The Sustainability Trends Report 2023

generation

14 September 2023

Contents

> **“Now this is not the end. It is not even the beginning of the end. But it is, perhaps, the end of the beginning.”**

Winston Churchill, 10 November 1942

Introduction

Dear Reader,

We find ourselves caught between hope and fear.

The year 2022 led to extraordinary progress on the climate crisis. The United States adopted an ambitious new climate law, finally committing the world's largest economy to decisive action. Europe responded to Russia's fossil-fuel blackmail by redoubling its own ambitious commitments. A change of government in Australia led to new policies there; likewise in Brazil, a government with appalling attitudes toward the climate emergency was thrown out of office. India is poised to freeze plans for any new coal-fired power plants. We see rising climate ambition in many parts of the world. Indeed, the report you are about to read makes the case that climate change has moved to the centre of global politics, a development long overdue but welcome.

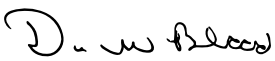
We rejoice in these signs of progress, yet our celebration is tinged with worry. The world is still not moving fast enough. If the stretch goal of the Paris Agreement, limiting global warming to 1.5 degrees Celsius, is to be met, emissions need to be falling sharply every year. Yet they are not falling; they are rising, moderately, from an already high level. The simple reality is that society has not committed itself to writing laws, mobilising capital, revising longstanding practices and building clean machinery at the pace required.

This is the seventh year that our firm, Generation Investment Management, has published the Sustainability Trends Report, with contributions in recent years from our new subsidiary, Just Climate. We submit the 2023 report for your consideration. Sustainability has several dimensions, of course, but given the rising urgency of the climate crisis, it is the primary focus of this work. The report is meant to answer a simple question with complex implications: In the transition to a low-emissions economy, where do we stand? You will learn in this report that for every beacon of hope and progress, another signpost makes clear how very far we still have to go.

The last year proved that immense steps forward really are possible. We need even larger steps, though, and we need them soon.

Al Gore, Chairman

David Blood, Senior Partner



Key Messages

01 Year in Focus

For decades, countries have set climate goals that were not matched by policies even remotely adequate to the task. Now, under the impetus of war and of a newfound enthusiasm for industrial policy, the era of serious climate action appears to be at hand.

02 Power

Some countries have made marked progress in weaning themselves off fossil fuels. In Europe, emissions from the electricity sector are expected to fall sharply this year. Worldwide, renewable energy is meeting 80 percent of new power demand, and we may be nearing a global peak in power emissions. A new bottleneck has cropped up, though: years-long delays for renewable projects trying to connect to the grid.

03 Transportation

Electric vehicles are now climbing a rapid adoption curve in the world's largest automotive markets. The looming problem will be producing enough vehicles to meet the demand. Shortages and high prices for critical battery minerals like lithium and cobalt raise big questions about securing additional supplies. Can we produce the new green minerals in a more ethical way than the old dirty minerals?

04 Buildings

Sales of heat pumps, the critical technology for cutting emissions in buildings, have jumped by double digits for two years running. They are up as much as 50 percent in some European markets, and heat pumps are now outselling gas furnaces in the United States. But governments have made less headway encouraging other types of retrofits, and we are still a long way from a package of policies that will eliminate emissions in buildings.

05 Industry

At long last, we are seeing investment beginning to move into the transformation of industry. Hydrogen announcements are now coming fast and furious; indeed, far more projects have been announced for 2030 than the anticipated market for hydrogen would seem able to support. Even abundant, low-cost hydrogen will be limited in its potential uses. How much of the hydrogen hype actually makes sense, and where does the developing hydrogen economy leave us in decarbonising the rest of industry?

06 Land & Food

Big new commitments were made over the past year to saving the natural world. On the international stage, the most important was a global agreement to halt biodiversity loss and stop deforestation by 2030. Even more important, in the long run, might be binding law adopted in the European Union that seeks to put teeth into such efforts, prohibiting the importation of products of deforestation starting in 2025. The good news, however, was matched by a surfeit of bad: events over the past year created turmoil in the market for 'offsets,' projects designed to sequester carbon in forests or elsewhere.

07 Financing the Transition

Investment in the energy transition is rising rapidly. The flow of funds into clean energy is now 70 percent larger than investment in fossil fuels. But much of the increase has been driven by rising enthusiasm for electric cars, and in other sectors, particularly the clean-up of industry, investment is still lagging. We are far from the levels of investment we will need by 2030 to meet the goals of the Paris climate agreement.

08 Looking Ahead

The fate of the planet will be decided in developing countries, where most of the world's emissions growth is occurring. They are at risk of being left behind in the energy transition. Interest rates for clean-energy projects in these countries are still two to three times higher than in developed economies, and urgent efforts are needed to correct the imbalance.

01
Year in Focus

Climate takes centre stage

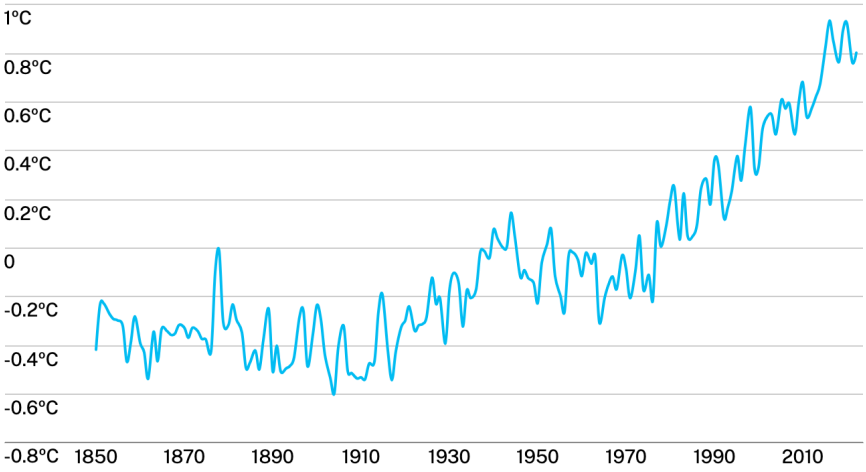
Society may finally be turning a corner.

Important countries have made bold new commitments to cutting greenhouse emissions, and are putting serious money into their plans. Clean energy and clean cars are growing fast. Global trade arrangements are being revised for the era of green energy. Batteries for electric cars are suddenly a top American trade goal. Getting gas boilers out of buildings has become a national-security priority across Europe. Producing clean hydrogen is now a strategic imperative in many countries. As the shift toward clean energy accelerates, nations are scrambling to keep up.

In short, after decades on the fringes, the energy transition has finally moved to the centre of global politics. These developments have all snapped into focus in the past year, but they were a long time coming.

By some measures it took well over a century to get here, for it was in 1856 that an amateur scientist named Eunice Foote first pointed out the role of carbon dioxide in heating the world.[1] In 1896, Svante Arrhenius published detailed calculations of how much extra heat an increase in carbon dioxide could trap.[2] The idea that industrial activity was in fact raising the amount of carbon dioxide in the air was confirmed by the early 1960s,[3] and an explicit warning of the consequences was put on the desk of an American president, Lyndon Johnson, in 1965.[4] Throughout the latter decades of the 20th century the warnings grew more and more urgent, until finally in 1992, the countries of the world signed a treaty agreeing to ward off "dangerous anthropogenic interference with the climate system."[5]

Figure 1: Temperature rising



This chart shows the change in global temperatures relative to the 1961 to 1990 average.

Source: Our World in Data

1. The role of Eunice Foote, an amateur American scientist and pioneering feminist, in the development of climate science was only recently rediscovered, by a retired petroleum geologist. She conducted experiments and published a clear statement about the effect of carbon dioxide on atmospheric temperature three years before British scientist John Tyndall began his famous experiments on the same topic. See Sorenson, Raymond P. "Eunice Foote's pioneering research on CO_2 and climate warming." Search and Discovery, 2011.

2. Arrhenius, Svante. "XXXI. On the influence of carbonic acid in the air upon the temperature of the ground." The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science 41, no. 251, 1896: 237–276.

3. The graph showing steadily rising concentrations of carbon dioxide in the atmosphere is known as the Keeling Curve. Book-length treatments of the science behind it are available, but for a concise account, see Harris, Daniel C. "Charles David Keeling and the Story of Atmospheric CO_2 Measurements." Analytical Chemistry, Vol. 82, No. 19, 1 October 2010.

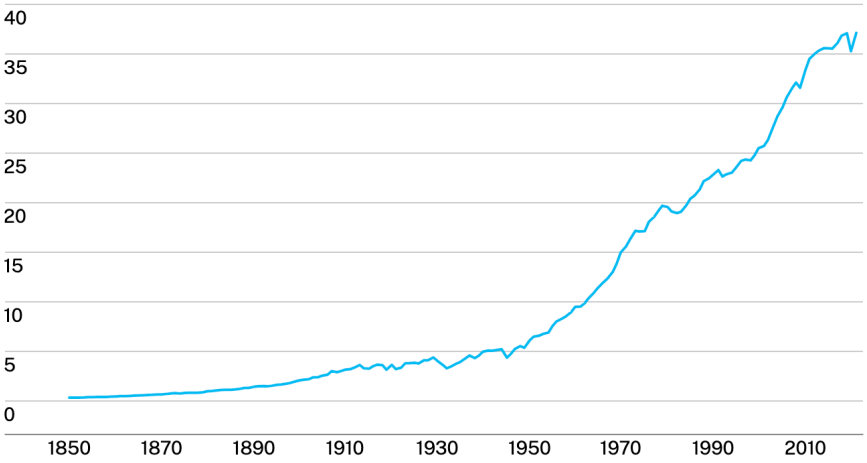
4. Environmental Pollution Panel, President's Science Advisory Committee. "Restoring the Quality of our Environment." The White House, 1965.

5. United Nations. "United Nations Framework Convention on Climate Change," 1992.

To meet that urgent goal, they did close to nothing. The ensuing three decades were ones of failure, as emissions rose higher and higher. They are, indeed, still rising today — but we finally appear to be nearing the point where they will peak and begin to fall. That is likely because some of the clean-energy technologies we need are now growing at a rapid pace, and that pace accelerated sharply just in the past year.

Figure 2: In the greenhouse

Annual CO_2 emissions, in gigatonnes



Carbon dioxide emissions from fossil fuels and industry. Land use change is not included, nor are greenhouse gases other than CO_2.

Source: The Global Carbon Budget

True, it was not solely a commitment to battling climate change that did the trick — it was also the war between Ukraine and Russia, a war that precipitated the first truly global energy crisis, with soaring prices and fears of shortage. For many countries, escaping their addiction to Russian fossil fuels converges perfectly with their ambition to switch to clean energy. That has led to rapid shifts in policy that are helping to change the pace and outlook for the energy transition.

We will explore these shifts in detail in the body of this report, but a few examples give the flavour of the moment. Sales of heat pumps, a critical technology for eliminating emissions in buildings, jumped 53 percent in Germany last year, and by double-digit percentages across much of Europe. In America, heat pumps are outselling gas furnaces for the first time. Worldwide, solar panels are now being installed at approximately the rate needed if emissions are to be cut nearly to zero by mid-century. Sales of electric cars jumped 60 percent last year and, on that higher base, are expected to jump another 30 or 35 percent this year. A growing number of countries intend to ban the sale of new petrol engines by 2035 or thereabouts, and those plans look increasingly credible. Contrary to expectations of just a year ago, European countries have curtailed their dependence on Russian gas without suffering critical shortages or industrial collapse.

6. The varying estimates of the cost of the law stem from its structure. Much of the spending is in the form of tax credits with no aggregate cap, so how much it ultimately costs will depend on how many clean-energy projects are actually built over the coming decade.

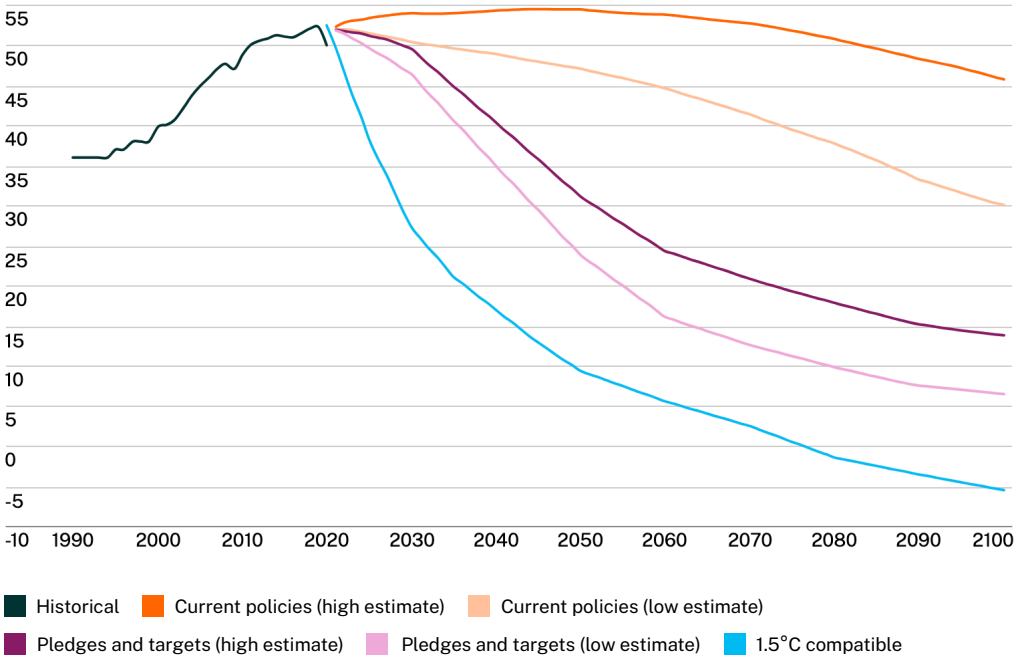
The biggest single shift in policy in the world last year was not a response to the Ukraine war, however: it was the fulfilment of a campaign promise that Joe Biden, the oldest president in American history, made to win over young voters. By the narrowest of majorities, Mr Biden won passage of the Inflation Reduction Act, which is primarily a climate law despite its name. The law will pour at least USD 391 billion, and possibly more than USD 1 trillion, into advancing clean energy, clean cars and related technologies in the United States.[6]

This law alarmed America's European allies, since it could lure factories to American shores that might otherwise have gone to Europe. The European Union has loosened its rules to allow member countries to offer their own big subsidies to speed the energy transition. It is unclear as yet how bold the member states will be, but for certain technologies, such as clean hydrogen, big subsidies have already been proffered.

