From the Editor

Facts and ideas from anywhere

William C. Roberts, MD.

CHERNOBYL

Serhii Plokhyy, the Mykhailo Hrushevsky Professor of Ukrainian History and director of the Ukrainian Research Institute at Harvard University, has written a splendid book entitled *Chernobyl: The History of a Nuclear Catastrophe*.¹ At the time of the explosion, the author lived about 375 miles from Chernobyl in the Ukraine. What follows here was taken almost exclusively from his book.

The city of Chernobyl and its nuclear power station is close to the city of Prypiat, which once housed 50,000 construction workers and operators of the nuclear power plant. (The city of Prypiat was located 12 km north of Chernobyl. Chernobyl is named for the common wormwood, a shrub recognizable by the black and dark red color of its branches.)

In 1917, Chernobyl had 10,000 inhabitants, with most being Orthodox Jews. During the Bolshevik Revolution, 60% of them were killed. In the 1930s, the Great Ukrainian Famine took the lives of close to 4 million survivors of the revolution and civil war. Some 1 million died in the Kyiv region of Ukraine. The Germans entered Chernobyl on August 25, 1941. Less than 3 months later, the Occupation authorities ordered the approximately 400 Jews remaining in the town to gather near the synagogue. They were then marched to the premises of a Jewish collective farm called “New World” and gunned down. In 1970, when construction of the Chernobyl nuclear plant and its satellite city, Prypiat, was started, there were only about 150 Jewish families in the town. The Red Army recaptured Chernobyl and its environs from the Germans in the fall of 1943.

The Chernobyl nuclear plant contained four units: units 3 and 4 were joined together in one huge building; units 1 and 2 were separate. In 1970, Chernobyl and the satellite city occupied >3460 acres of pastureland, forest, cultivated land, and gardens planted by the local population. The nuclear plant began operation in 1977. By 1985, the four units of the Chernobyl nuclear plant produced 29 billion kilowatts of electrical energy, enough to power 30 million Soviet apartments, housing roughly half the Soviet

population of 280 million for the whole year. Construction on unit 5 began in about 1985.

The explosion of unit 4 occurred the early morning of April 26, 1986. The immediate cause of the explosion was unknown for several days but was finally determined to be a turbine test gone wrong. During the test, a sudden roar was heard followed by several others. The workers initially thought there was an earthquake. The effects of the steam explosion destroyed the casing of the reactor, throwing the concrete plate—the upper biologic shield of the reactor, which weighed 200 tons—through the roof and into the air. The plate, to which the entire infrastructure of the reactor was fastened, landed back on top of the reactor but did not cover it completely, leaving an opening through which it could freely “spit” radiation into the atmosphere. Flames followed the explosion, illuminating the area. The roof of unit 4 was gone, as was a good part of the side walls. Not long after the explosion several operators from the plant complained of headaches, dry throat, nausea, and vomiting—classic radiation poisoning. It took nearly 6 h to extinguish the fire.

When the operators of the nuclear plant realized that the top of unit 4 had disappeared and Soviet officials realized what had happened, the KGB cut intercity telephone lines to prevent information about the accident from spreading beyond the city of Prypiat. About an hour after the explosion, the radiation level in unit 4 exceeded 200 roentgens per hour. The ionizing radiation at Chernobyl was activated by the radioactive fission products blasted into the atmosphere by the explosion of the reactor. They included isotopes of iodine and cesium, as well as gases such as xenon-133. It was later estimated that the debris around the damaged reactor emanated radiation at a level of 10,000 roentgens per hour. That radiation level killed human cells or made them malfunction. Five hundred roentgens sustained over a period of 5 h meant certain death.

On the day of the explosion, April 26, 132 people—firefighters, operators, and engineers—were admitted to the Prypiat hospital with signs of acute radiation poisoning. Chernobyl was the first nuclear explosion that had happened anywhere in the world except Hiroshima and Nagasaki. A day later, two senior Soviet officials refused to admit that the reactor had exploded. The Soviet hierarchy still believed the myth of the reactor’s safety. That day Ukrainian authorities had mobilized 1100 buses and used them to evacuate the

city. The plant operators had no good idea of how to keep the radioactivity from spreading. They initially dumped sand over the partially destroyed reactor roof, but most of it did not reach the reactor because the roof opening was relatively small. By the afternoon of April 26, radiation levels near the reactor were estimated to be 1000 microroentgens per second.

