# Introduction

There is much to do to create a modern energy paradigm, one that is clean, sustainable, and economically viable, but the changes are coming as overall efficiencies improve and manufacturing costs decrease for today's renewable technologies. In 2000, 0.6% of total global energy production was generated either by wind or solar, a 50% increase in a decade; by 2010, the amount had doubled.[1] By 2013, Spain had achieved a global first as wind-generated power became its main source of energy (21% of total demand, enough to run 7 million homes[2]), while both Portugal and Denmark now regularly produce days powered 100% by wind.

Historically cloudy England scored a first, as solar became the largest source of grid energy during an especially sunny 2018 spring bank-holiday weekend,[3] while in the midst of high winds from Storm Bella on Boxing Day in 2020, the UK was more than half powered by wind, a new record. On April 30, 2022, 100% of California's electricity was generated by renewables for a short period on the weekend, two-thirds from solar panels, an enviable milestone in the world's fifth largest economy.[4] Even in rural Africa, simple solar mobile phone rechargers now service hundreds of thousands of homes,[5] while in developing countries rural solar hook-ups provide basic lighting that reduces harmful kerosene burning as "micro-grids" bypass the need for expensive grid tie-ins.

Quoting the nineteenth-century philosopher Arthur Schopenhauer, the German parliamentarian Hermann Scheer stated, "A new idea will firstly become denounced as ridiculous, secondly there are many fights against it, and finally all people were in favor of it from the early beginning."[6] Scheer was responsible for the 2000 German Renewable Energy Act, which spurred on an avant-garde approach to energy technology via consumer subsidies and grid buybacks, transforming Germany into a world leader in solar power, all in a country with a mean latitude of 51.5° and a daily average of 4.1 hours of sunshine. As noted in a 2012 *New York Times* op-ed, "More than one million



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Germans have installed solar panels on their roofs, enough to provide close to 50 percent of the nation's power, even though Germany averages the same amount of sunlight as Alaska."[7]

Other countries are looking to Germany's example as renewable energy technologies become more viable year on year. In particular, China has seen remarkable double-digit growth over the past 20 years and is racing ahead in photovoltaic (PV) technology, producing solar panels cheaper than anywhere else and bringing the cost of solar infrastructure into the realm of everyday possibility. A Chinese-made solar cell today is 200 times cheaper than in the 1970s, spurring on the rise of gigawatt-sized power plants. As if announcing their coming dominance in globalized markets, some Chinese solar power plants are even being designed in the shape of a giant panda bear that employ three different types of modules (mono-c, bifacial dual-glazed, and thin-film). China also boasts more wind farms than any other country under its Wind Base program, having already installed over 200 GW of power with plans to reach 400 GW by 2030 and 1000 GW (1 terawatt!) by 2050, for a total national penetration covering two-thirds of its existing grid from wind power alone.

And yet in much of the developed world, green markets are still advancing slowly, while governments continue to support pollution-spewing coal, oil, and natural-gas (methane) industries that have alarming consequences for our health and well-being in an increasingly warming planet. If temperatures continue to rise at current rates, we may not be able to stop the damage.

Rather than encouraging cleaner technologies, the politics of the day hinders progress, including the United States Supreme Court overriding the ability of the Environmental Protection Agency (EPA) to regulate emissions and the European Union labeling natural gas and nuclear power as green in its taxonomy of environmentally sustainable economic activities. To be sure, a powerful, anti-environmental lobby is keeping carbon in business, preferring monopolistic, central-metered power over local, autonomous, grid independence. Some even claim global warming is a hoax to disadvantage leading industrialized nations.

Resistance is especially strong in the United States, where at the height of the 1970s oil crisis Jimmy Carter had 32 solar-thermal panels installed on the White House roof that were promptly dismantled by his successor Ronald Reagan, who alarmingly claimed that trees caused more pollution than automobiles, while working to maintain a gluttonous, unquestioning dependence on oil. In a strikingly similar anti-green reboot, Donald Trump actively promoted "clean coal," endorsed lower vehicle-emissions standards, and pulled the US out of the 2015 Paris Agreement, which had outlined new-energy transition initiatives and sought to coordinate worldwide climate action. Relishing his

role as a green Grinch, he even had a bike-sharing hub outside the White House removed.

But despite an apparent institutional resistance to change, the United States has pioneered many ground-breaking renewable energy sector (RES) projects, such as the first megawatt (MW) capacity photovoltaic solar-powered plant in Hesperia, California, in 1982, followed two years later at Rancho Seco, now run as part of the Sacramento Municipal Utility District power grid that generates 3.2 MW, enough to electrify 2,200 homes.[8] Another pioneering technology has been operating since 1989 at Kramer Junction in the Mojave Desert – concentrated solar power, ideal for a location averaging 340 days of sunshine per year.[9] Modern solar power plants are slowly being added piecemeal across the country, scaled to size as needed, while wind power is surging in the vast oil-laden regions of West Texas.

