# "How entropy drives us towards degrowth"

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## Introduction

A voracious beast devours the equivalent of an entire Mount Everest's worth of resources every 20 months. It also accelerates its metabolism, reducing this timeframe to just 10 months within the next two decades.[1] As it fills its belly, the beast exhausts its environment and burdens it with waste, disrupting natural systems for resource renewal and waste management. Ultimately, it annihilates its own habitat. I am, of course, referring to global capitalism.

This system demands continued accumulation of capital and falters when hindered in this process. The typical response to the ecological crisis is therefore not to restrict economic growth but to pin all hope on efficiency, circularity, dematerialization, decarbonization, and other profit-driven green innovations within capitalism. In this exposition, I argue that this hope is false because entropy always looms. Entropy serves as a physical measure of disorder, and we observe its inexorable increase all around us: everything decays, rots, disintegrates, and falls into disorder. Simultaneously, the biosphere establishes order through processes like photosynthesis, ecological succession, or cellular regeneration. These natural processes delay and reduce entropy.

In this article, I demonstrate how the capitalist system disrupts this equilibrium by raising entropy and overwhelming natural entropy-reducing processes. I then argue that circular and other green economies are trapped in fruitless efforts to divorce growth from its detrimental ecological effects. We must consider the idea of an economy that doesn't necessitate expansion. I therefore conclude by endorsing the radical proposition of *degrowth*.

## Conservation of energy

The environmental crisis stems not merely from a quantitative imbalance between available resources and their consumption by the world economy but also from the qualitative deterioration of matter and energy coursing through the economy. To comprehend this, we must turn to thermodynamics, a branch of physical science that explains how energy transforms from one form to another, following a few fundamental natural laws. Given the complexities of thermodynamics, I'll strive to present the arguments in a tangible manner.

In the heart of a forest, a monkey finds concentrated chemical energy in the form of a banana. The monkey quickly converts the banana into usable energy to maintain its physical condition, climb trees, fight enemies, and so on. *The first law of thermodynamics states that energy can change forms but*

[1] Calculated on the basis of Krausmann et al. 2018 en UNEP & IRP 2017.

*cannot be created or destroyed*. The initial chemical energy held within the banana transforms into: chemical energy regenerating cells in the monkey's body, kinetic energy fueling its physical activities, and thermal energy radiating as body heat. The same principle applies to natural gas: when one measures the energy contained in a cubic meter of natural gas and burns it to run a generator, the energy stored in the natural gas equals the energy consumed in electricity generation plus with the heat released by the generator. In short: *energy changes form but never disappears*.

**The Entropy Law**

Why do we face an energy crisis when energy is indestructible? The second law of thermodynamics, also known as the Entropy Law, holds the answer. When we turn off the heating in our house, the heat from the radiator will disperse and seep through the walls until a state of 'thermal equilibrium' is reached, meaning that the indoor and outdoor temperatures are equal. At this point, entropy, a measure of energy dispersion, reaches its maximum. *According to the Entropy Law, thermal energy flows spontaneously from a hotter body to a colder one, never the reverse*. If we do not restart the heating system, the heat will eventually escape into the outside world, and new energy will be needed to raise room temperature once more. Inevitably, this newly added energy will also dissipate, rendering it unavailable for further use. This encapsulates the essence of the energy crisis.

The Entropy Law applies not only to heat but to energy in general. A charged battery contains concentrated chemical energy. When connected to a device, this chemical energy transforms into electrical energy that spontaneously flows out of the battery. Essentially, the Entropy Law dictates that energy moves naturally from areas with high energy concentrations to areas with lower concentrations, resulting in an increase in entropy. The radiator from the earlier example held a higher concentration of thermal energy than its cooler surroundings, causing this energy to radiate outwards. In short: *energy flows from high to low concentrations*.

This dispersion of energy also affects matter. For example, it can lead to food spoilage, metal corrosion, and clothing wear and tear. This deterioration occurs through the spontaneous release of energy that binds atoms and molecules together. According to the Entropy Law, both energy and matter therefore tend to disperse, increasing overall entropy. This process also underlies the gradual breakdown of our cells. " Entropy carries a rather ominous connotation," my partner once remarked.

