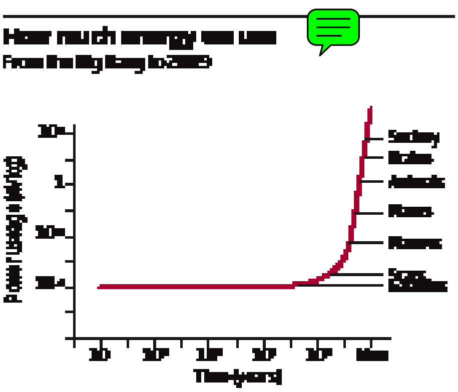
The heat to come…

Forget global warming for a moment, just going about our everyday lives could heat Earth by a devastating, extra 2 to 3 °C. Only one thing can save us from this knock-out punch, says astrophysicist **Eric Chaisson**

AFTER decades of debate and acrimony, science and society seem to have reached a consensus that greenhouse gases are increasing global temperatures. What is less clear to most people, however, is this: starkly put, even if we stop soiling our atmosphere with greenhouses gases, Earth will still get hotter. It is an inevitable consequence of the second law of thermodynamics.

This is the famous but elusive "entropy" rule which stipulates that order tends to crumble and energy tends to dissipate, and its main outcome is thermal waste. In the complex societies of the early 21st century, this means that as humans go about their daily business, they are polluting the planet with waste heat. Although it's imperceptible now, the heating of our biosphere could grow by several degrees over several centuries unless we stop using energy from non-renewable sources, and that means all non-renewable sources, from oil and coal to geothermal and nuclear power.

Civilisation has always run on energy and it always will. Energy is needed to power societies quite as much as it drives galaxies, stars, planets and life. All complex structures in nature are dynamic systems, and as such are sustained by flows of resources in and waste out. Whether living or non-living, organised systems need energy to endure.



Throughout the history of the universe, as each type of ordered system emerged and became more complex, its energy budget, or power density, increased. The graph (below left) shows how much energy is used by systems that have experienced, in turn, physical, biological and cultural evolution. So stars and planets have smaller power densities than plants and animals, and humans and societies have the largest.

"Energy flow threatens to overheat us, even if we do curb greenhouse gases"

Zero in on the "society" label in the graph, and the power density increase is clear. The rate of energy used in the "recent" past among our hominini ancestors goes like this: hunter-gatherers a million years ago used about 0.05 kilowatts per person ; agriculturists of several thousand years ago used about 0.5 kilowatts each; industrialists a couple of centuries ago used about 2.5 kilowatts and every resident of the affluent US now uses about 15 kilowatts.

These energy rates have clearly risen over the course of recorded and pre-recorded history, but not because of population growth: these are per capita increases caused by the cultural evolution and technological advances of our civilisation. What's more, given that world population is still growing, developing countries are still maturing technologically and humankind is still evolving culturally, it is likely that society's total energy budget will continue to grow worldwide, both individually and collectively.

Heat is an unavoidable by-product of the energy extracted from any non-renewable energy source. We already experience this in the big cities, which are warmer than the suburbs, and in the warmer waterways near nuclear reactors and conventional power stations. And in our digital lives, every last Google search creates heat in the web servers and each click of the keyboard generates heat in our laptops.

The emitted heat comes in part from the poor efficiency of everyday appliances. Electricity production is 37 per cent efficient, car engines 25 per cent, incandescent bulbs only 5 per cent, and so on: the rest is lost immediately as heat. In fact, all energy from all sources will eventually dissipate as heat.

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This is to do with the first law of thermodynamics: all energy is conserved, it cannot be created or destroyed.

Right now, the waste heating of Earth by its societies is indiscernible. Globally, we use about 18 terawatts, and the resulting increase in the temperature of the biosphere is less than 0.1 °C. But as our power needs multiply and become ever more complex, by the close of the 21st century these energy demands are likely to exceed 100 terawatts. Amazingly,

The heat really is on as societies become more complex and their energy needs multiply

even this figure will not heat our environment appreciably. Only when humankind's insatiable thirst for energy reaches a few thousand terawatts will significant waste heating of our globe occur.

Is this much energy a reasonable estimate, and if so when might a society using such quantities arise? Here's how the logic might play out, based on some likely trends. Let's suppose that world population plateaus at 9 billion inhabitants by 2100. Meanwhile, developed countries increase their use of non-renewable energy at 1 per cent annually, and developing countries do so at 5 per cent annually until east/west energy equity is achieved in the middle of the 22nd century. From then on, all countries continue increasing their energy use by 1 per cent a year.

The likely outcome is that a 3 °C rise will occur in about 300 years, even if we manage to sequester all greenhouse gases. And that 3 °C, remember, just happnes to be the very figure that the Intergovernmental Panel on Climate Change regards as a tipping point for producing drought, famine and mass extinctions. Scenarios like this imply that the heating effects from rising consumption of energy seem unavoidable sometime within the next millennium.

Of course there is a way out – and it doesn't take an astrophysicist to figure it. The heating that must occur because of the second law of thermodynamics comes only from non-renewable energy sources. That's because renewables, which come directly or indirectly from solar energy, are already accounted for in the thermal balance of our planet and their use would not additionally heat the environment of Earth. Nor, incidentally, would energy derived from solar-driven wind, water, and waves.

Is there enough solar energy to power civilisation? The answer is yes, and more. Sunlight landing on Earth's surface every day totals a whopping 120,000 terawatts, nearly 10,000 times the power currently used by all humans. And it is clean, abundant and free – provided we can learn to harvest it more economically. Most importantly, by using solar energy and its renewable derivatives, human societies would not add extra heat to the biosphere.

Energy has guided the varied changes that have given rise to life, intelligence and civilisation on our planet. Energy also now helps our species to untold health, wealth and security. Yet this same phenomenon – energy flow – threatens to overheat us, even if we curb greenhouse gases and adopt nuclear energy.

Some of my colleagues claim that this second law argument kills off all other arguments about the global environment on Earth – they think it may presage the ultimate collapse of our technological society. For myself, I just think that it is the single strongest scientific justification for using solar energy and its derivatives to power the future of our civilisation. ■

PROFILE

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This essay is based on a paper published in *Eos*, a journal of the American Geophysical Union, vol 89, p 253: http://www.tufts.edu/as/wright_center/eric/reprints/eos__agu_transactions_chaisson_8_july_08.pdf.

How much energy we use

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