It took the local physicians a while to treat the patients exposed to the radiation. Intravenous fluids appeared to diminish the headaches, dizziness, and uncontrollable vomiting. Some of the radiation victims were unable to walk. Their skin turned brown ("radiation tan") and their lips were swollen, making it difficult for some to talk. A total of 134 men and women were diagnosed with acute radiation syndrome. Twenty-eight died within the first month of the explosion. Twelve of the 13 patients who received bone marrow transplants did not survive.

For 36 h after the explosion, the local citizenry was given no reliable information about the event. They were never provided details on how to protect themselves and their children. After their evacuation, the people of Prypiat never returned. They were not allowed to take their pets, and several days later the police created special squads to kill stray dogs. The 45,000 people who were evacuated were moved to 43 different nearby settlements. The evacuees brought not only their irradiated bodies to their temporary homes but also their contaminated clothing and personal belongings. The buses used for the evacuation returned to Kyiv and were assigned to their regular routes, where they spread radiation around the city to their people. The helicopters that flew hundreds of times over the open roof of reactor 4 to dump the sand received a good bit of radiation.

Another worry was to prevent the destruction of units 1, 2, and 3. After some initial deposits of sand on the reactor area, clay was added to the sand to help extinguish the graphite fire within the reactor. Altogether, close to 5000 tons of various substances, mostly sand, were dropped onto the reactor. It is a miracle, according to the author, that the reactor roof did not collapse into the lower levels.

Despite the evacuation of tens of thousands of people from Prypiat, the Soviet government refused to tell its citizens and the world at large what had happened. Television, radio, and newspapers, even local ones in Ukraine, remained silent about the accident. The Soviets used military conscripts to deal with the consequences of the nuclear explosion. For the first few days after the explosion, what prevailed was the regime's unwillingness to admit disaster after having prided itself on being the first to build a nuclear power plant and successfully manage the peaceful atom. The concern was about unleashing panic and the inability to mobilize the resources needed to fight the disaster.

The Chernobyl disaster released 50 million curies. The winds spread the radiation and thus awareness of the accident to the countries of northern and central Europe. A radioactive plume swept to Belarus and then Lithuania and

across the Baltic Sea to Sweden, Finland, and Denmark. By being silent and then slowly providing pieces of information about the accident, the Soviets suffered a loss of legitimacy in contrast to enhancing the regime.

The contaminated areas around the power plant were initially a radius of 10 km, but that was extended a month later to 30 km. The zone would cover more than 2000 km² of territory, including more than 80 settlements, and result in the additional evacuation of more than 40,000 people.

The Chernobyl disaster was slowly driving a wedge between party officials in Ukraine and their bosses in Moscow. By May 4, 8 days after the explosion, over 1345 people had been admitted to hospitals in Ukraine's capital Kyiv. At that time, the Soviet government had trouble feeding its citizens and was importing 45 million tons of grain and close to 1 million tons of meat in 1985 alone. Moscow relied on a steady supply of agricultural products from Ukraine, the breadbasket of the Soviet Union. The Soviets ordered the police and military to patrol the exclusion zone. The peasants leaving the zone had to abandon not only their houses but also 10,000 hectares of winter crops and 13,000 hectares of spring crops, as well as 44,000 hectares of planted potatoes.

Easter Sunday turned out to be the worst day on record for radioactive emissions from the reactor. Radiation levels near the reactor amounted to 70 roentgens per hour on May 1 and rose to 210 roentgens per hour by May 4. The reason for the increase was unclear at the time. It was believed to be due to mounting heat within the reactor. The bushes and trees as well as agricultural products in the exclusion zone felt the effects of the radiation.