**Energy Consumption and Inefficiencies**

Fortunately, other natural processes operate in the opposite direction; otherwise, bananas would never grow. But how does energy become concentrated when, following the law of entropy, it spontaneously disperses? The answer lies in a sub-law of the Entropy Law: *heat can only flow from a cold body to a warm body by 'performing work' in the physical sense*. This means that additional energy is required to transfer energy from a dispersed to a concentrated state. For example, a radiator only emits heat after a heating system has concentrated thermal energy. A battery only delivers electricity after a charger has performed work by concentrating the chemical energy. Likewise, a monkey must perform work by picking and digesting bananas to replenish the lost chemical energy and concentrate it in its body. In short: *energy concentration requires supplementary energy*.

But beware, there's a catch: 'work' comes at a cost. Work can reduce entropy locally, but it consumes energy from an external source, thereby increasing entropy elsewhere. The monkey maintains its own low entropy by eating bananas but causes an increase in entropy in the forest through discarded banana peels, body heat, and feces. Gas heaters counteract heat loss but achieve this reduced indoor entropy at the expense of elevated entropy in the biosphere through the extraction, purification, delivery, and burning of low-entropy natural gas.

And there's another catch: total entropy net increases. *A second sub-law of the law of entropy states that no energy transfer to useful work is 100% efficient*. Work is deemed 'useful' when it diminishes entropy. As previously mentioned, our primate friend eats bananas to maintain relatively low entropy in its body. However, energy losses transpire during the energy transfer from banana to monkey in the form of food waste and perspiration. Not only does the monkey lower its own entropy at the cost of an increase in the forest, but due to these losses, the reduction is smaller than the increase. Useful work always entails losses, like the residue of peanut butter left on your knife after breakfast. In short: *Energy conversions are never 100% efficient*.

**Entropy and the Economy**

What do these natural laws mean for the economy? In the 1970s, Nicholas Georgescu-Roegen, the pioneer of ecological economics, foresaw the inevitable demise of capitalism, primarily due to its inherent tendency to escalate entropy.[2] He demonstrated that the economy involves not just a circulation system but also a digestion system directly connected to the environment at both ends. The growth rate of the economy essentially signifies the pace at which we transform low-entropy resources into high-entropy wastes. Fossil fuels enter our economy as organized matter and energy but exit as dispersed heat, chemicals, carbon dioxide, and microplastics.

We delude ourselves when we assume that our economies can establish order by converting low-entropy natural resources into materials with even lower entropy. This semblance of order is deceptive, as the production process invariably entails an increase in entropy in the environment. The purification of ores into usable materials may reduce entropy in the materials themselves, but the purification process requires external energy sources (as dictated by the first sub-law of the Entropy Law) and inevitably incurs energy losses (as dictated by the second sub-law of the Entropy Law), thereby augmenting the overall entropy. So, a lower entropy of semi-finished products compared to the materials from which they are produced does not mean that the law of entropy has been violated.

**Nature's Counterbalance to Entropy**

So far, I have mainly discussed how entropy increases, but what about its decrease? When monkeys eat bananas, they increase entropy in the forest. How can the forest then produce new bananas? The forest can recycle peels and feces, but this waste contains insufficient energy to produce new bananas because the monkeys have used up the difference. Nature steps in to compensate for this deficit through the inexhaustible energy of the sun. The biosphere taps into solar power to perform 'useful work,' namely concentrating dispersed energy and matter into the form of new bananas (as dictated by the first sub-law of the Entropy Law). A healthy and well-functioning biosphere thus stands as the only force on Earth capable of counterbalancing the rise in entropy.

Nonetheless, nature has its limits when it comes to absorbing and recycling waste streams. For example, banana regeneration depends on the rates of photosynthesis, nutrient uptake, tree growth,

[2] Georgescu-Roegen 1971

and fruiting. These rates also limit the monkeys' rate of reproduction. In contrast to the metabolism of a group of forest monkeys, the metabolism of the destructive beast called capitalism expands too fast for the biosphere to keep up. Ecosystems have evolved over millions of years to optimize energy consumption in ecological food webs and to delay and reduce entropy through biodiversity. Tragically, growth-oriented economies do the exact opposite by pushing against this natural order and increasing entropy at a devastating rate.

