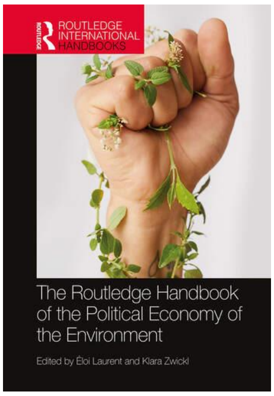

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A socio-metabolic perspective on (material) growth and inequality

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A SOCIO-METABOLIC PERSPECTIVE ON (MATERIAL) GROWTH AND INEQUALITY

Anke Schaffartzik and Fridolin Krausmann

Introduction: global growth and inequality

The Great Acceleration describes the global rise in resource use and in wastes and emissions since World War II (Steffen et al. 2015). Global material extraction – that is, agricultural and forestry harvest as well as mining for metals, fossil energy carriers, and non-metallic minerals – was increased from approximately 23 billion tons in 1970 to 92 billion tons in 2017 (UNEP 2019b): Per year, 70 billion tons *more* were extracted in 2017 than in 1970. This growth accelerated over time: It took 24 years to add 23 billion tons to annual extraction between 1970 and 1994 and then approximately the same time span (25 years) to add twice that amount (46 billion tons). This overarching growth trajectory powerfully communicates that society-nature relations are in crisis, with the global economy pushing hard on or even surpassing planetary boundaries (Rockström et al. 2009).

This global growth is the cumulative effect of diverging regional patterns: of expanding extraction, production, and consumption in some parts of the world as well as of stagnating or even decreasing material flows in others. At the regional and national level, extremely high per capita extraction and/or consumption in some places is juxtaposed with extremely low per capita values elsewhere (Schaffartzik et al. 2014; Pothen and Schymura 2015). In many of the wealthy, mature industrialized economies, material extraction has been stagnating (Wiedenhofer et al. 2013) with material imports, especially of fossil energy carriers, playing an increasingly important role for production and consumption (Schaffartzik and Pichler 2017). The wealthier an economy, the more material resources it tends to require (Duro, Schaffartzik, and Krausmann 2018) and the more greenhouse gas emissions are linked to its consumption (Chakravarty et al. 2009). Materials extracted elsewhere, especially in the middle-income economies, are needed in the production of the imported goods (and also services) (Wiedmann et al. 2015). Those economies directly and indirectly supplying not only material resources but also, for example, energy and human labor to the global economy tend to have lower levels of consumption. The extraction and processing of resources for export appears to aggravate rather than alleviate international inequalities (Schaffartzik, Duro, and Krausmann 2019).

Where extraction expands, land is claimed not only for mining, agriculture, or forestry but also for the energy and transport infrastructures and the processing plants through which resources are channeled. Extractive expansion commonly excludes other claims – for subsistence,

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for other extractive uses, for conservation – and is heavily contested (Temper, Del Bene, and Martinez-Alier 2015; also see Martinez Allier, "Environmental conflicts" and Alfredo Rosete, "Southeast Asia, agriculture, and contested forms of land rights: lessons from the Philippines," this volume). In the face of this contestation, extractive expansions are enforced through political, legal, and economic mechanisms, through cultural appeals, and through outright violence (Bene, Scheidel, and Temper 2018; White et al. 2012; Navas, Mingorria, and Aguilar-González 2018). Growth-led capitalist expansion relies on and reinforces existing socio-ecological inequalities – in the interrelated terms of access to resources, exposure to environmental burdens, decision-making power and economic influence, income and wage-dependency, and so on.

In this chapter, we investigate the international material inequalities that are simultaneously the outcome of and prerequisite for the globally unsustainable patterns of growth described as the Great Acceleration. To do so, we require a theoretical approach that allows us to consider society not only in terms of social relations, perhaps as related to growth-sustaining inequalities in capital and income (Piketty 2014; Milanovic 2012), but as dependent upon material and energy inputs, transformations, and the thermodynamically unavoidable outputs of wastes and emissions for their biophysical reproduction. As such, societies – in an analogy to living organisms – have a metabolism (Fischer-Kowalski and Haberl 2015) that is interrelated with their internal social organization and contingent upon relations with other socio-economic systems. We present these concepts in the section "Concepts: A Socio-Metabolic Perspective." By examining the quality and extent of social metabolism as well as its changes over time, we derive patterns in metabolic inequality as one aspect of international socio-ecological inequality. The section "Material Inequality" offers an overview of some of these empirical results. We provide a brief discussion of the role of inequality for sustainability transformations in "The Inertia of Growth." From considering inequality within the growth debate, we derive a need to assess the socio-ecological benefits and impacts of any further resource use expansion, requiring a balance between the two.