Within about 2 weeks of the explosion, the Soviets recruited hundreds of thousands of people, called "liquidators," mostly men, to liquidate (eliminate) the consequences of the Chernobyl nuclear plant accident. Some of them became known as "biorobots," their task being to remove radioactive debris from the premises. Close to 600,000 men and women were mobilized through the party apparatus, through government ministries and institutions, and most of all, through the Soviet army reserves to go to Chernobyl for clean-up tasks. Inept at ensuring the safety of the nuclear power industry, the authoritarian Soviet regime proved exceptionally good at mobilizing resources to deal with the consequences of the disaster. Although the scientists did not always know what to do, there seemed to be no shortage of people who could be dispatched to the most dangerous place on Earth.

The first to be sent into the eye of the nuclear hurricane were members of the military. The firefighters who fought the radioactive fire were on active duty and belonged to the interior troops. The helicopter pilots were members of the Soviet Air Force, and the officers and soldiers of the chemical troops belonged to the Soviet ground forces. Most of the general forces were draftees, boys aged 18 to 20 years. Altogether, close to 340,000 members of the military, most

of them reservists, took part in the liquidation of the consequences of the Chernobyl disaster between 1986 and 1989. The decontamination effort at Chernobyl became the responsibility of the military. Within a 30-km zone, the work of decontaminating villages, hamlets, and roads was shouldered by the army. Chemical troops on the ground used a special decontaminating solution to clean the surfaces of buildings as well as soil and vegetation. Engineering troops destroyed and buried buildings, structures, and machines that were beyond salvaging by decontamination. Among the best known burials by the military was the so-called Red Forest, a stand of pine trees 10 km² in an area that had turned red after absorbing radiation released at the time of the accident. The hardship was not only physical but also emotional as the young soldiers bulldozed and buried entire villages abandoned by their residents in the 30-km exclusion zone around the power plant.

The best-known clean-up operation conducted by the military took place on the roof of the third reactor of the power plant. Altogether, 3000 officers, reservists, and cadets did the job machines could not do: picking up radioactive pieces of the graphite from the roof of the reactor adjoining the damaged unit 4. Dressed in self-made leaden-protected gear, including lead aprons and swimsuits as well as pieces of lead placed to cover their genitalia, they were allowed to stay on the roof for only a few minutes, sometimes even seconds. The task was to get there, grab a piece of radioactive debris with a shovel, run to the edge of the roof, drop off the debris, and run back into the relative safety of the concrete building that housed the reactor.

Within a few months of the explosion, 28 people had died of acute radiation syndrome. In the months and years to come, many more would die from complications caused by exposure to high levels of radiation. The average dose sustained by almost 600,000 liquidators in the exclusion zone was 12 roentgen equivalent man (rem), or 120 times the yearly dosage considered safe by the International Commission on Radiological Protection. In subsequent years and decades, death and disability rates among the liquidators significantly exceeded those of the general population.

Mikhail Gorbachev, the leader of the Soviet Union, broke his silence on May 14, 18 days after the disaster. He provided the most accurate figures at the time on the number of people directly affected by the accident: 299 men and women diagnosed with radiation sickness, with the death toll rising from two to seven. But that was only 18 days after the explosion. Gorbachev's figures provided on May 14 were corrected at a press conference a day later. Nine people had died up to that point, and 299 were currently hospitalized with various degrees of radiation sickness. Thirty-five people were in critical condition, and 19 had been operated on. The American doctor, Robert Peter Gale, and his team had predicted that the number of those affected by radiation poisoning might reach 50,000 to 60,000. He appealed for more

drugs and equipment on top of what had already been brought to Moscow by the USA.

The Soviet leaders were surprised by the international reaction to their cover-up of the accident and its consequences in the first few hours, days, and weeks after it took place. In the USA, President Reagan created a special presidential task force on Chernobyl and the press secretary reported almost daily on its findings. Members of the administration attacked the Soviet government for its failure to release information in a timely manner. Close to one-third of all Soviet media coverage of the Chernobyl accident during the first month after the disaster was dedicated to attacks on the West.