When it comes to making fundamental changes, however, the United States is notoriously hands off, preferring coal-, oil-, and natural-gas-fired power generation with generous government subsidies. There is no rationale for the resistance other than to maintain the status quo in a presumed market economy, odd given the many paradigm-changing technologies developed there in the past, such as in aviation, satellites, and communication, and a well-established entrepreneurial ethos. As NYU physicist Martin Hoffert noted, "Most of the modern technology that has been driving the US economy did not come spontaneously from market forces. The Internet was supported for 20 years by the military and for 10 more years by the National Science Foundation before Wall Street found it."[10] To be sure, change comes slowly, especially when faced with a relentless and well-healed opposition.

Hoping to kick-start changes in a country that emits 15% of emissions from only 4% of the world's population, Barack Obama announced a new Clean Power Plan in 2015, letting states implement their own means to reduce carbon emissions by 20% by 2020 and providing $1 billion in guaranteed loans for household solar installation. In early 2016, Obama and Canadian Prime Minister Justin Trudeau also agreed to reduce methane gas emissions in their countries by up to 45% below 2012 levels by 2025, while discussing ways to transition to a low-carbon economy. Alas, many of the changes were undone by Obama's successor, who characterized regulations as a restrictive bureaucratic killjoy. In 2022, Joe Biden's Build Back Better clean-energy plan was also gutted, stuck in debate between those who want to incentivize new technologies (clean energy) and those beholden to the past (subsidized fossil fuels). Highlighting the extent of the challenge, annual government subsidies for fossil fuels in 2022 doubled across the globe from the previous year to almost $700 billion.

The role of international agreements seems even more fruitless. In December 2015, delegates from 195 countries gathered in Paris to hammer out a deal to reduce greenhouse gas emissions and curb increased global warming. The meeting helped to overcome previously intransigent positions, such as reporting on emissions, maintaining and updating nationally determined contributions (NDCs) every 5 years, and setting an ambitious goal of reaching "net-zero" emissions by 2050, although the final agreement was not legally binding. There were also problems with the report language, such as "shall" versus "should," while various high-carbon subgroups cut advantageous side deals. As with the earlier unratified 1997 Kyoto Protocol, the US pulled out before rejoining at the start of the Biden administration.

Agreement is an exasperatingly slow process as politicians first think about their own regions, unwilling to prod the well-established, fossil-fuel industries that propel much of their gross domestic products (GDPs). Scheer even wondered if international conferences have done more harm than good, noting that "While the delegates have been debating over the past decade, emissions have been rising by an unprecedented 30 per cent." Sadly, he surmised that "The effect of the climate change negotiations has thus been to preserve the status quo."[11] One meme doing the rounds at the 2021 COP26 meeting in Glasgow summed up the growing frustration: "Number of years leaders have been coming to COP – 26, number of years GHG emissions have dropped – 0." Or as the teenage Swedish climate crusader and youth activist Greta Thunberg put it, "three decades of 'blah blah blah'."[12] Green meetings may come with grand themes, but change is never easy. Unfortunately, as we argue about our differences and the consequences of our inaction, the stakes keep getting higher.

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It is hard to imagine life without energy. We burn fuel to heat and electrify our homes, light our streets, and run our cars. Modern industry demands cheap electricity to manufacture the basics of everyday life, while oil is refined to make numerous household products from plastics to lubricants and tires to ink, as well as keeping us moving from A to B. There is no turning back the modern, energy-based lifestyle we all enjoy. Alas, an economy that produces energy by burning carbon-containing fuel is responsible for millions of deaths per year, creating unwanted by-products in the process, primarily carbon dioxide and methane, but also nitrous oxide, benzene, and other carcinogenic aromatic hydrofluorocarbons.

The carbon economy is also limited. Deposited in the earth 300 million years ago during the Carboniferous Period, when high pressures converted decaying plants and animals into so-called "fossil fuels," the supply will eventually run out.

In 1956, the American geologist M. King Hubbert calculated how much was left in the ground, noting that oil output had doubled in the United States every 8.7 years from 1880 to 1930.[13] In his seminal report to the American Petroleum Institute Hubbert predicted that the US would reach a maximum production of conventional oil (a.k.a. "peak oil") in the 1970s, which it did, further predicting a world peak oil for 2000, a date still much debated and scrutinized.