Concepts: a socio-metabolic perspective

One of the principles of strong sustainability is that money and financial capital are no substitute for the functioning of ecosystems and biogeochemical cycles and for the (other) resources required for human and societal reproduction (Neumayer 2013). While money may buy resources, it cannot be used in their stead to construct shelter, to provide nutritional energy, or as a source of the comforts of indoor lighting and heating or cooling. Social ecology (of the Vienna variety, see Fischer-Kowalski and Weisz (2016)) understands society as socio-economically (or socio-culturally) and biophysically reproduced. Within a society, it is not possible for a socio-economic program (such as growth-led capitalist expansion) to be pursued without consequences for society's material and energy stocks and flows and the related exchange with the natural environment. Accordingly, such programs always have not only intended but also unintended environmental outcomes. Society not only is the outcome of social processes but also exerts tangible influence on its environment, effecting material and energetic changes therein. In turn, society is also directly affected by changes in the environment. This is so because society consists of human beings as living, bodily organisms who use buildings and infrastructures, machines and tools, a variety of (durable) consumer goods, and even animals to "make use" of their environment. In amassing and sustaining society in this biophysical sense, continuous material and energy inputs are required, must be distributed and transformed, and are eventually discharged as wastes and emissions. These material and energy flows can be understood as the manifestation of a society's metabolism (Fischer-Kowalski and Haberl 2015).

This metabolism can be charted with the tool of material and energy flow accounting, essentially a bookkeeping method for the inputs and outputs of a given socio-economic system (Krausmann et al. 2017; Fischer-Kowalski et al. 2011). A socio-economic system can be defined by two types of boundaries: those between the system and its (natural) environment and those with other socio-economic systems. Accordingly, inputs into the system can stem from the environment (through extraction) or other economies (through imports). These inputs are processed, transformed, and distributed within the socio-economic system, with a share of these flows integrated into societal stocks of buildings, infrastructures, and machinery (such as limestone processed into cement and used in construction) while others are almost directly transformed into wastes and emissions (such as coal burned to generate energy and producing ash and gas). Next to wastes and emissions as outputs to the environment, outputs can also go to other socio-economic systems as export commodities. Material and energy flow accounting (Fischer-Kowalski et al. 2011) investigates these flows and yields a variety of indicators which can be compared across systems in order to generate an understanding of material inequalities. These include:

1 domestic extraction – those materials extracted through agriculture, forestry, and mining and then further processed or used – as a measure of the intervention into the environment on a given territory,
2 domestic material consumption – domestic extraction plus imports minus exports, accounted for with their actual mass upon crossing the boundary into or out of the system in question – as a measure of the material consumed and (eventually) transformed into wastes and emissions on a given territory, and
3 the material footprint – the material extraction, no matter where in the world it occurs, required to meet final demand for goods and services in a socio-economic system (Wiedmann et al. 2015) – as a measure of not only the direct but also the indirect appropriation or provisioning of material resources.

