are indispensable for industries and applications that cannot be converted to the much more energy-efficient direct use of electricity. However, hydrogen production plants also require raw materials from which they are built. The plants need land on which to stand. Locations such as the Sahara or other deserts are often into the discussion. However, it is easy to forget that deserts are also special ecosystems. To avoid having to use groundwater for electrolysis, which is a problem in countries with few freshwater resources, water must be extracted from oceans and treated in desalination plants. These plants also require raw materials, space and energy. Desalination produces brine, which also has to go somewhere.

It is clear: even with important green technologies, there are impacts and challenges that we need to consider and take care of right from the start.

It is clear: even with important green technologies, there are impacts and challenges that we need to consider and take care of right from the start. This also applies to social aspects: green hydrogen and derivatives can become a new source of income for countries in low-income countries. However, there is also a risk that the overexploitation of nature in these countries will continue in the new guise of satisfying the energy hunger of the rich. It remains questionable how much will remain for the countries themselves. The establishment of fair energy and raw materials partnerships is therefore important in order to avoid undesirable developments.

From resource conflict to resource war

Cracks, holes and collapsing soils as a result of mining, leached and poisoned soils, growing mountains of waste at home and abroad, oceans filled with plastics and chemical residues in fresh water (our elixir of life) that remain for hundreds of years, and fish with plastic in their stomachs are an expression of the disposable and throwaway society. This is what science calls linear economy: taking from nature, processing, using and then throwing back into nature. Products that are only produced for single use (such as to-go tableware) are particularly symbolic of the linear economy, even though there are ecologically sound alternatives. Even worse are things that have been produced but are not sold and used and are then disposed of directly, such as some fast-fashion textiles. This is a particularly nonsensical form of economy: taking raw materials from nature, often destructively, producing them with the release of pollutants and throwing them back into nature - without having provided any benefit.

This extractive logic not only leaves behind ecological devastation but also fuels geopolitical competition and economic dependencies that increasingly shape the global landscape. The international race for raw materials and mining and plant capacities has long since intensified. A particular challenge for Europe is the fact that there is currently no processing infrastructure for mining products, such as heavy rare earths. In addition, the EU is over 80% dependent on imports for some critical raw materials.[17] The race for scarce and critical raw materials is leading to mining in areas that have so far largely spared, such as the deep sea. The subsurface is also increasingly being claimed: it is no longer just water and raw materials that are being extracted from it, but also energy (geothermal energy). In addition, waste, slag and CO^2 are increasingly being deposited there. Nothing in nature seems to escape the pressure of growth, prosperity and demand for raw materials according to the prevailing linear principle of economic activity. The run on scarce and critical raw materials inevitably leads to price increases in line with the rules of the market. However, in order to stop climate change, all countries must have access to affordable raw materials, especially those for renewable energies. Conflicts over raw materials are nothing new in human history. Overexploitation and debt bondage are still widespread today. European countries should have learned something from their colonial history and are less burdened with negative headlines due to their reappraisal of history. Nevertheless, they have also not yet managed to fully establish globally sustainable, internationally fair supply chains. Fair trade is a civil form of exchange, but the boundary to unequal trade or conflict is blurred, and the risks of outbreaks of war (resource wars) are also high and returning to the international stage.

Nothing in nature seems to escape the pressure of growth, prosperity and demand for raw materials according to the prevailing linear principle of economic activity.

The so-called resource curse[18] is also interesting in this context. This refers to the empirical and seemingly paradoxical observation “that economic growth in countries that are heavily dependent on the export of mineral and fossil resources is generally lower than in resource-poor countries” (own translation)[19]. A great wealth of natural resources can lead to an economy being one-sidedly focused on the exploitation of a raw material.

This makes them vulnerable to sharp price fluctuations. Sharp falls in crude oil prices, for example, have significant consequences for countries such as Venezuela and Nigeria, whose economies are heavily dependent on the sale of crude oil. Unfortunately, the relationship between ownership, the power of disposal and the national and international balance of power in relation to natural resources has been little studied to date. Power relations can express themselves internationally in direct neo-colonial violence or through the overpowering world market competition of multinational corporations. Nationally, this can lead to an excessive exploitation of parts of the population. In addition, there is the other side of the use of raw materials mentioned above: waste and emissions. They create no less serious problems. Nature’s absorption capacity is limited. The overexploitation of natural resources can also lead to flight and displacement, such as climate change already shows.

