From Chapter Five: AIR

CARBON DIOXIDE

When I started my investigation of modern concrete in earnest I visited the McInnis Cement plant at Port Daniel on Quebec's Gaspé peninsula. It is the newest cement plant in North America, and is billed as the least polluting one around per tonne produced. The air was sparkling that day, blue skies with fluffy clouds made the view across the Anse McInnis picture-perfect. But this was just before production started, and shake-down trials had been temporarily stopped because of a glitch in the bearings of the rotary kiln. When the plant was up and running, scrubbers would remove most of the particulate matter from the gases that would go up the smoke stacks, I'd been assured. Visible air pollution would be minimal.

However, the air would then contain a much higher percentage of an invisible gas than it did before production began. The gas, carbon dioxide, is what we've come to know as the poster kid for greenhouse gases, for climate change, for melting ice caps, for rising sea levels. World-wide, cement production is responsible for between 4 to 6 percent of all CO_2 emissions.

Two elements of the process of making cement produce CO_2 directly. First, the temperatures needed to reduce limestone or other similar rock to its basic components are extremely high, requiring burning great quantities of fuel. Second, the chemical process itself liberates much CO_2, After all, what's happening is that calcium carbonate is becoming calcium hydrate, and what's left over is CO_2. For each 1000 kgs of cement product 927 of Co_2 is emitted.

Thirdly, and perhaps most importantly, the way of life that concrete has made possible is responsible for an immense amount of green-house gases. This last contribution is somewhat difficult to quantify but we'll make an attempt because otherwise we really won't have an appreciation of what concrete has done to our world.

On average, the air we breathe is made up mostly of nitrogen, some oxygen, some hydrogen in combination with oxygen (water), and soupçons of many of the elements recognized by modern science. The usual proportions run something like nitrogen, 78 percent; oxygen, about 21 percent; argon, almost 1 percent; as well as carbon dioxide, and small amounts of other gases. Air also contains a variable amount of water vapour, around 1 percent at sea level, and 0.4 percent over the entire atmosphere.

The main components of air—nitrogen, oxygen, and argon—are like open doors, allowing light and energy in and out of the earth's atmosphere without impediment. That means that if they were the only components of air, energy from the sun would pass right through to warm the earth, and then be reflected back out into space almost as if the air were not there. But carbon dioxide, water vapour, and other gases like methane that are present in lower quantities absorb part of the heat radiated back by the earth. This creates a sort of gaseous blanket holding the heat in, the way that glass in a greenhouse does, which is where the name comes from. The more greenhouse gases the atmosphere contains, the greater the heating effect will be. Carbon dioxide is used as a proxy for the increase in all greenhouse gases, since when it goes up, it's almost certain that methane and the other greenhouse gases increase also. Therefore, the progression of CO_2 rates in the atmosphere is a handy shortcut to understanding a larger problem.

In the past, there have been times when the atmosphere contained much more carbon dioxide than it does now, but that was hundreds of millions of years ago, when the earth was much warmer and much lonelier. It was more like our sister planets Mars and Venus, which now have atmospheres full of carbon dioxide: Mars has about thirty times more than Earth does, and Venus has a whopping 300,000 times more.

What made the difference here is life, or rather the kind of life that has developed on Earth. Most of Earth's wealth of carbon (and there's no good reason to believe that all three planets started off with greatly different amounts of carbon) has become an integral and important part of plants, plant residues (including fossil fuels), and the skeletons of organisms such as those tiny ones who live in oceans, fall to the bottom, and over time became rocks like the limestone that we make into cement. Thus, slowly, slowly, carbon in the form of carbon dioxide was removed from the atmosphere and more or less locked up. Locked up, that is, until we started liberating it in massive quantities in the nineteenth century by burning fossil fuels and deforesting wide regions of the planet. Up until that point there had been a rough equilibrium for several million years between the carbon dioxide produced by natural processes such as forest fires and CO_2 given off by plants when they are not photosynthesizing and the CO_2 absorbed by growing plants and shell-forming animals.

