

CHAPTER 4

From Outer Space

Asia's Brown Cloud, and More

Veteran astronaut Richard Truly, speaking a number of years ago to fellows of the National Academy of Engineering, said that on repeated visits to outer space over the years, with each look back at earth, “the effects of human activity are dramatically apparent.”¹ Truly, who went on to be the head of the U.S. government’s National Renewable Energy Laboratory in Golden, Colorado, was referring to a sight that observant airline passengers will have noticed too. If you fly, say, from Chicago to Boston, from Frankfurt to Stockholm, or from Tokyo to Beijing, all along the way you’ll see smoke rising from tall stacks, most of which are venting emissions from coal-fired power plants. Seen from higher up, from a U.S. space shuttle or Russia’s Mir space station, those columns of smoke converge into larger plumes, and then sometimes into gigantic blankets of smoke and dust that cover whole regions. The most massive and portentous of those, which, oddly, was identified barely more than a decade ago, is a brown cloud that sometimes blankets the entire Asia-Pacific region, from India to China and Japan and down to South Pacific islands like Fiji and the Maldives.

When Truly said the impact of human activity is disturbingly evident from space, he was referring in part to the visible material known to be an acute health hazard as well as a threat to ecosystems, agriculture, and physical structures. That material, consisting of sulfur dioxide and nitrogen oxides, black carbon, white ash, and a toxic brew of miscellaneous other aerosols, emanates in massive quantities from the U.S. industrial heartland, northern Germany, and southern Scandinavia; the sprawling metropolis around São Paulo, Brazil; and many similar mega-

cities shooting up all over northeastern Asia. Much of it also is made up of combustion products from biomass—sticks, straw, dung, and other agricultural by-products—burned in the developing countries of Asia and Africa. Lesser but still significant constituents come from natural sources, notably dust and volatile organic compounds breathed out by some species of trees.

But what Truly also had in mind, most particularly, was that the visible matter converging into massive clouds is a sign of something even more insidious: the greenhouse gases known to be warming the earth alarmingly. The greenhouse effect, as such, is natural and benign, and now is familiar to all educated people: gases like water vapor and carbon dioxide in the atmosphere prevent some of the earth's heat from radiating back out into space, making earth warm enough for mammalian life to evolve and be sustained. But additional greenhouse gases that have been pumped into the atmosphere since the industrial revolution began have been enhancing that natural effect, perhaps to a dangerous degree. Carbon dioxide, from both combustion and animal respiration, is the best known and most important of the gases associated with human activity. But a variety of other gases—nitrogen oxides; methane, which comes from sources like rice paddies, animal excrement, and natural gas distribution lines; and chlorofluorocarbons (CFCs), which once were used ubiquitously in refrigerators and pressurized cans—also are quite significant.

Because of the discovery that CFCs destroy the stratospheric ozone layer that shields earth and protects life from ultraviolet radiation, they are being phased out in keeping with the Montreal Protocol of 1987, one of the most effective international agreements adopted to protect the global environment. Though the work of diplomats and the result of lobbying and pressure from a multitude of concerned citizens all over the world, the protocol can be attributed ultimately to the atmospheric chemists who recognized the subtle and devious ways in which CFCs, as well as nitrogen oxides, consume ozone. It was a singular instance of new knowledge getting translated promptly into good policy, and the scientists who produced that knowledge—Mario Molina, Sherwood Rowland, and Paul Crutzen—were fittingly honored with the Nobel Prize.

By the time they got that recognition, another scientist, an extraordinary Indian engineer turned atmospheric chemist by the name of Veerabhadran “Ram” Ramanathan, had discovered that CFCs, besides wrecking the ozone, also are one of the most potent greenhouse gases.

He showed that per molecule, they produce about 10,000 times as much warming as carbon dioxide. Accordingly, the phase-out of CFCs under the Montreal agreement has produced a big fringe benefit for the climate—a little noted fact with some big implications that will bear revisiting as the various dimensions of the climate problem are further explored.