Today, some analysts believe there may be only a few decades left given our current annual consumption of 35 billion barrels per year, and even less if demand from China, India, and other developing countries continues to increase. Newer methods to secure oil and gas are postponing the end, such as offshore drilling, fracking, and oil sands, but at some point in this century fossil fuels will diminish beyond easy extraction and eventually run out. Regardless the exact end day, there is no such thing as a fossil-fuel free lunch – when it comes to consumption, one always has to pay the bill.

Despite the declining supplies, worsening pollution, and increased greenhouse gas emissions, global energy consumption continues, however, to be powered primarily by fossil fuels – oil (30%), coal (27%), and natural gas (23%) – with biomass (10%), nuclear (4.9%), hydroelectric (2.6%), and renewables (2.5%) accounting for the rest. To be sure, the old-world infrastructure is massive with more than 60,000 power plants,[14] generating roughly four-fifths of all power, including almost 20,000 oil plants generating at least 1 MW in the United States alone. Globally, there are about 7,500 coal plants, more than a third in China, and 440 nuclear plants. Currently, wind and solar provide about 2.5% of the total primary energy supply (10% of electrical power), while renewable technologies (wind, water, sun – WWS) are beginning to account for more of the energy mix and in some places are already at parity or cheaper than traditional power production (Figure 1 and Table 1). No one can argue anymore about the cost.

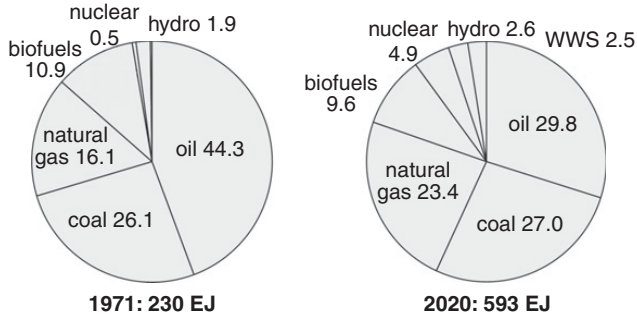


Figure 0.1 Global energy supply by fuel source: (a) 1971 percentage and (b) 2020 percentage. (*Source*: International Energy Agency).

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Table 0.1 *Global energy supply by fuel source: 1971 and 2020 (exajoules, percentage)*

| Fuel source | 1971 (EJ) | % | 2020 (EJ) | % |
|---|---|---|---|---|
| Oil | 102 | 44.3 | 177 | 29.8 |
| Coal | 60 | 26.1 | 160 | 27.0 |
| Natural gas | 37 | 16.2 | 139 | 23.4 |
| Biofuels | 25 | 10.8 | 57 | 9.6 |
| Nuclear | 1.2 | 0.5 | 29 | 4.9 |
| Hydro | 4.4 | 1.9 | 16 | 2.6 |
| Renewables | 0.5 | 0.2 | 15 | 2.5 |
| **Total** | **230** | **100.0** | **593** | **100.0** |

*Sources*: "Total primary energy supply by fuel, 1971 and 2019," International Energy Agency, August 6, 2021. www.iea.org/data-and-statistics/charts/total-primary-energy-supply-by-fuel-1971-and–2019 (1971) and "Total energy supply (TES) by source," World 1990–2020, International Energy Agency, October 26, 2022. www.iea.org/data-and-statistics/data-tools/energy-statistics-data-browser (2020).

The four great capital-accumulating world powers of history were the Genoese-backed Spanish, the Dutch – both nations powered by wind and the limits of intermittent favor – a coal-fueled industrialized Britain – vastly more advanced and wealthier than any before, yet as dirty as it was rich – and the oil-powered United States, whose brokered petroleum politics and never-ending thirst for more has created unparalleled convenience, yet put our planet on a perilous path of uncertain change. In the relentless quest for more, modern capital slows for no one, even as its seeds its own destruction.

Indeed, a modern renewable-energy paradigm will fundamentally change how we all live, creating abundance, independence, and security. As noted by Scheer, "Making the groundbreaking transition to an economy based on solar energy and solar resources will do more to safeguard our common future than any other economic development since the Industrial Revolution."[15]

It has been almost 60 years since the publication of *Silent Spring*, Rachel Carson's groundbreaking account of the effects of chemical pesticides on the environment, which helped forge new attitudes about our relationship with the Earth, ultimately leading to the creation of the Environmental Protection Agency (EPA) in the United States during the presidency of Richard Nixon and a better understanding of industrial neglect and waste. Here is the start of her final chapter, entitled "The Other Road." The case for change can't be made any better.