As it happened, my trip to McInnis Cement came a few days after the day when the highest level of CO_2 was recorded for that year. On April 26, 2017, the climatological research station on the Hawaiian volcano of Mauna Loa recorded 412.63 parts per million (ppm) of CO_2, the highest of the year in the northern hemisphere. It was followed by 411.27 ppm, recorded on May 15, 2017.[8] The observatory there is part of the Global Greenhouse Gas Reference Network, which since 1958 has been measuring gases that are strongly linked to climate change—CO_2, methane (CH_4), and nitrous oxide (N_2O.)

CO_2 measurements vary with the seasons. They rise during the winter when many plants stop growing, and decrease in spring and summer when plants begin growing again and take up CO_2 as they photosynthesize. But independent of this annual cycle is the recent continuous increase in greenhouse gases, particularly CO_2, due to the burning of fossil fuels. If you graph the ups and downs, what you get is a regular jagged pattern that is rising toward levels that most scientists say are going to spell deep trouble for civilization as we know it. The climb continues: in 2019 the high came on May 11, when 415.26 ppm were recorded. What's in store are melting ice caps, more extreme weather, and rising sea levels, according to the men and women who have been studying what we've been doing to the atmosphere over the last 150 years. Warmer air means that more water will be evaporated from the oceans and will fall according to patterns that are only now being to be understood: the increase in "exceptional" weather events, however, is one of the few things that all models of climate change predict...

At the moment two major strategies exist whose aim is controlling CO_2 emissions. Both make individual businesses who emit CO_2 pay a price for doing so. One is a tax charged directly to emitters based on how many tons of CO_2 they emit. The other is called "cap and trade." Under it, a government sets a limit on CO_2 pollution from industry and sets up pollution quotas that companies are given or buy through auctions. The "cap" is reduced each year, and companies must bring down their emissions, buy quota credits from other companies who have successfully reduced their own emissions, or pay fines. The price of quotas is determined by the market, which makes the method more palatable to some entrepreneurs and governments. Typically, the money raised by the fines and sales of credits goes into a fund earmarked for green initiatives. The European Union has had such a system since 2005 and has seen CO_2 emissions fall by 8 percent: the goal is that the sectors covered by the system will be 21 percent lower by 2020.

California and Quebec both bought into the idea too. The money Quebec has collected—C$3 billion through 2018—goes to green initiatives that include aid to businesses and industries cutting their own greenhouse gas emissions, installation of electric car recharging posts at work places, and transformation of compost and green waste to methane.

Ontario, which was going to join forces with California and Quebec, abruptly pulled out of the scheme in 2018 after the election of a Progressive Conservative government under Doug Ford, who campaigned on killing it. In contrast, nine New England and mid-Atlantic states—Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New

York, Rhode Island, and Vermont—have set up a similar plan for emissions from the power industry, but not the cement industry.

Another way to force a reduction is to place a tax on CO_2 per ton. The approach has been tried in British Columbia since 2008, rather successfully, although it should be noted that the Cement Association of Canada has complained about competition from cement produced in the United States and China where similar taxes haven't been levied.[16] The carbon tax in BC began at C$10 per ton, and rose by C$5 a year: in 2021 it will top out at C$50 a ton. The money collected is largely returned to citizens in the form of reduced sales and income taxes. That element probably accounts for the generally favourable attitude to the tax among people in BC.

When carbon taxes—either cap and trade or a straight tax—are not what the economists call "revenue neutral," opposition to them can skyrocket. Protesters took to the streets in France when the government of Emmanuel Macron imposed a similar tax in 2018, the proceeds of which were supposed to pay down the government debt, not reimburse taxpayers. The result was months of militant protest—the *gilets jaunes* movement. In the end, the Macron government responded by cutting a proposed fuel tax increase, but remained tough on the carbon tax itself.