Ram Ramanathan grew up in a small village near Madras (now officially known as Chennai), in southern India, a member of the usual extended family in which grandparents or great-grandparents presided over a sprawling clan of brothers, sisters, cousins, and unmarried aunts. His grandmother, whose home provided a summer retreat for Ram and his immediate family, cooked—like tens of millions of other Indian housewives—mainly with cow dung. Ramanathan remembers that soot from the burned dung blackened their kitchen walls.²

A strong pupil, Ramanathan earned an engineering degree from one of the region's polytechnic institutes and went to work for a local company, where he was given the job of developing containers, ironically, for CFCs. He hated working in the corporate world and soon made his way to the United States, to study at the State University of New York at Stony Brook, Long Island. There, he earned a Ph.D. in 1974 in the study of planetary atmospheres, seemingly a big step from CFC cans. Immediately his career took off, and soon he would be producing scientific work of the greatest importance. As with so many of his brilliant compatriots who attended American universities, became successful, and then sought ways to be of some use to their mother country—he would find his work relevant to the lives of those he had left behind.

In 1975, just a year after getting his doctorate, Ramanathan showed for the first time that CFCs are a potent greenhouse gas and a key factor in the earth's total greenhouse budget—the balance of gases and aerosols (suspended particles) that either trap heat radiating from the earth, making the globe warmer, or reflect solar radiation, making it cooler. (Ramanathan says now that even he was astounded to discover that the CFCs, even though they are but a minuscule fraction of the gases in the atmosphere, are so potent that they have an appreciable effect on the total radiation budget.³) Three years later, he made a second major contribution to the field, showing that the stratospheric ozone being consumed by the CFCs also was a significant greenhouse gas.

In 1979 Ramanathan helped design, and then became principal scientist—basically the manager—of the Earth Radiation Budget Experiment, in which the objective was to use data from earth satellites to measure and assess the earth's inflows and outflows of radiation. Over fourteen years and with a cumulative budget of \$150 million, ERBE would collect a wealth of data from three NASA satellites. By the end of the 1980s, the project showed that the earth's cloud cover has a net cooling effect on climate: the amount of solar energy that clouds reflect back out to space far exceeds the amount of energy they trap. At the same time, ERBE data measured the extent to which water vapor—gaseous water in the atmosphere, as opposed to the water droplets that make up clouds—warms the planet, exerting an undesired feedback effect. The warmer earth gets, the more water evaporates from the oceans; the more vapor there is in the atmosphere; the warmer the oceans get; and so on.

Over its twenty-five-year life span, ERBE has taken the greenhouse effect from the realm of theory and computer modeling to workaday empirical science, showing that it can be measured directly and accurately. So Ramanathan, in just the first fifteen years of his scientific career, firmly established two previously unknown important facts about the greenhouse budget, directly measured the budget itself, and identified what stands out as the biggest single quandary in all of climate science: the net role of clouds. As the earth gets hotter with increases in greenhouse gases, will increased cloud cover dampen the effect or make it even more potent? Ramanathan calls this “the Gordian knot” of the climate problem. At the end of the 1980s, he wrote an overview of cloud science for *Physics Today* magazine,⁴ a monthly read by almost all physicists in the United States and many overseas as well, in which he delineated the main elements of the conundrum. If he were to write that article today, he says, it would be hardly different.⁵ None of the decisive issues has been resolved.

In the next decade, however, it's likely that many of the uncertainties associated with clouds and climate will be reduced or even eliminated. A set of earth-observing satellites known collectively as the A train, after the famous New York City subway line immortalized in a Duke Ellington tune, is being launched in coordinated fashion, all to follow similar orbits and cross the equator at roughly 1:30 p.m. mean local time.⁶ Aqua, Aura, CALIPSO, and CloudSat already are in orbit, systematically gathering observations of the earth's water and energy cycles,

atmospheric chemistry, aerosols, and clouds. Aqua alone carries a half dozen sophisticated instruments that produce data being analyzed by scientists all over the world: for example, the Moderate Resolution Imaging Spectroradiometer (Modis), the Humidity Sensor for Brazil (HSB), and Clouds and the Earth's Radiant Energy System (Ceres). The Franco-U.S. satellite, CALIPSO, contains just two major instruments, one to measure the way aerosols polarize light, the other to do infrared imaging of atmospheric processes. The initial four satellites will be joined by Parasol, which will further evaluate the earth's radiative budget, quantify the atmosphere's reactions to anthropogenic gases, and track its evolution in time. An Orbiting Carbon Observatory, to be launched in 2006 or 2007, will monitor the carbon cycle.

