The Jus Semper Global Alliance

In Pursuit of the People and Planet Paradigm

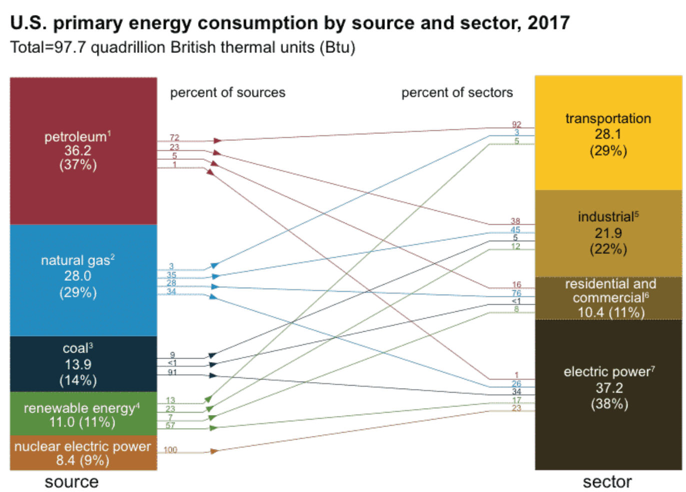
Sustainable Human Development

May 2021 ESSAYS ON TRUE DEMOCRACY AND CAPITALISM

Energy, Economic Growth, and Ecological Crisis

Erald Kolasi

Can economic growth continue forever? This relatively simple question has posed some intellectual headaches for modern capitalism. In the Grundrisse, Karl Marx argued that capital cannot tolerate any limits, by which he meant that the drive for growth and the search for new markets are both necessary for the political and economic survival of capitalism.[1] Viewed in this light, the implications of the question present something of an existential challenge to the current order. Capitalism cannot acknowledge any natural limits to economic growth, for that would mean acknowledging its ultimate demise. To keep up the pretence that capitalism represents a quasi-eternal and invincible system, most political leaders and economists who support the current order have begun reciting a series of elaborate narratives about the relationship between human economies and the natural world.



Energy Information Administration, Annual Energy Outlook for 2018.

These narratives all revolve around the central idea that we can decouple economic growth from the material needs of human civilisation. Until the late twentieth century, economists generally understood that more economic growth required the use of more energy and materials. But as the postwar compromises between labour and capital began

1 ↩ Marx writes that "the tendency to create the world market is directly given in the concept of capital itself. Every limit appears as a barrier to be overcome." See Karl Marx, *Grundrisse* (London: Penguin, 1973), 334.

Inspired by neoclassical theories, a new generation of economists began to argue that economic growth could continue without the consumption of additional resources from the environment. They claimed that we could reach this economic nirvana by doing more with less, investing in clean energy, and developing energy-efficient technologies. In short, they were arguing for nothing less than the long-term sustainability of capitalism, ignoring all the science and evidence piling up along the way.

collapsing in the 1970s and '80s, economic theories started to shift in emphasis and direction. Inspired by neoclassical theories, a new generation of economists began to argue that economic growth could continue without the consumption of additional resources from the environment.[2] They claimed that we could reach this economic nirvana by doing more with less, investing in clean energy, and developing energy-efficient technologies. In short, they were arguing for nothing less than the long-term sustainability of capitalism, ignoring all the science and evidence piling up along the way.

At a basic level, pundits and economists generally define decoupling as a process in which the size of the economy expands while resource impacts, usually either carbon emissions or primary energy consumption, decline.[3] More specifically, relative decoupling occurs when resource impacts are rising at a slower rate than economic growth. Absolute decoupling occurs when resource impacts are declining in absolute terms, even as the economy keeps expanding.[4] Macroeconomic theories supportive of capitalism measure economic size and activity by calculating the gross domestic product (GDP), which stands for the annual market value of goods and services produced in an economy by adding together gross private investment, consumer spending, government spending, and the trade balance. It should be noted that, although widely accepted by governments and most economists around the world, there are some fundamental scientific problems with using this measure as an accurate barometer of aggregate economic activity.[5]

Divergence between growth in carbon emissions and economic growth, and between economic growth and primary energy consumption, are often conflated in both public and academic discourse about the issue of decoupling, creating all sorts of confusions.[6] Some economists have also looked at how aggregate demand relates to the consumption of raw materials. Other ideas and concepts related to decoupling regularly circulate in the literature, reflecting the general ambiguity surrounding the issue.

---

2 ↩ See Robert M. Solow, "The Economics of Resources or the Resources of Economics," *American Economic Review* 64 (1974): 1–14.

3 ↩ For a prominent example of this line of thinking, see Barack Obama, "The Irreversible Momentum of Clean Energy," *Science*, January 9, 2017. Obama writes: "This 'decoupling' of energy sector emissions and economic growth should put to rest the argument that combatting climate change requires accepting lower growth or a lower standard of living."

4 ↩ See Tim Jackson, Prosperity Without Growth: Economics for a Finite Planet (Abingdon, UK: Routledge, 2011).

5 ↩ A major issue is the aggregation problem, one of the central weak points in all of macroeconomics. For an excellent, nontechnical introduction to the aggregation problem, see Blair Fix, "The Aggregation Problem: Implications for Ecological and Biophysical Economics," *BioPhysical Economics and Resource Quality* 4, no. 1 (2019). For a more technical treatment, see Jesus Felipe and Franklin M. Fisher, "Aggregation in Production Functions: What Applied Economists Should Know," *Metroeconomica* 54, no. 2 (2003): 208–62. The essence of the aggregation problem is the following question: Under what conditions can you add up a bunch of stuff and be certain that you have the right total value? The basic answer is that you can add things up when you have a stable unit of measurement, like mass or energy. In a natural science, like physics, unit stability is a critical requirement for measurement and aggregation. See Elizabeth Gibney, "Largest Overhaul of Scientific Units Since 1875 Wins Approval," *Nature*, November 16, 2018. By contrast, *aggregation* is a meaningless concept with unstable units of measurement, such as commodity prices in economics. One cannot define or determine a "real," inflation-adjusted aggregate through unstable units. Many economists find supposedly clever ways to get around this problem. In his famous 1956 paper, Robert Solow flatly declared: "There is only one commodity, output as a whole.… Thus we can speak unambiguously of the community's real income." In other words, he brushed aside the aggregation problem by creating an abstract economy with only one commodity. The flagrant absurdity of this move is par for the course in neoclassical theory, where ridiculous assumptions about the world are more common than breathing oxygen. See Robert M. Solow, "A Contribution to the Theory of Economic Growth," *The Quarterly Journal of Economics* 70 (1956): 65–94. There are other critical concerns with using GDP as a measure of economic value, such as the fact that it does not take into account ecological degradation and vital social services. For more on this line of criticism, see James Ward et al., "The Decoupling Delusion: Rethinking Growth and Sustainability," *The Conversation*, March 12, 2017.

