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RESEARCH ARTICLE

Four economic principles of just sustainability transition

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Abstract

Equitable income distribution is desirable for moral, economic, and social reasons. Recent studies, however, indicate that improved income allocation will result in increased environmental impacts due to our socio-economic system's current settings. Therefore, we explored the key aspects of a system that can more evenly reallocate natural and economic resources while reducing negative environmental impacts. We found that the capital is extremely important as a means of material flows and stocks. Thus, effective policy interventions should target mechanisms at this very market. Based on a comprehensive literature review and statistical analyses at various levels, we proposed a four-step policy framework that includes 1) reducing and targeted savings, 2) reshaping governments' spatial decisions and 3) role in the housing market, and 4) changing the rates of depreciation in income tax legislation used globally.

Author summary

Over the last decade, there has been an increasing emphasis on economic inequality in the sustainability discourse. Inequality in wealth and earnings evokes social tensions and keeps holding back the efforts towards a just and sustainable society. However, recent studies show, that we cannot reach an aim of a more equal society and decreased pollution and natural resource use in the same time. We discovered that the capital market is extremely important with regard to the connections between the society and its effect on Nature. As a result, a fundamental intervention should attempt to considerably reshape this layer of the economy in order to address the various problems of our ecological crisis and the inequality issue that it entails. However, a disruption in the capital market would cause substantial social damage, such as shortage on the housing market or through the discontinuation of innovations. The aim, then, is to identify selective yet market-oriented regulatory instruments. Our findings propose a four-step policy framework that provides a theoretical basis for selecting these instruments.

Introduction

Over the last decade, there has been an increasing emphasis on economic inequality in the sustainability discourse. The rich's inequitable resource allocation and disproportionate environmental impacts are frequently addressed in the literature [1]. Understanding the links between economic inequality and climate change drivers is necessary for effective mitigation [2].

Moreover, vulnerable social groups and regions are more prone to suffer the consequences of ecological crises, such as climate change [3–5], while inequalities tend to rise in line with intensifying environmental changes, as Baarsch et al., (2020) have proven on climate change effects in Africa. A research conducted by Dolsak & Prakash (2022) identified multiple dimensions of climate injustice. Disproportional exposure of unprivileged communities is a result of the development path supported by fossil fuels and climate inaction, with a manifestation in an international context as a division of rich and poor countries on the one hand, and also within a country, on economic, racial, and gender grounds. Furthermore, the benefits and costs of climate action affect communities in various ways. A study by Alvarado et al. (2021) reported that in low and low-middle income countries, the economic inequalities are rooted in a high portion of natural resource rents and interact with the shadow economy. Therefore, as Scott et al., 2022 advocate, just adaptation to the climate emergency calls for placing equity into the center of planning processes in all communities.

Although multiple inequalities exist and have been well documented worldwide, the pathways of economically generated inequalities and their environmental implications are yet to be discovered [6]. Eradicating poverty and mitigating climate change and other interconnected ecological crises in line with the emerging prosperity are all at the core aims of the development goals of humanity. The ultimate question is under what conditions we can transcend both social inequalities and environmental degradation.

According to [7], the top ten percent of income earners are responsible for 45 percent of global carbon emissions, while [8] estimate 36 percent. In terms of natural resource extraction, one-fifth of the world's population with the highest income accounted for 44 percent of global material extractions in 2010 [9]. The rich are driving emissions and increasing demand for natural resources [10], while the population of the poorest regions lacks the resources to meet basic needs.

Although an equitable distribution of income and returns is morally desirable, the environmental benefits of achieving such outcome are debatable. Any modification in income distribution would affect the environment, even if aggregate income remained constant. The direction of this effect is determined by the relationship between individual income and individual pressure, as [11] explained. Reduced environmental impacts are achieved by increased inequality when marginal environmental pressure decreases in lockstep with marginal changes in income. The literature often support this type of link [5,6,12,13].

In economics, the statistical dispersion representing income or other inequality is frequently described by the Gini coefficient or index, where zero represents perfect equality. At the same time, one refers to the extreme distribution. The global income distribution is incredibly skewed [10], with the global Gini-index (around 75) significantly exceeding any other country's index. In a research conducted by [14] has been found that the Gini coefficient of consumption-based carbon emissions and that of material footprint were 0.579, and 0.533 respectively in their population-weighted cross-country sample. The richest ten percent earned 51 percent of income globally in 2018 [15] versus 45 percent of carbon emissions; income distribution appears to be more concentrated than carbon emissions.

Numerous studies show that the greenhouse gas (GHG) intensity of consumption declines as income levels rise, implying that the income elasticity of emissions falls below 1 [16].

According to [17,18,19], goods and services with a higher energy intensity tend to have higher consumption inequality as well as higher income elasticities, assuming constant total expenditures. Therefore, the redistribution of income to a lower concentration would increase the aggregated energy consumption intensity. Thus, aggregated energy demand will continue to rise, either as a result of economic growth or as a result of the emerging consumption of energy-intensive goods and services by the hitherto low-income groups, although, in both trajectories, additional consumption is allocated to different social groups.

Several attempts have been made to model the environmental impacts of reduced income inequality. Bruckner et al. (2022) estimated the effect on carbon footprint associated with poverty alleviation at seven different poverty lines. These scenarios displayed all increase in global carbon footprints, ranging between 2.1–18%. The effects of poverty reduction on carbon emissions and global warming were calculated by [8]. The eradication of extreme poverty resulted in a slight increase in emissions, causing a 0.05˚C increase in the average global temperature by the end of the century. The emergence of a global middle class would result in a 0.6˚C increase in global temperature. Similar findings were presented by [1] when studying income inequality and carbon emissions at the state level in the U.S. [20] estimated that the carbon emissions would be 30% lower by 2030 under a scenario that would limit the emissions of the highest billion polluters to the level of the lowest polluters in that group. Both [8,20] scenarios are associated with a reduction in income inequality. However, as reported recently by [21], potential policy measures and economic consequences have not been addressed.

According to [6], with respect to 32 countries of the Global North, reduced emissions have been detected in allocations without redistribution or reallocation of income in the form of government expenditure. The emission intensity of these government expenditures was assumed to be lower. However, equitable income distribution and reduction in emissions can only be achieved by decreasing aggregated expenditure.

When quantifying the potential consequences of alternative global income distributions on energy use [3] suggest that a lower-income concentration is coupled with higher energy consumption, with or without income redistribution. The simulation suggest that a lower-income concentration is coupled with higher energy consumption, with or without income redistribution. Furthermore, a trade-off between the energy requirements for housing and the energy use of transportation in line with emerging income levels has been identified. These results highlight the co-benefits towards equality and sustainability through the prevention of infrastructure-intensive consumption, like transportation or energy transmission services, for instance.