To people who have long worked in the trenches, trying to alert the world's citizens to the magnitude of the climate crisis, the new political commitments of the past year feel nearly miraculous. They keep alive, if barely, the hope that the most ambitious goal of the Paris Agreement on climate change, limiting global warming to 1.5 degrees Celsius, can still be met.

Figure 3: The emissions gap

CO_2e/year, in gigatonnes



The orange lines give high and low estimates of future emissions if countries continue with the policies now on their books. The reddish lines give high and low estimates if countries were to adopt policies stringent enough to meet the promises they have made. The blue line shows an emissions trajectory that could meet the strictest goal of the Paris Agreement, limiting global warming to 1.5°C; in that scenario, residual CO_2 emissions in 2050 would need to be offset by uptake from forest growth or other atmospheric removals.

Source: Climate Action Tracker

However, nobody should make the mistake of thinking the energy transition will be smooth sailing from here. In fact, the clearest evidence that climate policy is getting real is that new fights about it are breaking out all over the world.

The German governing coalition came under considerable strain this summer in a battle over exactly how hard to push on installation of residential heat pumps. The United States is seeing more and more local resistance to the installation of wind farms and solar panels, some of it — though certainly not all — dredged up by fake 'citizens' groups created by fossil-fuel interests.[7] After some American towns banned gas appliances, including cooking stoves, in *new* construction, Republican politicians whipped up a national panic that the authorities were going to rip them out of existing homes.[8] Hobbled by inadequate planning rules, utilities the world over are dragging their feet on installing new power lines. That has produced backlogs and waiting lists for renewable developers wanting to connect to the grid, and these queues are growing quickly; they can stall projects for years.[9] Shortages and soaring prices for certain critical minerals threaten to slow, if not derail, aspects of the energy transition, but proposals to dig new mines are encountering sharp opposition. A halting effort to speed up the transition in developing countries like Indonesia and Vietnam may already be falling apart.

The biggest fight of all, however, is the intensifying struggle over industrial policy between China and the West. Both the United States and Europe will use their new industrial policies to try to take market share in clean energy technologies from China, and we expect China to open the purse strings and defend its markets in response.

China has been focused for 30 years on winning the industries of the future; while the West dawdled, China built immense new factories and mines to produce solar panels, batteries for electric cars, the rare-earth magnets that make wind turbines work, and much more. That scale-up helped to drive costs of the new technologies down, but it had a dark side, including the use of forced labour in parts of the solar supply chain.[10] The Ukraine war has ratcheted up these concerns, illustrating the perils of depending on a single authoritarian country for critical commodities or technologies.

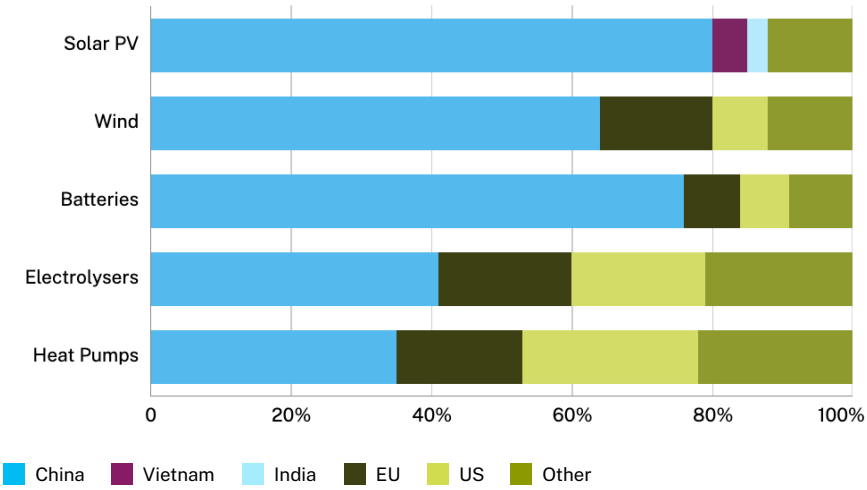
7. Peters, Adele. "These Groups Fighting Offshore Wind Say It's About Whales — But They're Funded by Big Oil." Fast Company, 1 March 2023.

8. Daly, Matthew. "Stove Wars: Republican-Controlled House Approves Bills to Protect Gas Stoves." Associated Press, 14 June 2023.

9. Gillis, Justin and Tyler H. Norris. "Here Is What Is Really Strangling the Energy Transition." The New York Times, 16 December 2022.

10. Murphy, Laura T. and Nyrola Elimä. "In Broad Daylight: Uyghur Forced Labour and Global Solar Supply Chains." Helena Kennedy Centre for International Justice, Sheffield Hallam University, 2021.

Figure 4: China in charge



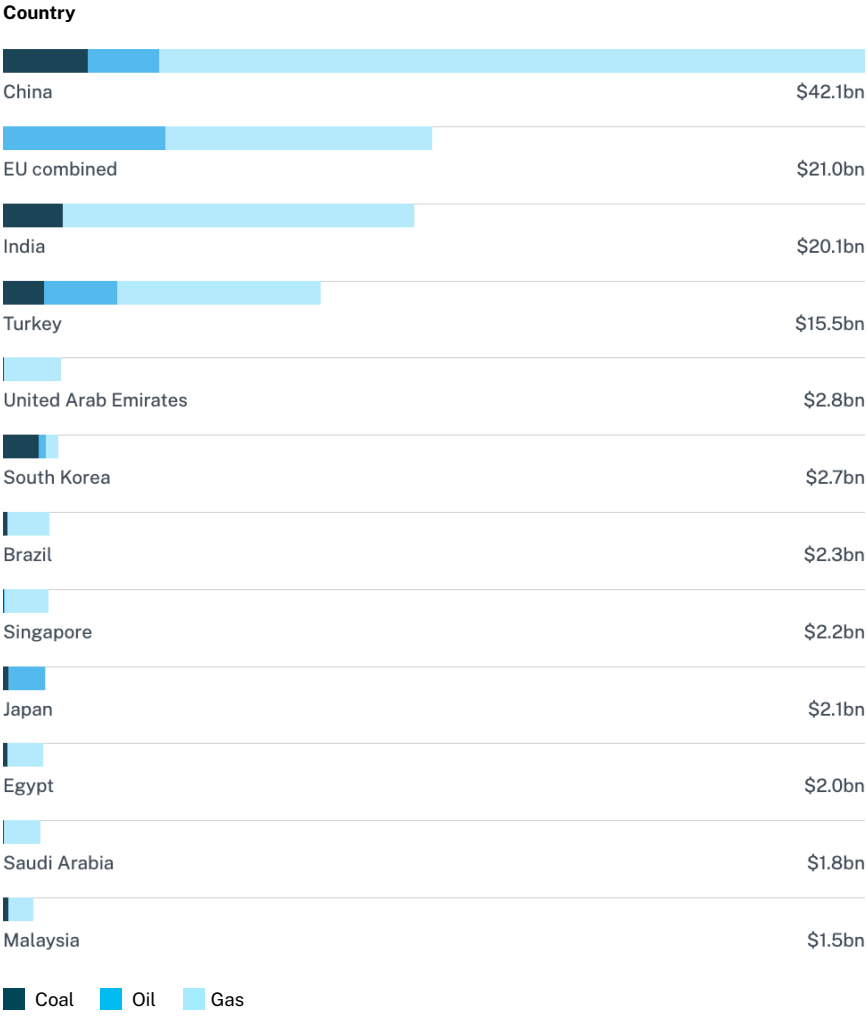
Geographical concentration of the supply chains for key clean energy technologies.

Source: IEA

The new policies that are pushing the energy transition forward therefore embody a paradox. If the goal were simply to move as fast as possible in the name of solving climate change, Western countries would likely go and buy the gear they need from China, where the metal refineries and the assembly lines already exist. They have chosen instead to try to recreate the supply chains and the factories that China already built, a decision that will surely cost time. New mines can take a decade or longer to open. New factories cannot be built overnight, even when public money is being spent on them.

The role of China in the energy transition is itself paradoxical. No country is spending more on clean energy; no country is moving faster on nuclear power; no other country can bring to bear the sheer industrial might of China to try to scale up solutions. Yet China is also building more coal-burning power plants than any country in the world, and the pace has accelerated sharply in the past couple of years as China copes with power shortages. Global emissions will likely reach their peak and begin to fall only when the Chinese finally stop doing that. Russia still has a market for its oil, and the funds to finance its war machine, because China is the top buyer.

Figure 5: Fuel imports from Russia in 2023



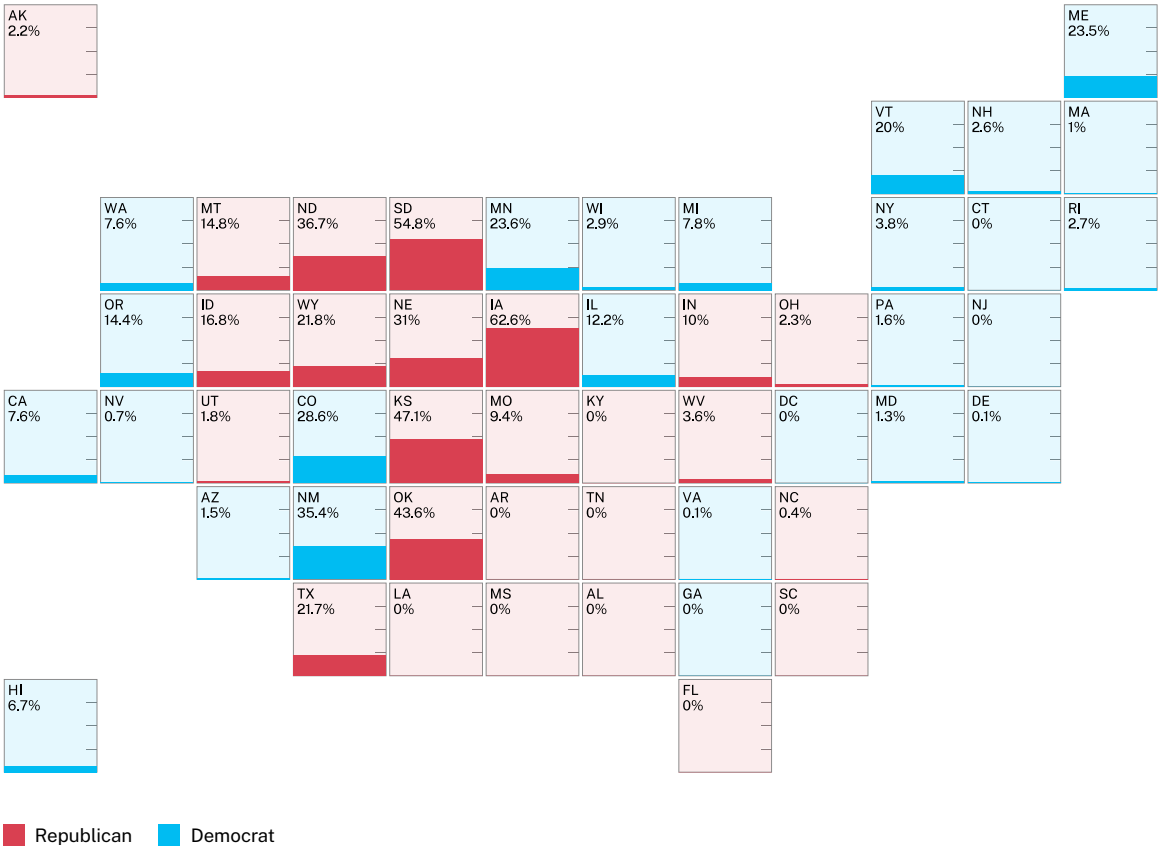
Imports from 1 January 2023 until 28 August 2023.

Source: Russia Fossil Tracker, CREA

Exactly how far Western countries will go in trying to decouple their economies from China's, and how much that will slow down their energy transitions compared to the maximum achievable pace, is largely unclear. Complete decoupling will almost certainly be impossible; activities like refining rare-earth metals are messy, and citizens of few Western countries will tolerate the imposition of factories such as those the Chinese people have been forced to accept.

But, to the extent the Western countries succeed in creating new jobs and new factories at home, the political benefits might ultimately prove to be worth the cost. The United States again provides a good example. Ideologically, many of Mr Biden's Republican opponents oppose his push for clean energy, and in a budget stand-off this year, they took a run at trying to gut the Inflation Reduction Act. But they did not put up much of a fight, and the effort failed. It is not hard to see why.

Figure 6: Wind and politics in America

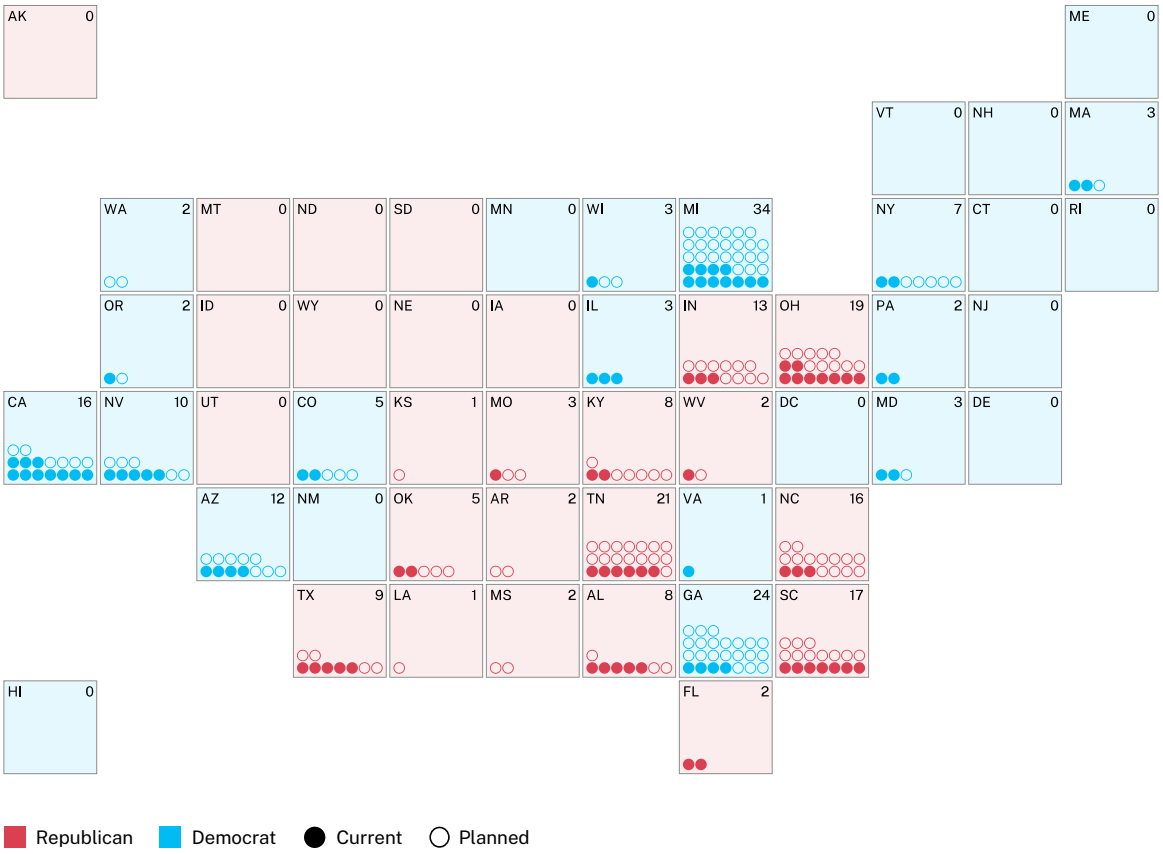


The height of each bar shows wind-power production in every American state as a percentage of all electricity generated there, and the colour shows the state's political leaning as reflected in the results of the 2020 election. Republican states in the middle of the country are the biggest wind-power producers. The Web version of this report provides additional detail.