A different economy is needed

There is growing concern that the sharp rise in demand, particularly for critical raw materials, is creating a new dimension of conflict potential and the risk of war. Both nationally and internationally, the fair use of resources makes a decisive contribution to world peace. The deeper drivers of resource conflicts and wars would be addressed with the five turnarounds described in *Earth for All*, but not yet completely eliminated. There is growing unease in society, business and politics that today's global capitalism no longer solves the multiple crises. Fewer and fewer, but increasingly powerful profiteers are linking their unrealistic vision for the future of us all to the fact that they are individually doing well. But for the vast majority, appeals for change often remain empty phrases. After all, wellbeing in industrialised countries has not increased since the 1960s.[20] Economic growth and consumption have not significantly improved our quality of life since then.

The fundamental question of whether reforms within the system are sufficient or whether the system needs to be reformed is becoming increasingly urgent. We authors understand the Giant Leap as described by Earth for All as a transformative ("revolutionary") reform approach, but for good reasons we leave the socio-political goal of this transformation open. The *Earth4All* Transformational Economics Commission has presented a pluralistic variety of conceivable future economic and social forms in a global context and calls them "Earth4All economies". These include approaches such as the economy for the common good, post-growth, green growth, the ecological economy, the doughnut economy and prosperity beyond GDP (see Figure 1).

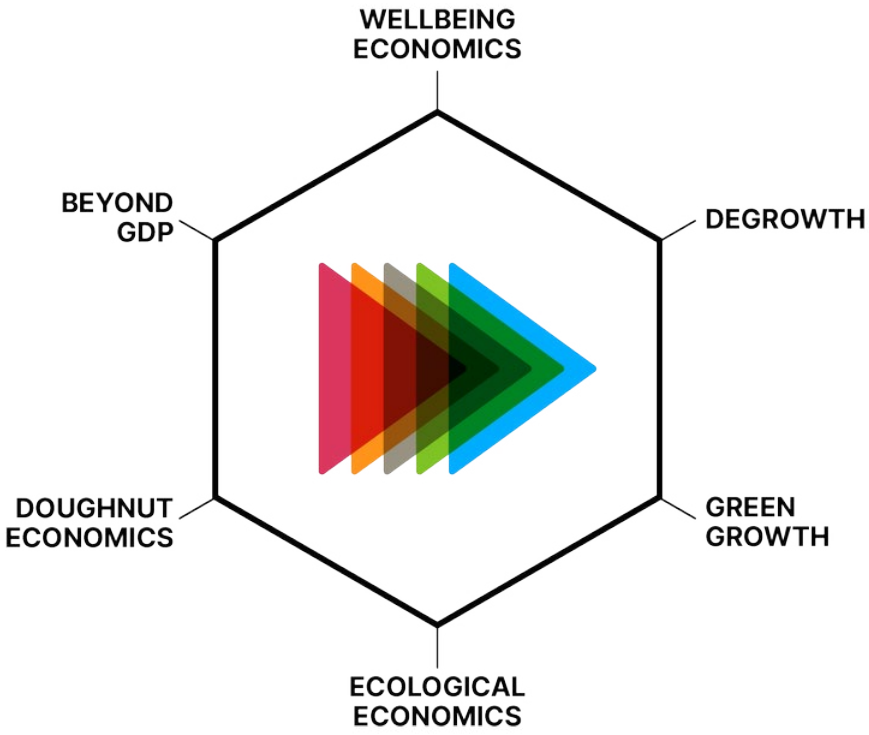


Figure 1: Some of the alternative economic paradigms explored by Earth4All

In our view, a Giant Leap must include a broad social discourse. Politicians must initiate, coordinate and moderate it in a participatory manner at many levels of society in order to raise fundamental visionary questions, such as: where should a Giant Leap lead? How is a good life for all really possible? And what does this mean for today's capitalist economic system? These are questions that we want to bring into the debate with this paper.

Circular economy within planetary boundaries

We need an economy that does not serve individual profit maximisation, but the wellbeing of all people and nature as a whole. Science speaks of the "decoupling of social prosperity from environmental consumption".[21] However, this is not possible with a wasteful throwaway society and rampant luxury consumption. The counter-model to a linear economy is a circular economy: its central principle is to use as few primary raw materials as possible and to keep these materials in use for as long as possible ("keeping them in the loop") in order to minimise the need to extract further raw materials from nature on the one hand and throw them away on the other. In its Circular Economy Roadmap for Germany, the German Academy of Science and Engineering writes: "*A systemically conceived and sustainable circular economy makes a comprehensive contribution to the EU target of net-zero greenhouse gas emissions by 2050 and enables economic growth to be completely decoupled from resource consumption. It ensures compliance with planetary boundaries and sustainability goals and contributes to increasing the quality of life and securing fair prosperity through collaborative, i.e. joint, cross-company value creation and innovation.*" (own translation)[22]

We need an economy that does not serve individual profit maximisation, but the wellbeing of all people and nature as a whole.