By the second decade of this century it ought to be possible, given all the data that will be delivered by the A train and a number of other planned satellites, to make much more exact statements about how clouds of different kinds at various heights affect climate, and how human activities, clouds, and climate interact in real time. Not only that, the instruments will elucidate certain large-scale regional phenomena that are well known to be affecting the whole world's climate, but in complicated and poorly understood ways. That includes deforestation fires and changed land-use patterns in Brazil's Amazon. And at least as important, the satellites will cast light on the huge brown cloud that covers India, Bangladesh, Southeast Asia, China's industrial heartland, and much of the Indian Ocean, mainly between the months of December and April—another major Ramanathan discovery, and the one most closely linked with his name.

The usual story goes that Ramanathan first noticed the big brown cloud over Asia and the Pacific on flights between India and the United States, but the reality is of course a little more complicated. Why, after all, didn't anybody else notice something so big and brown? Why didn't other world travelers, not to speak of astronauts and cosmonauts, see it? The short answer is that Ramanathan noticed it because he was primed to look for it. In the course of the ERBE study, his attention had been drawn by a kind of super-greenhouse effect.⁷ When Pacific Ocean temperatures went above 27 degrees Celsius, suddenly the rate at which the temperature rose would accelerate, as water began to evaporate faster and faster. But at almost exactly 29.5 degrees, the temperature would abruptly stabilize. Why? Ramanathan and one of his students theorized

that perhaps a kind of natural thermostat was at work. They thought that as the oceans heated up, there might be much more production of cumulonimbus clouds—the kind that Americans and Europeans think of as thunderheads—and that these might reflect sunlight back into space, so that the ocean surface cooled.

Ramanathan designed an experiment in 1993, working from a base in Fiji and using data from aircraft, ships, and satellites, to test that theory. The results were startling. The amount of sunlight reaching the surface of the ocean was much smaller than expected, which set Ramanathan's mind working on a different track. On flights from India and the United States to the Maldives and Fiji, he had noticed a brownish haze over the Pacific, and it occurred to him that the haze might be blocking sunlight from reaching the sea's surface. He supposes that pilots must have noticed the haze too, but they probably attached no special significance to it. As for astronauts, because the surface of the brown cloud is light and reflective, it's not especially obvious from outer space. You have to be actually in it to see it clearly.

Together with Crutzen, the Nobelist who had discovered the deleterious effects of nitrogen oxide emissions, Ramanathan named the haze the "Asian Brown Cloud," or ABC, and the two men set about establishing a major new long-term experimental program to study it. Crutzen recalls that one afternoon at Scripps, looking out over the Pacific Ocean, they realized that it would be worth studying the haze of pollution wafting into the Indian Ocean from the Indian subcontinent (which, in hindsight, he considers slightly hilarious, inasmuch as they were having the conversation under another brown cloud, spreading from Southern California westward into the Pacific).⁸ Crutzen and Ramanathan dubbed their new enterprise the Indian Ocean Experiment (INDOEX), and in the next decade, it firmly established the cloud's huge scope and outlined its main origins and causes. The United Nations Environment Program (UNEP) asked Ramanathan to do a summation report, which led to the launching of the even broader Asian Brown Cloud (ABC) program, with UNEP funding.

In the course of INDOEX, the brown cloud was found to consist largely of gaseous pollutants like carbon monoxide, which came mainly from biomass burning, and aerosols, mainly from coal combustion. And it was found to be the combined product of certain characteristic weather patterns making for large-area inversions and of home and

commercial heating during winter—whether that involved burning straw and sticks in the traditional grass-roofed huts of Ramanathan’s ancestral home, or burning coal, oil, or gas in the skyscrapers being erected by multinational corporations in cities like Bangalore and Shanghai.