As discussed above, economic inequality and sustainability cannot be addressed simultaneously in a status-quo socio-economic system. Due to this trade-off between income equalty and sustainability, the desired outcomes in both dimensions require transforming the socio-economic system [22,23]. Therefore, any real solutions for inequality and sustainability issues will inevitably touch upon the fundamentals of the dominating capitalist market economy. One of these fundamentals is the role of capital in the current economic systems. Capital returns account for a large share of about one-third of domestic income globally [24,25] while according to data from the World Bank, one-fourth of worldwide GDP finance investments in capital. In their impactful study, [26] have found that material accumulation has become a primary goal of society, accounting for well over half of all extracted materials.

Therefore, the returns of the capital are higher than the investment cost in their maintenance, thus, capital accumulation appropriates the majority of the natural resources. This framing underpins that the role of ownership and the amount of available capital lies at the heart of any transformative model. Even though some investments aim to improve "soft infrastructure" such as human capital, IT solutions, or intellectual capital [27], most investments result in material stock accumulation in production, dwellings, and other infrastructures. As [28] discussed recently, global social and economic inequalities are "functional and systematic" features of economic growth.

As a result, material stock may serve as a critical component in mitigating both environmental and social conflicts. Material stock has recently been incorporated into major ecological economics and industrial ecology models [29–32] and has become a central part of the discussion due to their pivotal relevance in GHG emissions [33,34], natural resource use and waste issues [26].

In this article, we intend to comprehensively analyze the links between the shared economic roots of the ecological crisis through the overexploitation of natural resources and economic inequalities. We first proved the contradiction between simple pro-equity and pro-ecological policies, then shed light on the material accumulation process in the previous section through the review of the recent literature on economic and physical disparities through the lens of environmental impacts and the role of material flows and stocks of the society in the evolution of economic inequalities. We applied several broadly recognized socio-economic indicators, such as material stock in mass, carbon footprint, inequality measures, and macroeconomic variables. A panel regression model of 150 countries explains the role of the capital market as a cornerstone of the capitalist regime in the dynamics of material stock accumulation afterward. Finally, we discuss a set of potential fiscal and other policy measures that could reduce income and wealth inequalities while also reducing environmental impacts.

Results

Inequality of wealth and material stock

As the previous section presented, capital lies at the heart of the sustainability transition both in economic and material dimensions. In the following part of this article, we focus on the interactions between the assets of these two very dimensions, namely the monetary capital and material stock on the one hand while the flows of their creation and gains on the other.

In 2010, the market value of wealth in the USA and Europe was fourfold and more than fivefold higher than income, respectively [25]. Wealth is even more unevenly distributed compared to income (Table 1). Since material stock constitutes the physical manifestation of wealth, one may assume that the concentration of material stock also exceeds the concentration of flows.

As we have already pointed out, the response of material requirements to improved income is key to understand the impact of income inequality on environmental pressures. Evidence shows that the overall income elasticity of these pressures is lower than one. Since the accumulation of material stock evoke excess resource needs, furthermore, it shapes the flow-type resource use and emissions remarkably; it is crucial to examine the impact of inequality and its dynamics on stocks as well. The question then arises whether the distribution of the material stock is a logarithmic, exponential, or linear function of income [11].

Table 1. Income and wealth inequality in several countries.

	France	India	China	South-Korea	Russia	South Africa	United Kingdom	United States of America
Top 10% earners share of pre-tax national income	0.31	0.55	0.41	0.44	0.45	0.65	0.36	0.45
Top 10% earners share net personal wealth	0.55	0.63	0.67	0.67	06.8	0.89	0.52	0.73

Source: [15]

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Several studies have analyzed the distribution of the material stock recently. The long-term inequalities in the distribution of six primary metals between 1900 and 2010, covering 231 countries in a cross-country context were analyzed by [35]. They have found that the in-use metal stock is unevenly distributed to a high degree; the top 20% of the population own 60–70 percent of the stock, while the bottom 20% own only 1%. The Gini coefficient of metals is also extremely high; it was reported as 0.8–1.0 in 1970, followed by a steady decline to 0.6–0.8 in 2010, driven by a sharp increase in metal stock accumulation in the upper-middle-income countries, especially in China [36]. In a previous article, [37] have previously found similar cross-country distribution of aluminum stock. [38,39], reported extreme inequalities in concrete stocks. The Gini coefficient in our sample of 150 countries' concrete stock distribution (see Methods) performs significantly lower than the above referred coefficient for metals; the concentration dropped from 0.61 to 0.49 between 1980 and 2016. This drop is probably because metals are used in goods that meet the needs of higher living standards, e.g., devices, vehicles, high-rise buildings, unlike construction materials.

Data imply that there is a negative correlation between income inequality and material stock endowment. Higher income disparity, measured by the share of income by the upper one percent of the population, is observable in South-American and African countries (Fig 1). Fossil fuel producing Arab states are both unequal in income and rapidly developing in their stocks. From a four decades perspective, inequality grew in rich countries, while poor ones started to invest in their infrastructures and so accumulate material stocks intensely, especially in the last decade.

The cross-country allocation of stocks is thus highly concentrated. It is plausible that it is much more concentrated than the distribution within a country, as in the case of the income distribution. In the following part of the section, we outline evidence on the level of inequality with regard to four different pools of materials, covering all the materials accumulated in the socio-economic system, namely residential building stock, durable goods, capital stock (consisting partly of non-residential buildings), and public infrastructure (e.g., railways, roads, dams).

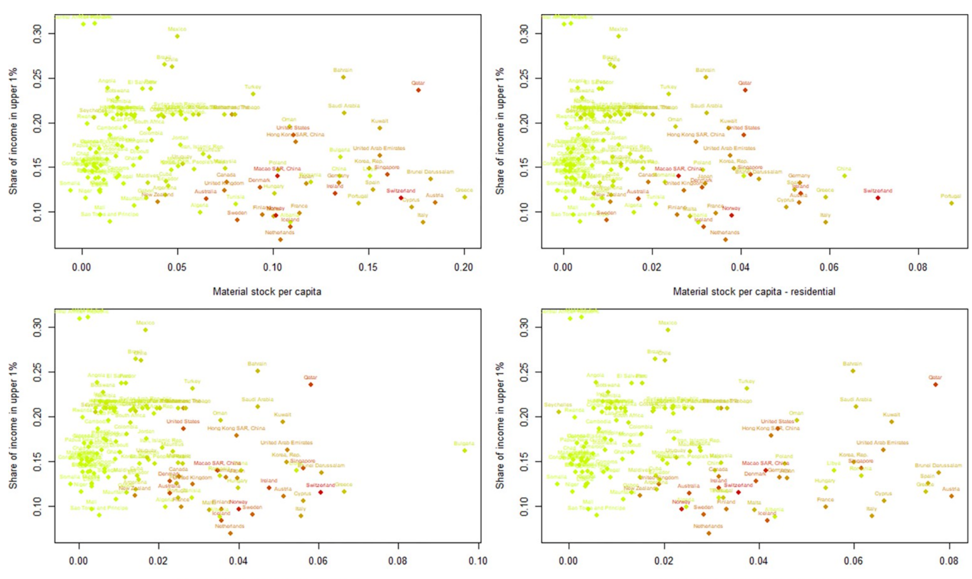

Fig 1. Material stock (kt concrete) in the analyzed countries, 2016. The darker the color the higher GDP per capita. The dark red dot indicates the highest value, while the light green color indicates lower value.