Collaborative, cross-company and equitable wellbeing are undoubtedly essential characteristics of an economy and distribution proposed by the Transformational Economics Commission of Earth4All. But do we already have the the right concept? No! All known economic theories - whether Marxism, neoclassicism or Keynesianism - are generally based on a linear and not a circular approach. This poses a mega task for economic theorising - because mastering the circular economy of the future with the theories of the past will not work. At the moment, the theories are still not very connectable. In addition, the cross-company collaboration that is necessary for the circular economy (more on this later) still fails all too often due to individual profit orientation or unregulated (global market) competition. In our economic system, companies have the task of generating returns. This distinguishes a commercial enterprise from other legal forms, such as associations, which also have social objectives. Fair prosperity for all is therefore not usually part of a company's mission statement.

This is why the widely recognised demand for a circular economy also has transformative potential. However, without a new formative role for the state and without more innovative framework conditions, companies cannot operate as comprehensively in a circular economy as is ecologically necessary and fair for all. Perhaps this will also result in a social basis for new alliances in which companies have no interest in capital exploitation at any price, but rather their

own interest in ensuring that natural production conditions also preserved for them in the long term. Trade unions want to secure a decent living for their members. But the price of ruining the natural basis of life would be paid primarily by their members.

All of this speaks in favour of pursuing very fast and very pragmatic strategies towards a fairer and more ecologically compatible circular economy. And there are many further strategies:

- People can use items for longer both privately and professionally. For example, they could throw away a new cell phone not after two years, but after three or more; they could wear high-quality clothing for several years and avoid disposable products altogether.
- Politicians and companies could make ecological purchasing decisions easier with comprehensible environmental labels.
- Companies could offer products that can be (guaranteed) repaired and/or retrofitted.
- Industries can take back products or parts and refurbish them so that they are comparable to new goods.
- The waste of one is the raw material of the other, for example in industrial symbioses.
- Designers could design products and packaging in such a way that they are recyclable. Waste could then be separated much better, used in other applications and recycled later.
- Companies could replace environmentally harmful or questionable chemicals and substances with those that are less harmful to the environment.
- Policymakers can and must ensure that small and medium-sized enterprises benefit just as much as larger companies.

But we also have to be careful in a circular world. The so-called rebound effect can be challenging: if goods can be used for longer or produced more efficiently, they become cheaper overall. Care must be taken to ensure that the additional money available as a result is not used for things that consume more resources and/or energy. The social benefits and counteracting rebound effects can undoubtedly become an important principle in these strategies. All of these strategies are known and are already being implemented – but usually only selectively.

In recent years, the EU has responded with many initiatives, such as the Circular Economy Action Plan of 2020.[23] It provides for a large number of legislative initiatives in resource-intensive or environmentally harmful value chains, including vehicles and batteries, construction industry and buildings as well as plastics and packaging. Implementation is challenging and, similar to climate protection measures, these projects are also met with reservations and backlashes. After decades of making far too little change against better knowledge, a different pace is now required. Although it is obvious that further hesitation and delay will only exacerbate the challenges, some people are still more interested in short-term gain than securing our natural resources in the long term.

As a result, there is a need for great acceleration and expansion. A fivefold increase in speed is needed to meet the EU's target of doubling the proportion of secondary raw materials in total raw material consumption. The manufacturing industry and all service providers must and can improve their resource efficiency more quickly. Good examples, of which there are many, must be publicised more widely and imitated more quickly. New designs and technologies that facilitate

reparability and recycling should be developed much more quickly and become standard. Bureaucratic and legal hurdles that prevent or make it difficult to reuse usable waste should be removed. Extended producer responsibility, under which producers are also responsible for disposal, and which already applies to products such as electrical appliances or packaging, can be extended to many other products. Recycling quotas, such as those already in place for packaging, could also be applied to many other products. Analyses that take the entire life cycle into account can reveal potential savings and provide a basis for sensible decisions. However, they can only do this if they are done correctly: if, for example, only the packaging of bottled water is compared, it is easy to overlook the fact that high quality tap water is available without any packaging at all as the most ecological alternative.