6 ↩ For a recent example of this conflation, see Vincent Moreau, "Decoupling Energy Use and Economic Growth: Counter Evidence from Structural Effects and Embodied Energy in Trade," *Applied Energy* 215 (2018): 54–62. The author starts off right away by saying: "Decoupling economic growth from energy consumption is a widespread attempt to decarbonise economic activities and increase energy security."

This article aims to synthesise and understand these disparate ideas and to offer a comprehensive overview of the relationships between energy, economic growth, and social development. On a practical level, this debate has become fluid and chaotic because wealth and power are at stake. Intellectually, however, many of the arguments amplify confusion by resorting to inaccurate theories and misleading phrases. People often equate the concept of energy consumption with the term energy use, suggesting that they are unaware of important distinctions in how energy accounting works, or even what energy actually means. Many economists think about concepts like energy and efficiency in vastly different ways than physicists, creating ample opportunity for interdisciplinary confusion. This web of definitions and conceptions cries out for some attempt at clarification. Here I explore the nature of the relationship between energy and economic growth, highlighting areas where it makes sense to talk about decoupling while also emphasising some of the fundamental limits and problems of invoking the concept in relation to economics.

The Critical Role of Energetic Conversions

Energy consumption is a complex topic that touches on many different issues about the nature of civilisation. When most governments and organisations talk about energy consumption, they are typically referring to a metric called primary energy consumption, which represents the direct use of energy sources without any prior conversions or transformations.[7] Primary consumption includes burning coal at a power plant and distilling crude oil at a refinery. Primary forms of energy are not useful on their own, so they are converted and transformed into secondary forms of energy. For example, we burn coal so we can turn the resulting steam energy into electricity, and we distill crude oil so we can produce gasoline. Coal and crude oil are primary forms of energy while electricity and gasoline are considered secondary forms. The secondary sources can also be converted into other tasks and end uses, collectively known as tertiary sources. However, it must be emphasised that all primary energy sources are themselves the result of earlier conversions and transformations in nature, so they are not so primary after all. For example, the hydrocarbons of the dead plants and animals that make up petroleum are a secondary product of photosynthesis, which requires solar energy and water molecules. This fact hints at an important challenge for the usual methods of energy accounting: the concept of a primary form of energy is theoretically suspect.

There are two common methods of measuring primary energy: the partial-substitution method and the physical-energy content method.[8] Let me explain them with some examples. When a power plant burns through coal, the primary energy simply equals the energy of the coal that goes up in flames. In the case of fossil fuels then, things are pretty easy: just record the amount of stuff that we burn and call that primary energy. But the situation is more complicated for renewable energy sources, such as wind, solar, and hydropower, because nothing was burning while these energy sources generated electricity. Enter the two methods above. In the physical-energy content method, we simply count the electrical energy produced by these sources as primary energy, even though electricity obviously qualifies as a converted form of energy. This is the method used by the International Energy Agency to measure energy consumption for renewables. In the partial-substitution method, we pretend that the produced electricity came from a hypothetical thermal power plant, and then we assume some efficiency for this plant. For example, if the plant has an efficiency of 20 percent, then we would multiply the electricity generated by a factor of five. In this case, the primary energy required to produce that electricity is five times larger. The company British Petroleum has adopted this partial-substitution method

---

7 ↩ See "Primary Energy Consumption," *Organization for Economic Cooperation and Development*, November 20, 2001. For a list of things that are included under primary consumption in the United States, see the entry "Primary Energy Consumption" in the Glossary of the U.S. Energy Information Administration.

8 ↩ For an explanation of these methods, see "Statistical Resources" by the International Energy Agency.

in its popular global energy reports.[9] The main reason why these differences matter is because they can lead to diverging estimates of energy consumption, especially for nations that rely heavily on renewables.

We can always argue and wonder about which method is more correct, but this line of thinking entirely misses the central theme of the conversation. In reality, beyond the world of statistical accounting, only energetic conversions truly matter. The electrical energy produced by renewables came from dynamical flows in nature, such as sunlight hitting the earth and rivers roaring through dams. The concentration of fossil fuels at their points of processing and refinement required energetic conversions from machines and human labour, which first extracted these fuels and then transported them to a particular location. All of this happened before anything was burned and recorded on some logs and charts. Thinking in terms of primary energy consumption obscures the energetic flows and conversions that make all economic activities possible. It also establishes ample opportunities for confusion and misguided results in public discourse. When economists and media outlets show plots of GDP growth diverging from energy consumption, they are actually showing GDP growth diverging from primary energy consumption.[10] They then assume that this alone somehow proves that economic growth has become detached from energy use.

This assumption is highly misleading. To understand why, it helps to review the significance of energy in a broader context beyond economics. We can generally define energy as constrained states of motion that can be exchanged among different physical systems. It can come in many different forms, such as chemical, thermal, kinetic, and potential, to name just a few. The following arguments do not even depend on any particular definition of energy; they just depend on the basic fact that certain forms of energy can be converted into other forms. For example, chemical energy can be transformed into mechanical energy, which is what happens when our car engines burn through fuel and convert the resulting heat energy into the mechanical motion of the wheels. Heat and mechanical energy can also be transformed into electrical energy, like when power plants burn through coal and use the resulting steam energy to drive a generator that produces electricity. Focusing exclusively on primary energy consumption completely ignores and marginalises these energetic conversions, which should be the central elements of the story.

All conceivable economic transactions, from the exchange of money to the production of commodities, require energetic conversions from various sources. Energy is embedded in all human actions. It does not simply stop counting after we burn through natural resources at some power plant. The flow of energy through the various parts of civilisation facilitates all possible human actions, such as driving to the grocery store, surfing the web, playing video games, watching television shows, and reading romance novels at the beach. In this fundamental sense, economic activities cannot be decoupled from energy use, for that would be like asking economics to step completely outside the laws of physics—a clear absurdity. But this clear absurdity is exactly what certain economic theories imply can actually happen: they artificially detach capital and labour from energetic constraints and effectively sever any and all links between physics and economics.[11] Many economists use primary energy consumption as a crutch for how energy impacts economic

In this fundamental sense, economic activities cannot be decoupled from energy use, for that would be like asking economics to step completely outside the laws of physics—a clear absurdity. But this clear absurdity is exactly what certain economic theories imply can actually happen: they artificially detach capital and labour from energetic constraints and effectively sever any and all links between physics and economics.

---

[9] ↩ BP assumes an efficiency rating of 38 percent for the hypothetical power plant. See *BP Statistical Review of World Energy* (London: British Petroleum, 2018), 52.

[10] ↩ As a quick example, see the charts in Brad Plumer, "Can We Sever the Link between Energy and Economic Growth?" *Washington Post*, January 17, 2014.

