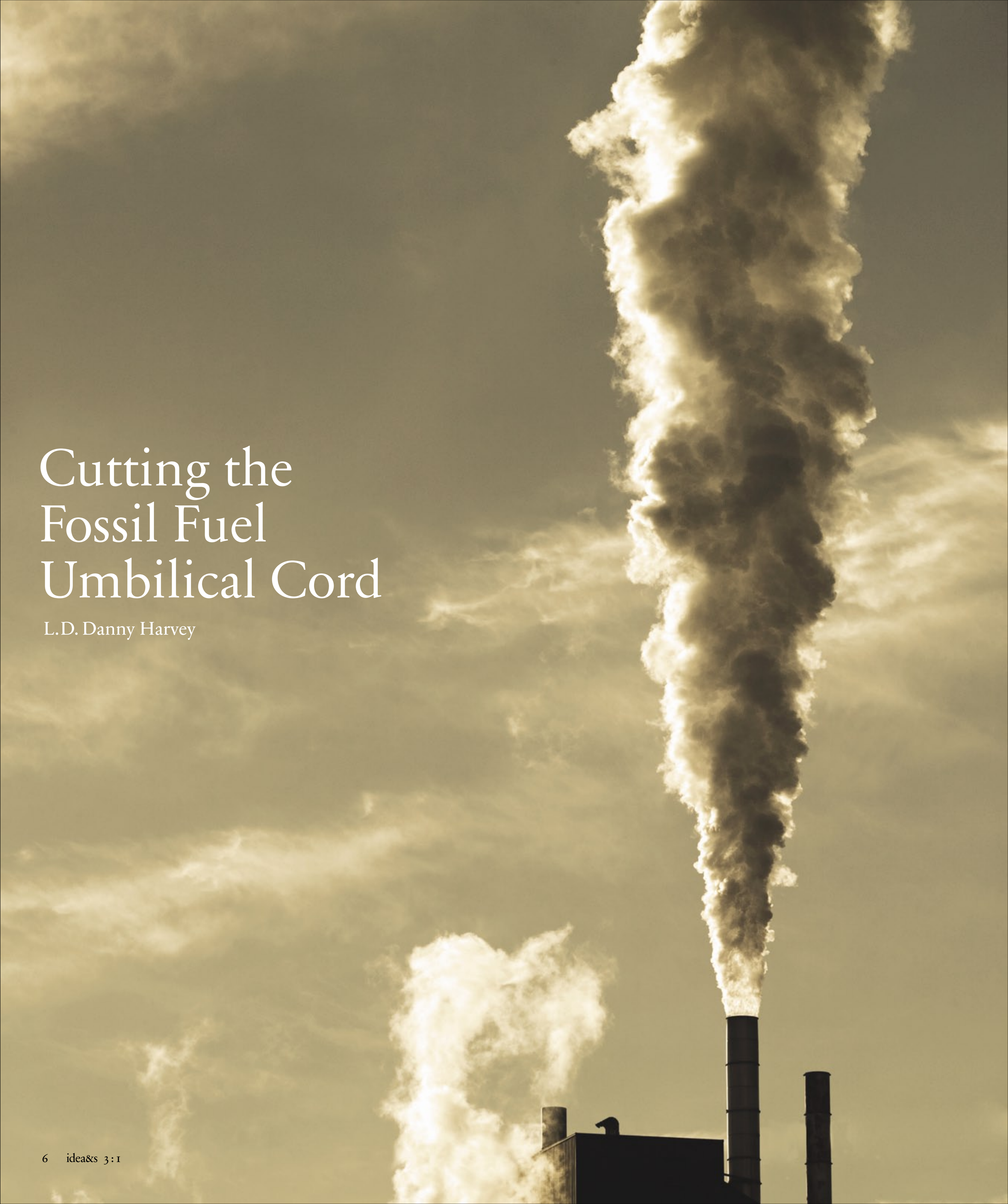

Cutting the Fossil Fuel Umbilical Cord

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A global mean warming of two Celsius degrees by 2050 will bring about the extinction of from one-sixth to one-third of terrestrial animal species and an abrupt increase in the number of people at risk from water shortages, hunger, malaria, and flooding. Do we have the moral right to risk such massive impacts?