Source: EIA

Half the wind energy produced in America comes from four states in the middle of the country, all of them controlled by Republicans — and all home to farmers who are benefiting enormously from the presence of wind turbines on their land. Much the same is true for solar farms in the American Southeast. Mr Biden's policies have precipitated a wave of announcements regarding new factories to build batteries and cars, and tens of thousands of new jobs are coming soon to Republican-controlled states as those factories go into operation. While Republican members of Congress may argue half-heartedly for gutting the climate law, Republican governors are tripping over themselves to take advantage of it.

Figure 7: Birth of an industry



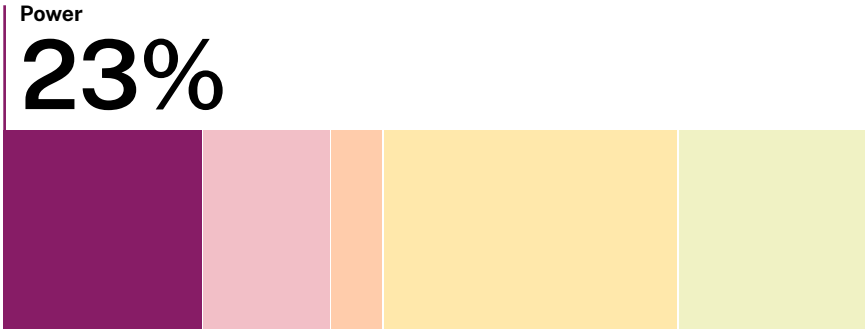
Republicans in Congress may want to kill Joe Biden's climate policies, but Republican governors are tripping over themselves to attract the jobs those policies will create. This map shows operational and announced plants to produce batteries for electric cars, with the colours reflecting the political leaning of each state according to the 2020 election results.

Source: Atlas EV Hub

So the approach of the Biden administration, even if it may ultimately be slower than the crisis demands, could in the end produce durable political coalitions in favour of action. This is exactly what will be required in every country. The climate crisis may originate with physics, but solving it is a problem of politics and money. Coalitions in support of the clean-energy economy must be built. Labour must be brought on board. The malign political power of the fossil-fuel interests must be offset by a growing constituency in favour of clean energy. For the clean economy to win, the political cost of trying to undermine it must become too high.

The energy transition is still a long way from succeeding. If it ultimately does so, we suspect we will look back on 2022 as the year when a magic key was found to turn the lock of politics and open the door.

02
Power

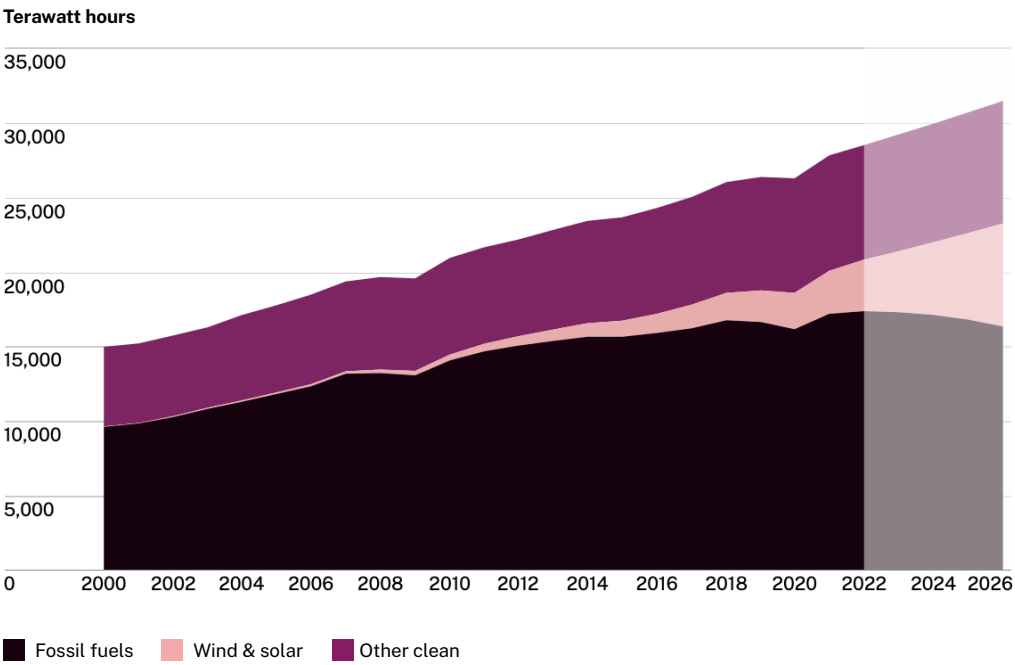


Share of direct global CO_2e emissions (IPCC)

An emissions peak is near

A cleaner electric grid is the key to the energy transition, the single most important requirement if the rest of the programme is to succeed. The reason is straightforward: many types of energy demand that now rely on fossil fuels can in principle be switched over to electricity. Cars are an obvious example, but by no means the only one. The clean-up of the electric grid is thus the most critical issue that we track in this report.

Figure 8: Growth of wind and solar



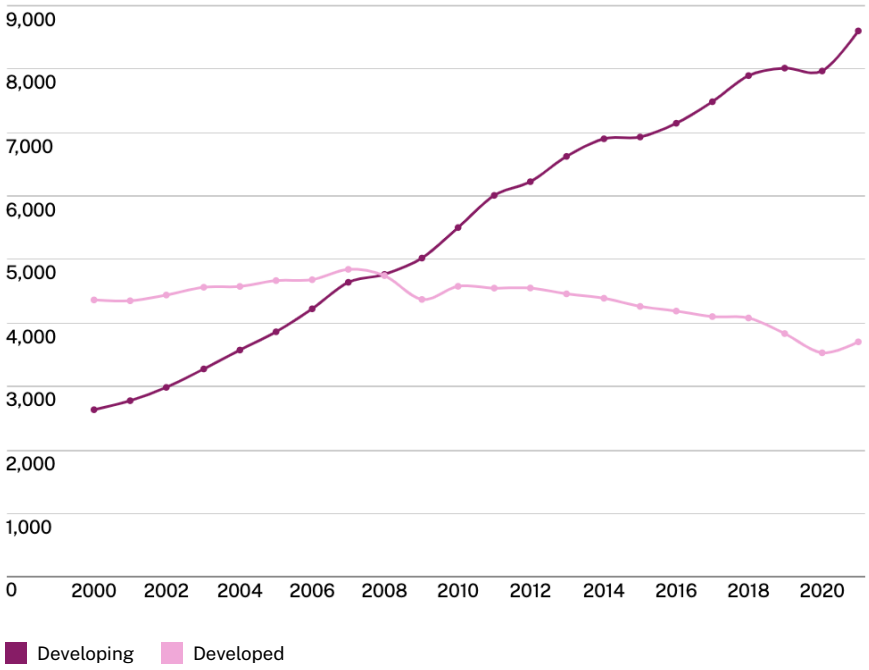
This chart shows the sources of global electricity production. "Other clean" includes nuclear plants and hydroelectric generation. Figures for 2023 to 2026 are projections based on recent trends.

Source: Ember, Generation analysis

We believe the moment is close when worldwide emissions from the grid will peak and begin to fall. One organisation that we respect, Ember, argues that the peak may already have been reached in 2022. We are less certain on that point, but it has definitely happened in many countries, proving that it can be done on a global scale. Even if 2022 proves not to be the year, we believe a peak will likely occur within the next few years, though we will then need years of after-the-fact data to know exactly when it was reached and a sustained decline began.

Figure 9: Diverging

CO_2e, in megatonnes

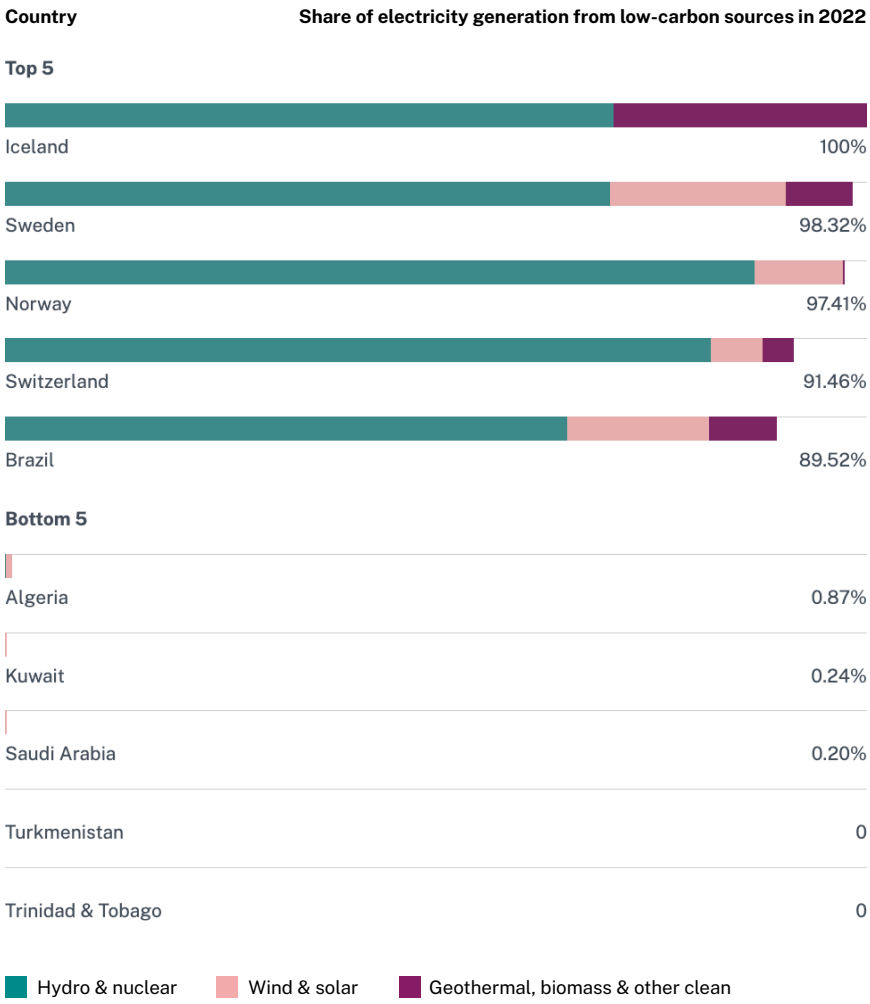


Electricity-related emissions in wealthy countries have already fallen, but the decline was more than offset by rising emissions in China and other developing countries.

Source: Ember

The chart above illustrates how sharply the emissions trajectories of the rich, developed countries have diverged from those of the developing world. The rise of emissions is unfortunate, but it is also a measure of how rapidly lives have been transformed in the developing world as hundreds of millions of people have been lifted from poverty in recent decades.

Figure 10: Clean power, dirty power



In the online version of this report, the chart shows the proportion of clean power for nearly every country in the world. It also demonstrates how much of the world's low-emissions power still comes from dams and nuclear plants. Newer sources like wind turbines and solar panels are just beginning to register in many countries.

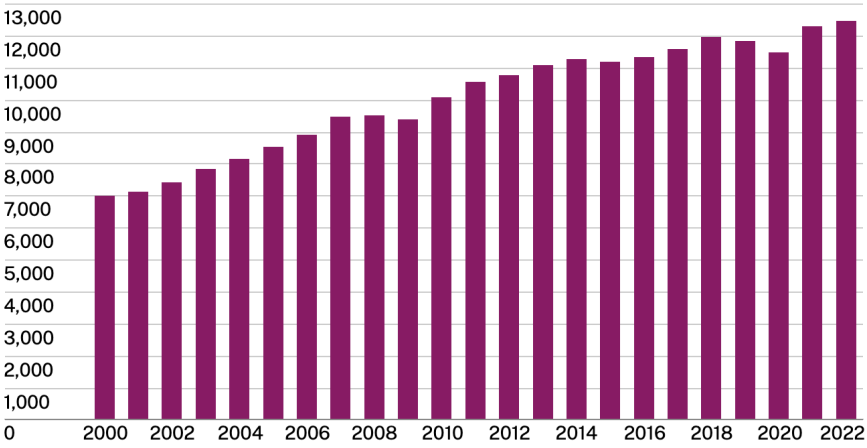
Source: Statistical Review of World Energy 2023

The phase of rapid growth in power emissions is likely coming to an end. They rose again in 2022, but only by a little more than 1 percent. Electricity demand is still growing fast, especially in the developing world, so what is holding back the rise of emissions? The main answer is the rapid growth of wind and solar power, which are now meeting 80 percent of the demand growth in electricity.[1] As new policies designed to speed up renewable power kick in, we expect that figure to exceed 100 percent, meaning that wind and solar will begin to claim market share from fossil fuels at a global scale.

1. Wiatros-Motyka, Małgorzata et al. "Global Electricity Review 2023." Ember, April 2023.

Figure 11: Electricity emissions

CO_2e, in megatonnes



Ignoring the dip associated with the pandemic, this chart of global emissions from electricity production shows that they are up only slightly in recent years. A peak is likely soon, followed by declining emissions.