Pressure from the West and the Soviet public's demand for accurate information had a major impact on Gorbachov's policy. Soviet journalists were suddenly given access to people in the nuclear industry with whom they could not have hoped to speak to earlier. The regime of secrecy was crumbling, and the era of *glasnost*, or openness, which would become a hallmark of Gorbachov's later reforms, was beginning. Coverage of the Chernobyl disaster marked a turning point in the history of Soviet communications. After Chernobyl, there was no way for the Soviet regime to hide the news of the Chernobyl accident from its own people and the world.

By May 15, the Soviet leadership had concluded that burying the exploded reactor was the only way to permanently stop the further spread of radiation. The Soviets decided to build a concrete structure incorporating the foundations, walls, and other elements of the reactor building that remained intact after the explosion. The new building above the reactor was referred to as the "shelter." Unofficially, it became known as the "sarcophagus." By early June, a total of 20,000 officers, and men, mostly reservists, had been organized into construction battalions. It took 6 months, approximately 200,000 workers, and 400,000 tons of concrete to build the sarcophagus that would prevent the raging radiation levels from emanating from the damaged reactor.

Later analysis of the Chernobyl disaster led to the conclusion that the design was faulty and unsafe. At the time, there were 10 similar nuclear reactors in Russia and 10 others in Eastern Europe.

The era of the militarized economy in the Soviet Union was over. It had not only produced the Chernobyl disaster but had also been mobilized to clean up its consequences. The cost of the Chernobyl disaster was enormous. Altogether, in Russia, Ukraine, and Belarus, close to 7 million people would receive some form of compensation for the effects of the Chernobyl fallout. These three governments adopted largely similar formulas, defining the most contaminated areas whose inhabitants needed resettlement or assistance and then establishing categories of citizens who were considered to be most severely affected, making them eligible for financial compensation and privileged access to medical

facilities. Ukraine recognized almost 90,000 of its citizens as Chernobyl invalids of the most severely affected category and, thus, most in need of social assistance. In Russia, that category included 50,000 people, and in Belarus, the republic that suffered the most from the Chernobyl fallout, 9000 individuals were similarly categorized. Ukraine also recognized almost 500,000 individuals, Russia 200,000, and Belarus >100,000. These three republics adopted a threshold of 7 rem as an acceptable lifetime radiation exposure—the average that a US citizen might absorb over a lifetime. The Ukraine, despite its terrible economy, allocated 5% of its budget to fund projects dealing with the consequences of the Chernobyl accident, and 65% of social welfare resources were devoted to the 3.3 million citizens characterized as victims or sufferers of the Chernobyl accident. Those two countries introduced a special Chernobyl tax in the early 1990s, amounting to 20% of all wages paid in the nonagricultural sector.

Russia, Ukraine, and Belarus, the three newly independent countries that were most affected by the Chernobyl disaster, estimated their overall losses from it in the hundreds of billions of dollars. In the Ukraine, close to 38,000 km²—approximately 5% of the country's entire territory and inhabited by up to 5% of the population of 54 million (1991)—was contaminated by the explosion. Even harder hit was Belarus, with more than 44 km² of land severely contaminated, amounting to 23% of the republic's territory and 19% of its population. Russia had the largest contaminated area, close to 60,000 km², but because of its huge size that area constituted only 1.15% of its territory with 1% of its population. Each of these three countries had to bear the cost of resettlement and deal with the health problems caused by this disaster.

Surprisingly, the immediate deaths attributable to the Chernobyl accident were relatively small. Whereas the nuclear bombing of Hiroshima and Nagasaki claimed close to 200,000 immediate victims, the Chernobyl explosion caused 2 immediate deaths and 29 deaths from acute radiation sickness in the course of the next 3 months. Altogether, 237 people were airlifted from Chernobyl to Moscow for treatment. Of them, 50 died of acute radiation syndrome and 4000 deaths were predicted in the relatively near future. The ultimate Chernobyl mortality role, though difficult to estimate, may yet turn out to be quite high. Current estimates place it between 4000 deaths, estimated by United Nations agencies in 2005, and 90,000 suggested by Greenpeace International. In the Ukraine, in the first 5 years of the disaster, cancer among children increased by more than 90%. During the first 25 years after the accident, approximately 5000 cases of thyroid cancer were registered in Russia, Ukraine, and Belarus among those who were younger than 18 at the time of the explosion.