[11] ↩ David Stern, "Economic Growth and Energy," in *Encyclopedia of Energy*, ed. C. J. Cleveland (San Diego: Academic Press, 2004), 43.

processes, and in so doing they make it seem like our lives are unfolding in some entirely separate realm from energetic constraints. Instead of focusing exclusively on primary consumption, we should emphasise the importance of what I call aggregate flow, defined as the total sum of all the energy converted through our economic activities. In other words, aggregate flow focuses on the energetic flows and transformations that make civilisation possible. A related quantity of interest is the aggregate flow rate, or AFR, which measures the aggregate flow per unit of time. In general, richer societies have a higher AFR than poorer societies. This means that they can produce and circulate larger amounts of real surplus wealth, in the form of use values. However, an enormous portion of this wealth also takes the form of social, economic, and ecological waste.

In addition to the critical role of conversions, we must emphasise the related importance of energy quality. Not all primary sources of energy are made equal. Some are more efficient than others. Some yield more mechanical work. Others produce more electricity. For example, producing one kilowatt hour of electricity in 2017 required, on average, 7,812 British thermal units (BTUs) of natural gas and 10,465 BTUs of coal.[12] By this measure, natural gas is roughly 25 percent more efficient than coal at generating the same quantity of electricity. The energy thinker Vaclav Smil identified the power density of an energy source as an important feature for the economic growth and development of civilisation.[13] He defined power density as the energy flux per unit area that could be released in the conversion process of an energy source. Smil has argued that fossil fuels are uniquely important for capitalism because they have higher power densities than other energy sources, such as wind and solar. Larger power densities help generate more production, leading to higher profits by extension. Other measures of energy quality are conceivable, but the basic point is that natural energy sources can have very different uses and attributes. The only way to understand these differences is by looking at the conversions and transformations that follow primary consumption. Failing to take this critical but routinely ignored step makes it seem like all energy sources should be treated equally, as if they all have the same capacities in the process of economic production and consumption.

Neoclassical theory is generally plagued by unrealistic assumptions about society, numerous mathematical inconsistencies, and has no predictive power at all.

The Central Flaws in the Neoclassical Theory of Growth

The intellectual foundations of the decoupling narrative derive from neoclassical economic theory, the prevailing paradigm of explanation among orthodox economists that support capitalism. Neoclassical theory is generally plagued by unrealistic assumptions about society, numerous mathematical inconsistencies, and has no predictive power at all.[14] In this piece, however, we focus on the cardinal sin of this intellectual train wreck: its rejection of physics and its ignorance of the natural order. In the 1950s, the economist Robert Solow developed one of the first major models to describe how economic growth happens.[15] In these versions of neoclassical theory, the production inputs of capital and labour combine to produce outputs, or finished goods, that are traded in the economy. Growth in capital leads to more

---

12 ↩ A BTU is equal to 1,055 joules, the standard unit of energy. A joule is roughly the amount of energy it takes to lift an apple up to your mouth. See Table 8.1, "Average Operating Heat Rate for Selected Energy Sources," *S. Energy Information Administration*, October 22, 2018.

13 ↩ For his primary work on the subject, see Vaclav Smil, Power Density: A Key to Understanding Energy Sources and Uses (Cambridge, MA: MIT Press, 2015).

14 ↩ The silly assumptions that form the core of neoclassical theory are almost too numerous to recount. One can begin with utility, revealed preferences, and marginal productivity, for just a few metaphysical concepts that must be indirectly inferred from things like prices and wages. The economist Joan Robinson was one of the most brilliant critics of neoclassical economics. For her classic text on the subject, see Joan Robinson, *Economic Philosophy* (Middlesex, UK: Penguin, 1964). On the mathematical front, neoclassical theory has severe problems related to aggregation and general equilibrium. Refer to footnote 5 for an explanation of the aggregation problem. For the issues surrounding general equilibrium, see Frank Ackerman, "Still Dead After All These Years: Interpreting the Failure of General Equilibrium," *Journal of Economic Methodology* 9 (2002): 119–39. Regarding its lack of predictive power, refer to every single dynamic stochastic model that somehow missed the Great Recession back in 2008.

15 ↩ See Solow, "A Contribution to the Theory of Economic Growth."

output, but depreciation in capital assets also drags down a portion of that output. The economy eventually reaches a stationary state where growth and depreciation balance each other out and there is no more growth. In order to produce continuous growth, neoclassical theory argues that the economy needs a steady stream of technological progress, defined as a gain in total productivity. This gain implies that productive output can increase while productive inputs are held constant. Solow came up with a mathematical scheme for detecting the impact of this technological growth on changes in GDP. Although his work earned widespread acclaim from other neoclassical thinkers, much of it was based on dubious mathematical results that did not actually validate his claims.[16]

In extensions of Solow's original theory, the productive inputs have typically included capital, labour, and technology. Energy is sometimes subsumed under the three traditional inputs, or it may be treated as a separate input in and of itself. Critically, the production inputs are viewed as largely independent from one another, meaning that they can be substituted as necessary in order to maintain or to boost the maximum level of production. If societies are running short on natural resources, neoclassical theory argues that these shortages can be overcome through technological innovation, efficiency gains, or other forms of substitution. Indeed, neoclassical economists tend to assume that the long-run sustainability of capitalism is materially possible and all we need to do is figure out the social and institutional arrangements that can ensure that sustainability.[17] Solow entertained the idea that the natural world does not provide limits to economic growth on the following grounds: "If it is very easy to substitute other factors for natural resources, then there is in principle no 'problem.' The world can, in effect, get along without natural resources, so exhaustion is just an event, not a catastrophe."[18] Although his model also showed that competition would eventually result in the exhaustion of natural resources, his statement nicely describes the general attitude that many economists hold about the inevitability of growth under capitalism.

For a highly simplified toy model of what this all means, consider your local pizza store. According to neoclassical theory, the pizza store can maintain or boost current levels of pizza production in the face of any shortfall. A shortage of workers can be overcome by adding more ovens. A shortage of cheese can be overcome through technical improvements that yield more efficient methods of making cheese. A shortage of electricity can be overcome by increasing labour productivity, perhaps by training the workers to make the pizzas faster under the new time constraints. Everything can be replaced. Everything can be substituted, seemingly without end. The ideas and principles just described represent fundamental assumptions in neoclassical economics and they are often used to explain the relationship between energy consumption and economic growth. If there were no hard limits to substitution, then it would be possible for our economies to keep growing even in an ecosphere with declining quantities of natural resources and with highly chaotic, nonlinear ecological consequences that result from the enormous energy losses of capitalist societies. In other words, better technologies and higher efficiencies would always be available to boost production, regardless of any depletions or instabilities in the wider natural world caused by those productivity gains.

