MARK RALSTON/AFP/GETTY

Melting permafrost near the town of Quinhagak, Alaska.

millennia ago. The Neolithic and Bronze Age dwellings at Links of Noltland have been exposed over decades by ferocious winds. Now the site is threatened by erosion — and funding issues. The excavations are something of a sprint.

When not scraping through layers of time and materiality, Jamie explores the store of finds — the biggest assemblage of Neolithic objects found in Britain. She is beguiled anew by worked bone and stone, from putative tattooing implements to the 'Westray Wife': a tiny sandstone figure with intent eyes, "ancestral and watchful". But when Jamie imagines which object might be sent into space as an emissary to alien cultures, she opts for a Neolithic stone ploughshare. Ugly and functional, it marks the start of how we've tamed and trashed the wild under "the weight of our stuff".

In the 1980s, Jamie travelled widely in remote regions of Asia: her 1992 book *The Golden Peak* recounts her time in northern Pakistan. A journey from that era — to Xiahe, a culturally Tibetan town in Chinese territory — unfolds in *Surfacing*. To reconstruct those weeks at a borderland fraught with uncertainty, Jamie turns domestic archaeologist, burrowing into piles of notebooks and photographs. Through them, she re-enters the "womb-like otherworld" of a temple at Labrang Monastery, meets Chinese students eager to build cultural bridges and joins a gaggle of fellow travellers escaping oppression in Europe. They have arrived, however, only to witness Tibetan culture besieged. The parallel with Yup'ik history is clear.

Surfacing is rich in such mirrorings and mergings. Spirals — carved into the Westray Stone, a magnificent tomb relic — crop up on a ceramic sherd in a newly ploughed field. The motif, she notes, symbolizes how unrelated events can "wheel back into proximity". And so they do, in the life trajectories of Jamie, her daughter and her father, and in the rise and fall of human settlements. Blazing moments light the way: an eyeful of eagle over a Scottish road, sockeye salmon in an Arctic stream "like silk slashes in a Tudor sleeve".

At one point, Jamie is midway through a forest somewhere in Scotland, grappling with how to frame the wars and environmental destruction that crowd our collective consciousness. She realizes she is lost. I found myself thinking of Dante Alighieri, coming to himself at life's midpoint "in a dark wood" as *The Divine Comedy* opens. But this is a book shrugging off literary allusions. Jamie comes to things openly, listening and looking. And as she shows throughout this astonishing work, it is in looking — attuning ourselves to nature and culture, past and present — that we find our compass. ■

Barbara Kiser *is* Nature*'s senior editor for Books and Arts.*

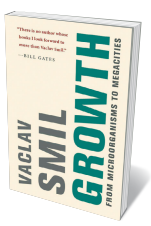
RESOURCES

The energy crunch

Vaclav Smil's latest book computes the cost of growth on a finite planet. **Melanie Moses** praises the result.

In 70,000 years, *Homo sapiens* has grown from thousands of hunter-gatherers teetering on the brink of extinction to a global population of 7.7 billion. In *Growth*, Vaclav Smil explains how we have peopled the planet through our growing capacity for harvesting energy from our environment: food from plants, labour from animals and energy from fossil fuels. Civilization has developed by dominating Earth's resources. Smil, whose research spans energy, population and environmental change, drives home the cost of growth on a finite planet. It is high: polluted land, air and water, lost wilderness and rising levels of atmospheric carbon dioxide.

He argues that most economic projections predict growth by ignoring the biophysical reality of limited resources. Economists emphasize that efficient use enables growth without pumping up energy consumption. Smil does not deny that energy efficiency has increased. For example, he details how agriculture now extracts ten times as much food energy from each parcel of land as it did a century ago. But the 10-fold increase in yield has been driven by a 90-fold boost in energetic inputs — caused by fossil-fuelled farm machinery, and electricity for irrigation and fertilizer production. When this complexity is accounted for, the story of efficiency is turned on its head: we now put more fossil-fuel energy in for each unit of food we get out.