In order to secure high-quality raw materials in sufficient quantities across the entire value chain, we need both vertical and horizontal cooperation. Vertical collaborations are those along the supply chain, while horizontal collaborations are those between companies within an industry. For this to succeed, transparency and supply relationships based on partnership between all parties involved are required at a vertical level, rather than mutual competition. On a horizontal level, we need the recycling of residual materials and the reuse of so-called waste through the ("horizontal") cooperation of several partners who jointly organise the collection, separation, recycling and material reuse of secondary raw materials. In this way, we could achieve faster and broader regional economies and close material cycles. Regions, countries, the EU and global actors should support each other cooperatively: they should regionalise material flows and globalise competencies. In this way, innovation and sustainable business models could drive each other forward - instead of working against each other.

We can take a big step forward if we turn away from the antiquated form of rentier capitalism. Rentier capitalism is an economic system in which particularly resource-rich and powerful players defend their privileges at the expense of other economic players and the general public.

That sounds challenging, and it is. We can take a big step forward if we turn away from the antiquated form of rentier capitalism. Rentier capitalism is an economic system in which particularly resource-rich and powerful players defend their privileges at the expense of other economic players and the general public. And it does not matter which economic system it is. Whether private rentier capitalism, state capitalist planned economies or democratic as well as autocratic systems: natural resources are privatised in almost all currently widespread economic systems and appropriated by a few who reap the benefits, while the general public - especially poorer sections of the population - bear a large part of the burden. Not all consequential costs are always clear from the outset and cannot be expressed in monetary terms. But many consequences are clearly identified and are sometimes deliberately concealed. For example, simulations by oil companies were already predicting climate change very well in the 1970s.[24] Some companies that have made and continue to make good money from the sale of fossil fuels have invested a lot of money in campaigns to suppress knowledge about the dramatic environmental and health consequences for humanity as a whole.

The shifting of environmental, repair and health costs onto the general public is not always so clear and deliberate in order to maximise one's own benefits. But in general, the environmental consequences and the associated effects are not priced in or are priced in too low. Take, for example, waste exports to countries that have no waste infrastructure[25] or the CO_2 price: in Germany, the latter was EUR 45 per tonne for heating with fossil fuels (such as oil and gas) and for fuel (such as petrol and diesel) in 2024. If all social and ecological costs were actually included, it would already amount to EUR 250 or 860 per tonne in 2023 according to the current methodological convention of the Federal Environment Agency.[26] A CO_2 price of this or a similar magnitude would have a huge steering effect, because companies and consumers normally have a vested interest in saving costs, they then seek and find cost-effective alternatives in the implementation of energy efficiency potentials or the expansion of renewable energies. This does not even begin to include the social costs of such a raw material and processing economy. However, such sharp increases in energy prices have a strongly regressive effect, meaning that poorer households would be relatively more heavily burdened than richer ones. The steering effect must therefore be weighed up against the distribution effect. A steering policy at complying with planetary boundaries is therefore not enough on its own. Rather, the social consequences of this policy must always be considered and anticipated from the outset.

Limitations on extraction from nature are already common practice in fisheries by means of catch quotas, and the principle could also be implemented in mining or forestry.

Of course, the switch to a circular economy also requires the right economic incentives. Fully internalising environmental costs would eliminate the separation between benefits and burdens. Higher levies on primary raw materials, a priority for environmental protection with high standards in mining, agriculture, forestry and fishing or the limitation of extraction from nature can be implemented individually or in combination and would make primary raw materials or primary products more expensive. Secondary raw materials can thus become more competitive.

Limitations on extraction from nature are already common practice in fisheries by means of catch quotas, and the principle could also be implemented in mining or forestry. If nature is understood as a common good or commons that has a value in itself, that should serve the common good and not just individuals - shouldn't we then also democratically decide how much we take today and how much remains in the soil, water or forest for later, for children and future generations? And does this basic principle of ensuring intergenerational justice not also apply to international justice, especially in the relationship between the rich minority population in high-income countries and the poorer majority population in low-income countries?

In the case of very scarce raw materials, the availability of which is fundamental to, for example, health, social welfare (e.g. municipal functions) and the production of essential goods, it is necessary to protect them from shortages or to be able to make them available for urgent needs in the event of shortages. Just how important this can suddenly be became clear during the coronavirus pandemic and during the war of aggression on Ukraine, in relation to the feared gas shortages. The principle of "first come, first served" is not always best for society as a whole.