Source: Ember

These basic facts hold despite some turmoil in the market for renewable energy, much of it stemming from the after-effects of the pandemic. For instance, the pandemic forced delays in the commissioning of new wind farms in China, the United States and elsewhere. Huge run-ups in the cost of commodities, many of them stemming from pandemic-related disruptions to supply chains, threw renewable-energy auctions in several countries into turmoil, mainly because the auction rules are not set up to allow power developers to capture higher commodity costs. Countries are now looking at revising those rules. The need to do so is urgent, for the inflationary spiral in commodities like steel has produced some bizarre circumstances. At a moment when Europe is making huge new commitments to wind power, for example, every supplier of wind turbines there is losing money, and thus in a weak position to invest to meet the expected future demand.

The Ukraine war sharply cut supplies of Russian gas to Europe and forced a reckoning in that region with decades of misguided energy policy. The outcome has been less dire, however, than anyone expected. The United States, flush with gas due to the technology called hydraulic fracturing, is sending it to Europe by the tanker load. But more important from the standpoint of the energy transition, gas demand in Europe fell sharply in the winter of 2022 and 2023, with gas use in Germany down by 18 percent, for instance.[2] The reductions came in part from a population willing to sacrifice for a cause; surveys in several countries showed that consumers responded to the pleas of the authorities by lowering their thermostats.

2. The figure compares total gas demand across households, industry and power in November 2022, December 2022, January 2023 and February 2023 with 2019–2021 average figures for the same months. Williams, B., Zachmann, G. "European Natural Gas Demand Tracker." Brugel, accessed 30 August 2023.

The superstar energy source during this period has been solar power, which hit a global installation record in 2022. The boom is not only because of supportive government policy, and not only because of rising adoption by power companies, but because individual households looked at their electric bills and realised the economics of rooftop panels had become more favourable. The Netherlands moved its electricity supply nearly 5 percentage points toward solar power in the course of a single year.[3] India is making a major push on solar power, with solar and wind together accounting for more than 90 percent of the recent generating capacity added to the Indian power grid.[4]

3. EurObserv'ER. "Photovoltaic Barometer," April 2023.

4. Lee, U. "Solar and wind dominate India's capacity additions in 2022," Ember, 17 March 2023.

Figure 12: Wind power capacity, China vs US

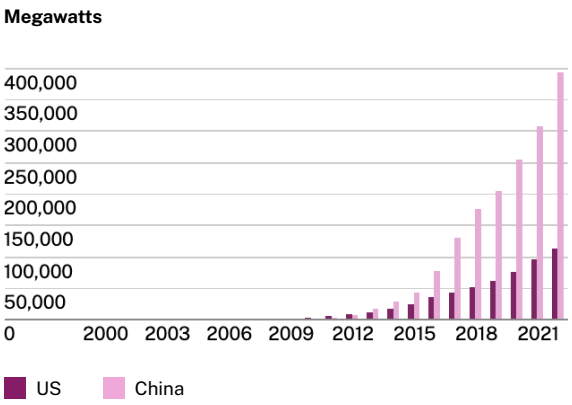
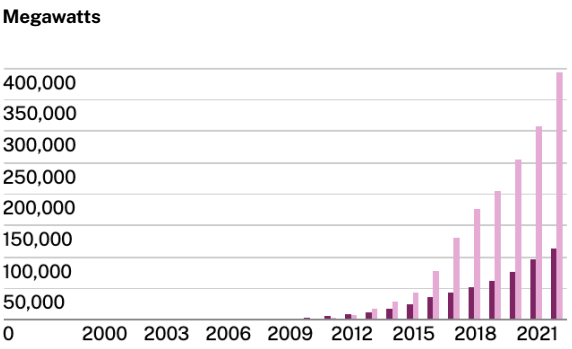


Figure 13: Solar power capacity, China vs US



Source: Statistical Review of World Energy 2023

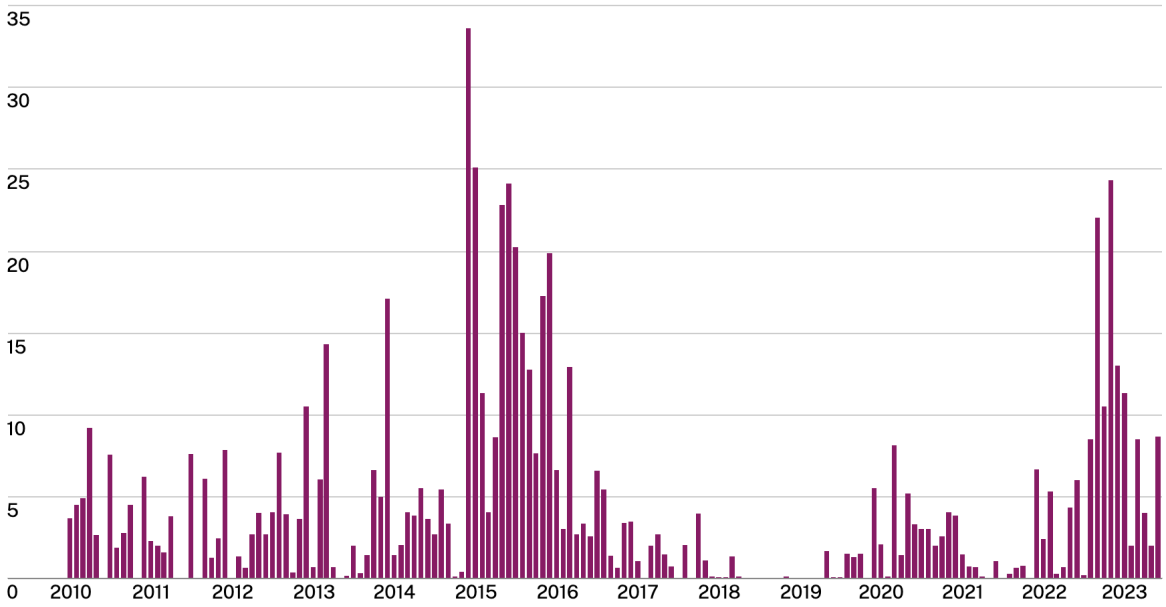
As it has done for years, China is leading the world in the installation of renewable power. Not only does it have most of the world's capacity to produce solar panels, it is also the world's largest market for those panels.[5] Unfortunately, China has also dialled up its approvals of new coal-burning power plants in the past two years, after the issuance of permits nearly came to a halt for a while. The Chinese leadership was panicked by large-scale power outages in 2021 and 2022, and has ordered the new power plants to prevent any recurrence.[6] The outages occurred during intense heat waves that scientists reported were made worse by global warming, so the new coal-burning plants — which will, of course, worsen the emissions problem — illustrate the dire feedback loop in which we are caught. The bright spot in this situation is that China is now using its coal plants approximately half the time and that figure has been falling; if the new plants are kept largely on standby, as seems possible, they need not necessarily torpedo China's emissions goals.

5. "World Energy Investment 2023." International Energy Agency, 2023.

6. Myllyvirta, L., A. Yu, F. Champenois, and X. Zhang. "China Permits two new coal power plants per week in 2022." Global Energy Monitor, 2023: 1–17.

Figure 14: The latest coal boom in China

Gigawatts

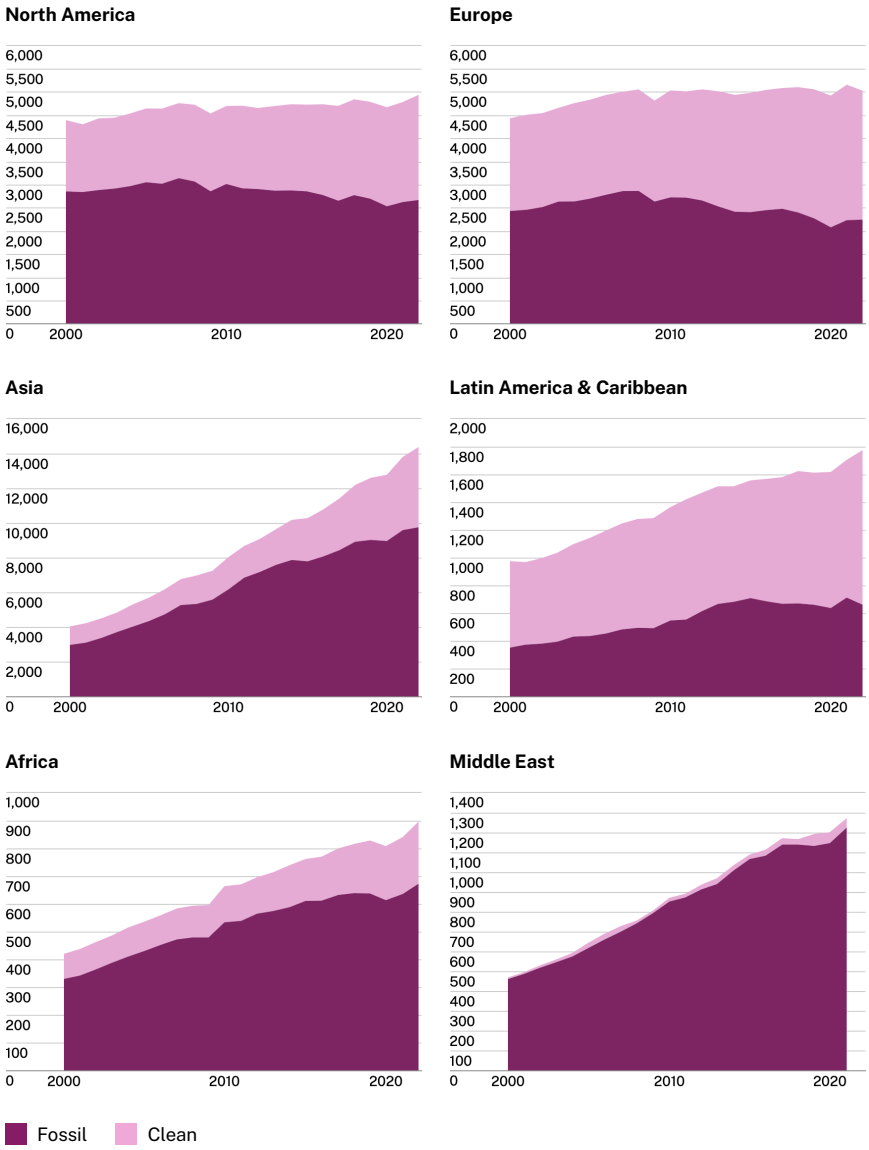


The chart shows newly permitted coal-fired power plants in China, by the month the permit was issued. The recent figures imply an increase in the construction of such plants that is likely to last for years.

Source: Global Coal Plant Tracker, GEM

In summary, we believe the clean-up of the world's electrical grids is moving in the right direction. The trend should get a huge boost from the new climate law in the United States and new policies in Europe, India and other regions. Like the rest of the energy transition, though, the clean-up is not moving quickly enough.

Figure 15: The big clean-up



Fast-growing regions are getting closer to meeting the growth in power demand with clean sources. This chart shows electricity generation in terawatt hours; note the differing scales.

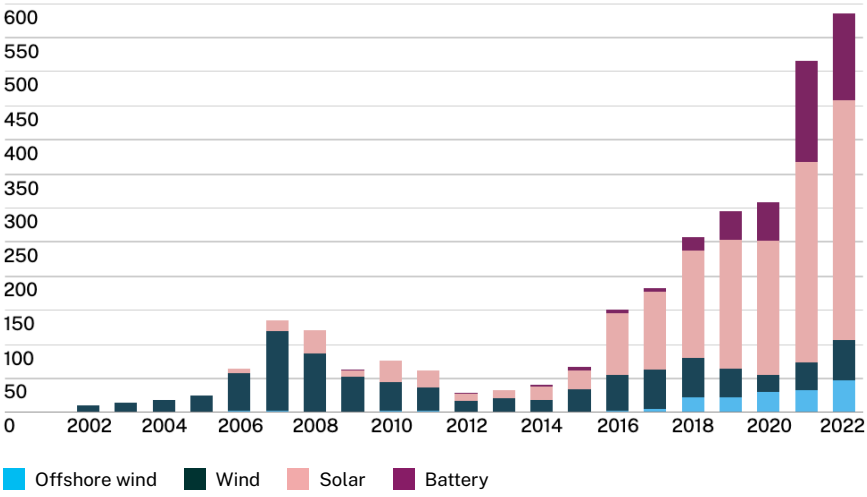
Source: Ember

We are concerned by a relatively new problem that is bogging things down. First in the United States, and then increasingly in countries all over the world, lengthy queues have developed for renewable-energy developers wanting to connect to the grid. The procedures used to plan for the expansion of power lines have turned out to be wholly inadequate to accommodate the rapid growth of renewable energy.[7] Waiting lists that used to stretch for 18 months are now running to five years, and the situation is getting worse. Governments need to move urgently to break this bottleneck.

7. For a detailed discussion of the problem and potential solutions in the American context, see Norris, Tyler H. "Beyond FERC Order 2023: Considerations on Deep Interconnection Reform." Nicholas Institute for Environment, Energy & Sustainability, Duke University, August 2023.

Figure 16: Rising backlog

Capacity, in gigawatts



This chart shows the capacity of renewable electricity and battery projects that have applied to connect to the grid in the United States. The waiting time has ballooned to years, and is also rising rapidly in other countries.

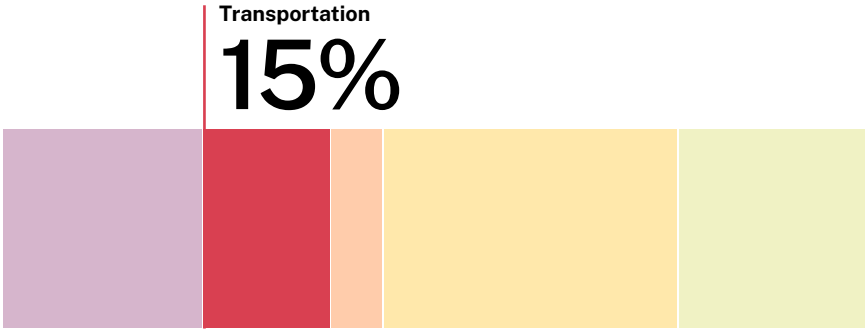
Source: Lawrence Berkeley National Laboratory

On top of that, developers trying to answer the call for more renewable power face additional hurdles, including red tape in getting the land-use permits they need, as well as rising citizen opposition in many jurisdictions. If they want to meet their own stated goals, countries have to find ways to slash through the red tape, bring citizens on board and speed up the needed permits.

Not only must existing generation capacity be replaced by clean sources if the goals of the Paris Agreement are to be met, but the coming electrification of transport, industry and heating implies potentially large increases in power demand. Meeting that demand will require not just a massive wave of clean-power generation, but also the construction of extensive new power lines to supply power at times when solar and wind are not delivering. Grid-sized batteries will be needed to help cover the demand, as will new types of longer-duration electricity storage.