The cloud, two miles thick at its winter maximum, absorbs solar radiation before it can reach the surface and reflects it back out to space, so that on average, about 10 percent less sunlight reaches the surface of the earth than otherwise would be the case. Because of that effect, the cloud locally cancels the warming impact of the greenhouse gases arising from the same biomass and fossil-fuel combustion that generates the cloud. In a narrow sense, that might be considered a net good. But the cloud also has been found to have a highly deleterious effect on rainfall patterns, essentially because it cools the waters below, reducing rates of evaporation and cloud formation.⁹ In their most recent published work, Ramanathan and his colleagues have done simulations of the brown cloud’s effects from 1930 to 2000, in which they were able to replicate changes in surface solar radiation, surface and atmospheric temperatures over land and sea, and decreases in monsoon rainfall. Their work suggests that if current emissions trends continue unabated, the frequency of droughts on the subcontinent may double in the coming decades.¹⁰

Independent studies show that the brown cloud has been aggravating or even causing a drought that has been ravaging northwestern China for years, drastically reducing flows into the Yellow River, while shifting rainfall to the south. Similar droughts, but with a more patchwork pattern, laid waste to large swaths of India in 2003 and 2004. Ironically, by this time, the Indian government had dissuaded UNEP from providing extra funding to allow the ABC program to increase its scope to cover all of Asia. Evidently the country’s officialdom, according to a long front-page report in the *Wall Street Journal*, did not wish to see aspersions cast on economic activities it considered vital to its progress.¹¹ In a way, this didn’t matter. Ramanathan, by then a tenured full professor of ocean, atmospheric, and climate sciences at the Scripps Institution of Oceanography at the University of California–San Diego, was too prominent an authority to silence or even constrain. Besides being a member or fellow of just about every important scientific society, from the U.S. National Academy to the Pontifical Academy, he was well ensconced as Scripps at director of its Center for Atmospheric Sciences.

Something as big and pervasive as the Asian brown cloud cannot be attributed to just one cause or blamed on just one or two bad actors. Nevertheless, at first approximation, it consists mostly of products of coal and biomass combustion in China and India. Though China's controversial big dams, like Three Gorges on the Yangtze and Xiaolangdi on the Yellow River, get a lot of attention outside China, more than four fifths of the country's electricity is produced from coal. Coal also is the preferred fuel for home heating and cooking in much of the country. This is especially true in rural areas. Public authorities have sought to encourage conversion to natural gas in the bigger cities, but even there, coal is still very widely used. The hexagonal briquettes, perforated vertically with holes so as to better mix oxygen and carbon, are sold ubiquitously by vendors on China's street corners (see photo).

The energy picture in India is essentially similar, except that its economy is only about half as big and its extremes are more pronounced. Nuclear power plays a somewhat greater role, partly because the central government promoted it starting in the 1950s, for reasons connected with international prestige and a desire to lay the foundation for a weapons program. Yet India's rural population still relies almost entirely on biomass for fuel, and by and large it is coal that runs India's factories, powers its electricity generators, and drives its quaint locomotives.

Environmentalists in the United States and Europe may fret about whether air quality is getting better or worse, or whether it is getting better fast enough.¹² In China and India, the situation is unambiguous. As these countries strive to attain higher standards of living, their hunger for energy gets fiercer all the time—though their per capita consumption is still a tiny fraction of that in advanced industrial countries. And as their energy requirements escalate, so too does their coal combustion. Though they may want in principle to equip their coal generators with state-of-the-art pollution-control technology, it's almost a foregone conclusion that these two relatively poor but very ambitious countries tend to economize on such equipment. Even when they have properly outfitted plants, they often do not use it when demand for electricity is highest and there is pressure to run plants at maximum capacity.