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In China, dwellings and home appliances exhibit a logarithmic relationship to income, while transportation has an exponential relationship [40]. According to our concrete stock dataset, the cross-country distribution of residential concrete material stock (dwelling stock) is affected by the income greatly (top right panel of Fig 1). The concentration of this type of stock, measured with the Gini coefficient, is higher than the concrete stock in general, i.e., 0.64 in 1980 and 0.53 in 2016, acting as the most significant concentration among the analyzed three stocks categories on concrete stock data.

However, we have limited knowledge of the stocked material at different income levels within a society. Table 2 shows the average size of a dwelling by income quintile in 2012, with an average of EU-28, as well as the countries with the most concentrated (Norway) and most dispersed (Slovakia) housing stock as per income [41]. The distribution of floor space among the quantiles is relatively even.

Unlike household expenditure, the assets of the household sector are rarely reported in national statistics and in the literature. In 2018 the office for National Statistics in the UK reported the ratio of households equipped with different types of durable goods, heating appliances were found to be equally distributed durable goods, along with home computers and tumble driers. The dishwasher was the only recorded device that divides the British households, as 20 percent of the first decile households owns it, this share is the highest income decile is 84 percent [42].

Another example of the representation of durables at different income levels is presented in a diary-based survey of direct household material consumption and material assets was recorded in Hungary, with the participation of more than 100 families [43]. Fig 2 shows the direct material input, income level, and the amount of stock in the different types, The level of income correlates significantly with all types of material stock. The strongest correlation was found with durable goods, including vehicles (0.597, $p = 3.188e-8$); the lowest with durable goods alone (0.428, $p = 1.789e-3$).

It is worth noting that none of the household assets were analyzed with regard to their origin, i.e., housing or durable goods purchased as new or through the secondhand market. It is plausible that the distribution of new appliances, homes, vehicles, is more concentrated. As many individuals cannot afford new goods, and dwelling solely based on their income; thus, the demand for other's savings will occur in the capital market.

Estimations of physically available capital stock are rare in literature as conceptually and methodologically, it is challenging to allocate buildings, machinery, and other infrastructures to their functions and services provided in the production processes. According to our dataset, the concentration of non-residential buildings, considered as capital stock, is moderate compared to housing; the Gini coefficient dropped from 0.62 to 0.49 between 1980 and 2016. Wealthy countries display the heaviest accumulated capital stock (Fig 1, bottom left), while several tourism-oriented economies are characterized by an economically disproportional stock (e.g., Cyprus, Greece, Bulgaria, Italy). Obviously, capital stock other than non-residential

Table 2. Residential housing floor space (m^2) among income quantiles (Average, and the extremes in the EU-28).

		Quantiles					
	Average	**First**	**Second**	**Third**	**Fourth**	**Fifth**	**Ratio ($5^{th}/1^{st}$)**
EU-28	96.4	81.6	87.2	94.2	101.3	114.6	1.40
Norway	123.2	86.9	115.9	127.6	136.4	158.3	1.82
Slovakia	87.4	81.3	87.2	88.9	91.4	89.2	1.10

Source: [41]

https://doi.org/10.1371/journal.pstr.0000053.t002

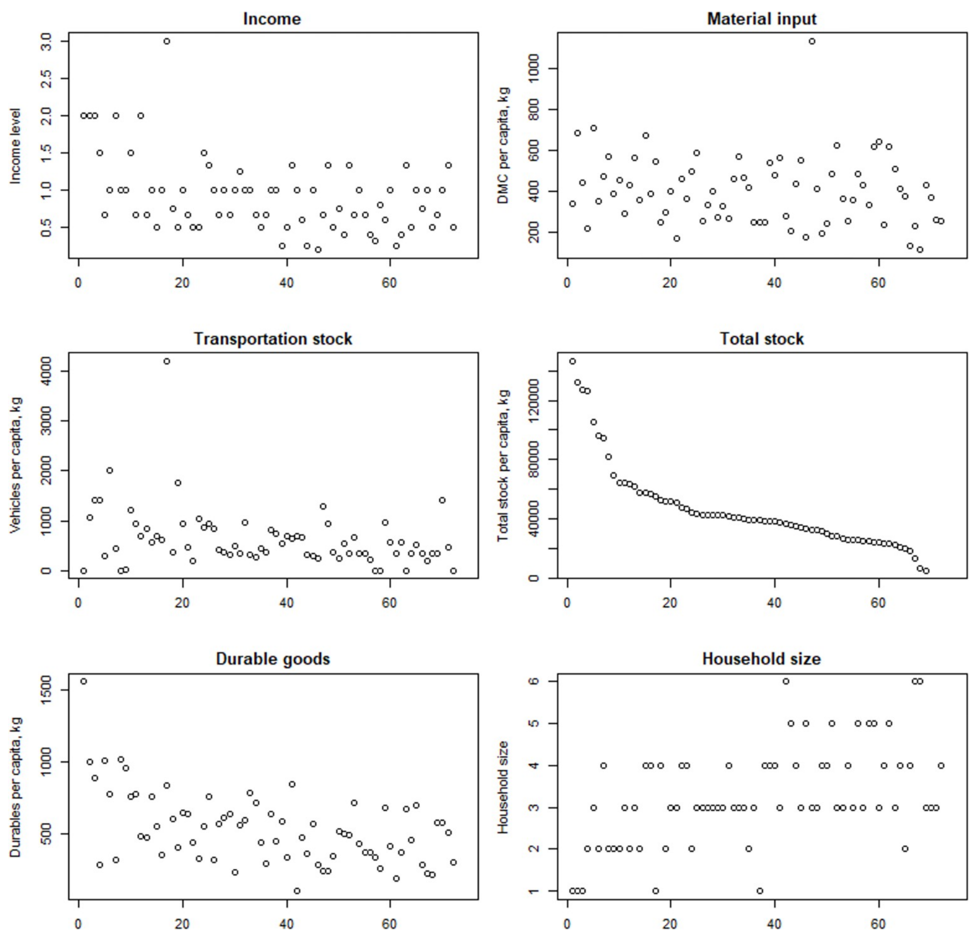

Fig 2. Material inputs and stocks in the Hungarian household sample. Horizontal axes display the number of households in the sample. The households are listed in the descending order of total stock per capita (kg) in the right middle panel. To maintain comparability of the visualized data, each panel follows the same order consequently.

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buildings play an essential role in economic processes, for instance, IT environment, machinery. Buildings, however, indicate the intensity of these processes in time and space. Access inequality to capital stock is challenging to observe within a society, and probably it correlates with consumption expenditures strongly.