> We stand now where two roads diverge. But unlike the roads in Robert Frost's familiar poem, they are not equally fair. The road we have long been traveling is deceptively easy, a smooth superhighway on which we progress with great speed, but at its end lies disaster. The other fork of the road – the one "less traveled by" – offers our last, our only chance to reach a destination that assures the preservation of our earth.[16]

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Despite the difficult choices ahead, there is cause for optimism. As if awakened to the challenges of remaking a failing industrial past with a revitalized green future, newly elected US president Joe Biden announced a host of measures to combat the growing "existential dangers" of climate change. In the preamble to his January 21, 2021, "Executive Order on Tackling the Climate Crisis at Home and Abroad,"[17] he announced plans to double offshore wind by 2030, build 500,000 roadside electric-vehicle charging stations, and update the entire 650,000-plus fleet of federal vehicles from gasoline to electric, initiating an American electric-vehicle "arms race" that soon saw $85 billion in promised spending by GM and Ford. The measures also included a pause on new oil-and-gas leases on federal lands and waters and signaled his intention to ask Congress to repeal $40 billion in annual oil-industry subsidies, while encouraging private-sector investment in modern renewables, increased international financing, and more directed research and development.

Ambitious in scope, yet full of practical plans, Biden, John Kerry (special presidential envoy for climate), and Gina McCarthy (the first-ever US national climate adviser and a former EPA head) outlined a way to fight climate change at home and across the globe. Rejoining the Paris Agreement, the United States also re-engaged with others to implement planet-wide actions on global greenhouse gas emissions, especially with China and Europe. The new president also stressed job creation in the burgeoning green sector, capping a million abandoned oil and gas wells, revitalizing dying fossil-fuel communities (particularly coal), and building 1.5 million new energy-efficient homes. Although late to the game, the US sought to lead with its enormous economic might, hoping to recapture the spirit of past ideals.

On the heels of Biden's clean-energy initiatives, the International Energy Agency (IEA) announced its own groundbreaking recommendations to transition to renewable-energy sources in a 2021 report entitled "*Net Zero by 2050: A Roadmap for the Global Energy Sector*." Recognizing that the emission-reduction goals pledged by national governments were insufficient to keep global warming below a targeted 1.5°C in the 2015 Paris Agreement, the IEA report listed 400 steps to achieve net zero emissions, in particular an immediate end to investing in new fossil-fuel supply projects or "unabated" coal plants, no

sales of new internal combustion engine passenger cars by 2035, and a net-zero global electricity sector by 2040. The report also called for "a major global push to accelerate innovation" by adding a gigawatt of solar photovoltaics almost every day, a gigawatt of wind power every other day, and energy efficiency improvements of 4% per year until 2030. Intermittency, cyber security, and critical mineral resources were also cited as potential areas of concern.

*Net Zero by 2050* outlined how different the energy landscape could look in 2050 if almost 90% of electricity generation came from renewable-energy sources (70% wind power and PV solar), while at the same time reducing global energy demand by almost 8% despite 2 billion more people. The report further emphasized how most emission reductions could come from already available technologies, requiring only increased investment to roll out advanced batteries, hydrogen electrolyzers, and carbon-capture systems, all of which exist in various stages of development. The IEA Executive Director, Fatih Birol, also noted that transitioning to net zero is a huge economic opportunity for national economies, but that "The transition must be fair and inclusive, leaving nobody behind. We have to ensure that developing economies receive the financing and technological know-how they need to build out their energy systems to meet the needs of their expanding populations and economies in a sustainable way."[18] The IEA also reported that $4 trillion was needed to fund the change to renewables over the next decade.

Other countries chimed in with their own plans, the UK announcing its goal to reach net zero by 2050 by revamping home heating (insulation and replacing boilers with heat pumps), decarbonized travel (electric-vehicle incentives, supply chains, and charging stations), and increased green-energy production (wind, solar, clean electricity by 2035). Tree planting, peat restoration, carbon capture, and hydrogen gas incentives for heavy industry were also cited, although with only £2 billion in investment and 440,000 new jobs promised, the plan was dismissed as insufficient to tackle the formidable problems that lay ahead. Policy reversals in a new government also impacted the proposed plans.

Biden's so-called Build Back Better "reset," which included provisions for home-energy efficiency, grid enhancements, electric ferries, and more electrified mass public transit, also hit a roadblock when $150 billion in clean-energy programs from his initial $3.5 trillion bill were scrapped after objections from within his own party, in particular by Joe Manchin, a coal-sponsored Democrat senator from West Virginia. After months of wrangling, the overall package was gutted because of presumed fears about inflation. The politics of jobs and fossil-fuel profits is still very much the norm, despite the devastating dangers of business as usual.