These three main indicators provide complementary perspectives on the material resource requirements of societal reproduction. They can theoretically be calculated for systems as small as a household and as large as the entire world. In our investigation of international material inequality and its role in growth-led development, we apply the material flow accounting framework at the national level. We are thereby able to capture some of the widely diverging trends underlying the globally observed Great Acceleration, at the expense of not being able to consider subnational inequalities that match and even exceed international inequalities (e.g., Wiedenhofer et al. 2016; also see Tony Reames, "Energy inequality"). In examining international inequalities through the lens of social metabolism, we contextualize – wherever possible – findings on current patterns of extraction, consumption, and appropriation or provisioning with the historical development of the resource use patterns of the system in question. Current material flows required for societal reproduction are also the result of material (and wider resource) use patterns of the past. Stagnation of per capita material extraction and consumption or even saturation with some of the central stock-building materials in those economies that industrialized early by international comparison (Fishman, Schandl, and Tanikawa 2016; Bleischwitz et al. 2018), for example, must be understood in the context of the decades (Mayer, Haas, and Wiedenhofer 2017) or even centuries of historical material accumulation. A society's current material stocks represent past and shape present and future resource use. While extensive built-up stocks may mean that less stock-building materials (e.g., stone and steel) are required than is the case in a country just building up its industries and infrastructures, more materials and energy may be needed for the foreseeable future in order to maintain and operate these stocks (Krausmann et al. 2017).

In this sense, the Great Acceleration is also based on the building up of material stocks (infrastructures, buildings, and increasingly also consumer products) after World War II and the material and energy then required to use and maintain these stocks. This role of stocks as a destination or a point of transmission for material and energy flows also means that they spatially distribute flows to where stocks are either built up or used and maintained.

We consider the international patterns of material flows in terms of metabolic profiles, that is, the average composition and per capita dimensions of the indicators considered. Differences in metabolic profiles do not only occur across space but also across time for the same system and correspond to (far-reaching) changes in the societal organization of the biophysical reproduction that they represent. Specific metabolic profiles are considered typical of so-called metabolic regimes (Krausmann, Weisz, and Eisenmenger 2016) with their typified organization around dominant energy sources (uncontrolled and controlled use of solar energy for hunters and gatherers and agrarian societies and fossil energy for industrial societies). Shifts between these regimes can be thought of as socio-ecological transitions, as far-reaching fundamental changes not only in the resource base of a society but also in the corresponding social organization (Fischer-Kowalski 2011). Within the global economy, a transition in one place may necessitate or limit socio-metabolic change elsewhere, potentially aggravating or reducing inequalities. Transformative future change will have to consist in a redistribution as well as reduction of global resource use (Scheidel and Schaffartzik 2019).

Material inequality

Material inequality in the global economy

The Great Acceleration of global material extraction described in the Introduction is the aggregate result of different underlying trajectories. The high-income countries expanded their extraction of material resources from approximately 12 billion tons per year in 1970 to 19 billion tons in the years before the 2007/08 economic and financial crisis, which was associated with strong decline in extraction. In 2010, this group of countries accounted for 25% of global extraction (Figure 4.1). The dissolution of the Soviet Union was associated with a drop in the extraction in the (upper) middle-income countries, but since this coincides with the acceleration of extraction in China, the global growth trajectory continues uninterrupted in this period. It is in particular growth in China’s extraction that also “compensates” the slump in the high-income countries following the 2007/08 crisis. In 2010, almost half of the global population lived in low- or lower-middle-income countries (including India), accounting for only 21% of global extraction. This potential for extractive expansion (Schaffartzik and Pichler 2017) has important implications for upholding growth-led development, to which we will return.

The Great Acceleration (especially in its second phase of even faster acceleration) of resource extraction with its far-reaching environmental and social impacts is clearly visible in Figure 4.1, as is the fact that it is an acceleration at the global level involving different subglobal trends. The effect that this global extractive expansion has on international material inequality depends, of course, not only on how much is extracted where but also on who has access to these resources. A very simple distinction in access lies in whether extraction is for domestic consumption or for consumption elsewhere, that is, used in the production of exported goods and services.

In the following, we contrast material extraction with the material footprint, that is, with the amount of material extraction required for domestic final consumption in the investigated