The fourth type of material stock with a particular interest in economic inequalities consists of infrastructures; established, regulated, and operated by the government or often state-owned companies, such as roads, rail, pipelines, airports, healthcare facilities. Economic inequalities may arise in the case of public infrastructures throughout the decision-making phase and their utilization. Development literature suggests that investment in public infrastructure pays off in the form of decreasing inequalities over a decade [44–48].

Wealthiest countries are positioned in the middle of the material stock range (bottom right panel of Fig 1.), while several countries with lower GDP, such as Albania, Hungary, Libya, and Romania, accumulated more materials per capita. Spatial structure, geographics, urbanization, and political decisions may all influence the level of public infrastructures per capita. The concentration of this category is similar to that of capital stock.

Three types of material stock out of four in our analysis tend to underpin that within-country allocation of stock is equal if compared to the cross-country distribution. To examine the

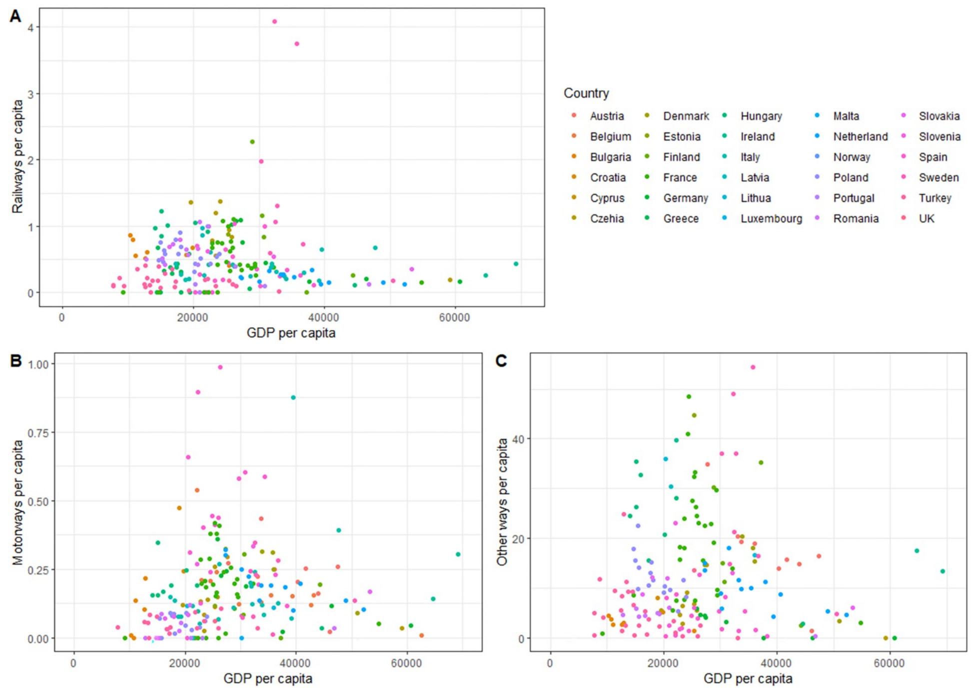

Fig 3. Infrastructure and GDP per capita in EU NUTS2 regions (2018). Source: [49].

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fourth material stock type, we indirectly assessed within-country public infrastructure's disparity by setting regional income against the available infrastructures. Fig 3 shows the distribution of three public infrastructures (motorways, other roads, and rail) in the European Union at the regional level. There is no clear correlation detected neither at the aggregate level of the EU nor within countries. Stock endowment tends to be independent of the region's income. Urbanization could be an intermediate means of this relationship; densely populated areas provide more wealth by more efficient infrastructure.

The roots of inequality and its environmental impacts–Savings and returns

We are now able to assess all the relations of cross-country and within-county distributions of assets and flows in monetary and material terms. In Table 3, we summarized the relations of the inequalities revealed according to the monetary and material dimension, on the one hand, the level of analysis on the other hand. The results imply, that *i*) both flows and stocks are more concentrated at the global level, with regard to the monetary and physical dimensions as well, and *ii*) stock-type inequality is more significant except one combination, i.e., material stocks in a within-country context. The relation marked with underline indicates the essential tie of interest.

Table 3. Relation of inequalities in the socio-economic system.

	Cross-country		Within-country
Income inequality		>	
Wealth inequality	^	>	^
Material flow / emission inequality		>	
Material stock inequality	^	>	v̲

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The allocation of durables, housing, and public infrastructure is relatively equal in mass. Stock inequality does not even approach within-country income inequality. Does that mean that material stock is irrelevant to economic inequalities? This is not the case. Inequality does not stem from the distribution of material stock but rather from the income it provides to the capital owners and providers (returns). Material stock in use, in contrast to wealth, is relatively dispersed in a within a country context. However, emerging return on capital goes hand in hand with income inequality to a high degree. Therefore, the most striking economic inequality is that of savings, fueling capital accumulation through investments.

The Gini coefficient of savings in EU, for instance, performed above 0.6 in almost all the member states, while income and expenditure inequalities remained below 0.4. The marginal propensity to consume (MPC) falls in line with income as material needs are satisfied and saturated. The higher the income, the greater the surplus is after the consumption has been covered. The savings rate of the highest income quantile in the EU is close to 40 percent, while it is negative for the lowest one in the majority of the EU member states. In the US, two bottom quantiles' savings rates remained well below zero in the last decades while developing countries share a similar path as well [50].

Thus, high income inequality fuels the capital market with excess supply (savings), while demand is driven by the need for dwelling, commuting, and enjoying services provided by productive capital. If one considers the material dimension of these needs, they are more or less equally distributed among a given society, as we presented above. Looking at the monetary dimension, the earnings of a substantial portion of society do not allow them to purchase these goods and services. Ample loans, however, still provide access to these material stocks for the households (both new and used assets) and the government–at the cost of continuously rising inequalities through returns on capital and natural resource requirements.

To test this very characteristic of the economic system in light of the natural resource use through material requirements, we conducted a panel regression analysis on the concrete stock data to test the mechanism described above, consisting of 150 countries in 37 years (1980–2016). The regression model results for the total concrete stock and the three sub-categories are presented in Table 4. According to these results, the savings rate reinforces the accumulation of the material stock, as one percentage increment of the *s* is associated with a 0.85 percent rise in total concrete stock if everything else is held constant. GDP, of course, affects the stock positively as well. The bond between the GDP and the stock is strong enough, as every percent GDP growth evokes 0.44 percent of predicted stock increment, ceteris paribus. However, net return on capital (*r*-*g*) negatively correlates with the stock; a 0.22% drop of predicted stock dynamics in case of a 1% rise in returns.

Our results imply that the higher the rate of return is, the concentrated the income will be. Thus, in countries with the same *s* and GDP, where a higher portion of income comes from capital investments, the society build less. Higher returns restrict the evolution of stock, as it is expensive to build them. These findings are absolutely in line with a classical view of a monopolized market. At the same time, the equilibrium of the capital market allows for limited investments, at high returns, paid in the form of excess rents, interests, and profits for the capital owners. In the same way, when the market shifts from competitive towards a monopolized one, barriers to entering the market occur, and controlled amount of market transactions (lower level of investments) causing capital prices to rise steeply (rents and interests).