Other governments have buckled to pressure. Six years before the French plan, Australia launched a cap and trade program which effectively set the price at C$23 a ton. It stirred up fierce opposition, playing a big role in bringing down the government that brought it in. A new, more conservative government elected in 2013 promptly abolished the tax, and business continued as usual: Australia is now fifty-seventh among fifty-seven countries when it comes to climate-change action and is the world's largest exporter of coal...

But carbon taxes can be accepted when handled properly. Portugal instituted its own in 2015 with rather little brouhaha: the burden on the ordinary consumer was offset by reductions in the tax on gasoline. The result was that the country had the best CO_2 reduction record in the European Union in 2018.

Opposition to carbon taxing comes despite the advice of groups headed by market-oriented lawmakers who might be thought to be against taxes on principle but who are championing carbon taxes. Americans for Carbon Dividends, supported by Conservation International, some fossil fuel giants, and companies in renewable and nuclear energy and consumer goods, is advocating a carbon tax plan for the United States "based on the conservative principles of free markets and limited government, and offer[ing] the most popular, equitable and politically viable climate solution," according to their mission statement. How much influence on decision makers in the United States and elsewhere they will have remains to be seen, but they certainly broaden the range of players in the game.

What is equally unclear, however, is just how high carbon taxes must be to prompt a significant enough difference in our behaviour to save us from a climate change apocalypse. William Nordhaus, who has been studying carbon taxing for four decades and who jointly won the 2018 Nobel Prize for Economics with Paul M. Romer, thinks perhaps the best way to avert complete climatic disaster would be to get countries to agree to a worldwide target carbon tax of perhaps US$23 a ton, with abstaining countries being punished perhaps by special tariffs for not complying. (Nordhaus thinks the BC model is one that should be widely adopted, by the way.)

Pie in the sky? Probably. And, sadly, there have been moments in the past when it appeared possible to turn back climate change. Most notable was the decade of the 1990s when, as Nathaniel Rich outlined in his long article in *The New York Times*, “Losing Earth,” the United States, Canada, and most European nations were near a tough, com- prehensive plan to cut back CO_2 and other greenhouse gases. That agreement fell apart, and we’re living with the consequences. Another big unknown is how governments in the developing world will act: China has begun some carbon taxing initiatives in seven regions, but it’s far from clear what that will accomplish.

When CO_2 measurements first were made at Mauna Loa, the carbon dioxide level stood at 316 ppm, which was higher than the estimated level before the Industrial Revolution of 280 ppm. Between 1950 and 2017, emissions from humans jumped from 5 billion tons of CO_2 per year to 35 million tons, with the resulting increase in atmospheric CO_2 that we’re concerned about. The growth slowed between 2014 and 2016, but in 2017, the year I visited McInnis Cement, the trend went in the other direction, increasing by 1.4 percent to 32.5 gigatons, a record high. The following year carbon emissions went higher, even though emissions from countries in the European Union remained steady, reversing a trend of toward lower levels as most member nations pursued policies in line with the Paris Accords on climate change. Note that some think this is a bit deceptive because much of the goods consumed in the EU are actually now manufactured in countries like China, where CO_2 emissions continue to rise. Indeed, China was the single most important driver of the increase in global emissions: in 2018 its fossil fuel consumption rose, even though an increasing part of the country's energy needs were being met by the hydroelectric projects that have recently come on line. In part that's because of lower than usual rainfall, which made hydroelectricity projects less productive than planned and which in turn meant more reliance on coal for producing electricity.

CO_2 emissions in India have been growing at a slower rate: the increase dropped during the last decade from 6 percent a year to 2 percent, in part because there was a 6 percent reduction in cement production. That last statistic is instructive. As said before, the cement industry in recent years has directly accounted for between 4 and 6 percent of all CO_2 emissions, while transportation has accounted for about 15 percent. A decrease in emissions from cement-making could have major impacts on the effort to keep the proportion of CO_2 in the atmosphere from climbing higher. How to do that is a thorny question, though.