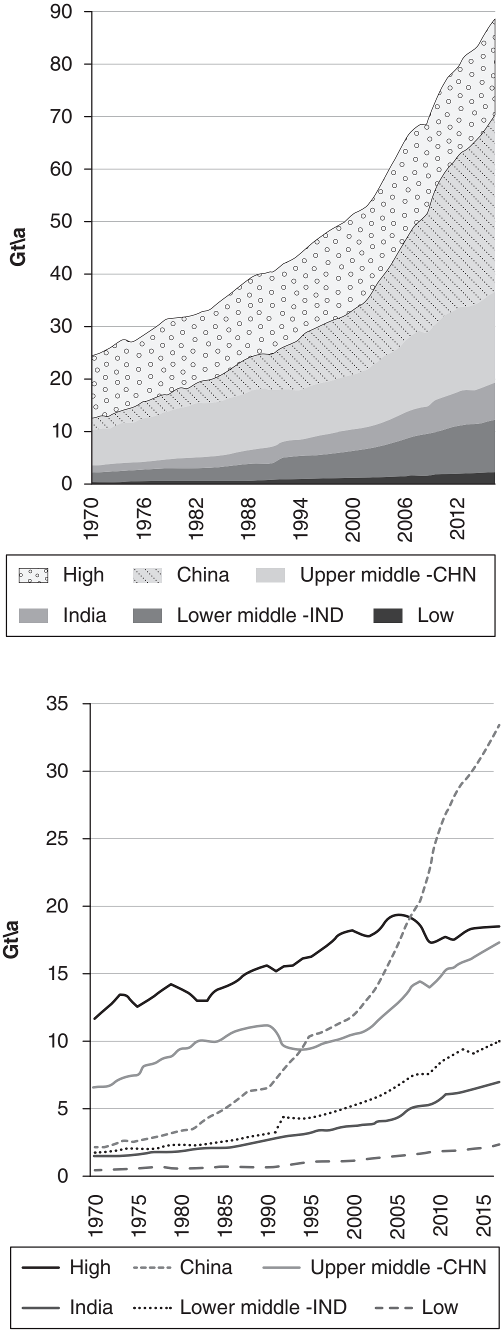

Figure 4.1 Material extraction 1970–2017 by World Bank (2016) 2010 income-based groupings and China and India. In 2017, approximately 10% of the world population lived in the low-income countries, 15% each in the upper-middle-income countries without China and in the high-income countries, and 20% each in the lower-middle-income countries without India, in India, and in China.

Source: Data from UNEP (2019b).

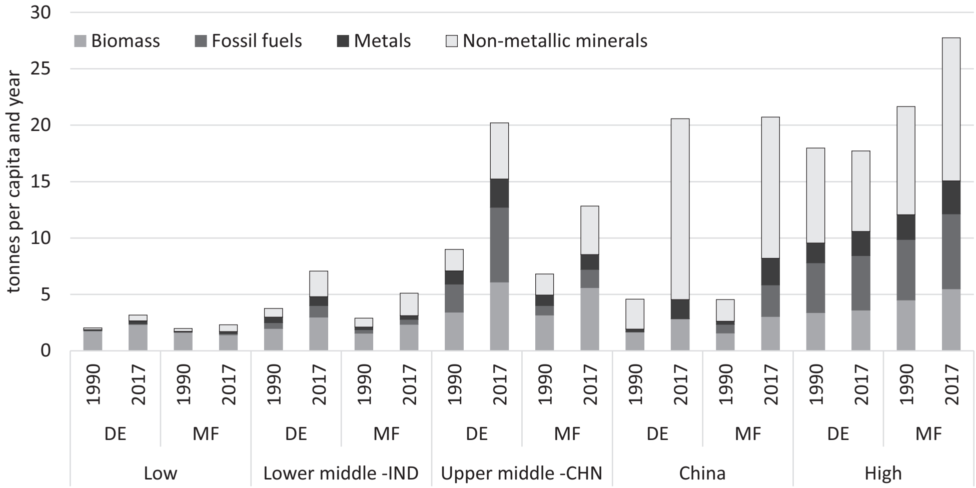

Figure 4.2 Domestic extraction (DE) and the material footprint (MF) of 2010 income-based country groupings and China in 1990 and 2017 in tons per capita and year

Source: Data from UNEP (2019b).