The difference in the coefficients of the four models in Table 4 imply on altering motivations on the sub-markets. First, residential building stock depends on returns less than non-residential housing investments, probably due to the household's independent need for housing services. Housing investments do not contribute to increasing returns on capital; while on the contrary, a need for housing occurs in periods and countries with lower returns as well.

Table 4. Estimation results of the panel regression.

Total stock				
	Coefficient (β)	e^{β}	Std. Error	p
r-g	-0.2515	0.7776	0.0426	3.937e-09 ***
s	0.6154	1.8504	0.0616	< 2e-16 ***
LogGDP	0.4429		0.0298	< 2e-16 ***
Total Sum of Squares: 9.0622 Residual Sum of Squares: 7.6537 R-Squared: 0.1554, Adjusted R-squared: 0.1231				
Residential buildings				
r-g	-0.0017	0.9983	0.0002	1.78e-08 ***
s	0.7018	2.0173	0.0675	< 2.2e-16 ***
LogGDP	0.3324		0.0327	< 2.2e-16 ***
Total Sum of Squares: 10.326 Residual Sum of Squares: 9.147 R-Squared: 0.1142, Adjusted R-squared: 0.0802				
Non-residential buildings				
r-g	-0.2050	0.8146	0.0349	4.858e-09 ***
s	0.5022	1.6524	0.0509	< 2.2e-16 ***
LogGDP	0.3417		0.0246	< 2.2e-16 ***
Total Sum of Squares: 6.1125 Residual Sum of Squares: 5.2307 R-Squared: 0.1443, Adjusted R-squared: 0.1115				
Civil engineering				
r-g	-0.2623	0.7692	0.0533	9.4e-07 ***
s	0.7232	2.0610	0.0774	< 2.2e-16 ***
LogGDP	0.6031		0.0372	< 2.2e-16 ***
Total Sum of Squares: 13.973 Residual Sum of Squares: 11.706 R-Squared: 0.1623, Adjusted R-squared: 0.1297				

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Second, the civil engineering segment of the material stock is affected by returns for the highest extent, and it displays the heaviest reaction on the available savings as well. That implies public infrastructure investment being a residuum of the capital on the market. In case of ample savings, mostly government-led and financed investments rise sharply. However, if the price of investments, indicated in our model by net returns, emerges; public infrastructure loses its dynamics rapidly, contrary to housing or non-residential building activity.

Public investments are prone to be exposed to economic performance as well. On the one hand, they are strongly correlated with GDP per capita, while net returns depend on the GDP growth on the other hand. Building a new motorway, train station, or sewer pipeline is usually not an object of maximized returns but other social, environmental, and political aspects; however, as long as the financial basis of these investments depend on available capital, worsening economic conditions make them shortfall immediately.

Policy implications

Halting the rapid expansion of material stock is a primary aim of the sustainability transition. Stock accumulation process not only require a significant part of our resource use, accounting for 61% of the total resource extraction in 2021 (Circle Economy 2022); it also entails the use substantial amount of energy for extracting, manufacturing, operating, and demolishing stock.

Capital owners need to invest their excessively high savings in high-return industries (usually material-intensive) to maintain their wealth. Many economies have pursued fast material stock accumulation for economic growth but doing so has lock-in effects as material stock requires periodic maintenance and renovation (resource use). Future policy measures should address economic growth, income inequalities, and sustainable development by taking a cautious view of those material-intensive investments. The only exception is public infrastructure (e.g., transportation, social housing, education, public health), which can improve economic equality while minimizing the risk of over-investment, as long as the government can manage the balance between economic equalities and economic growth.

Policy intervention should aim to significantly constraint the savings to tackle the multiple challenges of our inequality issue and the ecological crisis which accompanies it. However, the disruption of the capital market would result in severe social damage, e.g., on the housing market or through discontinued innovations. The aim, therefore, is to identify selective yet market-oriented regulatory instruments that limit the investment yields of space-intensive properties while also allowing financial resources to be channeled to innovation, R&D, and human capital [51,52].

In theory, the four principles of equitable and sustainable transition below provide an ecologically feasible, socially acceptable, and peaceful set of policies.

1. Reduce the savings significantly. In our regression model, GDP represents the development stage of the capital market, while savings and returns act as factors influencing supply and demand for stock accumulation, respectively. Savings, return, and income elasticities are the estimation coefficients for material stock accumulation. Saving rates are higher across all stock categories than returns, so policy interventions that focus on savings may lead to a more significant drop in the amount of accumulated stock than reducing returns. Measures to control savings generally include altering consumption taxes (VAT) or imposing large inheritance or wealth taxes.

Theoretically, promoting consumption by lowering VAT could result in descending savings rate; in the reality, though, savings of few individuals surpass the others extremally. The framework we propose limits the savings of the highest earners while increasing savings for the lowest earners in the way, that aggregates savings still decrease. This can only be done after ensuring the basic needs of people are met. Thus, we propose a universal basic income or services which according to the literature, are considered pro-equality policy measures (Coote 2020; Gough 2019). Based on the findings of this study, the latter one is proposed since assessments of possible policy interventions report on the adverse environmental impact of redistribution of income.

Limiting the savings of the highest income earners is in fact targeted towards their income and their income sources, particularly capital income generated from owning and investing in material-intensive real estate. There are many ways this could be achieved, progressive floor-space-based property taxes, progressive property transfer taxes, progressive second and third homeownership taxation. The ultimate goal is to make these investments unattractive. While also channeling capital to other areas where capital gains might be lower but will have a better impact technologically, socially, and ecologically as pointed out before. While on the opposite side, policy interventions increase the savings for the lowest earners by subsidizing their wages through the universal basic income, and in order to control their consumption levels and increase their savings. Exemptions will be effective tools to encourage earners to save excess income in material stocks especially housing these saving in essence are turning into wealth which can generate income in the future. Transfer tax exemption, reduced property tax and interest rates for first home buyers are few examples of these tools. Carbon or other ecological taxes can be imposed on corporations to steer the consumption structure and promote ecological competitiveness.

This intervention would reduce the available savings generally, which according to results in Table 4, probably limits non-residential and civil engineering stock accumulation the most. The following steps aim to evade the effects of a rapid drop in savings.

2. Reshape spatial decisions. The government forms the stock accumulation in multiple ways, such as zoning regulation, development planning, and transportation policy. Spatial planning determines natural resource use [53]. Spatial decisions should prioritize dense, multifunctional urban spaces in transportation, zoning, education, and other policies, the society to resists urban sprawl. Even though in case the decision on reduced investments is made, universal basic services, when applied, would evoke additional demand for public infrastructure (see 1.), which is more evenly distributed and are capable of boosting economic growth and social prosperity.