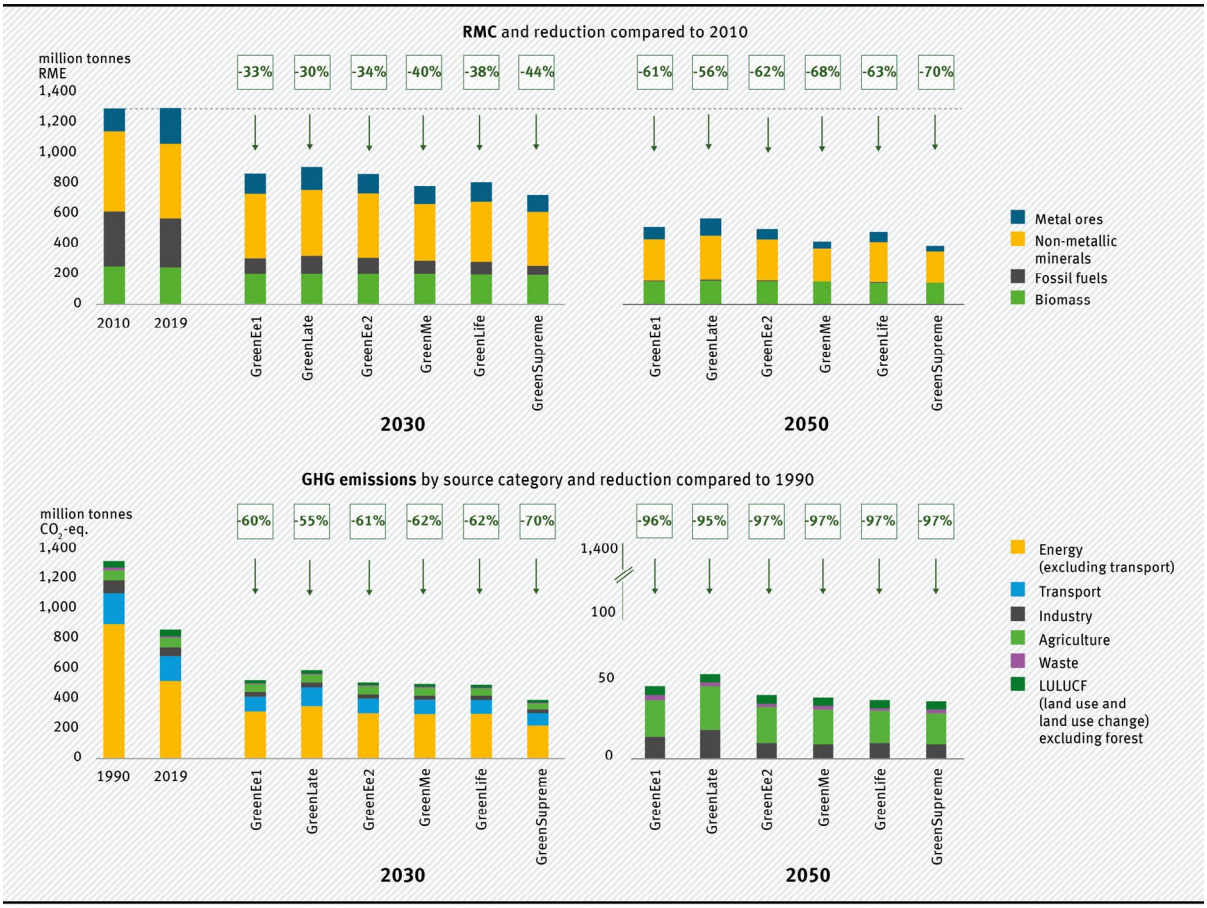
Unfortunately, there have been many examples in the past of this ending in chaos, possibly even civil war and interstate conflict.

For example, do we really want - under current market conditions - the scarce lithium to be used in expensive luxury cars that only very few people can afford, but which promise manufacturers higher margins per car? Climate-friendly mobility requires the use of the materials in batteries for small cars or buses, which are useful for many people and would reduce mobility poverty. Concentrating on niche markets cannot be desirable. Do we want to turn trees into paper, cardboard or firewood - or should they rather grow old, store CO_2 and defy climate change? This is not a proposal to introduce a dirigiste planned economy. But the relationship between the market and the state and between the private appropriation of public goods ("commons") and their social benefit must also be reconsidered with regard to critical raw materials: raw materials that are particularly scarce and that are urgently needed for the socially necessary energy transition or to maintain the functionality of our ecosystems should also be used primarily for these applications. This also applies to the focus on the use of environmentally incompatible products such as plastics if they do not demonstrably contribute to the faster achievement of sustainable development goals.