This is a big agenda, and the time to deliver is short.

03 Transportation



Share of direct global CO_2e emissions (IPCC)

Vroom...

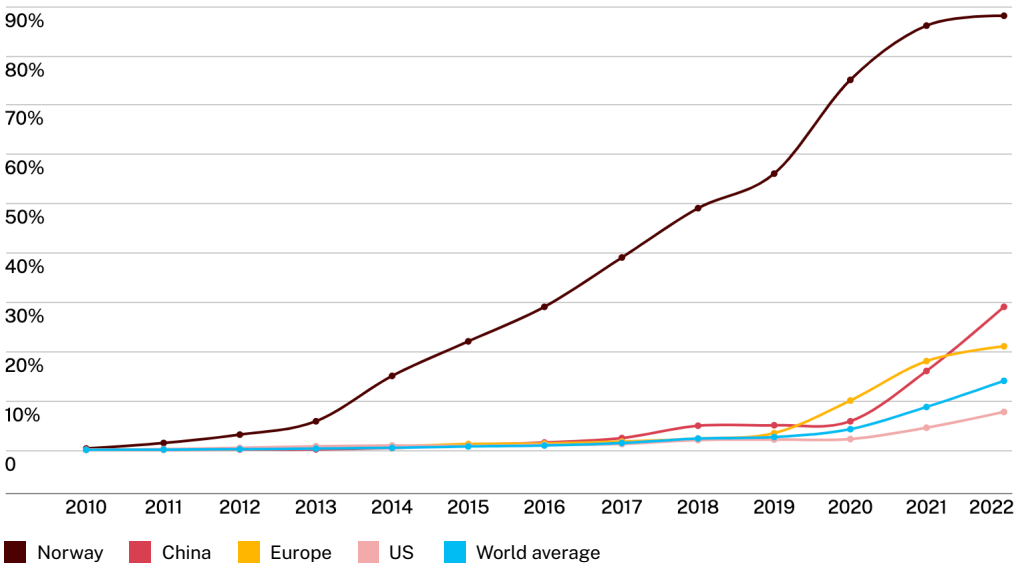
We have entered the fast-growth phase for the electrification of transport. Worldwide, sales of cars with plugs jumped nearly 60 percent last year, and on that higher base, another jump of 30 to 35 percent is forecast for this year.[1] By 2024, electric cars could be 20 percent of the entire global new-car market. These figures include fully electric vehicles, as well as plug-in hybrid vehicles, which can run for a fair distance on electricity before switching over to petrol. These hybrid cars have been an important transitional technology, but they are losing the race to fully electric cars, which now represent three-quarters of cars sold with plugs.[2]

1. The International Energy Agency forecasts a 35 percent increase for this year, but we are slightly more cautious. See Alsauskas, Oskaras et al. "Global EV outlook 2023: catching up with climate ambitions." International Energy Agency, 2023.

2. Alsauskas, Oskaras et al. "Global EV outlook 2023: catching up with climate ambitions." International Energy Agency, 2023.

Figure 17: Cars with plugs take off

EV share of total car sales



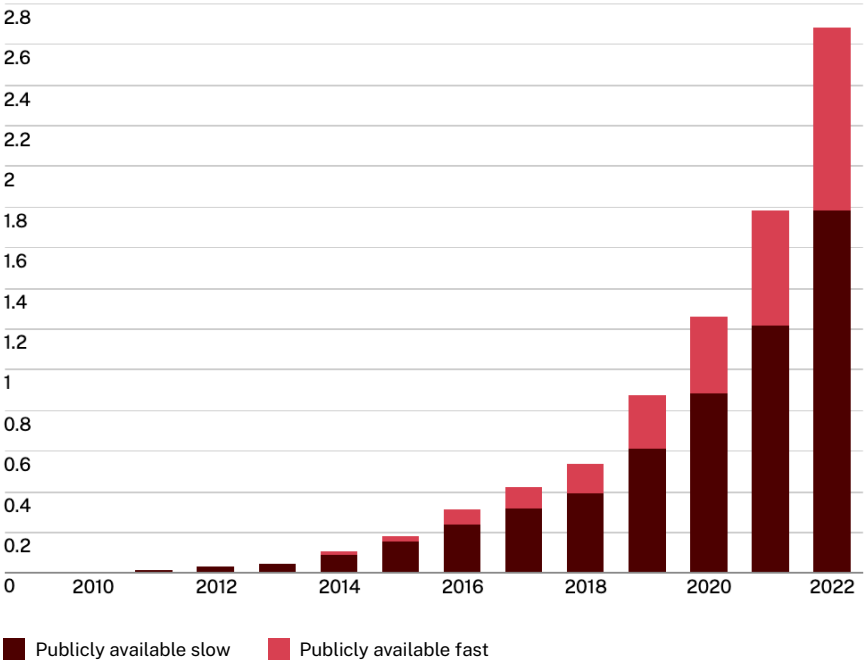
Norway was early adopting favourable policies toward electric cars, and its entire new-car market has shifted. The rapid climb toward mass adoption is now occurring in many countries.

Source: IEA

The turnover of the car fleet is slow, and in most countries, those fast-rising sales mean that only a few percent of the fleet is electric as yet. We still have a long way to go to get fuel-burning cars off the highways. But we are certainly on our way: public interest in electric vehicles is intense and rising. In the major countries where car ownership is commonplace, we are at the point where the broad mass market is willing to consider making the switch. Buyers still confront serious problems that may deter them: too few charging stations, difficulty charging in apartment buildings or urban neighbourhoods, and more. The cars themselves are still far from perfect — taking too long to charge, for example. The 2020s will need to be a decade of confronting and solving thorny problems in the transition to electric vehicles.

Figure 18: Car chargers start to appear

Global number of EV chargers, in millions



Source: IEA

Norway led the world in adoption of electric cars, with laws long on the books that charged markedly lower taxes for electric cars compared to ones burning petrol or diesel. Virtually the entire new-car market has switched to electric in Norway. Much of Europe is chasing Norway, with sales of electric cars well into double-digits: nearly a quarter of the market in the United Kingdom and 30 percent or more in Germany, the Netherlands, Finland and Denmark.

Electric cars also represent 29 percent of the market in China, where overall car sales are now double those of the United States. More than half of the electric cars being sold worldwide are being sold in China,[3] which also dominates the supply chains for production of battery materials and batteries.

3. Alsauskas, Oskaras et al. "Global EV outlook 2023: catching up with climate ambitions." International Energy Agency, 2023.

4. "California Energy Commission Zero Emission Vehicle and Infrastructure Statistics." California Energy Commission, last modified 20 August 2023.

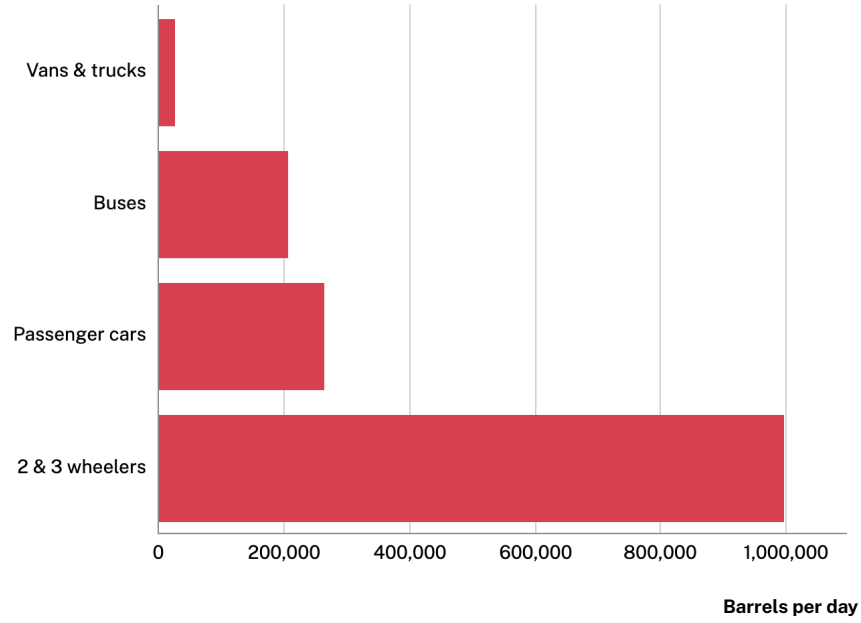
5. "Fuel Taxes Statistics & Reports." California Department of Tax and Fee Administration, accessed 4 September 2023.

6. Alsauskas, Oskaras et al. "Global EV outlook 2023: catching up with climate ambitions." International Energy Agency, 2023.

In California, the most populous American state, automobiles with electrical plugs now represent 24 percent of new-car sales.[4] Enough of the state's car fleet is now electric that total demand for petrol has begun to fall. In fact, ignoring the pandemic disruption of 2020, California petrol demand is down 13 percent[5] from its recent peak in 2017. A truism of American life is that where California goes, the rest of the United States eventually follows. Cars with plugs now constitute 8 percent of all sales in the United States as a whole,[6] a number that is expected to rise sharply under that country's new climate law.

The electrification trend extends beyond passenger cars to encompass buses and some lorries or trucks, as well as the two-and three-wheeled vehicles so common in the developing world. In fact, electrified motorbikes have taken over approximately half of that market worldwide. This is likely to change in the future, but at the moment, the electrification of two-and three-wheeled vehicles is displacing more oil demand than the electrification of cars.

Figure 19: Oil displacement from vehicle electrification

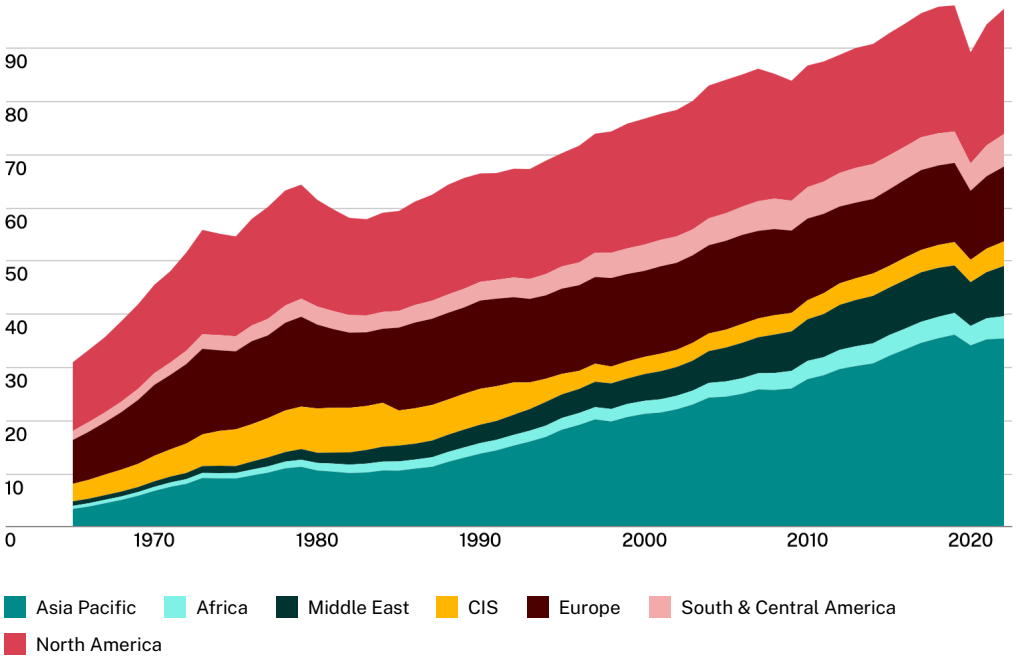


Source: BloombergNEF Electric Vehicle Outlook 2023

Despite the rapid growth of electrified transport, global oil demand has yet to go into a persistent decline. Again ignoring the pandemic year of 2020 and the recovery year of 2021, demand has hovered close to 100 million barrels per day since 2018. One reason is the slow turnover of the fleet, with cars these days lasting a decade or longer before being recycled. Bloomberg New Energy Finance calculates that without aggressive new policies in favour of car electrification, it could be 2040 before half the world's car fleet has an electrical plug. This implies that we could be in for a long plateau in oil demand, with a sharp decline not beginning until late this decade, unless governments push even harder on electric cars and lorries than they are doing now.

Figure 20: Global oil consumption, 1965–2022

Million barrels



The 'CIS' category includes the former Soviet Union and its successor states.

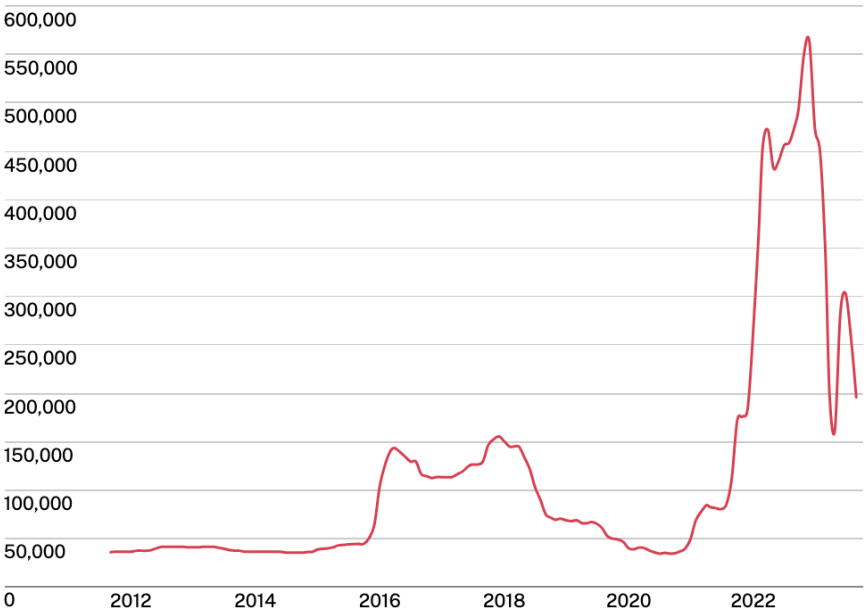
Source: Statistical Review of World Energy 2023

Perhaps the biggest question about the electrification of transport is whether the fast-rising demand for these vehicles can be met. An electric vehicle requires far more metals, chiefly for the battery, than a petrol car. The most important of these is lithium, the lightweight metal at the centre of modern battery technology. Several studies calculate that at least an eight-to 10-fold expansion of lithium production will be necessary if global climate goals are to be achieved.[7]

7. Researchers at the International Energy Forum and the Colorado School of Mines compared multiple studies forecasting demand for critical minerals. For lithium, the studies found a very wide range of potential demand by 2050, from 500 kilotonnes to more than 2,000. The median in those studies was 1,049 kilotonnes in 2050, leading us to say that 'at least' an eight-fold increase in production will be needed over the 130 kilotonnes produced in 2022. In Figure 22 of this report, we purposefully made a different choice, selecting a higher forecast of lithium demand from the International Energy Agency. This is a way of showing that even at the high end of forecasts, the future demand for lithium is likely manageable compared to production levels previously achieved for other metals. For the full range of demand forecasts, see Akamboe, Juliet et al. "Critical Minerals Outlooks Comparison: A Report by the International Energy Forum and the Payne Institute of Public Policy at the Colorado School of Mines," August 2023.