The result is a public health catastrophe. A careful and reputable scholar at Pittsburgh's Carnegie Mellon University, Keith Florig, has estimated that as many as a million people die each year in China from diseases that are closely related to air pollution.¹³ If that figure is correct, about twice as many Chinese die yearly from air pollution as die



Charcoal briquettes are used everywhere as domestic fuel in China. *Source:* William Sweet

in accidents of all kinds. The World Bank's estimates are lower—on the order of several hundred thousand premature deaths each year, attributed to air pollution mainly from coal and biomass combustion, and from cement production.¹⁴ In any case, it's generally recognized by all who care to look that China's air pollution is not just a problem but a public health emergency.

Vaclav Smil, an expert on energy and the environment at the University of Manitoba, has observed in one of his many China studies that exposure levels in the country's towns "call to mind conditions in the cities of Western Europe and North America two to four generations

ago.”¹⁵ Bjørn Lomborg, the Danish specialist on global trends who has styled himself “the skeptical environmentalist,” does not gloss over the fact that Beijing, like Delhi and Mexico City, often suffers from particulate levels that are eight times those in Europe or the United States. He notes that of the fifteen most polluted cities in the world, thirteen are in Asia.¹⁶

In China, indoor air pollution from coal and biomass combustion often reaches levels deemed unsafe for *outdoor* air pollution by authorities like the World Health Organization. So if you live in or near one of China’s most heavily polluted industrial cities, you may not do yourself any good, in contrast to your counterpart in North Carolina or Ohio, by staying inside when it’s too nasty outside. An especially tragic result of this indoor air pollution, which is often associated with inefficient and poorly vented cooking stoves, is that the country’s women—and evidently this is uniquely true of China—die of lung cancer at rates about as high as those for men, even though they smoke much less.¹⁷

In India, the picture is just as grim. According to the world’s leading authority on indoor air pollution, Kirk R. Smith of the University of California–Berkeley’s School of Public Health, between 400,000 and 550,000 women and children under five die prematurely each year as a result of fumes from domestic biomass combustion.¹⁸ Smith considers that number a pretty firm low-end estimate of the death toll from indoor air pollution because it leaves out men, many of whom smoke—counting them too would produce much greater uncertainties in the calculations, but clearly the total mortality would be much higher.

According to Smith’s studies, about three quarters of Indian families rely on poorly designed, unvented stoves, which produce pollution far in excess of world standards. In the few areas like West Bengal where coal is used instead, the toxins spewed into homes may be even worse. Thus, altogether, some 750 million rural Indians are systematically poisoning themselves, and that leaves out the whole modernizing part of the economy, the urban and industrial sectors relying on coal to produce electricity and steel. When this is factored in, India’s toll from air pollution must be similar to China’s—perhaps as high as a million people a year, and certainly hundreds of thousands. (Ramanathan guesses from everything he has read that the air pollution toll for each country is in the hundreds of thousands a year, and for Asia as a whole at least 1.5 million.¹⁹)

Almost all of those premature deaths can be traced either to coal or to biomass, for which coal is the generally preferred substitute. At the same time, emissions from coal and biomass are the major constituents of the Asian brown cloud, which is having adverse climatic effects, at least locally. And because combustion of coal and biomass produces more carbon dioxide per unit of energy than any alternative fuels, continued reliance on them also contributes significantly to global warming. To be sure, if biomass is replenished as sticks and straw are burned, the net effect is carbon-neutral: the growing crops absorb the carbon dioxide emitted when the old crops are combusted. But as the Chinese and Indian economies modernize, which inevitably involves some permanent clearing of land without replenishment of crops or grass, biomass combustion also comes to have a net negative impact on regional and global climates.²⁰

To its credit, China's government is not oblivious to the country's air pollution crisis. Besides prodding municipalities to switch to cleaner and more efficient fuels, notably natural gas and oil, Beijing has systematically encouraged hundreds of millions of farmers to buy more efficient cooking stoves. It also has sought to phase out the highly polluting small boilers that were the hallmark of the "town and village enterprises" that sprouted like mushrooms with the introduction of free markets under Deng Xiaoping, Mao's reformist successor. The State Environmental Protection Administration in Beijing set limits for the major pollutants like sulfur dioxide, nitrogen oxides, and particulate, and in the late 1990s, its media-savvy head would often show up at a plant site with camera teams in tow to denounce a "yellow dragon"—his term for a tall stack spewing out toxins.²¹ The country even boasts a nascent environmental movement, which is small but independent and sometimes surprisingly aggressive.