3. A government-driven housing intervention. By this point, society has experienced a drop in government-led infrastructure development as well as a reduction of available capital supply. The shortfall in savings has led to emerging returns, except for government investments, as we reduced the demand in the meantime (see principle 2.). Private investments, however, suffer from rising capital prices and interest rates. To meet the reshaped demand for urban housing described above (2.), the state will have to intervene with social housing programs, local housing agencies, and state-led real estate investments. The outcome of such a step would be ample housing under social considerations on the one hand and a reduction in rents and interest rates on the primary housing market on the other hand. With the return elasticity of housing investments being significantly lower than savings elasticity, state-induced additions to the housing supply would result in a modest rebound in investments. A majority of the aggregated effect is manifested in a drop in rents and prices.

4. Expand the lifespan of the capital stock. Right after the state became an active investor in the housing market and private capital returns dropped, the relative capital gains on the segment of business-led investments have started to ascend. As bonds, stocks, ownership, and other forms of capital investment are now attractive substitutes for real estate investments, capital supply rebounds to some extent on the market segment of non-residential material stocks. However, to avoid the rise of aggregated material stock accumulation, the business-led demand for the material stock should also be reduced. Macro-scaled policy needs to support the market penetration of technological solutions provided by the emerging circular economy concept, like modular design, planning for reuse, or utilizing equipment as a service. A promising financial instrument to prolong the lifetime of an asset could be the system of mandatory rates of depreciation defined in national accounting legislation. The depreciation is used to write off the cost of an asset over its useful life, and it is a mandatory deduction in the profit and loss statements of an asset item. The rate of depreciation refers to the percentage of a long-term investment as an annual tax-deductible expense. In the US, for instance, the Income Tax Act 1962 defines the rates for different classes of assets, in which two rates refer to permanent buildings (5 and 10%), while multiple rates for vehicles, machinery, with rates ranging from 15% to 100%. Thus, 5% rate translates into 20 years of writing off, while 50% into two years. As depreciation deducts the tax paid by the company, a reduction in the annual depreciation of an asset reduces the deduction, so the company should pay higher taxes. Significant extension of the rates defined by law could deliver this effect, especially in the case of buildings, where the depreciation period is much longer compared to equipment or IT assets. This way, the profitability of investments falls as the sum of taxes imposed on the company's revenue rises even by the exact total costs of the investment. Several decisions on less profitable investments turn to rejection, while innovative investments remain reasonable.

According to Johnstone & Newell (2018), the required radical transition toward sustainability demands intensifying state participation in economic and social processes, especially in financial systems, through regulatory roles and defining clear sectoral transition policies (Nykvist & Maltais, 2022). Our proposed policy mix meets these requirements. A recent review by Hedfield & Coenen (2022) reveals a spatially uneven capitalist structure at a city level, which co-exists with global financial markets. Governance of sustainability transition thus calls for transparency, accountability, and "social, environmental, and place-based value propositions" at the local level. These features of the local capital accumulation processes are prerequisites for our suggested principles nr. 2 and 3. Furthermore, our proposed policy measures overlap the ones suggested by Hartley et al. (2020) to a high extent.

Edmondson et al. (2019) highlight the role of timing and sequencing of policies during the sustainability transition and argue that supporting policy instruments should be prioritized over destructive ones until the novel socio-technical regime cannot resist the opposition of the current elite. In this regard, steps 2 and 3 in our proposed policy have to lead the transition; however, it requires the state budget to invest in housing and new infrastructures before additional revenues appear (steps 1 and 4). Indeed, recently, the Inflation Reduction Act agreed in the US took these steps simultaneously, raising corporate taxes and investing in renewable infrastructures.

This policy mix helps countries situated at the development stage to varying extent. According to our concrete dataset, some countries signal an absolute material stock saturation (Cyprus, Denmark, Germany, Iceland, Ireland, Japan, Kuwait, New Zealand, Norway, Malta, Singapore, Sweden, UK). On the contrary, those countries still at the beginning of their development path, need to have high savings guaranteed to establish essential infrastructures.

The actual changes in material stock accumulation of a country depend also on the shift of the demand curve in step 2 and the supply in step 3. Some countries with striking housing deficit may witness a rebound in housing stock dynamics, although, considering the slope of the demand curve it is supposed to be not a significant one. Also, some countries may lack essential infrastructures, while others deliver broader path of action through halting excess road infrastructure investments, for instance. The policy toolkit above, thus, is applicable in each situation in a specific way; however, they are all necessary to prevent adverse environmental effects due to overinvestment.

The four principles above are in line with [53] recent findings of the dynamic efficiency of economies. The author argued towards lowering the environmental impacts, coupled with the economic output, savings and depreciation rates need to be reduced simultaneously. In terms of ecological damage, there is a lower level of per capita infrastructure to operate with compared to the status quo. Altered housing, transportation, and spatial development policies prevent consumption add up to satisfying personal mobility demand. Actors with economic power may resist the proposed changes. However, the social acceptance of its elements, especially the promise of higher consumption, provision of universal basic services, and housing programs, may help the policy makers to consider the political benefits.

Methods

Concrete material stock data

The historical concrete stocks are estimated using a top-down time-cohort-type (TCT) method, which has been used to estimate global cement stocks. The TCT method divides apparent cement consumption (i.e., production plus import minus export) into sector-specific cement consumption and assigns a specific lifetime to each sector. As concrete is a composite material made of cement, fine aggregates, coarse aggregates, and cement substitutes, we expand the system boundary of the cement cycle to include these material flows. Data on cement production are collected from Mineral Yearbooks of the United States Geological Survey. Data on cement trade are collected from the United Nations Comtrade Database. Sectoral splits are based on our previous research. Lifetime functions are determined based on a global review. Data on aggregates-to-cement ratios are collected from previous studies. Data on cement substitutes are collected from the Getting the Numbers Right Database [38,54].

Panel regression

We defined the per capita concrete stock volumes of the above introduced dataset as the dependent variable of the panel regression, first the total stock, and the residential, non-residential, and civil engineering categories. Afterward we included three explanatory variables, the savings rate, as portion of the annual GDP not spent on any actual expenditures; the internal rate of return (IRR) at macroscale was also included, which is calculated by the ratio of capital income (GDP less wages and rents) in total GDP. We controlled the economic performance with the constant USD per capita GDP in 2010. According to [25], inequalities arise when returns on capital exceed the growth rate of the income (GDP) for the long run. Our dataset reported a strong correlation in a cross-country context between the income inequality and both the return itself and the return less the growth rate of GDP. We decided to use the return less the growth rate to capture the effects of the monetary variables on the inequality. Additionally, as it is often proven in the literature the GDP determines the stock accumulation remarkably; therefore, it was included in this current model as well. The data source for GDP and savings rate is the World Bank, the inequality measure is the World Inequality Database, and the Penn World Tables 9.1 provided the data for the IRR. The dependent variable was defined as the annual change of material stock. Stock dynamics and GDP had been log-transformed, while savings and return less growth dynamics variables have lagged one year to display a time delay effect of investments.