Growth: From Microorganisms to Megacities
VACLAV SMIL
MIT Press (2019)

On a crowded Earth, we mostly address this challenge by eating up more land. A 2019 report from the Intergovernmental Panel on Climate Change, called *Climate Change and Land*, shows that we are in danger of running out of space: humans shape more than 70% of ice-free terrain, much of it for crops and livestock. As grasslands and forests are converted to

PAULO FRIDMAN/BLOOMBERG VIA GETTY

Agriculture now has much bigger yields than it did a century ago, but also requires vastly more energy input.

agriculture, the land is no longer available for carbon storage or biodiversity-sustaining wilderness. Human history is a story of innovation and increased efficiency, but also of relentless depletion of Earth's resources. Is there a path to prosperity and well-being that does not rely on overconsumption?

Growth is not optimistic. There are no solutions to reconcile our species' burgeoning consumption with a viable future. Instead, Smil focuses on simple equations that can be used to model (but rarely predict) growth and the energetic, physical and biological principles that are its foundations. He amasses examples of seemingly disparate systems that start small, enter a phase of exponential increase and then plateau.

In some cases, the trajectories tip into dramatic decline, as happened with video tapes and CDs. In others, a decline can rebound. US oil production, for instance, was in decline from 1970; with the expansion of hydraulic fracturing, or fracking, a decade ago, it rebounded. In 2018, it surpassed its 50-year-old peak. Smil shows repeatedly how beautifully fitting models have failed to predict the future.

Lurking beneath the modelling suppositions and assumptions lie some inescapable facts, he shows: the physical law of conservation of energy, the limited resources on our planet and mathematical constraints on how those resources can be converted to human use. On this foundation, we cannot continue to add 2 billion people every 25 years.

As energy use has increased, per capita gross domestic product and life spans have risen while birth rates and infant mortality have fallen. Smil admits that disentangling cause from effect and fundamental drivers from correlative happenstance is enormously difficult. However, he argues that energy is essential to the growth of our immensely complex modern civilization because it is required to do work. Every baby born, bit transmitted, material moved demands energy.

Growth draws facts and figures from Smil's other books, for a quantitative accounting of just how much energy we consume. He estimates that our hunter-gatherer forebears consumed energy per capita for food and firewood equivalent to 5–6 gigajoules per year. People in high-income countries now consume 50 times that, mainly from fossil fuels. We have turned this energy into travel that is 100 times faster than in ancestral societies; weapons that are thousands of times as destructive; and a nearly infinite increase in stored information.

"Human history is a story of innovation and increased efficiency, but also of relentless depletion of Earth's resources."

This is an astounding return on our investment, but Smil is sceptical of the "techno-optimists" who envision solutions to our immense challenges coming from greater efficiency, shrinking material inputs to economic production, or information technology. He looks at technologies such as smartphones, laptop batteries and supercomputers, in which growth follows Moore's Law — computing capacity doubles approximately every two years. In that exponential growth, he sees no hope of solving environmental crises.

As for the cost of computing, it has, in Smil's estimate, fallen an astonishing 100 billion times since the days of vacuum tubes. But again, he sees little evidence that the 'saving' will save us from planetary crises, quipping that social media proves "convincingly that the volume of communication must be inversely related to its quality". Our most spectacular technological achievements have, thus far, done little to abate our impact on the planet. Many have exacerbated it.

Smil is particularly sceptical that an artificial-intelligence (AI) singularity of exponentially self-improving machines can save us from the impacts of growth. AI has so far recapitulated trends Smil describes over human history: generating more powerful weapons and information, but little reduction in the destruction of resources. However, it seems only rational to leverage AI and computational approaches that are revolutionizing other scientific disciplines to help solve planetary-scale problems by spurring innovation and identifying economic and technological solutions. Smil devotes relatively few pages to how solar power and other types of renewable energy could grow fast enough and with a small enough footprint to be a viable path to a sustainable energy future. Yet so far, solar energy has a promising Moore-like growth trend in efficiency, while rapidly falling in price.

Growth urges us to think differently. That is desperately needed to manage the trade-offs in making renewables more efficient, improving economic incentives for fast adoption, minimizing environmental degradation and bettering lives in a swelling population. We face, after all, our most crucial singularity: a single planet whose resources have fuelled the spectacular growth of human civilization, and are now running out. ■

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CORRECTION

The book review 'The energy crunch' (*Nature* **573**, 344–345; 2019) misstated the energy consumption of hunter-gatherers; it should have been 5–6 gigajoules per year.