---

16 ↩ Solow's conclusions relied on a function known as the Cobb-Douglas production function, which was widely used in economics back then and remains popular to this very day. However, Anwar Shaikh brilliantly tore apart Solow's results in 1974, when he showed that the Cobb-Douglas production function could accurately model data sets for which a production function should not exist. See Anwar Shaikh, "Laws of Production and Laws of Algebra: The Humbug Production Function," *The Review of Economics and Statistics* 56 (1974): 115–20. It turns out that there is a kind of trivial and profound reason for this behaviour. In 2005, Jesus Felipe and J. S. L. McCombie convincingly proved what had been widely suspected by Shaikh and others: that the Cobb-Douglas production function is nothing more than an identity equation, a different way of writing the additive equation *capital plus labour*, and reveals absolutely nothing about the neoclassical theory of distribution. See Jesus Felipe and J. S. L. McCombie, "How Sound Are the Foundations of the Aggregate Production Function?" *Eastern Economic Journal* 31 (2005): 467–88. The Cobb-Douglas function was picking up the factor shares inherent in the empirical data sets, most of which had roughly constant factor shares, because its exponents are the exact same as the factor shares from the identity equation. In sum, the Cobb-Douglas production function is an elaborate way of saying that one equals one.

17 ↩ Stern, "Economic Growth and Energy," 40.

18 ↩ Solow, "The Economics of Resources or the Resources of Economics," 11.

To chip away at this elaborate fantasy, it helps to begin with some basic physics. The most fundamental limits to substitution come from thermodynamics, the branch of physics that studies quantities like heat, work, and energy. Thermodynamic limits impose constraints on the maximum efficiency of energy flows through technological systems.[19] Car engines, power plants, and photovoltaic cells are all limited in their capacities to convert one type of energy into another. Technological progress cannot overcome these limits; no car engine can ever be more efficient than an engine running on the Carnot cycle.[20] In an earlier article for this magazine, I defined the aggregate efficiency of an economic system as the fraction of all primary energy consumption that produces mechanical work and electricity.[21] I argued that aggregate efficiencies are highly inertial over time because improving them substantially requires enormous investments that would disrupt the reigning economic order.

Once a society has settled into a particular energy structure, changing it much further becomes a daunting task because of elite classes and groups that rely heavily on that structure for their wealth and influence.

Once a society has settled into a particular energy structure, changing it much further becomes a daunting task because of elite classes and groups that rely heavily on that structure for their wealth and influence. We can look to the recent experience of Germany for a prominent case study. In 2000, the German government launched its ambitious *Energiewende*, a comprehensive plan to reduce greenhouse gas emissions by shifting energy production towards renewable sources, such as wind and solar.[22] For a time, the program made some notable achievements. Compared to 1990, greenhouse gas emissions had declined 28 percent by 2017. That same year, renewables reached a 13 percent share of primary energy consumption. Although these numbers are impressive, progress has recently come to a standstill. It has become increasingly clear that Germany will not reach the climate targets that it set for 2020. And once we dig into the numbers a bit deeper, even those that look impressive come with huge caveats. For example, the large reduction of carbon emissions since 1990 can be largely attributed to the collapse of heavy industry in East Germany after reunification.[23] Over the past eight years, greenhouse gas emissions from Germany have hardly changed. The variabilities associated with wind and solar power have opened up problems related to electricity storage. Prices fluctuate dramatically depending on weather conditions. To compensate for these and other issues, Germany began sabotaging its energy program by constructing a series of new coal power plants when the coal industry pressured Chancellor Angela Merkel's government to relax its policies. The German example offers an important lesson: the necessary substitution of fossil fuels with renewables will never come fast enough under the market logic of capitalism.

Another major limit to substitution comes from the ecological instabilities associated with excessive levels of economic growth. These instabilities can combine to pump and amplify existing natural phenomena. The amplifier effect works as follows. Economies absorb energy from the natural world and then exploit that energy for cycles of production and consumption. For highly energy-intensive economies, these cycles necessarily yield extensive levels of waste and dissipation, or energy losses that are dumped back out to the environment. These energy losses are not "useless" from the standpoint of physics or ecology. Under the

As a highly dissipative system, capitalism regularly produces very powerful amplifier effects. Collectively, these amplifiers are now creating what Marx called a "metabolic rift" between nature and society.

---

19 ↩ Stern, "Economic Growth and Energy," 42.

20 ↩ John W. Jewett and Raymond A. Serway, *Physics for Scientists and Engineers* (Boston: Cengage Learning, 2008), 618.

21 ↩ See Erald Kolasi, "The Physics of Capitalism," — The Jus Semper Global Alliance, April 2021.

22 ↩ Stanley Reed, "Germany's Shift to Green Power Stalls, Despite Huge Investments," *New York Times*, October 7, 2017.

23 ↩ Tobias Buck, "Energy Shift Fails to Cut German Carbon," *Financial Times*, October 8, 2018.

right circumstances, they can power the formation of other natural dynamical systems, including everything from viruses and bacteria to wildfires and hurricanes.[24] These highly chaotic effects associated with energy-intensive economies are largely ignored and dismissed by neoclassical theory, even though they have often played a central role in the evolution of human history.[25] As a highly dissipative system, capitalism regularly produces very powerful amplifier effects. Collectively, these amplifiers are now creating what Marx called a "metabolic rift" between nature and society, which means that the ecological basis of civilisation is steadily eroding under profit-seeking and energy-intensive development that does not care about replacing what it extracts.[26] The natural world has major tipping points that we should not cross, but indefinite economic growth through substitution virtually guarantees that some of those critical thresholds will be breached, threatening the broader ecosphere that supports human civilisation.[27]

Consider another problem. Substitution can occur quite frequently on small and restricted scales of economic activity. A pizza store can always substitute certain ingredients for others. A homeowner can substitute heating fuel for insulation. A company can replace older light bulbs for more efficient lighting in its offices. And even some countries can substitute various forms of wealth for others, at least temporarily. The Pacific island nation of Nauru provides a classic example that highlights the central themes of the debate. In the twentieth century, Nauru possessed vast deposits of phosphate, which is highly prized as an agricultural fertiliser. These deposits were extensively mined, depleted, and then traded in global markets, allowing Nauru to reach a sky-high standard of living by 1990.[28] Nauru converted a portion of its earnings from the phosphate trade into a public trust fund, which invested in manufactured capital through financial markets. However, its impressive standard of living collapsed sharply after the phosphate vanished, along with most of the money in the trust fund.[29] Nauru offers a cautionary tale for the world as a whole. If global civilisation runs out of natural resources, we cannot replace them by investing in commodities through financial markets. People cannot eat money. Substitution in the long run may be possible at the microlevel of economic activity, but long-term macro-level substitution is downright wishful thinking.

If global civilisation runs out of natural resources, we cannot replace them by investing in commodities through financial markets. People cannot eat money. Substitution in the long run may be possible at the microlevel of economic activity, but long-term macro-level substitution is downright wishful thinking.