It took 9 years after the fall of the Soviet Union to close the Chernobyl nuclear power station and more than 25 years

to build a new shelter over the damaged reactor. That latter project cost over 3 billion Euros.

The long-term consequences of the Chernobyl disaster remain unclear. While the actual impact of the radiation exposure on the health of the population is still debated, there can be little doubt that the whole society was left traumatized for decades. Every sixth Ukrainian adult reports being in poor health, a significantly higher percentage than in neighboring countries. And those affected by the Chernobyl radiation have lower levels of employment and fewer working hours than the rest of Ukraine's population. Despite the new shelter over the damaged reactor unit 4, the area around the nuclear plant will not be safe for human habitation for at least another 20,000 years. The half-life of cesium-137, one of the most harmful nuclides, is approximately 30 years. The iodine-135 half-life is only 8 days; cesium-134, 2 years; cesium-137, at least 180 years; and plutonium-239—traces of which were found as far away as Sweden—24,000 years.

What will happen to nuclear energy in the future? The world is growing bigger but not safer. The planet's population was close to 5 billion in 1987; today it numbers more than 7 billion and by 2050, an estimated 10 billion. Every 12 to 14 years the planet gains another billion residents. As the population of Europe declines and that of North America shows only modest growth, Asia and Africa are expected to show dramatic increases, with the African population more than doubling by mid-century, reaching a total of over 2 billion. Thus, most of the globe's population growth will occur in countries already struggling to feed their hungry and replenish their sources of energy.

Nuclear power seems to provide an easy way out for the growing demographic, economic, and ecological crisis. Most new reactors under construction today are being built outside the Western world, which is known for the relative safety of its reactors and operating procedures. Presently 21 new reactors are under construction in China, nine in Russia, six in India, four in the United Arab Emirates, and two in Pakistan. Five new reactors are currently being built in the USA and none in the UK. The next great nuclear power frontier is Africa. Volatile Egypt is currently building two reactors, its first in history. Are all these reactors sound? Will safety features be followed to the letter? Will autocratic regimes run most of these new plants, and will they not sacrifice the safety of their people and the world to get extra energy and cash to build their military, ensure rapid economic development, and try to head off public discontent? This is what happened in the Soviet Union in 1986.

The immediate cause of the Chernobyl accident was a turbine test that went wrong. Its deeper roots, however, lay in the interaction between major flaws in the Soviet political system and major flaws in the nuclear industry. One such flaw at Chernobyl was the military origin of the nuclear power industry. Chernobyl-type reactors were adapted from the technology created to produce nuclear bombs. Another

flaw was the violation of procedures and safety rules by station personnel, who bought into the myth of the safety of nuclear energy and adopted a reckless type of attitude. It was the same attitude that characterized the country's desperate attempts to catch up with the West in the economic and military spheres. Immediately after the accident, as panic spread, the authoritarian Soviet regime imposed control over the flow of information, endangering millions of people at home and abroad and leading to enumerable cases of radiation poisoning that could have been avoided.

Today, the chances of another Chernobyl disaster taking place are increasing as nuclear energy technology falls into the hands of rulers pursuing ambitious geopolitical goals and eager to accelerate economic development, while paying lip service to ecological concerns. Future accidents like those at Chernobyl and Fukushima may have various causes—a lapse in personnel discipline, a fault in reactor design, or an earthquake. There is also the growing danger of terrorists attacking the plants. Cyberattacks by hackers are another danger. We cannot afford any more Chernobyl disasters.