As the snow that falls over central Antarctica is compressed and transformed into ice, the air between snowflakes becomes trapped within the bubbles that form. In this way, an archive of atmospheric composition through time is created. The longest published records extend back over 400,000 years. They reveal that two gases that trap the radiant heat which is emitted from the Earth's surface—carbon dioxide (CO_2) and methane (CH_4), the so-called "greenhouse gases" (GHGs)—have varied almost lock-step with the waxing and waning of ice sheets as the Earth's climate shifted from an interglacial to a glacial climate state, and back again. However, over the past two centuries, concentrations of these two gases have shot far above any level witnessed during at least the last 400,000 years. The CO_2 concentration is now more than 30 percent greater than it was prior to the Industrial Revolution, and there is over 2.5 times the CH_4. Furthermore, concentrations of both gases (and of other GHGs) continue to increase rapidly, with CO_2 projected to reach three, four, or even more times its pre-Industrial-Revolution concentration, under typical, business-as-usual scenarios of economic growth and energy use.

There is a perhaps unprecedented scientific consensus—based on computer models of the atmosphere and oceans, direct observations of key processes, and studies of ancient climates and recent global-scale temperature variations—that GHG increases of this projected magnitude will lead to significant, highly disruptive warming of the climate. The average global temperature will rise anywhere from three to six Celsius degrees by the end of this century, a warming comparable to the transition from an ice age to an interglacial climate—but 100 times faster.

In 1992, at the United Nations Conference on Environment and Development in Rio de Janeiro, Brazil, the world community adopted the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC sets out the principles which 180 countries—almost every sovereign nation in the world—and their legislatures have agreed should guide humanity's response to the risk of global warming posed by human-generated emissions of GHGs. Article 2 of the UNFCCC reads:

> The ultimate objective of this Convention . . . is to achieve . . . stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner.

In other words, GHG concentrations are to be capped at levels that protect ecosystems and food production and that do not undermine sustainable economic systems, which, being tied to renewable energy and biological resources, are climate-sensitive. Species and ecosystems are to be protected independently of any perceived value to humans, as part of a planetary trust to be passed intact to future generations.

The UNFCCC does not state what set of GHG concentrations constitutes "dangerous anthropogenic interference" (DAI). Indeed, there is no single set that represents a threshold for DAI; rather, as concentrations rise, there will be a growing risk of more widespread and more severe negative impacts. This threshold is, to some extent, a subjective judgement: Are concentrations that pose a one percent risk of loss of one or two major, irreplaceable ecosystems to be considered "dangerous," or does a 10 percent risk constitute the threshold for "dangerous"?

Nevertheless, several groups, including the Parliamentary Commission of the European Union, have recommended a maximum allowable global average warming of two degrees and a maximum rate of warming not to exceed 0.2 degrees per decade. However, recent assessments indicate that the GHG increases that have occurred already pose a 10 percent risk of inducing more than a two-degree warming. That is, we are already violating the UNFCCC under the European criterion for DAI. We have yet to see the full impact on climate of current GHG concentrations because their heating effect is masked temporarily by the same pollution that causes acid rain, and because of the delay in surface warming caused by the mixing of heat deep into the ocean.

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We are not in a position, at this point in time, to determine whether the climate would stabilize at a warming of less than, or greater than, two degrees, given current GHG concentrations. Furthermore, the argument can be made that a two-degree global average warming is too much, as it threatens the widespread devastation of coral reef ecosystems and risks triggering the irreversible melting of Greenland and the collapse of the West Antarctic ice sheet—with a collateral rise in sea level of more than 10 metres. According to a recent assessment by 19 ecologists based in Europe, North and South America, Africa, and Australia, a global mean warming of two degrees by 2050 will bring about the extinction of from one-sixth to one-third of terrestrial animal species. This is a staggering impact! Impacts on the distribution of plants and animals are already being observed, although it is too early to attribute the extinction of any species to global warming. It is estimated that, with a one- to two-degree global mean temperature rise, the number of people at risk from water shortages, hunger, malaria, and flooding will increase abruptly. The question is: Do we have the moral right to risk such massive impacts?