Besides carbon taxes three other ways suggest themselves. The first is efficiency in cement production. A second is changing the amount of cement used to make concrete. And a third, but perhaps the hardest to accomplish, is a radical move away from using concrete. This might come because of decisions made worldwide to work toward a low-growth economy, or it could happen because the way of life we are collectively living collapses because of drastic climate change or massive civil upheaval. The Covid-19 pandemic could turn out to be the catalyst for such a change. This book was being finalized for publication during the first months of the pandemic, when the long-term environmental and economic effects of the virus were unclear. Something of the latter happened in the 1990s, it seems, when the collapse of the Soviet Union led to wholesale abandonment of collective farms as well as drastic decreases in economic activity in Eastern bloc countries. This double whammy both lowered the amount of CO_2 going into the atmosphere and also removed some of what was already there by locking up some CO_2 in the plants that flourished in the fallow fields.

Careful analysis of cement production data shows that such dips in emissions from cement production were particularly marked in the Baltic states of Estonia, Latvia, and Lithuania, and in Ukraine and Russia. Similarly, after the financial crisis of 2008 cement production dropped abruptly in several countries: Iceland, Greece, and Ireland, which had enjoyed spectacular growth in construction in the early 2000s, were hard hit, as was the United States.

There is another menace looming that lies beyond the scope of this book, but which nevertheless should be mentioned: the prospect of a quick transition to a low-carbon economy through quickly dropping prices for renewable energy technologies. In a paper published in *Nature Climate Change* in June 2018, a group of economists predicted that by 2035 a rapid transition to clean energy could lead to a major crisis for countries whose raison d’être is producing hydrocarbons.

The bursting of this “carbon bubble” would have severe consequences for countries such as Canada and Russia, whose economies depend on producing hydrocarbons for a substantial part of their wealth. Quite possibly this crisis would lead to a drop in construction, and therefore to a lower demand for cement and concrete.

That's pure speculation at this point. Certainly those who might look on a financial collapse as the cure to the greenhouse gas problem shouldn't bet on it. What is certain is that China and India, by far the two biggest producers of cement today, experienced little or no impact from either of the breakup of the USSR or the capitalist catastrophe of 2008. However, and the importance of this can't be stressed too much, in the 1990s China changed its path as radically as the former Soviet bloc countries did, but instead of a slump in Chinese cement production, that is the moment when it took off.

In 1990 China's urban population was 300 million, but by 2010 it had more than doubled. Housing all those new city dwellers meant new cities. The new cities, along with the infrastructure to serve them, meant an enormous increase in the production of cement, with the concomitant effect on the atmosphere. Between 1991 and 2010, the amount of cement China produced grew by 936 percent.[40] A year later, the country was producing about 1.6 tons of cement per person, four times higher than the historic peak in the United States. And by 2018 China was turning out nearly 60 percent of global cement production.

In India cement production has also soared, but even though it is now the second largest producer of cement in the world, its production is only a bit more than a tenth of China's: 290 million tons[43] compared to China's 2,378 million tons. The uses to which this cement will be put vary also, and that will have repercussions on the atmosphere and more ephemeral manifestations of spirit...

In the past, India—particularly some Indian states—were more aggressive on the housing front. Chandigarh, the capital of Punjab, was created out of nothing on the plain below the Himalayas in the years following 1948. As a monument to concrete, it has no parallel aside from Brazil's capital, Brasília.

More modest projects have been undertaken elsewhere in India. I saw one of them dating from the 1970s when I visited Kochi in Kerala State on the west coast of India. It is an attempt that does not have many cousins. While researching another book, I visited an apartment in Gandhi Nagar, a development that was one of the first two planned housing "colonies" built by the Greater Cochin Development Authority and which stands on what was low-lying land formerly used for growing rice. The scheme included housing for "economically weak" clients, but also featured a sizeable amount of housing for wealthier folks. My contact's low-rise building sat on a gated lot, with plenty of parking for residents' cars that was guarded by a gatekeeper. It also had elevators, but no built-in air conditioning. Nevertheless, the interior space was arranged so that air circulated through open-work concrete blocks into cool corridors even when the afternoon sun beat down.

