Countering Climate Change With “Greener” Economics

By Robert U. Ayres , INSEAD

Truly understanding the fundamental role of energy in the economy is key to a more sustainable future.

“Spending more money” has long been seen as an equitable reward for the creation and accumulation of wealth. But, as I have argued in my work spanning more than six decades, how we make money is more important than how we spend it. If the goods and services that we produce leave behind a vast trail of waste, this can easily outweigh their benefits to society and ultimately make the world a poorer place, not to mention a more perilous one.

Humans are producing more waste than ever before. The oceans are a plastic dump and industrial pollution is choking the air. We are injecting massive amounts of fertilisers to make plants grow and neglecting the toxic consequences for freshwater aquifers. Life-sustaining tropical forests are

being destroyed to clear land for logging, cattle raising and livestock. The consequence of that is loss of habitat for many species of animals and birds that we – and our children – would like to preserve.

Alarmingly, **some well-known economic models predict** that global warming of the planet by a couple of degrees Celsius can be "accommodated" by the economy as it is. These models predict that GDP would decline only very slightly if global temperatures were to rise by two degrees. These scholars dangerously underestimate the impact of climate change on all industries and our economies.

Exergy is what matters

We know that climate change is mainly a consequence of carbon dioxide accumulating in the atmosphere. The combustion of fossil fuels like coal, petroleum and natural gas is the main culprit. One of the reasons the levels are so high is because of our inefficient use of energy from nature. This is where the notion of exergy comes in.

All transformations on earth require exergy to be "activated". This is the share of energy that can be put to productive use, i.e., to do "useful work" (overcoming inertia) in the engineering sense, like pumping water, lifting weights or propelling a ship. Exergy comes directly from the sun as photovoltaic electricity, indirectly as power from falling rain and flowing water, or as biomass from photosynthesis.

Exergy is the fundamental and unique "factor of production": it is the only "substance" that is needed to drive any transformation of material inputs into material outputs. According to the first law of thermodynamics, materials can be transformed, but do not disappear. All possible transformations are driven by the dissipation of exergy; therefore transformations consume exergy to perform useful work. The second law of thermodynamics tells us that degraded materials can be recycled (by consuming exergy) but the degraded exergy cannot be used again.

Economists need to consider externalities

While some raw materials are replenished by natural processes, many scarce elements are not. Not only are we using – but not recycling – finite natural resources, our current industrial production processes are leaving behind dangerous wastes. If these are not effectively disposed or detoxified, they

will impose an increasing cost on our children and grandchildren. These costs were labelled “externalities” in a **paper I published with Allen Kneese** in *the American Economic Review* more than 50 years ago.

In this now widely cited paper, we argued that economic models need to recognise the harmful by-products of consumption and production, such as wastes and emissions, in a total cost framework. We argued that the benefits of current activities should always factor in hidden future costs. The most obvious, but not the only example, is the cost of climate change.

Five decades later and counting, economic theorists have not sufficiently adjusted their mindsets and models. This is concerning as policymakers rely on those theories for policy decisions. As a result, governments have still not implemented regulations to seriously clamp down on the externalities associated with exergy consumption. This negligence has hindered the necessary transition to sustainability and has further fuelled the climate crisis we are now in.

Our economy is an “island of order” far from equilibrium

Current economic models, based on ideas dating back to 1870, generally consider the economy as a closed system where everything produced in the system is consumed in the system. In such an equilibrium, all economic activity can continue forever without anything changing. The economy works like a Swiss clock that does not need rewinding.

Such models incorporate three false axioms that have catastrophic implications. First, at the input stage they do not take into account the “free” contributions the earth makes to the economy through nature’s recycling capacities. Second, they assume that the global economy is always approaching equilibrium. Growth in equilibrium is thermodynamically impossible.

Third, existing models do not consider all of the externalities generated by decisions regarding transformations, from production to consumption of end-products. Hence, they ignore waste accumulation in the atmosphere or in the oceans.

Instead of thinking about the economy in terms of sustainability, it is more accurate to describe the economy as an “island of order” that exists far from both thermodynamic and economic equilibrium. This is in line with the views

of physical chemist Ilya Prigogine, who received the **Nobel Prize in Chemistry in 1977** for his work.

The economy is a living, dynamic system, in constant evolution and seeking order at the cost of introducing greater complexity and interconnections.

Exergy as the main driver of economic growth

Neoclassical economists consider capital and labour as the key “factors of production”, even though most work converting raw materials into useful products is done by machines driven by exergy. Without accounting for exergy, it is as if the economy is unaffected by energy constraints. It also incorrectly implies that energy-related emissions, such as greenhouse gasses, can be reduced or eliminated without consequences for growth.

In previous **studies**, Benjamin Warr and I demonstrated that exergy is crucial for predicting economic growth. By analysing the energy inefficiency of economies like that of the **United States,** we demonstrated that energy consumption can explain the part of economic growth that was typically (and magically) attributed to endogenous “technological progress". Our view is that a country’s output over time is limited and should be explained by the flux of exergy captured from various sources that is needed for the economic system to deliver its goods and services.

Unfortunately, knowing that exergy has always been at the source of economic growth does not tell us much about the future. We need to know how much will be used for space heating, mining, manufacturing, transportation, distribution, agriculture, health services, education, entertainment, defence, law enforcement, IT and so on. And this hugely depends on the conversion efficiency of energy into exergy. Only then can we estimate the future rates of growth and energy inputs per unit of output produced in each sector, in each country.

Cutting greenhouse gas emissions is important, for climate reasons, and the world increasingly understands this. What we don’t fully realise is that energy efficiency is likely the central strategy for economic growth in the future. We can see that space heating and transport are obvious opportunities for increasing efficiency. **Vertical farming** is one example of how built-up cities can reduce the environmental impact of agriculture and improve its energy efficiency.

The harsh reality is that if we continue along the current path of extremely inefficient energy use, we are headed for social, economic and environmental catastrophe. The “good” news is that because our current energy efficiency is low, significant improvements are possible. We need to better rely on and exploit common renewable energy sources that electrify and energise the planet, such as solar power, wind power, hydro power and even ocean energy.

By integrating the laws of physics with economic theory and recognising the open nature of the economy, as **I have outlined** for the past five decades, economic theory will do a better job at counteracting the current climate crisis.

This article was edited in collaboration with Brian Henry.

Find article at
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About the author(s)

Robert U. Ayres is an Emeritus Professor of Economics and Political Science and Technology Management at INSEAD and the Novartis Chair in Management and the Environment, Emeritus. His most recent book is “The History and Future of Technology”.