countries and country groupings. We also add some detail to our investigation of which materials are extracted by turning to the four main material resource categories of biomass (extracted through agriculture and forestry, mainly), fossil energy carriers (coal, oil, and gas), metals (extracted as metal ores and traded as concentrates or metal products), and non-metallic minerals (most of which is accounted for by materials used in bulk for construction). This view of global material flows is highly indicative of an increasing polarization as a type of inequality (Figure 4.2). The low- and lower-middle-income countries, including India, were home to half of the global population in 2017 and appropriated (as reflected by the material footprint) between 2 and 7 tons of material per capita. Biomass constituted the majority of these material flows. The growth that had occurred since 1990 was slight. In the wealthier countries with upper-middle- or high-income growth, already higher levels of extraction became much more pronounced and occurred especially for non-metallic minerals and to a lesser extent for fossil energy carriers. During the quarter century traced here, China moved out of a metabolic profile similar to that of the economies with lower income into one that, in terms of magnitude although not quite of composition, is similar to the high-income country grouping. Throughout the entire period under investigation here, China's material footprint was lower than its domestic extraction – the economy was a net provider of material resources to the global economy. By 2017, however, these two indicators had become very similar. The high-income economies, on the other hand, have remained net appropriators of material resources from the global economy; their material footprint is consistently higher than their domestic extraction.

Based on these generalized metabolic profiles, we can identify patterns of growth in the high-income countries' final demand (growth of the material footprint, Figure 4.2) as requiring extractive expansion for export elsewhere, especially in the middle-income countries (Figure 4.1). This extractive expansion relies on claims to land realized in the face of controversy, dispossessing the local population from their livelihood resources, oftentimes violently (Martinez Allier, "Environmental conflicts").

International highly unequal material resource flows underlie the Great Acceleration as the overwhelmingly disastrous global growth trajectory. These inequalities simultaneously result from and support power relations: The observed material flows are inextricably linked to colonialism and modern-day trade relations and agreements (Shiva and Mies 2014; Infante-Amate and Krausmann 2019; Hornborg 2003).

Metabolic regimes and transitions

Although the need to reduce material resource consumption (Akenji et al. 2016; UNEP 2016) and the generation of wastes and emissions (e.g., of greenhouse gas emissions, see IPCC 2018) is increasingly acknowledged, the transition currently occurring at the global level is one of increased material extraction, of intensifying claims to land for resource extraction, and of growing international trade flows. This transition in material flow patterns is part of a larger socio-metabolic transition that also encompasses the energy system. At the global level, an ongoing transition to a fossil energy system can be observed, with the development and use of renewable energy sources currently still confined to pockets of the fossil energy system (Schaffartzik and Fischer-Kowalski 2018).

In material terms, the stagnation or even decline of (per capita) material and energy flows in those economies that industrialized early (Wiedenhofer et al. 2013; Bleischwitz et al. 2018; Fishman, Schandl, and Tanikawa 2016) appears to be based on both enormous amounts of extraction in the past and present-day appropriation of resources extracted elsewhere. The imperial mode of living is collateralized by past and present claims to resources (Brand and Wissen 2012). Even though it relies on unlimited growth in a physically finite world and can clearly not be universally implemented, Western industrialization remains a blueprint for "development," tied to the acknowledged need for economic and – by extension – material growth. As this growth-led trajectory continues globally, it implies continuing along a path of persistent inequality. Some countries or regions use significantly less of global resources and sinks than others do: They extract far less (in the case of the low-income countries) and consume less and also emit less into the global environment. In contrast to the high-income countries, they provide their material resources to the global economy. Even leaving aside the expected growth of the global population, generalizing the current material footprint of the high-income countries (of approximately 28 tons per capita and year; Figure 4.2) to the entire global population would require an annual material resource extraction of 197 billion tons, more than 100 billion tons in addition to what is currently already extracted each year. On each and every square kilometer of the earth's land surface, over 1,300 tons of material resources would have to be extracted every year. And all these materials would eventually be transformed to wastes and emissions (see the "Concepts" section). The shift to the "industrialized" metabolic profile would have an impact not only because of its extent but also because of its composition. Whereas the economies with low and lower incomes currently mainly extract (and appropriate) biomass, the industrialized countries rely on large amounts of non-renewable minerals, including construction minerals, a broad range of metals, and fossil energy carriers, with their corresponding legacies (Krausmann et al. 2017) and environmental impacts (IPCC 2018). Large amounts of the currently extracted stock-building materials continue to go into the infrastructures that prescribe further use of fossil fuels: roads, airports, and power plants, for example (Krausmann, Wiedenhofer, and Haberl 2020). The use of established and currently planned fossil fuel–based structures alone would, by 2030, result in annual emissions twice as high as the amount that would allow for a realistic chance of limiting global heating to 1.5°C (UNEP 2019a).