Figure 21: Lithium carbonate price

Chinese yuan per metric tonne



Source: Bloomberg

Other problematic metals are required for the transition. Cobalt is a component of some types of batteries, and much of the world's supply comes from a single country, the Democratic Republic of the Congo, where it is commonplace for children to be exploited in small-scale mining operations. Another big problem, over the long term, could be the supply of copper, which is required not just in electric cars but in wind turbines and other technologies of the energy transition. Many of the world's best copper deposits have already been exploited, and the quality of available ores has been declining.

Future of mining?

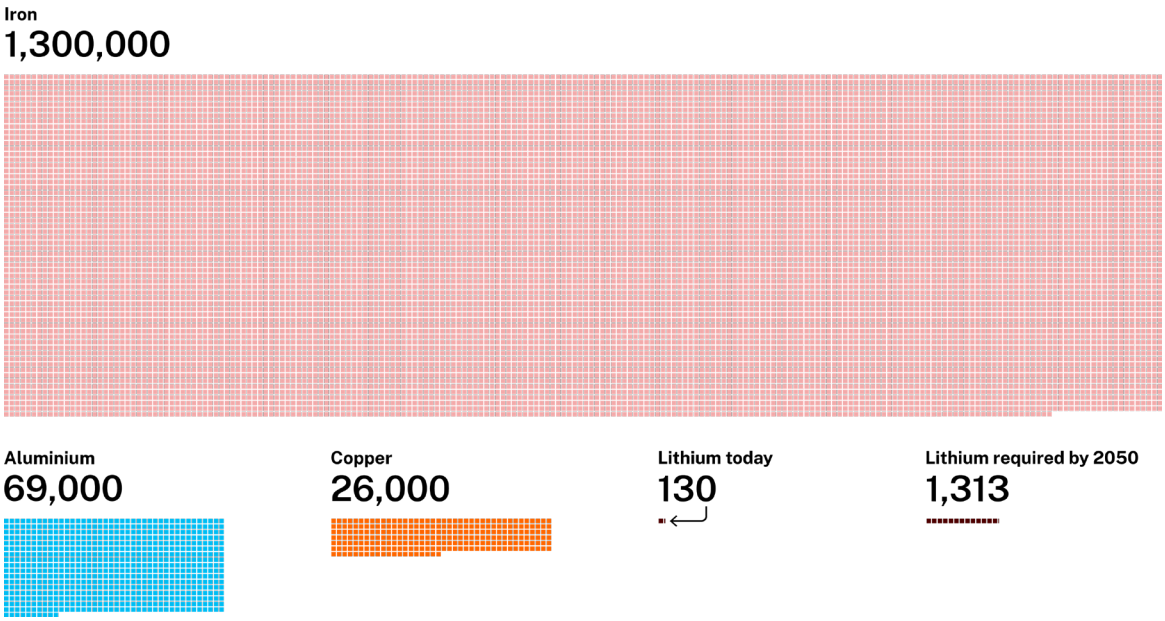
The Democratic Republic of the Congo holds the world's largest cobalt reserves, and the conditions under which the ore is mined there belie that metal's image as one of the keys to a greener future. Children often work in the Congolese mines, as in this one in the Mwenga territory of South Kivu province. Image: Augustin Wamenya/Anadolu Agency via Getty Images

These concerns about the supply of critical minerals for the transition have become serious enough that they are now a talking point for climate deniers, who use the fear of shortages to argue that climate goals cannot be met without severe economic disruption. Though rooted in reality, this is a disingenuous argument: not only is it ill-motivated, but it ignores the basic economics of commodity supply and demand.

Most people understand that in times of shortage, prices rise in order to allocate supply: if lithium is scarce, you will have to pay more to get your hands on it. But rising prices have a more important economic function: they call forth additional supply. That has already happened in the case of lithium, for example, where past price spikes prompted companies in Australia to open new lithium mines, so that Australia is now supplying almost half the world market.[8] If prices continue to signal a shortage, we would expect more new lithium mines to come into production, though it will certainly take time. Lithium is sufficiently abundant in the Earth's crust that there is no theoretical barrier to meeting future demand. As the graphic below shows, the potential future demand for lithium is far smaller by volume than some of the metals we already mine at scale.

8. Venditti, Bruno and Sam Parker. "Visualizing the world's largest lithium producers." Visual Capitalist, 12 June 2023.

Figure 22: Metals we mined in 2022, in kilotonnes



Large increases in the production of critical minerals will be required for the energy transition. The chart element at bottom right shows a forecast by the International Energy Agency of lithium demand in 2050, for example. The rest of the graph shows current production levels of various metals, leading us to believe that future lithium demand can be met.

Source: USGS and the IEA

High prices and shortages also create a powerful incentive for substitution of one material for another, and so do concerns about social welfare. Estimates of future cobalt demand have come down sharply, for example, as companies concerned about the situation in the Congo have figured out how to reduce or eliminate the cobalt required for their car batteries.

We are cautiously optimistic about the future supply of critical minerals for one more reason: the price gyrations in these markets are calling forth not just new supply, but new technology to help us augment that supply. One way of producing lithium is to extract it from brines in huge evaporation ponds, a slow and dirty technique. But several companies are working on modernised methods that could recover the lithium more quickly, and recover more of it. Similarly with copper, a new technique appears to allow the metal to be recovered from mine tailings that were previously treated as waste. If they live up to their promise, these approaches could deliver meaningful increases in the supply of critical minerals.

Lithium mining in Chile

Some lithium mines use immense evaporation ponds to concentrate the metal, demanding excessive land and water. But new technologies may allow for more efficient extraction.
Image: John Moore/Getty Images

We may well be in for some rocky years as companies struggle to meet the fast-rising demand for these metals. We are likely to see temporary blips in the long-term trend of declining costs for electric vehicles, and possibly other technologies too. But economic history suggests the supply problem can and will be solved. We hope, this time, it will be solved with due regard for the rights of the people from whose lands these minerals will have to be extracted, and with due consideration for the welfare of the workers.

We also think as the global fleet of electric vehicles grows, battery recycling needs to become a critical priority. As we have seen in other markets, it can be tricky to get the economics of recycling to work, and doing so may require specific public policies, like the disposal fees already imposed on conventional car batteries. Do we need a disposal fee on electric-car batteries, paid up front by the first buyer of the car, with that stream of cash going to support the operations of battery recyclers? The time to figure this out is now.

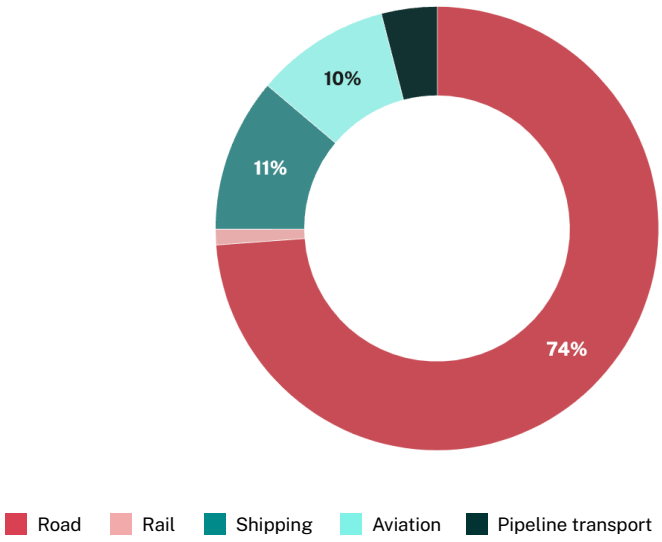
Reclaiming metals

A worker wearing a protective mask uses a tool to push a load of batteries onto a conveyor at the Li-Cycle lithium-ion battery recycling facility in Kingston, Ontario, Canada. Image: Christinne Muschi/Bloomberg via Getty Images.

While the electrification of the car fleet is proceeding apace, it is less clear how society can tackle emissions from other forms of transportation. Batteries are improving fast enough that heavy lorries may yield to electrification, though some experts believe running them on hydrogen may be the easier path forward. Battery-powered planes are under development, but are likely to be useful only for short trips. Cutting the emissions from longer plane journeys will almost certainly involve sustainable aviation fuel, essentially a form of jet fuel made by methods that limit emissions. Yet again, the difficulty is cost: sustainable jet fuel today is several times as expensive as conventional fuel. But airlines are beginning to commit to using limited amounts of it, in hopes of sparking an industrial scale-up that drives the cost down. Ammonia, which can be made from green hydrogen, may turn out to be the fuel of choice for global shipping. A.P. Moller-Maersk, the huge Danish shipping conglomerate, is already pursuing that approach.

On the ground, public policies designed to cut vehicle emissions have focused heavily on electrification of transport. But everyone needs to recognise that electric cars and buses are not a magic answer. If we simply substitute an excessive number of cars on the roads with an excessive number of electric cars, we will still have congested cities, extravagant waste of metals and plastics, and many other problems. Electric cars do not even eliminate all harmful emissions at the point of use: some of the most damaging particles in the air come from brake and tyre wear, and because electric cars are heavier than conventional cars, those problems could even get worse.

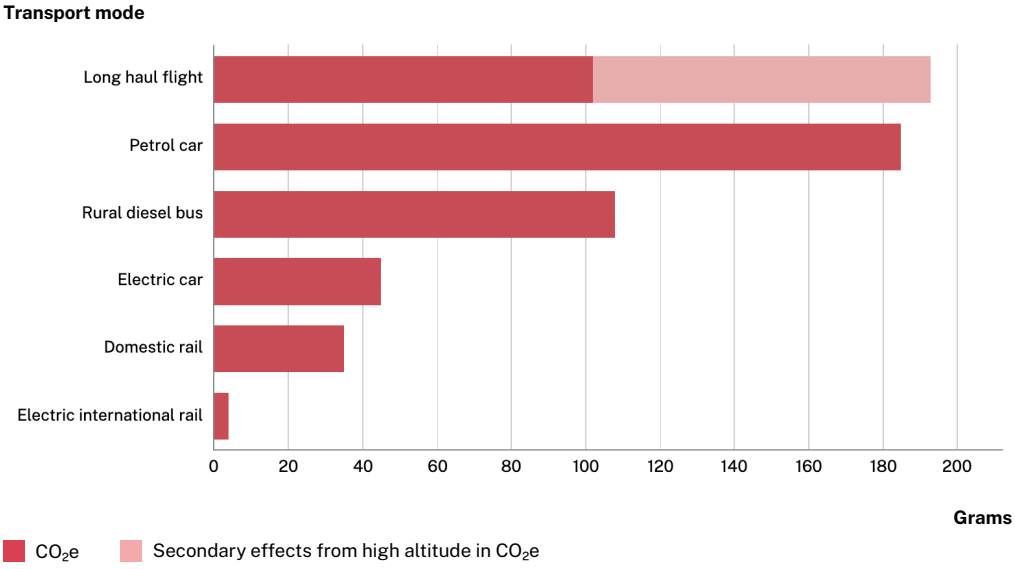
Figure 23: Transport emissions, 2022



Source: IEA

It is critical, therefore, that governments begin to broaden the suite of policies they are using to tackle transport emissions. Redoubled investments in public transit need to be a priority in every part of the world with the population density to support it. If we can move people out of cars entirely, that would be better than simply moving them from petrol to electric cars. In cities overwhelmed by traffic, the congestion can be managed with a technique called congestion charging, in use for decades in Singapore and adopted more recently in London and Stockholm. New York City, after years of political struggle, finally appears to be on the verge of adopting a congestion charge, with the money raised from it devoted to improvements in public transit. We hope that success in New York will prompt other American cities like Chicago, Seattle and Los Angeles to move congestion charging to the top of the political agenda, and we also hope to see the trend spread to cities around the world.

Figure 24: Emissions per passenger kilometre



This chart shows emissions typical of various modes of transport. The figures are broad averages, and real per-passenger emissions can vary considerably depending on location, on how many passengers a bus or train is carrying, and other factors.

Source: UK Government

Congestion charging is one important part of a much broader project that we call city repair. If you have travelled to the Netherlands and seen how many thousands of people commute to work on bicycles, you should be aware that it was not always that way. In the 1970s, Amsterdam was as overwhelmed by cars, traffic and asphalt as any city in the world. But the deaths of scores of children playing in the street who were run over by motorists set off a political movement that, over time, wrought immense change in the cityscape. The same thing is happening now in Paris, which has launched a sustained campaign to reclaim road space from the automobile and turn it over to bicyclists and pedestrians.

Fixing cities

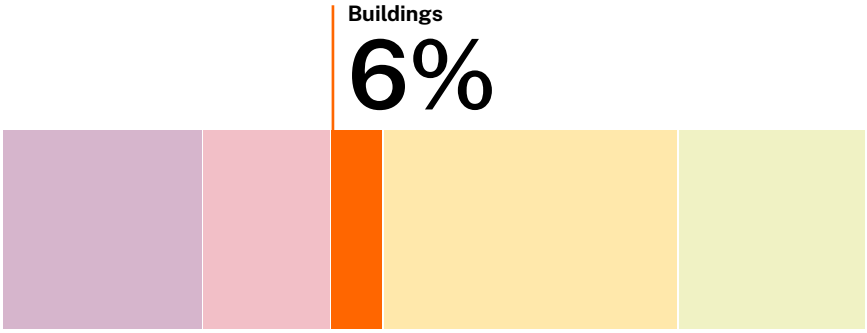
Utrecht, in the Netherlands, has undertaken an extensive programme of city repair. These before-and-after photos show how a freeway was torn down to make way for urban amenities, including the restoration of a historic canal. Before Image: Meijnen, W. After Image: Bas van Setten.