What's more, despite the change in green language at the government level, more drilling permits were approved in the first year of Biden's presidency than in the first three years of the previous Trump administration. Biden's climate advisor, Gina McCarthy, also announced she was leaving her post, upset at the slow pace of change. The reclassification of natural gas and nuclear power in the EU taxonomy – a green investment label to help consumers, energy providers, and governments implement renewable technology in a structural fashion – was also called out by environmentalists as "greenwashing."

Hoping to inscribe into law the tenuous agreements reached in Paris, delegates from around the world also met again in November 2021, in Glasgow for COP26, where a number of significant measures were passed, including pledges by some countries for an 85% reduction in deforestation, a 30% reduction in methane emissions, and an end to the financing of overseas fossil-fuel projects. The pact failed to call for an end to coal, however, because of disagreements between developing countries whose economies rely on cheap, accessible coal and developed countries who want to oversee and usher in their plans for a green-led economy. Nonetheless, the pact was signed by 197 countries, despite a last-minute change of wording in the final declaration to a phase *down* from a phase *out* of coal. Prompted by India and China, the change in wording was about more "targeted support" by the developed "carbon colonialist" nations. In other words, money.

No fossil-fuel "non-proliferation treaty" or ban on fossil-fuel subsidies were included in the text, but coal and fossil fuels were mentioned for the first time, to some a step in the right direction after 25 years of meetings. The chief EU delegate Frans Timmermans eloquently reminded everyone that "European wealth was built on coal and if we don't get rid of coal, European death will also be built on coal." Of course, a large emissions gap of 50 billion tons per year of GHGs still remains, while a week later the US proceeded with the largest-ever total acreage auction of oil-and-gas leases in the Gulf of Mexico at almost 7,000 square miles, whose extraction and burning will last beyond a decade and continue to pollute and increase global warming. Urging others to quit coal while ramping up oil, natural gas, and nuclear power may be more about ensuring that leading industrial nations maintain their competitive advantage over weaker countries than helping them to leapfrog fossil fuels.

The issue is particularly thorny for developing countries whose newly built coal plants will be rendered useless in a globally mandated closing. The 2022 outbreak of war in Ukraine also severely altered the energy landscape for European countries reliant on Russian natural gas, who then backtracked on their coal-reduction promises, even restarting previously shuttered plants. Winter warmth today trumps future concerns about the admittedly abstract

nature of global warming via unseen greenhouse gases. Alas, with each passing year, business as usual becomes less of an option.

And then in the summer of 2022, some hope appeared in the guise of a remade US federal bill, the Inflation Reduction Act (IRA), which provided $369 billion in green spending over a decade, especially for wind, solar, and battery technologies, although other measures for carbon capture also meant more funding for petroleum and pipelines as did the usual side deals. Our long-traveled road continues to be trodden upon by those with their hands on the steering wheel. To be sure, transitioning to clean, renewable energy is an enormous undertaking.

Given the extent of the resistance to change, however, one wonders if the lofty rhetoric is more about controlling finances than transitioning to renewables. At the start of 2023 at the World Economic Forum in Davos, Switzerland, the UN Secretary General António Guterres called out the continued extraction of fossil fuels as "inconsistent with human survival." Yet at the same time, the CEO of the Abu Dhabi National Oil Company was appointed COP president; in other words, more of the same for oil companies seeking to maintain control of world energy supplies.

The truth about energy is that we use too much, are insufficiently concerned about deleterious effects (pollution, GHG emissions, global supply chains), and aren't in any hurry to implement cleaner, safer alternatives. After more than two centuries of unchecked growth on the back of cheap fossil fuels, there is no urgency to mend our ways or corral those who would willfully destroy or damage Mother Earth. Although we can see the dangers, economic activity is primarily designed to make money without considering the consequences, while governments won't regulate or punish those who care nothing for the environment.

It may be simplistic to pass history off as a set of energy dominoes, each better constructed for consumption and growth than the previous, but the next revolution is creating rather than destroying and managing rather than exploiting resources to reinvent a cleaner future after centuries of neglect. A new energy era has begun, one that can be implemented over time, similar to how hydro, thermal, and other power-generation technologies were added to an expanding grid in the twentieth century. The answers are right in front of us, including new ideas about growth itself, there for all to see, just as Galileo showed us if we would only look: an empire of sun, wind, water, and earth.

It is time to make the change and plug into a better way – we simply can't keep burning away our future. It is time to learn more about how energy and power works and put into practice new ways of consuming in our everyday lives. It's time to learn the truth about energy.