At the same time, products and especially electrical and electronic appliances should be designed in advance in such a way that they can be recycled, so that scarce and, if possible, all other raw materials can be recovered and reused. It is therefore necessary to define economic framework conditions and rules that maintain a functioning state and a society that is capable of development, co-innovation and creativity. It should be worthwhile to act for the common good instead of just for profit. Under this framework, competition for every innovative and marketable idea is welcome and would be rewarded.

Moderation

The good news is that both the Earth4All modelling and detailed scientific studies such as the Federal Environment Agency's RESCUE project show that, for example, Germany could halve the amount of primary raw materials extracted from nature each year without losing its level of prosperity. The energy and food transition alone could significantly reduce our consumption of raw materials. Further reductions can be achieved through the circular economy, as described above. Tackling the various policy areas together makes implementation easier overall, as global studies by the United Nations Environment Programme (UNEP) and the Earth4All modelling show.



Source: UBA Resources Report 2022

Figure 2: Reduction of greenhouse gas emissions and raw material consumption in Germany. In the RESCUE project, the Federal Environment Agency developed solutions in six scenarios with which the amount of raw materials and greenhouse gas emissions in Germany can be reduced. This graphic shows the possible savings in primary raw materials and greenhouse gas emissions in the years 2030 and 2050 in the various scenarios ([27]).

If we bear in mind that not only some industrialised countries, but all lower-income countries want to maintain or achieve a level of prosperity that covers basic needs and allows people to live in dignity, then technical changes alone are not enough. The consumption of various goods must be reduced, as scientific studies clearly show. Binding targets such as halving the consumption of primary raw materials could provide clear guidance on what consumption would be (more) tolerable for the environment and for society. As with greenhouse gases, orientation targets for sectors such as buildings or transport would also be helpful. This would allow us to clearly measure whether we are on the right track. Incidentally, the goal of halving the consumption of primary raw materials does not mean that everyone should halve their consumption. Here, too, it is important to look at the distributional effect of measures, because the excessive consumption of the rich and super-rich is often tacitly tolerated, but in return moderation is demanded from those who already have little and contribute only marginally to environmental damage. It is therefore very important that the reduction does not mean that everyone must halve their consumption, but that people with particularly high consumption must reduce much more than people with low consumption.

It is therefore necessary to enable sufficient lifestyles for all, in the sense of a self-effectively defined good life in conjunction with new sustainability-innovative and eco-intelligent economic forms based on sharing and cooperation. We need a new way of dealing with materials and products, especially in the utilisation phase. This is what makes it possible to achieve a central goal of a circular economy in the first place: the far-reaching reduction of absolute resource consumption. Political measures must urgently set the framework for this.

This is what makes it possible to achieve a central goal of a circular economy in the first place: the far-reaching reduction of absolute resource consumption

And things are connected: if energy consumption decreases, as described in the energy turnaround, not so many photovoltaic and wind power plants will have to be built. Then not as much land will be needed and not as many (critical) raw materials will be in demand. Dependencies decrease; global raw material markets are less tense. Planning buildings in a more flexible, "modular" way and using them for longer, smaller (energy-efficient) homes that not only require less heating, but also cause less cleaning and maintenance work, or shared smaller cars (car sharing) in conjunction with public transport, especially in cities, will reduce the burden on the environment, as will a change in diet. If consumer and durable goods are also produced in such a way that they can be repaired and reprocessed and used after a longer period of use, and if citizens accept this, this also reduces the burden on the environment. Efficiency gains, as necessary as they are, can cause so-called rebound effects if no countermeasures are taken. Such growth effects, which consume or pollute more and more nature, urgently need to be limited. It is desirable for innovations to make products more environmentally friendly, for example by using fewer harmful substances or raw materials. At the same time, the sheer quantity of goods produced in an environmentally friendly way should only increase to the extent that they contribute to wellbeing but have little impact on the environment. This will make it possible for everyone to live within planetary boundaries.

A new economy for an Earth for All

We are faced with a fundamental decision: Do we want to preserve our ecosystems as we know them and as they continue to be necessary for our current life - in other words, a life within planetary boundaries? Or do we want to take the risk and adapt to droughts, floods, heat waves and other extreme weather conditions in a rapidly changing global environment that will inevitably come if everything continues in a Too Little Too Late scenario? Do we want all the deaths and refugees? Do we want to risk enormous damage to what we, our parents and grandparents or people in other countries have built up? Do we want the death of a large number of animals and plants? Or do we want to limit our excessive use of resources? The question seems pointless. A circular economy would be one solution.