We can better understand the limits to substitution on a global, macroscopic level by considering a specific example: a global economy meeting its electricity needs through the consumption of solar power. There are fundamental limits to the amount of solar energy absorbed by solar panels that can be converted into useful electrical energy. Most commercial photovoltaics convert less than 30 percent of the solar energy they absorb into electricity; the remaining energy balance is lost as heat and infrared radiation.[30] The theoretical efficiency limits for the most advanced photovoltaic designs are just under 90 percent, a number that not even the latest laboratory experiments have come close to matching.[31] But suppose neoclassical theory is right about its eternal commitment to technological progress and

---

24 ↩ For a comprehensive guide to some recent research on hurricanes and climate change, see Jennifer M. Collins and Kevin Walsh, eds., *Hurricanes and Climate Change*, vol. 3 (New York: Springer, 2017). For a review of the role climate change plays in the spread of infectious diseases, see Xiaoxu Wu et al., "Impact of Climate Change on Human Infectious Diseases: Empirical Evidence and Human Adaption," *Environment International* 86 (2016): 14–23.

25 ↩ See, for example, Jerry H. Bentley, "Environmental Crises in World History," *Procedia—Social and Behavioral Sciences* 77 (2013): 108–15.

26 ↩ For more on Marx and his theory of the metabolic rift, see John Bellamy Foster, *Marx's Ecology* (New York: Monthly Review Press, 2000).

27 ↩ See Johan Rockström et al., "A Safe Operating Space for Humanity," *Nature* 461 (2009): 472–75.

28 ↩ Stephen E. Kesler, Adam C. Simon, and Adam F. Simon, *Mineral Resources, Economics and the Environment* (Cambridge: Cambridge University Press, 2015), 302.

29 ↩ Anne Davies and Ben Doherty, "Corruption, Incompetence and a Musical: Nauru's Cursed History," *The Guardian*, September 3, 2018.

30 ↩ For an excellent introduction to how photovoltaics work, see "Solar Cell Efficiency," *Energy Education*, June 25, 2018.

31 ↩ Alexis De Vos, "Detailed Balance Limit of the Efficiency of Tandem Solar Cells," *Journal of Physics D: Applied Physics* 13 (1980): 839–46.

> *renewable technologies are important, but they cannot solve the global ecological crisis under the economic regime of capitalism, which is completely reliant on the false promise of eternal growth in production and consumption.*

that eventually we do manage to produce photovoltaics that are 90 percent efficient at converting solar energy. Once all theoretical efficiency limits are actually realised, boosting electricity production even further would require the construction of new solar panels, which takes up more land. As the earth has a finite surface area, indefinite growth would not be possible even with the proliferation of renewables. This argument underscores the central point that renewable technologies are important, but they cannot solve the global ecological crisis under the economic regime of capitalism, which is completely reliant on the false promise of eternal growth in production and consumption. Substituting fossil fuels for renewables while pushing for more growth would still lead to the total ruin of global civilisation in a few centuries.

Economists love to pretend that technological innovation can yield greater "qualitative growth" without any corresponding "quantitative growth."[32] On the basis of improving knowledge and technological growth, they believe that the monetary value of stuff can keep increasing even as the quantity of stuff itself remains stable. But what they fail to grasp is that technological innovations do not happen magically—they also require energetic conversions. Changes to the production cycle are dependent on the stock of electrical, chemical, and mechanical energy available for research and training. A coder sitting in front of a computer writing a new program needs energy to think and type. The computer itself needs electricity to continue operating. No possible improvement can be made to computer programs without a continuous stream of energetic conversions. Expansions in productivity require energy flows, meaning that all forms of technological change are intertwined with the energetic transformations that facilitate human existence.

Technological changes are physically embedded in greater knowledge among people and the development of more productive assets, both of which need energy and material flows to continue operating. Thermodynamic limits also

> *what they fail to grasp is that technological innovations do not happen magically—they also require energetic conversions. Changes to the production cycle are dependent on the stock of electrical, chemical, and mechanical energy available for research and training..... technological changes themselves are subject to hard physical limits... The bloated profit margins of capitalism depend critically on the energy-intensive basis of its entire existence. Take away that basis and there is no more capitalism.*

constrain the extent to which these flows can be reduced while sustaining labour and capital. In short, technological changes themselves are subject to hard physical limits, along with the qualitative growth that can be derived from them. Power plants provide one of the most well-known examples of the limits to technological growth. They have been hovering near their peak efficiency ratings for decades and getting them to go much further has proven to be extremely difficult.[33] The failure of breeder reactors for nuclear power plants highlights another prominent technological bust, and plenty of other exotic technologies, like fusion reactors, will inevitably end up in the same category. The bloated profit margins of capitalism depend critically on the energy-intensive basis of its entire existence. Take away that basis and there is no more capitalism.

---

32 ↩ See, for example, Tim Worstall, "When Physicists Do Economics We Seem Not to Get Economics as the Result," *Forbes*, October 6, 2014.

33 ↩ Stern, "Economic Growth and Energy," 42.

How Energy and Growth Relate to Emissions

All economic activities, as we have seen, require energy. To better understand what this means, we examine the relationships between energy, growth, and emissions more concretely by looking at the economy of the United States. In recent decades, U.S. economic growth has continued, albeit at a declining rate, even though per-capita primary energy consumption has gone down.[34] In addition, costs associated with primary energy consumption increasingly represent a declining share of U.S. aggregate demand. From these observations, many economists and pundits have concluded that energy use and economic growth have decoupled from one another.[35] But even a quick analysis of the underlying energy shifts in the U.S. economy reveals the falsehood of this narrative. An economy that starts using natural resources with higher energy efficiencies and larger power densities can experience growth even as primary energy consumption declines. Understanding this process would be difficult, perhaps even impossible, if we only looked at primary consumption, which totally ignores conversions. But once we consider that burning a smaller quantity of natural gas, for example, can still yield more electricity than burning a larger amount of coal, then the significance of conversions becomes immediately apparent. Resources with larger power densities can convert more useful energy for economic activities, some of which constitute the basic elements measured by GDP. Economists like David Stern and Robert Kaufmann, among others, have clearly shown that growth in U.S. energy consumption is tightly coupled with growth in aggregate demand once differences in energy quality are factored into the analysis.[36]

The energy crisis of the 1970s motivated the United States to reduce per-capita oil consumption and to focus on efficiency gains by using other natural resources. These efforts resulted in a trajectory of increased natural-gas consumption, which is much cleaner and more efficient as an energy source than coal. Both the switch to natural gas and the increasing proliferation of renewables helped substantially reduce carbon emissions. After peaking in 2005, greenhouse gas emissions in the United States had fallen 14 percent by 2016.[37] But the declines gradually stalled and emissions in 2018 actually increased by more than 3 percent, the largest rise in 8 years.[38] A hyperactive transportation sector, always critical to economic growth, was the leading culprit behind the latest surge. Recent U.S. experience further reinforces the notion that large-scale reductions in emissions are virtually impossible under an economic system that prioritises growth above anything else. The unlimited pressure to increase consumption and production can lead to rising emissions even in the context of macro-level efficiency gains and technological innovations.