Even in the land of endless low-density suburbs, the United States, this battle has finally been engaged. Cities and, recently, entire states are eliminating zoning laws that prohibit the construction of apartment buildings, so that cityscapes can grow denser over time, and therefore more conducive to urban living and to mass transit. Truly absurd laws requiring minimum levels of 'free' parking, which ate up unnecessary land and drove up the cost of homes, are being repealed. These policies are relatively new in America, but they are already starting to pay dividends. After overly restrictive zoning laws were repealed in Minneapolis, for instance, a wave of apartment construction has ensued, and inflation in the cost of housing has moderated.[9]

This project of city repair is mainly about the quality of life in cities, not so much about the climate crisis. But the policies needed to get people out of cars and onto their feet or their bikes are entirely consistent with the policies needed to cut emissions and reduce dependency on the automobile. It may be the ultimate example of the old injunction to think globally and act locally: to repair our cities, to knit the damaged urban fabric back together, is to repair the world.

9. Niquette, Mark and Augusta Saraiva. "First American city to tame inflation owes its success to affordable housing." Bloomberg, 9 August 2023.

04
Buildings



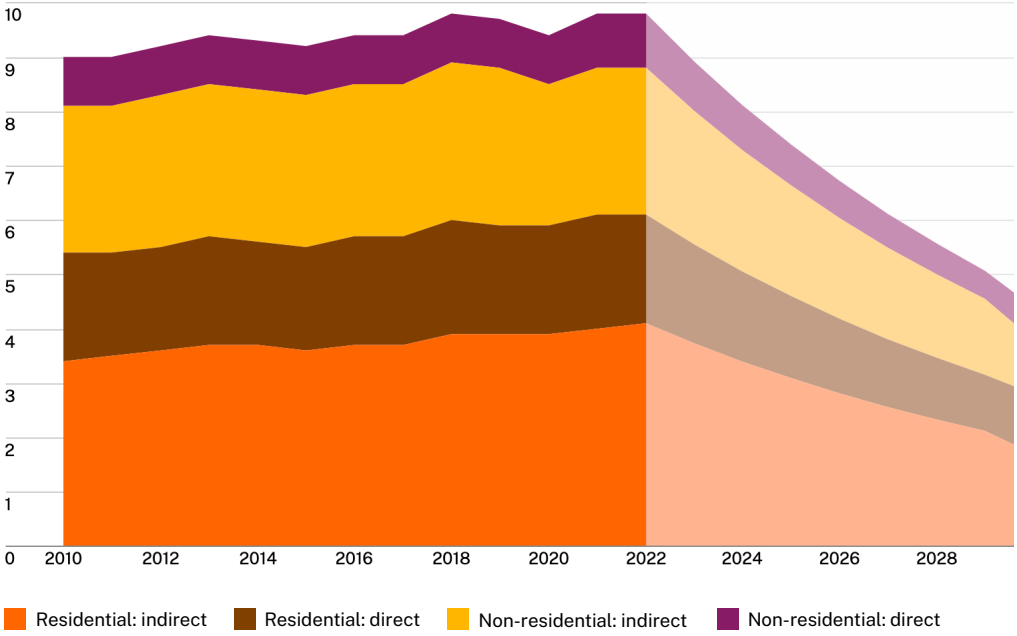
Share of direct global CO_2e emissions (IPCC)

The politics of heat

The buildings in which we live and work are among our greatest climate liabilities. And in contrast to the situation with electrical power and transportation, buildings are one of several economic sectors where momentum is still lagging. The following chart shows the recent history of emissions from the world's buildings, as compiled by the International Energy Agency, while the future years on the right show the scope of declines needed if the goals of the Paris climate agreement are to be met. There is little reason to think we are on track for such rapid declines.

Figure 25: Building emissions

CO_2, in gigatonnes



Historical emissions shown through 2022, while future years show emissions cuts required to stay on track for the most stringent goal of the Paris climate agreement.

Source: IEA, Generation analysis

At first buildings might seem to be one of our lesser problems: they are directly responsible for only 6 percent[1] of global emissions of carbon dioxide, mostly from burning gas for space and water heating. But the footprint of buildings more than triples when their indirect emissions are counted — that is, their use of electricity.[2] It is inside buildings that most of the world's electricity is used, of course, so the efficiency with which they use it is a critical issue.

Many people will have some familiarity with one aspect of this problem: the bulk of the housing stock in developed countries is decades old, with some homes dating back centuries. Their draughty windows and poor insulation mean that heating and cooling them requires enormous amounts of energy. Bringing them up to modern standards can be difficult and expensive. Unfortunately, the problem runs deeper than just older buildings, however. All over the world, we are still putting up buildings that waste more energy than necessary. Buildings that use little energy for heating and cooling are technically achievable, but in very few parts of the world are building codes in place to require such stringent construction; even where the codes are adequate, enforcement of them often lags.

A global push is under way to tighten both the building codes and the enforcement of them, but such measures are often resisted by the construction industry, because they cost money. It is typically the case that these improvements — tighter windows, thicker insulation, better air-handling systems — will pay for themselves over time by saving energy. But they do drive up the initial cost of buildings slightly. Like so many other industries that could make a contribution to solving the emissions problem, the construction industry keeps choosing short-term profits over the long-term welfare of the planet.

The problem of buildings is difficult enough in the developed world, but it is even more vexing in the developing world. Many poor and even middle-income countries make little attempt to enforce building standards of any kind. In parts of the world where urbanisation is proceeding at a breakneck pace, millions of slapdash buildings are going up with little attention to their long-term energy use. The governments of developing countries often simply lack the capacity to make and enforce building codes. Some serious thinking is needed about how to tackle this problem. One possibility would be to tie development aid and trade deals to the willingness of governments to make and enforce building standards, but that will only work if those governments also get help expanding their technical capacity to carry out the task.

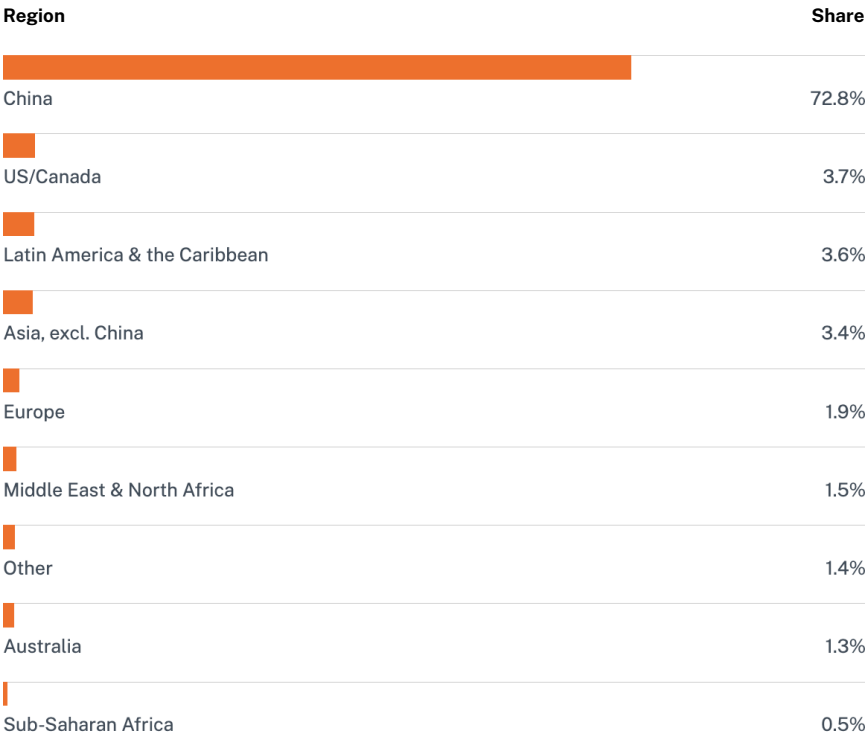
Repairing the world's buildings is undoubtedly one of the hardest problems we have to tackle — it may, in the end, prove to be the hardest, given that hundreds of millions of building owners need to be moved to action. However, some governments are finally coming to grips with the need to act.

1. Cabeza, L. F., Q. Bai, P. Bertoldi, J.M. Kihila, A.F.P. Lucena, É. Mata, S. Mirasgedis, A. Novikova, Y. Saheb. "Buildings." In "Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge University Press, Cambridge, UK and New York, NY, USA.

2. "Tracking Clean Energy Progress 2023: Buildings." International Energy Agency, 2023.

Modernising the building codes is a critical step. Reasonably strict codes are in place in Japan and across much of Europe, and they have been adopted piecemeal in parts of the United States. China has adopted a stricter building code that went into force in 2022 and, if adequately carried out at the local level, could yield major energy savings in that country. China has already achieved an enormous success in its building stock, one little heralded outside the country: hundreds of millions of solar water heaters have been deployed there, rooftop units that supply household hot water by passing the water through small tubes heated by the sun. China has more than 70 percent of the world's solar hot-water capacity. With thousands of manufacturers and savage competition in the marketplace, the devices can be had for as little as USD 200, and in some parts of the country, every home has one, alleviating the need to burn fuel for hot water.

Figure 26: Worldwide deployment of solar water heating

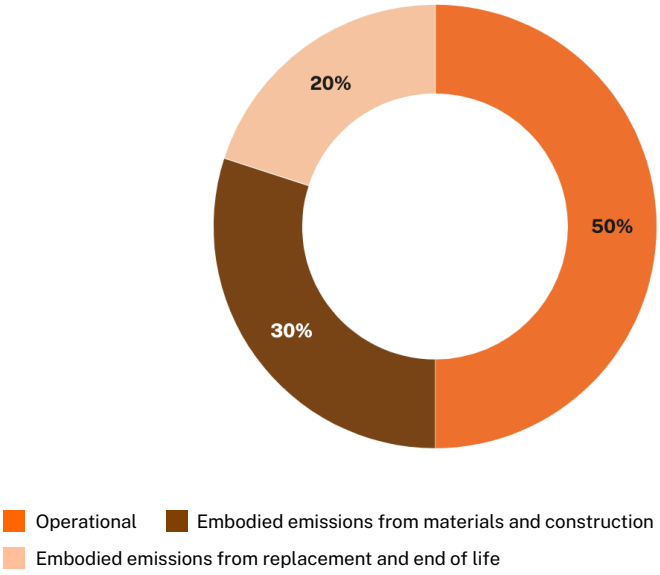


China is the runaway world leader in heating water with rooftop solar units. Figures are for 2021.

Source: IEA Solar Heating & Cooling Programme

With new buildings, the issue is not just the lifetime energy required to run them. As much as 30 percent of a building's emissions come from the materials required to build it in the first place: the cement, steel, wiring and so forth. These 'embedded emissions' have been the focus of far too little attention, but that, too, is starting to change. Public policy needs to require that embedded emissions be calculated when a building goes up, and it needs to set targets for cutting those emissions. This is entirely achievable: experts have found that many buildings use more cement, steel and other materials than is truly necessary, meaning there is scope for cutting the emissions just by cutting the volume of materials used. Buildings could also use cleaner steel and cement made by methods that we will describe later in this report.

Figure 27: Lifecycle building emissions



Breakdown of an average building's lifecycle emissions, from construction through the operational phase and then the final step of demolition. Too little attention has been paid to emissions at the beginning and end.

Source: WBCSD

If stricter building codes are the answer for new buildings, what about older buildings? In the West, governments have for decades cajoled building owners to make upgrades that would cut their energy bills, with only limited success. Governments are beginning to recognise that mandates are required. A policy moving through the European Union would demand that the worst-performing 15 percent of all buildings undergo mandatory energy upgrades.[3] Similar mandates are under consideration in about two-dozen jurisdictions across the United States and have already been adopted in New York City, Washington, D.C., Seattle and a handful of other cities.[4] In the early stages, these policies tend to apply to larger buildings. But it will eventually be necessary to impose rules on individual homes and apartments, with the requirement to bring them up to modern codes perhaps being triggered at the time of sale to a new

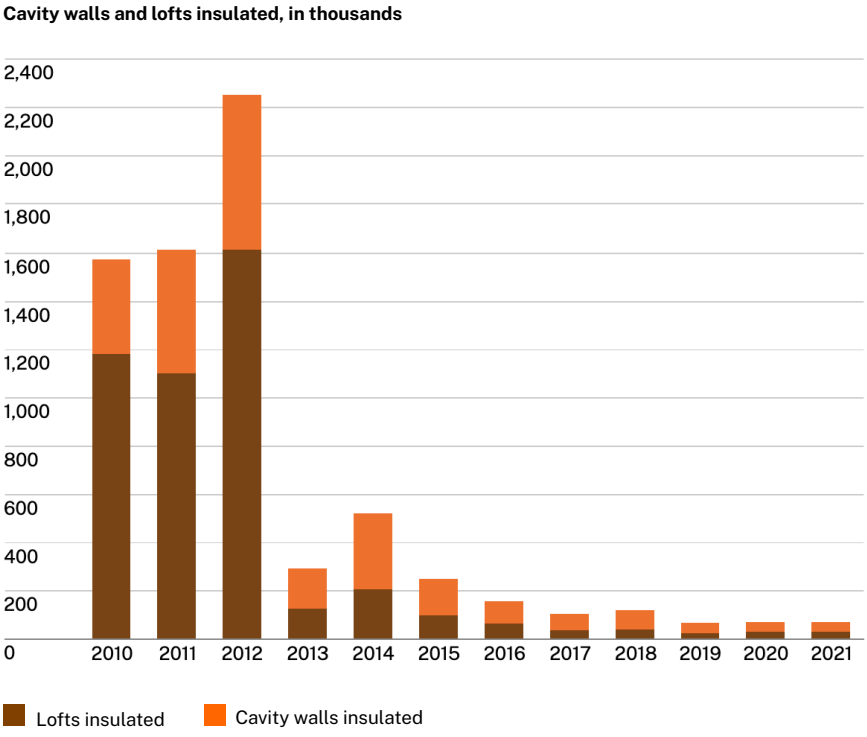
3. Note, however, that this policy is encountering resistance from some member states of the European Union, and it is unclear whether it will survive to final adoption. Symons, Angela. "The EU green buildings plan aims to slash emissions — but this European country isn't happy." Reuters, 2 June 2023.

4. For tracking of building performance standards in the United States, see the ongoing reports of the Institute for Market Transformation, Washington D.C., at www.imt.org.

owner. Some of the new laws are already proving controversial — building owners in New York are lobbying fiercely to get themselves exempted from the requirements there, for instance, so far without success.

Recent events in the the United Kingdom illustrate how much public policy matters in the realm of buildings. For years, the British government imposed an obligation on energy suppliers to help lower-income customers tighten the shells of their homes. But, after a new government came to power, that policy was replaced by a poorly designed, underfunded programme. The following chart shows what happened to the uptake of building-efficiency measures as a result of the policy change.

Figure 28: Smart policy matters: the impact of policy change on energy efficiency uptake in the UK



The number of efficiency measures enabled by government schemes plummeted in 2013 as new policies replaced those of the previous government.