If we want to live within planetary boundaries, we need to reduce our consumption of resources. Almost all environmental impacts and ecological crises are linked to the fact that people extract, recycle, use and dispose of raw materials. Reducing this and decoupling the preservation of prosperity from the amount of resources used is therefore a key lever. At least halving the amount of primary raw materials used each year is a sensible goal for industrialised countries. It is achievable if we combine the energy transition with a genuine circular economy.

Such an economic system is not compatible with rentier capitalism, in which a few benefits from the extraction of resources and the use of the new technology while many bear the costs directly or indirectly. The implementation of the turnarounds described by *Earth for All* requires capital for an investment offensive. Procuring this is a core task of politics.

Footnotes

1. United Nations Environment Programme (UNEP). 2024. Global Resources Outlook 2024: Bend the trend – Pathways to a livable planet as resource use spikes (p. xiv). Nairobi: UNEP. https://wedocs.unep.org/bitstream/handle/20.500.11822/44901/Global-Resource-Outlook_2024.pdf

2. Retsa, A. et al., 2020: Biodiversity and Ecosystem Services. https://www.swissre.com/dam/jcr:a7fe3dca-c4d6-403b-961c-9fab1b2f0455/swiss-re-institute-expertise-publication-biodiversity-and-ecosystem-services.pdf

3. United Nations Environment Programme, 2024: Global Resources Outlook 2024: Bend the Trend - Pathways to a liveable planet as resource use spikes. International Resource Panel. Nairobi. https://www.resourcepanel.org/sites/default/files/documents/document/media/gro24_full_report_1mar_final_for_web.pdf

4. Teske, et al. 2019: Achieving the Paris Climate Agreement Goals Global and Regional 100% Renewable Energy Scenarios with Non-energy GHG Pathways for +1.5°C and +2°C. https://link.springer.com/book/10.1007/978-3-030-05843-2

5. 5 EC, 2024: Resource productivity statistics. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Resource_productivity_statistics

6. 6 Marscheider-Weidemann et al., 2021: Rohstoffe für Zukunftstechnologien. DERA Rohstoffinformtaionen 50. Berlin. https://www.deutsche-rohstoffagentur.de/DE/Gemeinsames/Produkte/Downloads/DERA_Rohstoffinformationen/rohstoffinformationen-50.pdf;jsessionid=2D884EE3F81AA4D0790CBF297B41647E.internet982?__blob=publicationFile&v=4

7. 7 UNEP (2013) Metal Recycling: Opportunities, Limits, Infrastructure, A Report of the Working Group on the Global Metal Flows to the International Resource Panel. Reuter, M. A.; Hudson, C.; van Schaik, A.; Heiskanen, K.; Meskers, C.; Hagelüken, C. https://www.resourcepanel.org/reports/metal-recycling; European Commission (o.J.): Raw Materials Information System. https://rmis.jrc.ec.europa.eu/eu-critical-raw-materials

8. EC 2024: Critical Raw Materials Act - VERORDNUNG (EU) 2024/1252 DES EUROPÄISCHEN PARLAMENTS UND DES RATES vom 11. April 2024 zur Schaffung eines Rahmens zur Gewährleistung einer sicheren und nachhaltigen Versorgung mit kritischen Rohstoffen und zur Änderung der Verordnungen (EU) Nr. 168/2013, (EU) 2018/858, (EU) 2018/1724 und (EU) 2019/1020. https://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=OJ:L_202401252

9. IEA, International Energy Agency, 2022: Global supply chains of EV Batteries. https://iea.blob.core.windows.net/assets/4eb8c252-76b1-4710-8f5e-867e751c8dda/GlobalSupplyChainsofEVBatteries.pdf

10. OECD, 2019: Global Material Resources Outlook to 2060. Economic Drivers and Environmental Consequences. https://www.oecd-ilibrary.org/environment/global-material-resources-outlook-to-2060_9789264307452-en

11. Eurostat, o.J.: Material Import Dependencies. https://ec.europa.eu/eurostat/databrowser/view/env_ac_mid/default/table?lang=en

12. DERA, 2023: Importabhängigkeit der EU bei kritischen Rohstoffen im Jahr 2022. https://www.bgr.bund.de/DERA/DE/Downloads/DERA%202023_cdm_08_EU_Importabh%C3%A4ngigkeit.pdf?__blob=publicationFile&v=2