Recent U.S. experience further reinforces the notion that large-scale reductions in emissions are virtually impossible under an economic system that prioritises growth above anything else. The unlimited pressure to increase consumption and production can lead to rising emissions even in the context of macro-level efficiency gains and technological innovations.

---

34 ↩ See Table 1.7, "Primary Energy Consumption, Energy Expenditures, and Carbon Dioxide Emissions Indicators," *S. Energy Information Administration*, March 26, 2019.

35 ↩ For some relatively recent flavors of elite opinion on this topic, see John L. Seitz and Kristen A. Hite, *Global Issues: An Introduction* (Hoboken, NJ: John Wiley & Sons, 2012), 126. Also look at Devashree Saha and Mark Muro, "Growth, Carbon, and Trump: States Are 'Decoupling' EconomicGrowth from Emissions Growth," *Brookings Institution*, December 8, 2016.

36 ↩ See Stern, "Economic Growth and Energy," 35–51. In an important paper, Kaufmann also documented the structural shifts that occurred within the U.S. energy sector and analyzed their impact on economic growth. See Robert Kaufmann, "The Mechanisms for Autonomous Energy Efficiency Increases: A Cointegration Analysis of the US Energy/GDP Ratio," *The Energy Journal* 25 (2004): 63–86.

37 ↩ Zeke Hausfather, "Analysis: Why US Carbon Emissions Have Fallen 14% Since 2005," *Carbon Brief*, August 15, 2017.

38 ↩ Brad Plumer, "S. Carbon Emissions Surged in 2018 Even as Coal Plants Closed," *New York Times*, January 8, 2019.

For the world as a whole, a strong positive relationship exists between primary energy consumption and economic growth, and numerous studies on various countries and regions indicate that this relationship is fundamentally causal.[39]

In 2016, the International Energy Agency triumphantly declared: "Decoupling of global emissions and economic growth confirmed." What a difference two years can make. In 2017, greenhouse gas emissions worldwide saw a sharp spike.... emissions rose again for 2018, at a faster pace than the previous year.

Over the last few decades, the rate of global economic growth has started to slow down, mirroring the declining rate of growth in global energy consumption. Some major economies, like those of Japan and the European Union, have already entered periods of stagnation associated with very low growth rates and ageing populations. Because these economies are currently dominated by corrupt financial sectors, they are generating uneven growth patterns that mostly enrich wealthy capitalists. By contrast, ordinary people are increasingly drowning in debt so they can finance the cycles and crises of capitalism.[40] Economic progress for the vast majority of society has come to a screeching halt.[41] The global economy may continue to grow at modest rates for the rest of this century, but the signs are already evident that our potential for future growth is limited and constrained by what kinds of energy sources we can collect from the natural world, as well as by the economic irrationalities of today's financialised capitalism.

Capitalism is running out of steam, but not quickly enough to substantially reduce aggregate emissions. Global carbon emissions over the last century have closely followed changes in primary energy consumption. At the start of the decade, optimism about global warming was high. Greenhouse gas emissions flatlined for several years and the upper echelons of the global economy started to believe that economic growth could actually be decoupled from harmful emissions. In 2016, the International Energy Agency triumphantly declared: "Decoupling of global emissions and economic growth confirmed."[42] What a difference two years can make. In 2017, greenhouse gas emissions worldwide saw a sharp spike.[43] Against a backdrop of increasingly alarming scientific reports about the dangers of global warming, emissions rose again for 2018, at a faster pace than the previous year.[44] Even some advanced economies that had supposedly decoupled growth from pollution witnessed higher carbon emissions in 2018. Detaching emissions from economic growth has turned out to be a vastly more complicated problem than global elites originally believed.

A persistent albatross on this issue is the way that most elites talk about carbon emissions. When governments and organisations measure greenhouse gas emissions, they often do so at the point of manufacture and production. If a U.S. company sets up a factory in India to produce commodities that are then sold to U.S. consumers, the emissions coming from that factory are credited to India, not the United States. This basic process of what is referred to as geographic substitution, where corporations from the capitalist core transfer ecologically destructive manufacturing to developing nations with large pools of cheap labour, has been an important source of the observed divergence between carbon

---

39 ↩ For one of the most influential studies in this field, see David I. Stern, "The Role of Energy in Economic Growth," *Crawford School Centre for Climate Economics & Policy Paper No. 3.10* (2011). For a review of the statistical relationship between energy use and GDP growth worldwide, see Rögnvaldur Hannesson, "Energy and GDP Growth," *International Journal of Energy Management* 3 (2009): 157–70. For a major study on the link between energy and income in certain Asian countries, see John Asafu-Adjaye, "The Relationship between Energy Consumption, Energy Prices, and Economic Growth: Time Series Evidence from Asian Developing Countries," *Energy Economics* 22 (2000): 615–25. For a general overview of how energy use has shaped human history, see Vaclav Smil, *Energy and Civilization* (Cambridge: MIT Press, 2017).

40 ↩ Jessica Dickler, "Consumer Debt Hits $4 Trillion," *CNBC*, February 21, 2019.

41 ↩ Drew Desilver, "For Most U.S. Workers, Real Wages Have Barely Budged in Decades," *Pew Research Center*, August 7, 2018.

42 ↩ See "Decoupling of Global Emissions and Economic Growth Confirmed," *International Energy Agency*, March 16, 2016.

43 ↩ Zeke Hausfather, "Analysis: Global CO2Emissions Set to Rise 2% in 2017 After Three-Year Plateau," *Carbon Brief*, November 13, 2017.

44 ↩ Damian Carrington, "Brutal News: Global Carbon Emissions Jump to All-Time High in 2018," *The Guardian*, December 5, 2018.

emissions and economic growth in the Western world.[45] In other words, measuring emissions from the point of consumption hardly reveals any decoupling at all. In any case, multinational corporations can only keep shifting production around so much before they run out of places to go. There are limits to geographic substitution as well.

Besides comparing aggregate demand to emissions, another approach for understanding the material foundations of economic growth focuses on the flow of raw materials on their way to the final point of consumption. In a landmark 2012 paper, a group of Australian researchers analysed the aggregate raw materials exchanged among countries through international trade and introduced the concept of the material footprint, defined as the global allocation of used raw material extraction to the final demand of an economy. They concluded that "with every 10 percent increase in gross domestic product, the average national [material footprint] increases by 6 percent."[46] In their view, "achievements in decoupling in advanced economies are smaller than reported or even nonexistent." They also estimated that roughly 40 percent of all global raw materials are extracted to facilitate the export of goods and services to other nations, which indicates that reducing the international flows of global capital could be a critical strategy in addressing our intensifying ecological crisis.