But far more common, it seems, is the kind of housing just down the road. It was a completely illegal stretch of small, attached living quarters. They lined the Peradoor canal, a remnant of the lovely waterways that are the signature feature of Kerala State. There I got an impromptu tour from a proud resident who wanted to show me how she lived—and to enlist my support to make the little neighbourhood less threatened by floods during the monsoon season.

The settlement was shaped like an L and lay between a concrete wall that marked the edge of officially recognized development and the canal. Going inside was like entering many other informally constructed developments around the world, ranging from Brazilian favelas to Chinese courtyard houses: intruders are kept out and a community life goes on inside.

One woman invited me in to meet her two daughters and one son. The latter was in X Standard, the last year of secondary school, and seemed delighted to try his English on me. Their house had three rooms: a bed-sitting room that opened off the footpath that served as the street, a middle room with a fan and television, and a third that was part kitchen, part washroom and which looked out on the canal. Inside was dark because the only windows were on the canal side. But outside was bathed in sunlight. Along the wall that formed the front of the houses were many plants, including chilis, marigolds, jasmine, basil, and other herbs. Some were in pots, others in dirt-filled plastic bags. A hose ran along the common wall and women were collecting water. My guide said they had four hours of water and four hours of electricity a day.

The overall impression was of a certain coziness: protection from the outside world, cleanliness in contrast to the trash blowing on the city-approved streets outside, plus sunlight and strong colours: blue of sky and water, green of plants, coloured saris, painted doors, poly-chrome religious icons.

City officials told me the next day that the little neighbourhood was slated for removal. Not only had it been built without official permission, its location was indeed periodically flooded, sewage was discharged directly into the canal, and the pirated electric connection was unsafe. Today, the settlement appears to have disappeared: it doesn't show up on Google Maps, although the canal does.

The people have moved, obviously. That fact suggests two questions: Where? And would upgrading housing like this bring bigger bang for the buck than the totally new developments that recent Modi initiatives promise?

I have no way of knowing the answer to the first question, and the jury is still out on the second. Relatively low-cost schemes like Mexico's *piso firme* initiative, which subsidizes putting in concrete floors, have proven that a small outlay can have great positive impacts on people's lives. Regularizing land tenure is particularly important in this kind of intervention because people and governments are unlikely to underwrite plans that spend money where no clear right to build is available. One of the great motors for housing improvement in Brazil, as an example, was a concerted campaign by unions, the Partido dos Trabahaldores (PT), and later the PT governments of Luiz Inácio Lula da Silva and Dilma Rouseff to clarify land title in Brazil's informal housing, including favelas where about 11.25 million people—6 per- cent of the country's population—live. Lula's government launched *Minha Casa Minha Vida* (My House, My Life), a program to aid low-income, first-time homebuyers, setting minimum standards for housing, arranging affordable mortgages, and clarifying land title. About C$272 billion (US$207 billion) were invested and more than four million housing units were delivered. The program was one of the few that the conservative government of Michel Temer endorsed when it took over in 2017. But when the even more conservative Jair Bolsanaro took office as president in 2019, he effectively axed the program on his first day in office by eliminating the Ministry of Cities, which ran the program.

One criticism of the Brazilian initiative had been that much of the new housing is far away from neighbourhoods where the target beneficiaries previously lived. I heard the same thing in Shanghai at the beginning of China's massive housing makeover in 2006. Ten years later, *The India Times* found 20 percent vacancy rates in schemes that built houses in areas far away from employment or that were incompletely served by infrastructure. Research by three Indian academics similarly found that proximity to a city's central business district increased desirability of housing, as reflected in house prices. Slum dwellers, three-quarters of whom had incomes of less than US$156 per month according to one study, were willing to pay more than US$466 more a year for a house closer to downtown.