Although the development narrative reiterated by governments and government-based institutions all around the world continues to be one of the poorer or "less developed" countries catching up to the wealthier ones, this is – from a materials and mass perspective – not possible. Growth requires and exacerbates inequality, in material terms but also along other socio-metabolic and socio-economic dimensions. As a global trajectory, it currently pairs extreme poverty with extreme wealth, dispossession with appropriation (Martinez-Alier 2003), and peripheral with core economies in the sense of dependency and world systems theory (Frank 1966). In this sense, "catching-up development" – based on the assumption that the world's wealthiest countries set the example that should and can be followed by the world's poorer countries – must be understood to be a myth rather than a plan (Mies 1993). In order not to further limit the access to resources and thus the option space, especially for the poor and dispossessed segments of the global population, massive dematerialization and decarbonization of the world's wealthiest economies are a necessity (Scheidel and Schaffartzik 2019; Rodríguez-Labajos et al. 2019).

Inequality in control over material flows

So far, we have argued strongly from a socio-metabolic perspective for the necessity of material degrowth in order to alleviate (or at least not further exacerbate) existing inequalities. We now turn to the role of the predominance of the economic system in shaping resource use and the implications for the role of power relations in both upholding this system and shaping resource use patterns. Next to material inequalities, asymmetrical power relations rely on far-reaching inequalities in the (international) division of labor based on wealth, gender, race, and a rural-urban as well as a North-South divide. In our current economic system, power – amongst other implications – is also the power to externalize costs, providing an important incentive for upholding existing power relations (Shiva and Mies 2014). Resources such as clean water and air and soil fertility as well as (reproductive) labor can be used (up) without financial compensation – often, this is possible because those who should be compensated have insufficient access to decision-making power (an access that is often reclaimed through innovative, powerful, and generally dangerous interventions in ecological distribution conflicts, see Martinez Allier, "Environmental conflicts"). The international patterns of extraction and appropriation, which we discussed in the section "Material Inequality in the Global Economy," and the externalization of costs are important cornerstones of international trade as ecologically unequal exchange (Hornborg 1998). Ecologically unequal exchange analytically considers the net transfer of resources from the Global South to the Global North, from the poorer to the wealthier countries, and the asymmetrical monetary flows that accompany these transfers. Seen from an integrated socio-metabolic and political-economic perspective, ecologically unequal exchange mediates between different but functionally dependent metabolic profiles and along asymmetrical power relations. Current patterns in international trade mean that access to resources and sinks improves for some countries while it deteriorates for others, linking expanding to constricting option spaces. Power asymmetries between economies play a role in determining which costs can be externalized, where they are internalized, and who ultimately has to bear these costs. This, in turn, has a decisive impact on the profit margins on exports and hence on the asymmetrical monetary flows that are understood to contribute to ecologically unequal exchange.

We established in the "Concepts" section that the current Western industrial metabolic profile must be understood as the result of historical processes, including the material accumulation of the past. We also noted that – as long as societies' material stocks are to be further maintained and used – a dependency on resource inputs is locked in. Rather than giving leverage to the places where resources are extracted, the stock and flow relationships have hitherto implied that whoever controls the stocks also controls the flows. On the one hand, this has to do with the extraction, processing, transport, and even use of much of the material extracted globally being dependent on (large-scale) machinery and high amounts of technical energy. Without machines and energy inputs, metals ores could not be used to the current extent, for example. Most fossil energy carriers, including the expanding unconventional ones, are – in the absence of machines and appliances – of no use to humans. From harvest or mining to processing, transport, storage, retail, and manipulation during consumption and use, materials increasingly flow through stocks of buildings, infrastructures, and machinery. Accordingly, current patterns of ownership of (or comparable forms of control over) stocks are decisive in the distribution of resource use and of the services thereby generated. Where it occurs, extractive expansion typically coincides not only with changed material flows (for example the shift from subsistence biomass to market minerals) but also with changed control over these resource flows. Decision-making power shifts to economically and politically (more) powerful actors.