The best we can do at this stage is to limit emissions of CO_2 (the largest direct contributor to the growing greenhouse effect) and other GHGS as quickly as possible in order to cap their concentrations at the lowest possible levels, and hope that the climate response is small, that ecosystems are more resilient than we think they are, that farmers in the poorest countries can adapt successfully, and that the Greenland and West Antarctic ice caps are resistant to collapse.

CO_2 emissions are related, in large measure, to the use of fossil fuels for energy. There is a widespread, but erroneous, assumption that new, complicated, and currently prohibitively expensive technologies will be needed in order to wean us off of fossil fuels. All sorts of fancy analyses have been devoted to the question of whether it is better to start reducing emissions now, or to wait until the costs of the technologies needed to save us have fallen. The focus is invariably on new technologies for supplying energy, as an inexorable and unalterable growth in energy demand is usually accepted as a given. What is generally overlooked is the irreversible (or near-irreversible) loss of windows of opportunity to reduce emissions if we wait—opportunities involving urban form and infrastructure, and the construction of new, and renovations to old, buildings. In fact, it is a fairly easy matter to demonstrate that behavioural, planning, and organizational factors collectively have a greater potential to limit GHG emissions than do technological advances.

In industrialized countries, fossil fuel CO_2 emissions are derived equally from energy uses in transportation, industry, and buildings.

The two largest factors that influence transportation energy use in cities are urban form and the nature of the urban transportation infrastructure. The two extreme cities in the world in terms of urban form, Hong Kong and Houston, for example, differ by a factor of 25 in per capita energy use for transportation. In terms of transportation infrastructure, there is a factor of six difference in energy use per passenger-kilometre between subways and automobiles, given typical passenger loadings in a sample of world cities; in contrast, identifiable technological advances could only double the fuel economy of the present automobile fleet. Although there may be little that can be done to rectify the automobile-intensive, low-density, urban sprawl that we so short-sightedly allowed (and continue to allow) in North America, in many developing countries, important choices regarding urban form and transportation remain to be made.

Conventional, large-scale, renewable-energy systems are not the only options available. What is often overlooked is the enormous potential to transform the built environment itself into collectors and transformers of solar energy to meet our major energy needs.

With regard to industry, the potential energy savings to be gained through recycling often exceed those from any foreseeable technological advances. For example, the most efficient plants for processing scrap steel use one-sixth the energy per unit output of typical plants producing steel from raw ore, while the most efficient plants producing new aluminum from scrap use only one-twentieth the energy as that produced from raw bauxite.

As for buildings, it is possible, with available technologies, to erect structures that require one-quarter the operating energy of comparable buildings constructed according to current practices—as has been proven for a wide variety of building types in a wide variety of climates. Doing so, however, means pushing all available building techniques to the limit, which, in turn, requires a degree of coordination among architects, structural, mechanical, and electrical engineers, contractors and subcontractors, and building simulation specialists that has been achieved only rarely—and only when there is a client with the appropriate foresight, knowledge, and determination. In many cases, such buildings have cost little more than conventional buildings.

Fossil fuel emissions of CO_2 can be broken down into the product of four terms: human population, gross domestic product (GDP) per person, energy use per dollar of GDP (energy intensity), and carbon emission per unit of energy supplied (carbon intensity). This breakdown is referred to as the "Kaya" identity. While all four terms matter in the long run, many of the discussions about how to reduce GHG emissions have focused on energy intensity and carbon intensity.