Nevertheless, the time may have come for more development of dense neighbourhoods where very small houses take centre stage. At least their promise was internationally recognized in 2018 when Balkrishna Doshi won the Pritzker Prize, sometimes called architecture's answer to the Nobel Prize. The Indian architect, now in his ninth decade, designed buildings with twentieth-century giants like Le Corbusier, who was a mentor during the planning and construction of Chandigarh, and Louis Kahn, with whom he worked on the gorgeous buildings for Ahmedabad in Gujarat State. His friendship with Kahn lasted for decades—the evening before Kahn died he dined with Doshi and his wife—and Doshi's oeuvre includes more than 100 buildings, including museums and grand government buildings. But it was his work in the realization of Aranya, a modest rural town in a poor area of India, that was cited by the prize-selection jury in particular.

Doshi's plan for Aranya in the central Indian state of Madhya Pradesh was elaborated in 1989. Originally it was to include 6,500 dwellings on a planning area of 85 hectares. Six sectors, each with populations of between 7,000 and 12,000, were to lie to the east and west of a central commercial street. Ten houses, all with a courtyard at the back, would form a cluster that opened onto a street. Septic tanks were to be provided for each group of twenty houses, and electricity and water were to be available throughout. The development would be mixed, in that very basic housing—a concrete slab connected to services—would exist close to housing for more fortunate families.

"Housing as shelter is but one aspect of these projects," the jury stated. "The entire planning of the community, the scale, the creation of public, semipublic, and private spaces are a testament to his understanding of how cities work and the importance of the urban design." Photos of the village, located in a state where a third of the households are considered poor, show brightly painted little houses with banana palms in courtyards and children playing ball in the common areas. Doshi saw that sixty prototype houses were built, but in most cases the owners bought just a serviced lot. Design and material varied, with both brick and concrete block used in the construction. In some cases the houses reflect the rising income levels of the owners: a few three-storey ones now stand on lots where originally a one-room house was built. But as urbanist Rahul Srivastava emphasized after his visit in 2011, the whole plan was to develop the village incrementally. And development certainly has been incremental! It would appear that initial estimates of a 65,000 population for Aranya are far from being met: the 2011 Indian census put its population at 138 families and 785 persons.

Significantly, however, another recent winner of the Pritzker prize, Chilean Alejandro Aravena, also is a proponent of what he calls " half-built houses." The project that the jury particularly lauded was Quinta Monroy, a social housing project of ninety-three houses where most of the US$7,500 budget per dwelling went to buy the land where the residents already lived. What Aravena's group Elemental put up were three-storey structures that included a kitchen, a bathroom, structural walls, and a staircase. The rest of the houses, the half-buildings, were left to the residents themselves to construct, offering double the space normally given to social housing residents. It's notable that the work that Doshi and Aravena have done to provide decent housing for ordinary people was cited by the Pritzker jury. With the exception of the Chinese architect Wang Su, the 2012 winner who designed the Vertical Courtyard Apartments in Hangzhou, Pritzker laureates are usually chosen for their grand public projects or individual houses of great beauty.

Projects like these are far less flashy and much smaller than the high-rise cities being constructed in China, but they may point the way toward another model of providing better housing that is perhaps more respectful of community life, and certainly less concrete-intensive. Population density can be achieved by different models.

Take for example the trendy Mile End district of Montreal where the housing type is mostly two- and three-storey attached buildings that are now between 70 and 100 years old. In 2016 it had a density of 12,792.1 inhabitants per square kilometre. That's a lot more than the 2011 population density of Le Corbusier's baby, Chandigarh—9,258 per square kilometre[59]—and even of Beijing in 2010—11,500 per square kilometre. And, interestingly for those who think that Moshe Safdie's idea of "for everyone a garden" is an important principle of urban design, Mile End housing—built on lots that measure 6 or 7.5 metres by 23 or 30 metres—nevertheless usually comes equipped with tiny front and back gardens, or balconies.

Much of that housing was built a century or more ago, at a time when cities were designed to be walkable because there were few alternate forms of transportation for ordinary folk. Housing density made sense then. It still makes sense when governments in emerging nations around the world are trying to provide more and better housing for their people. But even if a lower-tech model is adopted—more small houses on small lots, instead of high-rises—more housing will mean more concrete used. CO_2 emissions will continue to grow.