ADMINISTRATIVE COSTS IN THE US VS CANADIAN HEALTH CARE SYSTEMS

It is likely that the presidential candidates for the November 2020 election will discuss the costs of health care in our country. Dr. Stephanie Woodlander, a health policy researcher at Hunter College and longtime advocate of the single-payer system, and associates published in January 2020 an article in *The Annals of Internal Medicine* comparing the costs of administering the US and Canadian health care systems.² In the US, the costs of administrative health care workers and health insurance employees, none of whom have a direct role in providing patient care, cost every person living in the USA (man, woman, and child) an average of \$2497 per year. In contrast, in Canada, where a single-payer system has been in place since 1962, the cost of administering health care is \$551 per person—less than one-quarter as much.

It has been decades since Canada transitioned from a US-style system of private health care insurance to a government-run single-payer system. The wait times for specialist care and some diagnostic imaging are too long. A 2007 study by Canada's Health Authority and the US Centers for Disease Control and Prevention found the overall health of Americans and Canadians to be roughly similar.

Some Canadians purchase private supplemental insurance, the cost of which is regulated. Outpatient medications are not included in the government plan, but aside from that, coverage of "medically necessary services" is assured from cradle to grave. The cost of administering this system amounts to 17% of Canada's national expenditures on health. In contrast, in the USA, twice as much, namely 34%, goes to the salaries, marketing budgets, and computers of health care administrators and hospitals, nursing homes, and private practices. Executive pay packages for five major

health care insurers in the USA reach close to \$20 million a year, and shareholders demand rising profits. Administering the US network of public and private health care programs costs \$812 billion each year. In 2018, 28 million Americans were uninsured.

The US-Canada disparity in administration is huge and growing. Compared to 1999, when the last study comparing US and Canadian health care spending was published, the costs of administering health care insurance have grown in both countries. The increase, however, has been much steeper in the US, where a growing number of public insurance programs have increased their reliance on commercial insurers to manage government programs such as Medicare and Medicaid. As a result, overhead charges by private insurers surged more than any other category of expenditure.

If the US health care system could trim its administrative costs to bring it in line with Canada's, Americans could save \$628 billion a year while getting the same health care.

BLACK GOLD

Amanda Foreman, writing in *The Wall Street Journal*, had an interesting piece on black gold.³ January 2020 marked the 150th anniversary of the Standard Oil Company, incorporated in 1870 by John D. Rockefeller and three partners. Within a decade, Standard Oil controlled over 90% of US oil refineries. Rockefeller was worth \$900 million when he retired in 1901, the equivalent of \$400 billion today. In 1911, Standard Oil was broken up into 33 separate companies.

Although clearly responsible for a great many evils, oil has also been key to the growth of human civilization. Bitumen, a naturally forming liquid found in oil sands and pitch lakes, was used in ancient times for waterproofing boats and baskets. As early as the 4th century, the Chinese were drilling for oil with bamboo pipes and burning it as heating fuel. It was used for treatment of mange in camels. By the 9th century, Persian alchemists had discovered how to distill oil into kerosene to make light.

The drilling of the first commercial well in the US in Pennsylvania in 1859 brought a range of benefits. In the 19th century, an estimated 236,000 sperm whales were killed to make oil for lamps. The whaling industry died overnight once Standard Oil began marketing a clean-smelling version of kerosene. Plentiful oil made the automobile industry possible. In 1901, when a massive oil gusher was discovered in Spindletop, Texas, there were 14,800 cars in the US; by 1921, just 2 decades later, there were 8.5 million.

After World War II, the world's oil supply was dominated not by private companies like Standard Oil, but by global alliances such as OPEC. When the OPEC nations declared an embargo in 1973, the resulting crisis caused the price of oil to increase nearly 400%. At that time, the US depended on foreign suppliers for 36% of its oil supply. In late 2019, the US Energy Information Administration

announced that the US had become a net exporter of oil for the first time in 72 years.

We are all aware of the effects of oil on our environment, but I suspect that over 90% of employees of this hospital got here because petroleum was used in their automobiles or in public forms of transportation.