Inevitably, though, in a decentralized and sprawling country like China, much depends on the honesty and zeal of local officials, many of whom are reluctant to restrict industries they see as their area's lifeblood and, not infrequently, are simply on the take. The corruption of China's state and local officialdom is legendary. An environmental bureaucrat representing the central government in Beijing recalled inspection tours he had made in Guangdong Province, the booming region around Guangzhou (formerly Canton) and near Hong Kong, in which the problem got worse the lower one went in the pecking order. "The more local the [environmental] board, the richer they got," he

remembered, taking it for granted that the lower officials were absconding with fees levied against environmental scofflaws—money that was supposed to be plowed back into environmental improvements. “The provincial one had a dingy office and was poorly equipped. The board from Guangdong city was somewhat better. But when I went to the Ping Yu county board, they picked me up in a luxury sedan and took me to a brand-new air-conditioned office building!”²²

It’s of course not just local officeholders who want those air conditioners. Go to Shanghai and look out on the famous Bund. One of the most prominent neon displays will be for Carrier, the top U.S. supplier. And air conditioners are not the only modern convenience fervently desired. In the streets of Shanghai and in every other major city of the industrial heartland, automobiles already have largely replaced the bicycles that blanketed all the roads just twenty years ago. Everywhere, in all facets of life, equipment and devices that depend on fossil fuels are replacing the old. It could hardly be otherwise in a country proud of its achievements, eager to improve its material condition still more, and determined to reclaim a preeminent place in the world.

To judge from what the government’s environmental officials say, privately as well as publicly, China would like to be not just a rich and powerful member of the world community but a good global citizen too. The Beijing government was the first to complete a survey of its greenhouse gas emissions, as required by the Kyoto Protocol, and it recognizes that the activities and processes producing those emissions also are fouling its cities, killing its people, and affecting regional ecology. But in trying to reduce the twin burdens of pollution and greenhouse gases, China faces terrible quandaries, as does the other developing giant, India.

Even if these two huge countries were growing much more slowly—in recent years they’ve been growing at rates of close to 10 percent yearly—they do not have the luxury of simply deciding not to burn coal anymore. Holland, in the 1960s, decided to wean itself from coal when newly discovered natural gas reserves proved a much more attractive option. The United Kingdom started to give up coal as a matter of policy in the 1970s, with the discovery of North Sea oil. (Today it is beginning to deploy offshore wind farms on a grandiose scale, following the example of Denmark and drawing on technology developed for high-seas oil extraction. Basically Britain is opting for large-scale wind energy because it prefers that to a new round of nuclear reactor construction, even

though the latter course might be cheaper.) The United States, taking cues from them, also could and should give up coal and adopt a variety of low-carbon or zero-carbon technologies.

But the technologies and fuels that rich countries like the United States can easily afford are often too expensive for fast-growing poor countries like China and India. In the last five years, for example, China has invited foreign nuclear reactor suppliers to bid for construction of several very large power plant complexes. But nuclear energy, which produces no air pollutants to speak of and no greenhouse gases, comes at a distinct cost premium—the exact figure is very hard to pin down, but nuclear electricity is at least 10 to 20 percent more expensive than average electricity. So while it may be an attractive substitute for coal in fully industrialized countries, where electricity sectors are growing slowly if at all, it is not going to be much help in a country like China, which is adding the equivalent of England's entire power sector every two years.²³ China and India can barely afford to build the additional power plants they need just to keep growing at the impressive rates they want; they clearly want to keep the costs of providing that added capacity to a minimum.