13. EUROSTAT 2024: Circular Material Use Rate. Data browser, available at: https://ec.europa.eu/eurostat/web/environment/information-data/material-flows-resource-productivity

14. Ressourcenkommission am Umweltbundesamt, 2023: Chancen und Grenzen des Recyclings im Kontext der Circular Economy Rahmenbedingungen, Anforderungen und Handlungsempfehlungen. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2023_uba_kom_ressourcen_bf.pdf

15. 15 Christis et al., 2023: Analysis of the circular material use rate and the doubling target. ETC/CE Report 2023/6. https://www.eionet.europa.eu/etcs/etc-ce/products/etc-ce-report-2023-6-analysis-of-the-circular-material-use-rate-and-the-doubling-target

16. 16 FAO, 2024: Global Forrest Products. Facts and Figures 2023. https://openknowledge.fao.org/items/3740bc34-b22a-4ba9-8962-1486af5ba25a

17. 17 DERA, 2023: Importabhängigkeit der EU bei kritischen Rohstoffen im Jahr 2022 https://www.bgr.bund.de/DERA/DE/Downloads/DERA%202023_cdm_08_EU_Importabh%C3%A4ngigkeit.pdf?__blob=publicationFile&v=2

18. 18 Richter, S., 2018: Ressourcenkonflikte. bpb. https://www.bpb.de/themen/kriege-konflikte/dossier-kriege-konflikte/76755/ressourcenkonflikte/

19. 19 Richter, S., 2018: Ressourcenkonflikte. bpb. https://www.bpb.de/themen/kriege-konflikte/dossier-kriege-konflikte/76755/ressourcenkonflikte/

20. 20 Binswanger, M., 2012: Die Tretmühlen des Glücks. In Fischer, E.P.; Wiegandt, K. (Hg): Dimensionen der Zeit. Frankfurt. S. 248-267

21. UNEP-IRP, 2011: Decoupling natural resource use and environmental impacts from economic growth. https://www.resourcepanel.org/reports/decoupling-natural-resource-use-and-environmental-impacts-economic-growth

22. Acatech, 2021: Circular Economy Roadmap für Deutschland. https://www.acatech.de/publikation/circular-economy-roadmap-fuer-deutschland/

23. Europäische Kommission, 2020: Ein neuer Aktionsplan für die Kreislaufwirtschaft: Für ein saubereres und wettbewerbsfähigeres Europa. https://eur-lex.europa.eu/resource.html?uri=cellar:9903b325-6388-11ea-b735-01aa75ed71a1.0016.02/DOC_1&format=PDF

24. Supran G. et al., 2023: Assessing ExxonMobil's global warming projections. Science. 2023 Jan 13;379. doi: 10.1126/science.abk0063 ; McCarthy, A., 2023: Exxon disputed climate findings for years. Its scientists knew better. The Harvard Gazette. https://news.harvard.edu/gazette/story/2023/01/harvard-led-analysis-finds-exxonmobil-internal-research-accurately-predicted-climate-change/

25. WWF, 2021: Plastics: The Costs to Society, the Environment and the Economy. https://theoceanmovement.org/wp-content/uploads/2021/09/wwf-plastic-rapport-english-min.pdf

26. Umweltbundesamt, 2024: Gesellschaftliche Kosten von Umweltbelastungen. https://www.umweltbundesamt.de/daten/umwelt-wirtschaft/gesellschaftliche-kosten-von-umweltbelastungen#gesamtwirtschaftliche-bedeutung-der-umweltkosten; The difference between the two prices is calculated from the assumed time preference: If it is assumed that the welfare losses today and in the future are weighted equally, the higher price results.

27. Lutter et al., 2022: The Use of Natural Resources. Resources Report for Germany 2022. https://www.umweltbundesamt.de/publikationen/the-use-of-natural-resources-resources-report-for

This deep-dive paper was produced in collaboration with the Materials and Consumption Taskforce.

Earth4All is an international initiative to accelerate the systems changes we need for an equitable future on a finite planet. Combining the best available science with new economic thinking, Earth4All was designed to identify the transformations we need to create prosperity for all. Earth4All was initiated by The Club of Rome, the Potsdam Institute for Climate Impact Research, the Stockholm Resilience Centre and the Norwegian Business School. It builds on the legacies of *The Limits to Growth* and the planetary boundaries frameworks.

www.earth4all.life