... life expectancy in the United States has declined for three consecutive years, the first such sustained decline in a century. The U.S. economy grew in every one of those years. But the press did not blare the sirens declaring that life expectancy has decoupled from economic growth. Such an admission would raise an unthinkable prospect for the reigning plutocracy: that the lives of common people might actually be getting worse while some billionaires become even richer by selling the rest of us more stuff that does not actually improve our lives.

For another perspective on why claims about decoupling are premature, consider the following fact: life expectancy in the United States has declined for three consecutive years, the first such sustained decline in a century.[47] The U.S. economy grew in every one of those years. But the press did not blare the sirens declaring that life expectancy has decoupled from economic growth. Such an admission would raise an unthinkable prospect for the reigning plutocracy: that the lives of common people might actually be getting worse while some billionaires become even richer by selling the rest of us more stuff that does not actually improve our lives. However, when two or three years of mixed and uncertain data suggest that the rise in harmful global emissions has slowed down, the story gets blown out of proportion and becomes a masterful causal narrative about how capitalism can be ecologically sustainable. The collapse of the decoupling delusion offers an important lesson—we should resist the temptation to make grand conclusions about the world when we notice marginal trends over just a few years.

The collapse of the decoupling delusion offers an important lesson—we should resist the temptation to make grand conclusions about the world when we notice marginal trends over just a few years.

The Accelerating Crisis and the Social Dimension

The early phases of the ecological crisis have already arrived. In 2017, Puerto Rico was struck and heavily damaged by a powerful hurricane lurking over unusually warm waters. That same year, a historic drought in Argentina crippled agricultural exports and triggered a massive recession, which eventually coupled with a currency crisis and forced the

---

45 ↩ See Ward et al., "The Decoupling Delusion."

46 ↩ Thomas O. Wiedmann et al., "The Material Footprint of Nations," *Proceedings of the National Academy of Sciences* 112 (2013): 6271–76.

47 ↩ Lenny Bernstein, "S. Life Expectancy Declines Again, a Dismal Trend Not Seen Since World War I," *Washington Post*, November 29, 2018.

> *The early phases of the ecological crisis have already arrived... thousands of other simultaneous developments are only the opening lines in a multi-act play that human civilisation will nervously witness and experience over the next few centuries.*

country to borrow billions from the International Monetary Fund for the second time in less than two decades.[48] Severe and unusual droughts in Central America are also disrupting agricultural production and playing a major role in convincing hundreds of thousands of migrants to head north.[49] Major droughts and water shortages in Afghanistan have fuelled widespread resentment against the central government in Kabul and have incited tensions between the country and its neighbours.[50] These and thousands of other simultaneous developments are only the opening lines in a multi-act play that human civilisation will nervously witness and experience over the next few centuries.

Ecological and other left-wing economists have long criticised the dangerous fantasies of neoclassical thinkers. But there is evidence that some elites are also beginning to change their minds on the issue. In 2016, the International Resource Panel concluded that the global consumption of materials since 2000 had grown at a faster rate than global GDP, adding that "global material efficiency, for the first time in a century, has started to decline."[51] In 2017, the chief economist of Norway's Equinor, Eric Waerness, wrote that decoupling economic growth from energy consumption "might be impossible."[52] In 2018, a major report from the International Panel on Climate Change stated that preventing catastrophic levels of global warming would require "rapid, far-reaching, and unprecedented changes in all aspects of society."[53] Antonio Guterres, the Secretary General of the United Nations, told a climate conference in early December 2018 that "we are in deep trouble with climate change."[54] Optimism has finally given way to realism, even if many of these individuals and organisations fail to notice the next required step: a full-blown social, political, and economic confrontation against capitalism.

> *Ecological and other left-wing economists have long criticised the dangerous fantasies of neoclassical thinkers. But there is evidence that some elites are also beginning to change their minds on the issue.... Optimism has finally given way to realism, even if many of these individuals and organisations fail to notice the next required step: a full-blown social, political, and economic confrontation against capitalism.*

An analysis of class and society remains critical to understanding the horizon of crisis spearheaded by capitalism. In large part, the ecological crisis is a product of very rich people using and consuming vast amounts of energy. Any proposed solutions to our current existential ills must thoroughly address the class differences responsible for creating them in the first place. Specifically, we must ensure that the transition to an ecological order ends up helping the poor and the working classes while hurting the capitalists, who are mostly responsible for global warming and the planet's other ecological disasters. Western plutocracies have rolled out various market-based taxing and pricing

> *Under modern capitalism, the class structure of our societies can be broadly divided into three categories: employees, managers, and capitalists... a plutocracy in which a small group of rich people have completely hijacked the political process and thumbed their noses at any demands for democratic change.*

---

48 ↩ Nicolás Misculin and Gabriel Burin, "How a Year of 'Endless Storms' Battered Argentina's Economy," *Reuters*, December 20, 2018.

49 ↩ Adam Wernick, "Climate Change Is the Overlooked Driver of Central American Migration," *PRI*, February 6, 2019.

50 ↩ Rupam Jain, "In Parched Afghanistan, Drought Sharpens Water Dispute with Iran," *Reuters*, July 16, 2018.

51 ↩ Heinz Schandl et al., *Global Material Flows and Resource Productivity* (Paris: International Resource Panel, 2016), 40.

52 ↩ Frédéric Simon, "Decoupling Energy from GDP Growth 'Might Be Impossible,' Statoil Says," *Euractiv*, June 15, 2017.

53 ↩ "Summary for Policymakers of IPCC Special Report on Global Warming," Intergovernmental Panel on Climate Change, October 8, 2018.

54 ↩ Brady Dennis and Chris Mooney, "We Are in Trouble: Global Carbon Emissions Reached a Record High in 2018," *Washington Post*, December 5, 2018.

schemes designed to reduce the consumption of fossil fuels, but have been largely oblivious to the fact that these proposals would hurt the livelihood of common people. The proper way to shield the masses during this transition is to establish stronger social control over the production and distribution cycles around fossil fuels and then to impose temporary price controls at the point of consumption. The capitalists lose out on their profits, as they should after having trashed our ecosphere, and the masses do not have to face any sudden sticker shocks.