What goes for nuclear energy also goes for hydroelectricity, which is, if anything, even more controversial among environmentalists—not only globally but also in India and China. The construction of China's Three Gorges Dam on the upper Yangtze River divided the country's political elites like no other issue, even before Mao died and the reform era began; in India, the noted novelist Arundhati Roy has spearheaded passionate opposition to construction of any new big dams.²⁴ Like nuclear energy, dams provide, for all practical purposes, zero-carbon electricity, but there are premiums to be paid both monetarily and environmentally.

From an environmental point of view, wind turbines and solar energy have the potential to be much more than just niche players in China and India. Especially in remote areas, where there is no electricity grid or centrally generated electricity has to be delivered over very long distances, wind and photovoltaic cells are appealing alternatives. Saving on transmission of electricity compensates for the higher installation costs of wind and solar facilities.

Even in the most optimistic projections for renewable energy technologies, however, it's clear that wind and solar cannot come anywhere close to supplying the additional electric power that China and India will need in the next decades, let alone make a dent in the coal combus-

tion that's already killing millions and warming the world. But what about substituting lower-carbon oil and natural gas for coal? Clearly, it would be desirable for these countries to switch as much as possible from coal to oil and gas, which burn more cleanly and generate much less greenhouse gas per unit of energy produced. But as China and India furiously negotiate long-term development and supply contracts for oil and gas with nations in Central Asia and the Middle East, the effect is to drive up global prices, making it all the harder for them to afford replacing coal with less carbon-intensive fuels.²⁵

Faced with the extreme difficulty of bringing down their carbon emissions as their economies rapidly advance, India's and China's policy makers might be tempted to decide that it's really not necessary after all, inasmuch as the regional warming effects of carbon dioxide are roughly balanced by the cooling effects of the Asian brown cloud. But that doesn't really work, as health policy or climate policy. Cutting the pollutants that are killing millions each year and making life seriously unpleasant for hundreds of millions more is an inescapable moral imperative. It's not just a matter of air pollution, either. In the advanced industrial countries, coal mining is by and large no longer a dark and dangerous business that takes hundreds of thousands of lives, and blights hundreds of thousands more, each year. But in China and India, it's still dismal work done in places "dark as a dungeon," as the American country song puts it, amid conditions reminiscent of those described by European writers like Emile Zola and Friedrich Engels at the end of the nineteenth century. Thousands die mining in each country every year.²⁶

The World Bank has estimated that if all the added health costs associated with coal combustion in China were taken into account in setting the price of coal, it would cost twice as much as it does. Adopting policies to actually drive up coal prices to reflect social costs would powerfully encourage adoption of more efficient technologies and conversion to alternative fuels. But the World Bank also has cautioned that a significant decline in China's coal use in the next couple of decades, given current technology, "can only be achieved at enormous financial cost."²⁷

In the United States, and to a lesser degree in countries like Australia and Canada, opposition to the Kyoto Protocol has centered largely around a feeling that its requirements are unfair because China and India—unlike the advanced industrial countries—are not required to

cut emissions to meet definite targets. Realistically, however, there's no chance that these two fast-industrializing countries can cut their total emissions anytime soon. "It's a problem of decades," observes Ramana-
than—meaning it will be at least twenty years before China or India will be in a position to actually stop the increase of greenhouse gas emissions, and then reverse it. This is not because they are self-indulgent or indifferent to the social and global costs of coal combustion. On the contrary, they are quite acutely aware of the costs; and as caste-ridden India becomes more socially conscious and authoritarian China becomes more democratic, that awareness will only sharpen.

If global warming were merely a matter of the world's getting incrementally a little warmer, with the advantages and disadvantages more or less evenly distributed, then it might make sense to carp about the fairness of each country's contributions to slowing the process. But the effects, though impossible to predict with complete precision, will be very uneven. And it's not a foregone conclusion that they will be merely incremental. Climate scientists have found in the last fifty years that climate change can be sudden and cataclysmic. Changes in greenhouse gas levels associated with past climate catastrophes have been smaller than the changes we are inducing now. We don't and can't know whether what we are doing to the atmosphere today could bring on a climate cataclysm in the lives of our children or grandchildren, but we cannot dismiss the possibility.