Decision-making power with regard to resource flows can be equated with responsibility for those decisions and accordingly also for resource flows. This is a fundamentally different interpretation from the one commonly offered by neoliberal politics and based on neoclassical economic principles. Based on the understanding that demand drives supply, responsibility for environmentally and socially destructive patterns of production and consumption is often assigned to the consumers: If they cease demanding unsustainable products and services, these will no longer be produced. This interpretation has been referred to as consumer scapegoatism (Akenji 2014), because it blames consumers for something that is not within their power to change.

The inertia of growth

The globally unsustainable and internationally unequal patterns of material resource extraction and use are shaped at the intersection of social metabolism and political economy. Past and current global growth in material flows – as part of the Great Acceleration – have depended on net transfers of resources, often along a trajectory of power. Since World War II and especially since the dissolution of the Soviet Union and the end of the Cold War, the volume of net transfers has increased dramatically with much of the extractive expansion occurring for export. While world systems theory and ecologically unequal exchange tend to generically conceptualize these asymmetrical flows as stemming from the Global South and destined for the Global North, the socio-metabolic perspective reveals that those countries with the lowest per capita incomes (commonly thought to represent the Global South) are far less integrated in the global economy than are the wealthier upper-middle-income countries (this is also true for agricultural trade, Krausmann and Langthaler 2019). This is not to say that exports might not play an important role for the individual low-income economies but that they – from the perspective of the net-importing high-income countries – are not (yet) very relevant as suppliers. For many resources, this crucially limits the leverage of those countries and regions currently providing materials to the global economy: Possibilities for extractive expansion may appear plentiful, especially in the Global South. As we have demonstrated, this perspective is based on the notion that currently established (non-)uses of land and resources can be displaced as needed. The maintenance and even the possible future change of global resource use patterns support current asymmetrical power relations. In this sense, the (global) political economy with its inequalities in wealth and decision-making power is also structured according to material flows and material stocks and the control over flows they imply. Western industrialization has been (and is) based on massive accumulation of largely inflexible stocks (i.e., stocks that do not lend themselves easily to alternative, more sustainable, and socially useful modes of use) and the concentration of decision-making power with regard to resource flows. To a large extent, the generation and distribution of societal benefits from resource use is shaped within the confines of stocks and flows.

From a socio-metabolic perspective, potential lock-ins into patterns of high and growing global resource use with substantial subglobal (and also subnational) inequalities is forged not only by institutions and actors and their vested interests but also by past and present patterns of resource use. From the emergence of colonialism until today, the ability to control transport infrastructures and the ability to control resource flows have been closely interlinked. The accumulation of material resources – regardless of where they were extracted – in certain places then gives rise to the need to similarly channel further resource flows. Material stocks and flows have a tremendous impact on the potentials of and barriers to sustainability transformations.

Conclusion: transforming growth

The material growth that stands at the starting point of our deliberations is not a process of change of the global economy and the inequalities it harbors but a system of their preservation. It is not the growth which – according to the neoclassical maxim – like a rising tide would lift all boats but which distributes resources in such a way that unlimited appropriation for the imperial mode of living becomes possible within the physical confines of planet earth. Global growth is not a symptom of underlying contraction and convergence but of increasing polarization as a form of inequality (Duro, Schaffartzik, and Krausmann 2018). In this sense, global patterns of material resource consumption are disconnected from human needs' satisfaction. They do not entail the distribution of the available resources where they are needed most. This implies that future societal transformations must and can address not only the curbing of material and energy inputs and outputs and hence of degradation and pollution of the environment but also the organization and reconfiguration of society at large, as centered around human needs.

With the aim of enabling sustainability transformations, material growth may be necessary to satisfy human needs and improve human well-being, but even then, these benefits must be gauged against the incurred resource flows and legacy effects, opposing those forms of growth in which no acceptable balance is struck (airports, coal mining, thermal power plants) and favoring decentralized, flexible options with high returns for human well-being.

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