TRANSPORTATION AND GREENHOUSE GAS EMISSION

Road, aviation, waterborne, and rail transportation put together now account for 8 metric gigatons of carbon dioxide equivalents, which is 24% of global greenhouse gas emissions, according to the International Energy Agency.⁴ In the USA, this figure rises to 34%. In theory, electric and plug-in hybrid vehicles chart a clear path to lower emissions. Even after considering the costs of making the batteries and generating the electricity that feeds them, most estimates suggest that they emit roughly half as much greenhouse gases as a gasoline-powered car. Recent experience, however, proves that consumer tastes can easily sabotage steps toward sustainability: In the US, rising demand for pickup trucks has offset any gain from electric vehicles!

Faster economic development in emerging nations will inevitably mean higher emissions, even if each vehicle pollutes less. In China and India, the number of motorized vehicles per person quintupled and tripled, respectively, between 2007 and 2017, according to US Department of Energy data. Catching up with US levels of motorization—which admittedly are very high—both countries would need 2 billion extra vehicles. Even if 100% of those were electric, they would add more emissions on their own than the total level allowed by the Paris Agreement goals.

Greenhouse gases coming from aviation also keep surging, even though planes are becoming increasingly fuel efficient, because air traffic growth has surged. While environmental policies have tended to focus on passenger transport, half of transportation emissions now come from freight. Trucks are harder to electrify due to the extra weight and shorter range of batteries. Between 2005 and 2015, passenger transport energy intensity fell by 27% compared to only 5% for freight, with road cargo vehicles showing no improvement at all. Adoption of rail, a cleaner alternative, is not picking up. Meanwhile, ocean freight, which is by far the most efficient transport per ton mile, faces a reckoning from new rules that took effect in January 2020 because it relies on the dirtiest fuel to be economical.

No technological solution on its own is likely to be enough to meet the climate demands. Urban planning that emphasizes the use of trains, as well as allowing more employees to work from home, will play a bigger role. But higher targets and harder limits on travel and freight might be the only solution.

HOTTEST DECADE

In an annual climate report, scientists at the National Aeronautics and Space Administration (NASA) and the

National Oceanic and Atmospheric Administration (NOAA), which independently track world temperatures, each ranked 2019 as the second warmest since systematic recordkeeping began in 1880.⁵ The warmest year to date was 2016, when an unusually strong El Niño current in the Pacific Ocean boosted warming worldwide by influencing the formation of high- and low-pressure weather systems, trade winds, and rainfall.

The director of NASA's Goddard Institute for Space Studies in New York indicated that every decade since the 1960s has been warmer than the previous one. During 2019, the average temperature across global land and ocean surfaces was 1.8°F above the 20th century mean. The NOAA scientists calculated the average global temperature as 1.71°F above the average for 1901 to 2000. The European Union's Copernicus Climate Change Service calculated 2019 as the second warmest year on record. All told, the 10 warmest years in their records occurred in the past decade.

Since the 1880s, the average global surface temperature has risen about 2°F. The rising temperatures, of course, are attributed to greenhouse gases, such as carbon dioxide, methane, and nitrous oxide from fossil fuel emissions, agriculture, cement production, and land use changes. Atmospheric carbon dioxide levels increased in 2019, reaching a seasonal peak of 415 parts per million. It was the seventh consecutive year of global increases and concentrations of carbon dioxide.

In 2019, Europe reported its warmest calendar year, experiencing two of the most intense heat waves in its modern history in June and July. Paris registered a high temperature of 109°F in July, breaking a 72-year-old record by 4°F. For the entire USA, the annual mean temperature for 2019 was the third warmest on record. Fourteen weather-related billion-dollar disasters occurred in 2019.

THE AMAZON, GLACIERS THAWING, CORAL REEFS DYING—WE ARE DOING THIS TO OURSELVES

A recent piece by Mooney and Dennis describes the effects of continued deforestation and other fast-moving changes in the Amazon and how these changes threaten to turn parts of the rainforest into savanna, devastate wildlife, and release billions of tons of carbon into the atmosphere.⁶ The Amazon is teetering on the edge of functional destruction. It is warming at an accelerated rate. Almost the entirety of Brazil has already warmed by more than 2.7°F since the late 1800s. Because water evaporates at higher temperatures, warming combined with deforestation is drying out parts of the Amazon and posing a fundamental threat to the rainforest. The Amazon is now 17% deforested. That figure inside Brazil is closer to 20%. The fear is that soon there will be so little forest that the trees, which not only soak up enormous quantities of rain water but themselves give off columns of mist that aid agriculture and sustain enumerable species, will not be able to recycle enough rainfall. At that point, much of the rainforest could decline into a drier savanna ecosystem.