A fixed effects ordinary least squares (OLS) estimation was conducted on the panel based on the assumption that individual characteristics exists in the panel [55]. Statistical test confirmed the presence of fixed effects and inconsistency of the random effects model.

The specification of the model is given by

$$\ln dMS = \beta_0 + \beta s + \beta(r-g) + \beta \ln GDP$$

Where *dMS* is the total annual change in material stock per capita, *s* is the savings rate, *r-g* is the return on capital (IRR less GDP growth rate), *GDP* is gross domestic product per capita.

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References

1. Jorgenson A, Schor J, Huang X. Income Inequality and Carbon Emissions in the United States: A State-level Analysis, 1997–2012. Ecological Economics. 2017; 134: 40–48. https://doi.org/10.1016/J.ECOLECON.2016.12.016
2. Alcañiz I, Hubacek K. Closing the climate inequality gap. Journal of Cleaner Production. 2021; 292: 126076. https://doi.org/10.1016/j.jclepro.2021.126076
3. Oswald Y, Steinberger JK, Ivanova D, Millward-Hopkins J. Global redistribution of income and household energy footprints: A computational thought experiment. Global Sustainability. 2021; 4: 1–24. https://doi.org/10.1017/sus.2021.1
4. Hardadi G, Buchholz A, Pauliuk S. Implications of the distribution of German household environmental footprints across income groups for integrating environmental and social policy design. Journal of Industrial Ecology. 2021; 25: 95–113. https://doi.org/10.1111/jiec.13045
5. Feng K, Hubacek K, Song K. Household carbon inequality in the U.S. Journal of Cleaner Production. 2021; 278: 123994. https://doi.org/10.1016/j.jclepro.2020.123994
6. Millward-Hopkins J, Oswald Y. "Fair" inequality, consumption and climate mitigation. Environmental Research Letters. 2021; 16: 34007. https://doi.org/10.1088/1748-9326/abe14f
7. Chancel L, Piketty T. Carbon and inequality: from Kyoto to Paris. Trends in the global inequality of carbon emissions (1998–2013) & prospects for an equitable adaptation fund. Paris School of Economics. 2015.
8. Hubacek K, Baiocchi G, Feng K, Patwardhan A. Poverty eradication in a carbon constrained world. Nature Communications. 2017; 8: 1–9. https://doi.org/10.1038/s41467-017-00919-4 PMID: 29066777
9. Schaffartzik A, Duro JA, Krausmann F. Global appropriation of resources causes high international material inequality–Growth is not the solution. Ecological Economics. 2019; 163: 9–19. https://doi.org/10.1016/j.ecolecon.2019.05.008
10. Wiedmann T, Lenzen M, Keyßer LT, Steinberger JK. Scientists' warning on affluence. Nature Communications. 2020; 11: 1–10. https://doi.org/10.1038/s41467-020-16941-y PMID: 32561753
11. Berthe A, Elie L. Mechanisms explaining the impact of economic inequality on environmental deterioration. Ecological Economics. 2015; 116: 191–200. https://doi.org/10.1016/j.ecolecon.2015.04.026
12. Kartha S, Kemp-Benedict E, Ghosh E, Nazareth A, Gore T (Oxfam). THE CARBON INEQUALITY ERA. An assessment of the global distribution of consumption emissions among individuals from 1990 to 2015 and beyond. 2020.
13. López LA, Arce G, Morenate M, Zafrilla JE. How does income redistribution affect households' material footprint? Journal of Cleaner Production. 2017; 153: 515–527. https://doi.org/10.1016/j.jclepro.2017.01.142
14. Teixidó-Figueras J, Steinberger JK, Krausmann F, Haberl H, Wiedmann T, Peters GP, et al. International inequality of environmental pressures: Decomposition and comparative analysis. Ecological Indicators. 2016; 62: 163–173. https://doi.org/10.1016/j.ecolind.2015.11.041
15. World Inequality Database (WID). World inequality database USA. 2020 [cited 18 Jan 2021]. Available: https://wid.world/country/usa/
16. Rao ND, Min J. Less global inequality can improve climate outcomes. Wiley Interdisciplinary Reviews: Climate Change. 2018; 9: e513. https://doi.org/10.1002/wcc.513
17. Oswald Y, Owen A, Steinberger JK. Large inequality in international and intranational energy footprints between income groups and across consumption categories. Nature Energy. 2020; 5: 231–239. https://doi.org/10.1038/s41560-020-0579-8
18. Bjelle EL, Wiebe KS, Többen J, Tisserant A, Ivanova D, Vita G, et al. Future changes in consumption: The income effect on greenhouse gas emissions. Energy Economics. 2021; 95: 105114. https://doi.org/10.1016/j.eneco.2021.105114
19. Pothen F, Tovar Reaños MA. The Distribution of Material Footprints in Germany. Ecological Economics. 2018; 153: 237–251. https://doi.org/10.1016/j.ecolecon.2018.06.001
20. Chakravarty S, Chikkatur A, De Coninck H, Pacala S, Socolow R, Tavoni M. Sharing global CO2 emission reductions among one billion high emitters. Proceedings of the National Academy of Sciences of

the United States of America. 2009; 106: 11884–11888. https://doi.org/10.1073/pnas.0905232106 PMID: 19581586