And when nature imposes limits, capitalism actively seeks ways to circumvent them, inevitably leading to new limits. As an illustration, we develop monocultures to facilitate mechanical agriculture, but as a result, the soil dries out. In response, we introduce irrigation, which then depletes groundwater, and so we come up with drought-tolerant crops. When these crops degrade soil life, we come up with something else. Unfortunately, this pattern carries grave consequences, as evidenced by the ongoing climate crisis and biodiversity decline. Capitalism, in its pursuit of relentless growth, damages the very biosphere it relies on to mitigate its entropy-amplifying activities. If we stay on this path, the planet faces a bleak future as an environmental wasteland.

## Decoupling the economy from Nature?

Can we not combat entropy through frugal and circular production? The typical response to the ecological crisis isn't to slow down growth but to rely on dematerialization and circularity. However, "green capitalism" cannot maintain itself, let alone grow, by merely reusing its own waste and by-products. Just as monkeys require fresh bananas from the forest and can't survive on their own feces, production systems require new input of low-entropy matter and energy to function. The same goes for a forest that depends on solar energy from space and can't survive solely on falling leaves. Shifting to biomass as a raw material for production also won't save green growth as it will intensify pressure on land, water, and soil.

At first glance, it may seem that there remains immense potential for circularity and efficiency, given that the global economy recovers less than 10% of waste material[3] and retains only 28% of global primary energy consumption after conversion.[4] Nevertheless, substantial constraints arise long before reaching 100% circularity and efficiency. The potential for circularity is restricted to a mere 29% of total throughput. The remaining portion includes food and energy that have undergone irreversible degradation, along with net additions to buildings and infrastructures unavailable for recycling.[5]
Even achieving that 29% will be difficult. As explained, the reconcentration of dispersed materials requires energy investments and comes with inevitable transmission losses that increase overall entropy. Energy consumption increases as recycling rates increase, and energy itself can't be recycled. And even if we had access to inexhaustible renewable energy sources, closed loops won't be established for agrochemicals, coatings, lubricants, adhesives, inks, and other complex materials for which recycling technology is not available.

Let me emphasize: even though we are far from achieving 100% circularity and efficiency, the laws of nature will always obstruct us from attaining such a goal. To counteract all unavoidable losses and inefficiencies, we require a constant influx of fresh, low-entropy matter and energy. This requirement holds true for circular economies and other green growth models as well. The encouraging news is

[3] UNEP & IRP 2020

[4] Forman et al. 2016

[5] Haas et al. 2015

that the biosphere can convert certain types and quantities of waste back into raw materials. However, we should not anticipate the biosphere to sustain this service at the same accelerating pace at which our economies increase entropy.

## In Search of Radical Alternatives

Our presumed dominion over nature is an illusion. No matter how clever technological innovations may seem, they remain subject to the laws of thermodynamics. Consequently, a growth-centered capitalist economy finds itself trapped in futile attempts to completely decouple itself from nature – aiming for a 100% circular, service-oriented and zero-waste existence. This obsession stems from an incapacity to imagine an economy that does not grow, where both the quantity and quality of its metabolism remain within secure ecological and planetary boundaries.

Hence, we must seek radically different pathways (the Latin *radix* means root). One such alternative is *degrowth*. In the broadest sense, degrowth represents a socio-economic transformation aimed at reducing and redistributing material and energy flows, with the goal of respecting planetary boundaries and promoting social justice.

The growing metabolism of the voracious beast with which I began this article has unevenly distributed burdens and benefits. World trade has resulted in a net outflow of low-entropy resources from the poorer areas of the world[6] and an inflow of high-entropy waste back into those same areas.[7] This has the consequence of depriving the poor of vital resources and damaging their local ecosystems, while wealth continues to accumulate for a small minority.

The argument for degrowth extends beyond a response to the ecological crisis and includes the pursuit of a more just system. The voracious beast must yield to the turtle. As a child, my parents gave me a small turtle. Over time, I noticed that it stopped growing before it became too large for the aquarium. Nevertheless, we bought a larger aquarium, and the turtle resumed its growth. But once more, it stopped before becoming too big. Although the turtle no longer grew in size and weight, it continued to change in its proportions, colors and behaviors. Thus, the end of growth does not mean the end of development but rather the opportunity to free ourselves from the compulsive and ruinous capitalist system. This will enable us to lead a healthier, more social, sustainable, and just life.

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[6] Dorninger et al. 2021

[7] Hornborg 2009

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