Rainfall patterns would change across much of South America. Several hundred billion tons of carbon dioxide would wind up in the atmosphere, worsening climate change. That point of no return is commonly referred to as a tipping point, and that point is much closer than scientists had previously estimated.

In December 2019, nearly 100 polar scientists detailed how the Greenland ice sheet losses have accelerated in recent decades, growing from 33 billion tons per year in the 1990s to a current average of 254 billion tons annually. Greenland apparently is losing ice faster than expected, partly because climate models are not good at predicting extreme melting events but also because melting of many of the ice sheet's small glaciers has started to speed up. The global arctic already has become a net emitter of carbon dioxide due to thawing permafrost. That would mark a profound shift for a region that includes vast stretches of Alaska, Canada, Siberia, and Greenland and that has long stored massive amounts of carbon in its frozen soil.

A global die-off of coral reefs in 2016 and 2017, which included the loss of nearly half of the Great Barrier Reef, shocked scientists, who did not fully realize the reefs were capable of such rapid losses. And the recent huge forest fires in Australia and the volcano in the Philippines throw huge quantities of carbon dioxide into the atmosphere.

COSTS OF GUN VIOLENCE

The Joint Economic Committee's Examination of Gun Violence found that the effect of shootings on local economies, employers, police and criminal justice departments, and health care systems amounts to \$229 billion each year in the USA.⁷ Gifford's Law Center reports that each year in the USA, there are 36,000 gun-related deaths and 100,000 injuries; 35% are homicides and >60% are suicides. One-third of the victims who are shot do not have health insurance. The average medical bill for someone hospitalized for a gunshot wound is approximately \$33,500, which is three times higher than the average hospitalization. While most patients

who are uninsured can apply for government funding and receive aid, these programs along with Medicare and Medicaid only foot about 40% of the bill. This lack of coverage leaves a sizeable portion for patients and their families to pay out of pocket, costing more than \$155 million annually for all uninsured patients. This number does not include the cost of readmission, outpatient rehabilitation, or medications, placing an even greater financial strain on victims and families. The lesson here is don't shoot or be shot, but it is difficult to dispense with guns in the USA.

William Clifford Roberts, MD
January 31, 2020

ORCID

William C. Roberts <http://orcid.org/0000-0001-7735-5641>

1. Plokhy S. *Chernobyl: The History of a Nuclear Catastrophe*. New York: Basic Books; 2018.
2. Healy M. Canada's single-payer system less costly to run. *Dallas Morning News*, January 12, 2020: 3A.
3. Foreman A. The blessing and curse of 'black gold.' *Wall Street Journal*, January 10, 2020. <https://www.wsj.com/articles/the-blessing-and-curse-of-black-gold-11578668067>.
4. Sindreu J. In the green transition, transportation is the next big bad-die. *Wall Street Journal*, December 23, 2019. <https://www.wsj.com/articles/in-the-green-transition-transportation-is-the-next-big-baddie-11577119404>.
5. Hotz RL. 2019, second warmest year, caps decade of rising temperatures. *Wall Street Journal*, January 15, 2020. <https://www.wsj.com/articles/2019-was-second-warmest-year-on-record-federal-climate-scientists-say-11579105990>.
6. Mooney C, Dennis B. Amazon at a 'tipping point.' *Dallas Morning News*, December 22, 2019: 2A.
7. Carr B. One cost of gun violence is the burden it places on our health-care system. *Dallas Morning News*, January 3, 2020. <https://www.dallasnews.com/opinion/commentary/2020/01/04/one-cost-of-gun-violence-is-the-burden-it-places-on-our-health-care-system/>.