21. Semieniuk G, Yakovenko VM. Historical evolution of global inequality in carbon emissions and footprints versus redistributive scenarios. Journal of Cleaner Production. 2020; 264: 121420. https://doi.org/10.1016/j.jclepro.2020.121420
22. Hopwood B, Mellor M, O'Brien G. Sustainable development: Mapping different approaches. Sustainable Development. 2005; 13: 38–52. https://doi.org/10.1002/SD.244
23. Sovacool BK, Newell P, Carley S, Fanzo J. Equity, technological innovation and sustainable behaviour in a low-carbon future. Nature Human Behaviour 2022. 2022; 1–12. https://doi.org/10.1038/s41562-021-01257-8 PMID: 35102347
24. Koh D, Santaeulàlia-Llopis R, Zheng Y. Labor Share Decline and Intellectual Property Products Capital. Econometrica. 2020; 88: 2609–2628. https://doi.org/10.3982/ecta17477
25. Piketty T. About capital in the twenty first century. American Economic Review. American Economic Association; 2015. pp. 48–53. https://doi.org/10.1257/aer.p20151060
26. Krausmann F, Wiedenhofer D, Lauk C, Haas W, Tanikawa H, Fishman T, et al. Global socioeconomic material stocks rise 23-fold over the 20th century and require half of annual resource use. Proceedings of the National Academy of Sciences of the United States of America. 2017; 114: 1880–1885. https://doi.org/10.1073/pnas.1613773114 PMID: 28167761
27. Chester M V., Sperling J, Stokes E, Allenby B, Kockelman K, Kennedy C, et al. Positioning infrastructure and technologies for low-carbon urbanization. Earth's Future. 2014; 2: 533–547. https://doi.org/10.1002/2014ef000253
28. Dorninger C, Hornborg A, Abson DJ, von Wehrden H, Schaffartzik A, Giljum S, et al. Global patterns of ecologically unequal exchange: Implications for sustainability in the 21st century. Ecological Economics. 2021; 179: 106824. https://doi.org/10.1016/J.ECOLECON.2020.106824
29. Fishman T, Schandl H, Tanikawa H. Stochastic Analysis and Forecasts of the Patterns of Speed, Acceleration, and Levels of Material Stock Accumulation in Society. Environmental Science and Technology. 2016; 50: 3729–3737. https://doi.org/10.1021/acs.est.5b05790 PMID: 26927731
30. Pauliuk S, Majeau-Bettez G, Müller DB, Hertwich EG. Toward a Practical Ontology for Socioeconomic Metabolism. Journal of Industrial Ecology. 2016; 20: 1260–1272. https://doi.org/10.1111/jiec.12386
31. Haberl H, Wiedenhofer D, Erb KH, Görg C, Krausmann F. The material stock-flow-service nexus: A new approach for tackling the decoupling conundrum. Sustainability (Switzerland). 2017; 9: 1049. https://doi.org/10.3390/su9071049
32. Haberl J, Koralewska R, Schlumberger S, Schuster M. Quantification of main and trace metal components in the fly ash of waste-to-energy plants located in Germany and Switzerland: An overview and comparison of concentration fluctuations within and between several plants with particular focus on valuable met. Waste Management. 2018; 75: 361–371. https://doi.org/10.1016/j.wasman.2018.02.015 PMID: 29478958
33. Resch E, Lausselet C, Brattebø H, Andresen I. An analytical method for evaluating and visualizing embodied carbon emissions of buildings. Building and Environment. 2020; 168: 106476. https://doi.org/10.1016/j.buildenv.2019.106476
34. Berrill P, Miller TR, Kondo Y, Hertwich EG. Capital in the American carbon, energy, and material footprint. Journal of Industrial Ecology. 2020; 24: 589–600. https://doi.org/10.1111/jiec.12953
35. Watari T, Yokoi R. International inequality in in-use metal stocks: What it portends for the future. Resources Policy. 2021; 70: 101968. https://doi.org/10.1016/j.resourpol.2020.101968
36. Watari T, Nansai K, Giurco D, Nakajima K, McLellan B, Helbig C. Global Metal Use Targets in Line with Climate Goals. Environmental Science and Technology. 2020; 54: 12476–12483. https://doi.org/10.1021/acs.est.0c02471 PMID: 32915547
37. Liu G, Müller DBDB. Centennial evolution of aluminum in-use stocks on our aluminized planet. Environmental Science and Technology. 2013; 47: 4882–4888. https://doi.org/10.1021/es305108p PMID: 23480626
38. Cao Z, Shen L, Løvik AN, Müller DB, Liu G. Elaborating the History of Our Cementing Societies: An in-Use Stock Perspective. Environmental Science and Technology. 2017; 51: 11468–11475. https://doi.org/10.1021/acs.est.7b03077 PMID: 28836769
39. Haberl H, Wiedenhofer D, Pauliuk S, Krausmann F, Müller DB, Fischer-Kowalski M. Contributions of sociometabolic research to sustainability science. Nature Sustainability. Nature Publishing Group; 2019. pp. 173–184. https://doi.org/10.1038/s41893-019-0225-2
40. Liu J, Wang M, Zhang C, Yang M, Li Y. Material flows and in-use stocks of durable goods in Chinese urban household sector. Resources, Conservation and Recycling. 2020; 158: 104758. https://doi.org/10.1016/j.resconrec.2020.104758

41. Eurostat. Average size of dwelling by household type and degree of urbanisation. In: April 21, 2016 [Internet]. 2016 [cited 24 Mar 2021]. Available: https://data.europa.eu/euodp/en/data/dataset/RBKPtr5e4DtpyFqnQYFMTQ
42. Office for National Statisitics. Percentage of households with cars by income group, tenure and household composition: Table A47—Office for National Statistics. 2019.
43. Dombi M, Karcagi-Kováts A, Tóth-Szita K, Kuti I. The structure of socio-economic metabolism and its drivers on household level in Hungary. Journal of Cleaner Production. 2018; 172: 758–767. https://doi.org/10.1016/j.jclepro.2017.10.220
44. Hooper E, Peters S, Pintus P, Hooper E, Peters S, Pintus P, et al. The Causal Effect of Infrastructure Investments on Income Inequality: Evidence from US States To cite this version: HAL Id: halshs-01684565 Working Papers / Documents de travail The Causal Effect of Infrastructure Investments on Income Inequality : Evi. 2018.
45. Hooper E, Peters S, Pintus P. To What Extent Can Long-Term Investment in Infrastructure Reduce Inequality? SSRN Electronic Journal. 2017. https://doi.org/10.2139/ssrn.2952365
46. Pi J, Zhang P. Factor-biased public infrastructure and wage inequality. Review of Development Economics. 2018; 22: e79–e94. https://doi.org/10.1111/rode.12393
47. Gibson J, Rioja F. Public Infrastructure Maintenance and the Distribution of Wealth. Economic Inquiry. 2017; 55: 175–186. https://doi.org/10.1111/ecin.12371
48. Fisch-Romito V. Embodied carbon dioxide emissions to provide high access levels to basic infrastructure around the world. Global Environmental Change. 2021; 70: 102362. https://doi.org/10.1016/J.GLOENVCHA.2021.102362
49. eurostat. Regional gross domestic product (million PPS) by NUTS 2 regions. 2021 [cited 24 Mar 2021]. Available: https://ec.europa.eu/eurostat/databrowser/view/tps00071/default/table?lang=en%0Ahttps://ec.europa.eu/eurostat/databrowser/view/t2020_rt120/default/table?lang=enhttps://ec.europa.eu/eurostat/databrowser/view/teibs070/default/table?lang=en
50. Gandelman N. A Comparison of Saving Rates: Microdata Evidence from Seventeen Latin American and Caribbean Countries. Economia-Journal of the Latin American and Caribbean Economic Association. 2016; 16: 201–258.
51. Hartley T, Van Den Bergh J, Kallis G. Policies for Equality Under Low or No Growth: A Model Inspired by Piketty. 2020. https://doi.org/10.1080/09538259.2020.1769293
52. Jackson T, Victor PA. Confronting inequality in the "new normal": Hyper-capitalism, proto-socialism, and post-pandemic recovery. Sustainable Development. 2021; 29: 504–516. https://doi.org/10.1002/SD.2196
53. Dombi M. Types of planning systems and effects on construction material volumes: An explanatory analysis in Europe. Land Use Policy. 2021; 109: 105682. https://doi.org/10.1016/J.LANDUSEPOL.2021.105682
54. Global Cement Concrete Assosiation. GNR Project. In: Report [Internet]. 2021 [cited 21 Feb 2022]. Available: https://gccassociation.org/gnr/
55. Wooldridge JM. Econometric analysis of cross section and panel data. 2010.