Under modern capitalism, the class structure of our societies can be broadly divided into three categories: employees, managers, and capitalists. We define capitalists as individuals who earn such large incomes from their assets and companies that they can avoid wage work altogether, if they so choose. In the context of the United States, a rough approximation of a (small) capitalist would be anyone with a net worth greater than $10 million in liquid financial assets—which is not to deny the issue of scale here, with some capitalists having incomes of more than $100 million a year. Of course, plenty of capitalists do engage in wage work, such as CEOs of large multinational corporations. But the point is that, for the lucky capitalists, work is not a necessity; they could maintain their current standard of living without a formal salary. They could easily retire to the Bahamas next week and just live off the income flowing from their assets, such as stocks, equities, real-estate properties, and any companies they may own. However, this option is not available for the vast majority of people in society. Managers and employees both need salaries to survive and to purchase the commodities that enrich the capitalists. In addition, most workers increasingly live a life of debt servitude, in which they owe capitalists lots of money for going to school, buying a home, and using a credit card, among other things. The financial control that capital has over the rest of society also makes it very difficult for workers to demand higher wages and better living conditions. The result is a plutocracy in which a small group of rich people have completely hijacked the political process and thumbed their noses at any demands for democratic change.[55]

Despite these challenges, the social and ecological imperatives for a new direction are growing rapidly every year. A democratic, ecological, and socialist civilisation would substantially limit the commodification of natural resources while also linking the fate of the richest to that of the poorest. It would guarantee these six universals to all people: food, jobs, housing, health care, child care, and education. It would restrict and constrain the accretion of wealth. It could do so by imposing wealth taxes on capital and by socialising large parts of the economy, allowing a limited and tightly regulated market to survive. Capitalists all over the world are hoarding vast amounts of financial wealth, which they refuse to invest in the real economy because of low growth rates that offer few opportunities for excessive profits. Governments should seize the vast majority of this wealth and invest it in the improvement of social services, the rebuilding of infrastructure, and the delivery of affordable health care. To substantially reduce and permanently control income disparities, society could mandate that the highest salary in any company or organisation be restricted to no more than ten times the lowest salary.

By providing greater resources to the masses, a democratic society would also rescue our families from an escalating list of crises. Capitalism has torn apart the social fabric and crippled modern families by treating workers like cogs in the corporate machinery.

By providing greater resources to the masses, a democratic society would also rescue our families from an escalating list of crises. Capitalism has torn apart the social fabric and crippled modern families by treating workers like cogs in the corporate machinery. More and more families are stressed, depressed, and increasingly feeling alienated from a ruling class that no longer seems to care. An economic system that works for common people would empower families, strengthen relationships, and help kids grow into responsible adults. Part of helping families means that society should

55 ↩ See Ronald P. Formisiano, *Plutocracy in America* (Baltimore: John Hopkins University Press, 2015).

> *Instead of organising our societies and economies around the principle of growth, we should organise them around the principle of sustainable human development, which requires the metabolic stability of the wider ecosphere... The social and the ecological are inseparable, and together they represent the intensifying political battleground of this millennium.... The impending convergence of crises, from the economic to the ecological, demands nothing less than a new vision for our social order.*

also invest in rural communities that have been destroyed as jobs and assets flow to wealthy cities. These public investments should include the creation of well-paying jobs, the construction of new clinics and hospitals for easier access to medical services, the delivery of regular cash payments to low-income households, the installation of fibre-optic cables for faster Internet, and infrastructure spending on roads, schools, and homes. Only by providing a critical balance of economic and political concessions to rural areas can we prevent the urban plutocracies from dictating terms to the rest of society. An ecological society would strive to make the allocation of resources between cities and the countryside far more equitable than the one-sided relationship that currently predominates under capitalism.

Our political and business leaders, indoctrinated by capitalist propaganda throughout their lives, have come to believe that economic growth is like a magical elixir capable of curing all evils. For most people in the modern world, it does not seem like an alternative to economic growth, as currently calculated under capitalism, is even conceivable. But imagining and realising these important alternatives may be the only way to spare human civilisation from a looming disaster. Instead of organising our societies and economies around the principle of growth, we should organise them around the principle of sustainable human development, which requires the metabolic stability of the wider ecosphere. By tightly constraining the levels of production and consumption around some dynamic equilibrium and emphasising qualitative human-social relations, as opposed to the cash nexus, we can avoid the periodic bubbles and crises of capitalism while also prolonging the duration of human civilisation. And by distributing more wealth and resources to workers and common people, we can build a fair society untroubled by recurring spasms of political and economic instability. The social and the ecological are inseparable, and together they represent the intensifying political battleground of this millennium. Future generations will judge us harshly if we fail to seize this exceptional moment in history. The impending convergence of crises, from the economic to the ecological, demands nothing less than a new vision for our social order.

Related links:

- The Jus Semper Global Alliance
- Monthly Review
- Erald Kolasi: The Physics of Capitalism
- John Bellamy Foster and Alejandro Pedregal: The Return of Nature and Marx's Ecology
- John Bellamy Foster: Marx's Open-ended Critique — Two hundred years after Marx's birth, the real struggle is only just beginning…
- John Bellamy Foster: The Long Ecological Revolution
- John Bellamy Foster: Marxism and Ecology
- John Bellamy Foster and Brett Clark: The Expropriation of Nature
- Intan Suwandi: Labour Value Commodity Chains — The Hidden Abode of Global Production
- Álvaro J. de Regil: Transitioning to Geocratia — the People and Planet and Not the Market Paradigm — First Steps
- Paul Burkett: An Eco-Revolutionary Tipping Point? — Global Warming, the Two Climate Denials, and the Environmental Proletariat
- Ian Angus: When Did the Anthropocene Begin… and Why Does It Matter?

❖ **About Jus Semper:** The Jus Semper Global Alliance aims to contribute to achieving a sustainable ethos of social justice in the world, where all communities live in truly democratic environments that provide full enjoyment of human rights and sustainable living standards in accordance with human dignity. To accomplish this, it contributes to the liberalisation of the democratic institutions of society that have been captured by the owners of the market. With that purpose, it is devoted to research and analysis to provoke the awareness and critical thinking to generate ideas for a transformative vision to materialise the truly democratic and sustainable paradigm of People and Planet and NOT of the market.

❖ **About the authors: Erald Kolasi** is a research associate in the Income and Benefits Policy Center at the Urban Institute. He develops computer models and simulations designed to study the effects of proposed retirement and economic policies. His research areas include state and local pension systems, Social Security, and the federal budget. Kolasi received his BA in physics and history from the University of Virginia and earned his MS and PhD from George Mason University, both in physics.

❖ **About this paper:** This paper was originally published in English by Monthly Review magazine in June 2019. This paper has been published under Creative Commons, CC-BY-NC-ND 4.0. You are welcome to reproduce the material for non-commercial use, crediting the author and providing a link to the original publisher.

❖ **Quote this paper as:** Erald Kolasi: Energy, Economic Growth, and Ecological Crisis – The Jus Semper Global Alliance, May 2021.

❖ **Tags:** Capitalism, Marx, Marxist Ecology, Metabolic Rift, Political Economy, Theory of Economic Growth, Physics, Energy dissipation, Thermodynamics.