The energy intensity of the economy depends on both energy efficiency and the mix of goods and services. Energy efficiency can be defined at the levels of individual energy-using devices, energy-using systems, and behaviour—all of which need to be taken into consideration in order to maximize efficiency. To return to buildings as an example, improved motors and fans for ventilation may yield a savings of from 10 to 20 percent in electricity use; if, however, the rate of airflow that is required in the first place can be cut in half (which can be achieved readily by redesigning the entire ventilation and air conditioning system), then the energy that the air handler must provide is reduced by a factor of eight. The switch from a mid-efficiency to a high-efficiency furnace or boiler can yield up to a 20 percent savings in heating energy use; however, through a high-performance thermal envelope (a high degree of insulation and airtightness coupled with a cocktail of controlled ventilation, heat recovery, and windows that lose so little heat they serve as a net heat source in winter because of the sunlight that passes through them), heating loads can—and have been—reduced by a factor of five to 10 compared to recent standards for new buildings in cold-climate countries. Finally, human behaviour, which can either erode or supplement the expected energy savings gained through the design of entirely new energy-using systems, can be influenced by economic signals and information.

Carbon intensity can be decreased by increasing the supply of renewable energy. Where natural gas supplies permit, a short-term option is to shift from coal to natural gas for electricity generation. Another, limited, option is to capture CO_2 from a new generation of fossil fuel power plants and inject it deep into the ground. However, if GHG concentrations are going to be stabilized at the climate-equivalent of a doubling in the CO_2 concentration—a level that poses a risk of an eventual three- to four-degree warming and can surely be regarded as dangerous (thereby violating the UNFCCC)—the use of fossil fuels will have to be phased out completely before the end of this century and replaced with renewable energy sources.

The challenge of providing sufficient renewable energy on this time frame may appear impossible to meet. At a global scale, the major renewable-energy options are solar, wind, and biomass energy; others—such as hydro-electric power, geothermal energy, and wave energy—are potentially significant only in select regions. For middle-population and GDP per person growth scenarios, and continuing the recent rate of improvement in the energy intensity of the global economy (i.e., a decrease of about one percent per year), by 2050, the required renewable-energy supply would be comparable to the present total world energy supply. At a two percent per annum reduction in energy intensity until 2050, the required renewable energy supply is still about half the present total world energy supply. In an eventual renewable-energy system, the two complementary carriers would be electricity and hydrogen, the latter produced from renewably-based electricity using electrolysis to split water molecules. If the electricity were to be produced centrally through some combination of photovoltaic (PV) arrays, large wind farms, and new hydro-electric developments, the required land areas would be enormous.

That said, much of the electricity use in industrialized or industrializing countries is in buildings, and much of that is to provide services which, for the most part, can be supplied through direct solar energy, without the intermediary generation of electricity. Furthermore, the required solar energy can be provided by the building fabric itself. In particular, much of the daytime lighting needs can be supplied through various daylighting systems; much of the ventilation needs can be supplied passively by exploiting indoor-outdoor temperature differentials and by enhancing the available wind forces; the need for air conditioning can be reduced significantly through building designs that minimize cooling requirements and that exploit passive cooling techniques wherever viable. Any remaining cooling requirements can be met through low-temperature, solar-thermal energy, from, for example, building-integrated, solar-thermal collectors that can drive desiccant-evaporative cooling systems, even in hot, humid climates. Once these uses of electricity are stripped from the building energy loads, the remaining loads are often small enough that they can be satisfied primarily through building-integrated, PV power.

In other words, conventional, large-scale, stand-alone, renewable-energy systems—whether hydro-electric dams, PV arrays in the desert, biomass plantations, or big wind farms—are not the only renewable-energy options available. What is often overlooked is the enormous potential to transform the built environment itself into collectors and transformers of solar energy to meet some of our major energy needs.

These considerations bring us back to the issue of the irreversible loss of windows of opportunity. If the built environment is to serve as our major power plant, it will do so most effectively if it is so designed from the beginning. Energy efficiency and renewable energy supply are inseparable and interdependent in the built environment. Every building under construction that is not designed to reduce its energy use by a factor of two to four compared to conventional practice, that is not designed to work with rather than against the laws of nature, and that is not designed to serve as the collector and transformer of solar energy in order to supply the bulk of its reduced energy needs—that building is a testament to our inability to apply existing knowledge to solve foreseeable problems. It is a lost opportunity and a future liability. Unfortunately, we continue to build these future liabilities. &