Source: Carbon Brief and the UK Climate Change Committee

Without doubt, imposing mandatory energy requirements on building owners all over the world is going to be a stark political challenge. Fortunately, a technology has become available that can help us to decarbonise the world's building stock. And the good news is that it is starting to take off. This technology can sound almost magical. Put one unit of electricity into a device called a heat pump, and you can get three or four units of heat out of it. That is to say, a heat pump can be 300 percent to 400 percent efficient, which sounds on first blush like it must defy the laws of physics. It does not.

The reason is that instead of creating heat, a heat pump moves heat around. Every person in the developed world is familiar with one variety of heat pump: the refrigerator. By compressing and then decompressing a gas called a refrigerant, the machine is able to transfer heat from one place (the inside of the refrigerator) to another (typically, the air space behind the refrigerator). A household air conditioner is also a heat pump, one set up to move heat from inside a home to the outdoors. Essentially the same equipment can be used for heating, not just cooling, by reversing the direction of flow and moving heat from the outdoors to the interior of a home in winter. It can do this even when the outdoor temperatures are frigid, just as a refrigerator can pump heat out of a chamber that is already cold to begin with.

For decades, heat pumps have been a technology of choice for heating homes in mild climates. They were perceived not to work as well in cold climates, but the technology has improved in recent years. Now heat pumps can work even in extreme cold, though their efficiency does suffer in frigid temperatures. If they are run on clean electricity, heat pumps can heat or cool buildings with no emissions, making them one of the essential technologies of the energy transition.

Heat pump installation

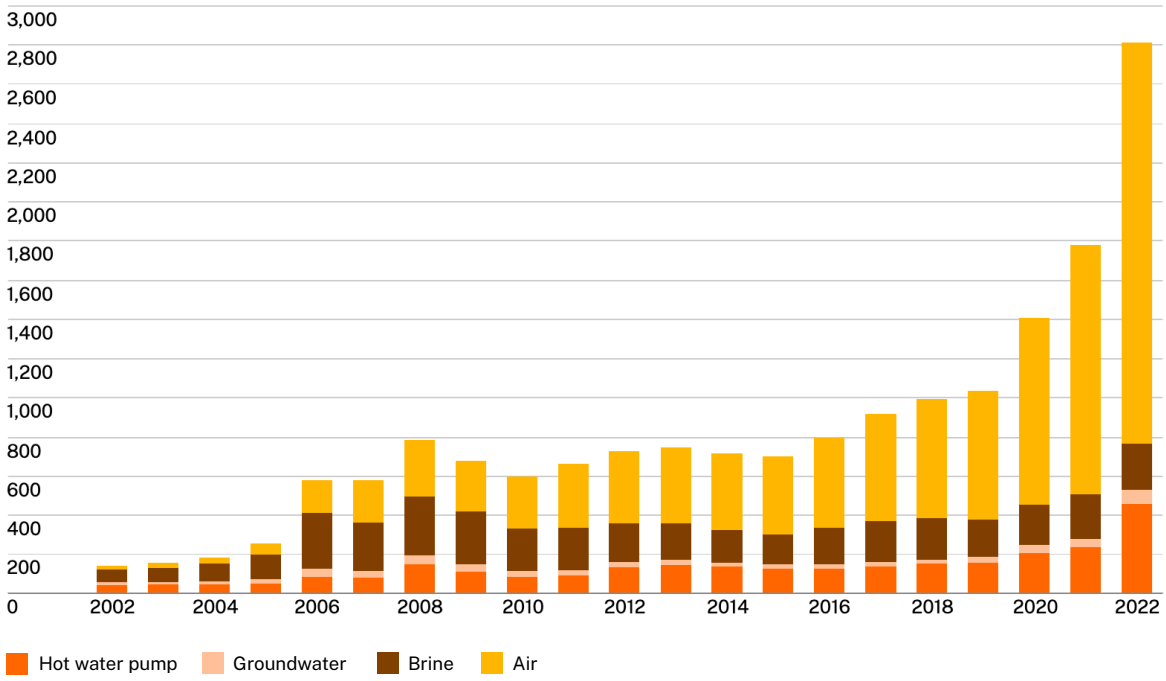
In Folkestone, a town in England, installers set up a heat pump for a house built in the 1930s. Image: Andrew Aitchison / In pictures via Getty Images

The good news is that this technology is finally on its way to wider adoption: the installation of heat pumps is booming across many regions of the world, with global sales up by double digits for two years running.[5] Installations are up by as much as 50 percent across some countries of Europe, with certain governments pushing them hard as an answer to the Ukraine war and the need to cut Russian gas. For the first time, heat pumps are now outselling gas furnaces in the United States, and we believe subsidies embedded in the new climate law there should accelerate the market.

5. Monschauer, Yannick et al. "Global heat pump sales continue double-digit growth." International Energy Agency, 31 March 2023.

Figure 29: German heat pump sales

Units sold, in thousands



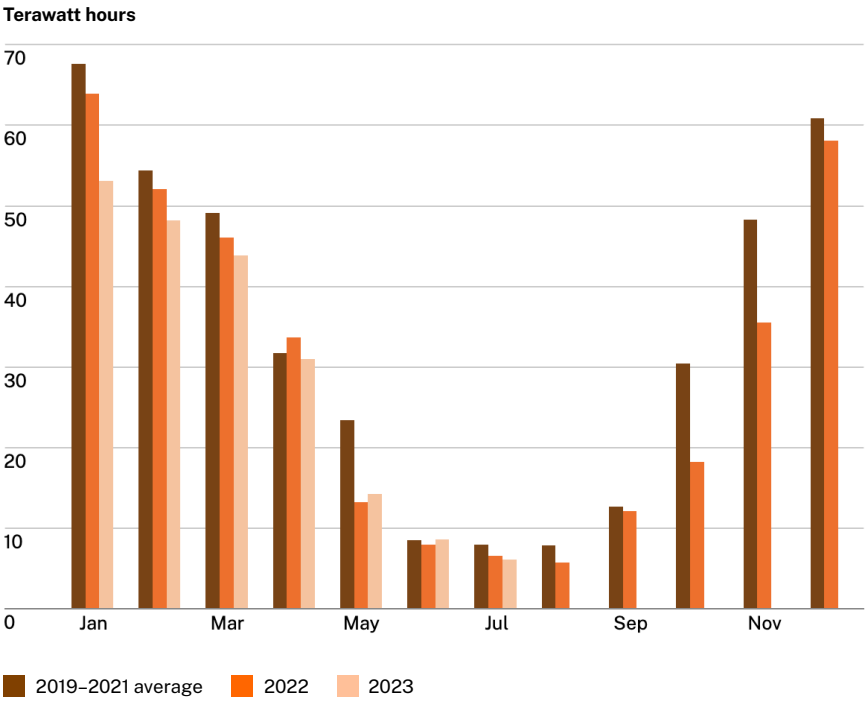
Sales of heat pumps have boomed in Germany as the country works to wean itself off Russian gas.

Source: Bundesverband Wärmepumpe e.V.

But heat pumps are also embroiled in a rising political controversy. Who would have imagined that the lowly heat pump could tank an entire government in one of the world's most stable democracies? Yet that nearly happened this summer, in Germany, and it is one more example of the fights breaking out worldwide over seemingly mundane issues as climate policy starts to get serious.

The controversy revolved around an aggressive policy pushed by the Green Party, one element of the three-party coalition that governs Germany. The Greens wanted to ban the installation of new gas boilers in homes as of 1 January 2024, in favour of heat pumps, an aggressive timeline. A junior party in the coalition, the centre-right Free Democrats, raised strong objections. That party turned out to have its finger on the public pulse, for polls showed 75 percent of Germans thought the Greens were moving too fast. Heat pumps are still more expensive than gas boilers, and the subsidies on offer from the German government would not have fully offset the difference. Just as important, with heat pump sales already booming, installers were backlogged by many months, so that anyone who needed an emergency replacement for a failed boiler would likely have had a long wait for a heat pump.

Figure 30: German monthly household gas demand



Households in Germany have done their share to help the country wean itself off Russian gas.

Source: Bruegel

With the stability of the coalition government threatened, the Greens were forced into a compromise that will likely delay their gas-boiler ban by years. Other European countries, after watching that experience, are likely to tread carefully as they push a switchover to heat pumps, although France has already managed to pull off a ban on new gas boilers without nearly as much drama as in Germany.

Heat pumps are not just politically tricky: they are also a two-edged sword when it comes to the electric grid. A rapid, large-scale switch away from gas toward heat pumps has the potential to drive up electrical demand to an excessive degree in the winter. It may in some circumstances drive up summer demand, too, for certain types of heat pumps can be used as air conditioners in homes that might not previously have had air conditioning. In principle, even a wasteful building can eliminate its emissions if it uses a heat pump powered by renewable electricity, but failing to tighten the shells of buildings as heat pumps are installed would risk putting too much strain on the grid.

That same logic applies to other electricity-using devices inside buildings. These 'plug loads' are a growing source of electricity demand the world over. Once upon a time, devices had switches that allowed them to be turned off, but nowadays, a television set that is 'off' is almost always on, waiting for a command from a remote control. We have entered an era when most devices are on all the time, so how much power the equipment draws in standby mode has become a critical issue.

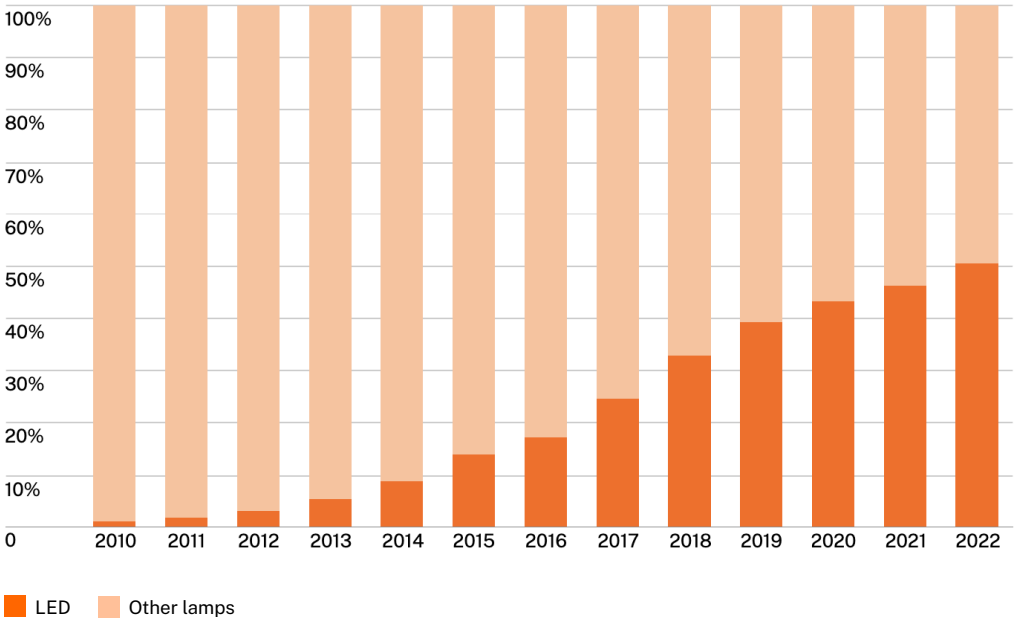
New appliances like refrigerators, air conditioners and washing machines tend to be manufactured in just a handful of countries. Right now, rich countries like the United States and the western European nations are enforcing reasonably strict efficiency standards and keeping the lowest-quality products off their domestic markets. But those products are still being made and sold at low prices in the developing world. We need a global deal that sets minimum efficiency standards worldwide and raises them over time. This has effectively been achieved with certain select categories of products, like power bricks for electronic devices, but it needs to be achieved across the entire range of consumer goods.

One important global deal is already in place. Remember we mentioned that heat pumps require gases called refrigerants, and so do refrigerators and air conditioners. These gases are potentially problematic, for they often leak out of refrigeration equipment and, once in the atmosphere, act as potent greenhouse gases themselves. This leakage can somewhat undercut the benefit of mass adoption of heat pumps running on clean electricity.

Fortunately, under a new amendment to the Montréal Protocol on Substances that Deplete the Ozone Layer, certain refrigerant gases with a high potential to exacerbate global warming are to be phased out and replaced with climate-friendlier gases. This so-called Kigali Amendment has now been ratified by the large majority of the world's countries — including, on 21 September last year, the United States. The 69 to 27 vote in the United States Senate to accept the deal was the first approval of a climate treaty by that body in decades. The treaty gives some countries long timelines to come into compliance, with the problematic gases not entirely banned worldwide until 2047. But with a ban now inevitable, there is a good chance the market will shift entirely to climate-friendly gases earlier than that.

Over the past decade, despite the broader lack of progress, the world's buildings have been the scene of one major triumph in energy policy. Bulbs based on LEDs, or light-emitting diodes, are rapidly replacing older types of light bulbs. Developing countries have played a major role in this achievement, with Chinese manufacturers helping to drive down the cost of the bulbs and India organising large-scale procurements that created one of the world's largest markets for the bulbs. These bulbs cut electricity use by more than 90 percent compared to old-fashioned light bulbs, and their adoption in recent years has been credited with holding electricity demand flat in many countries.

Figure 31: LED share of global residential lighting sales



LED lights have seized half the market for residential lighting worldwide and are on their way to taking all of it, a boon for the efficiency of lighting.

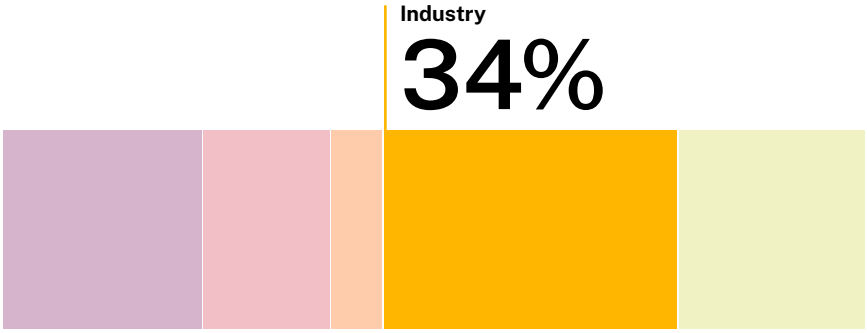
Source: IEA

While the electrification of buildings has the potential to put excessive new loads on the power grid, dawning technological possibilities offer us a way to avoid that outcome. In fact, our buildings could potentially become a major asset to the power grid, helping to balance out fluctuations in the supply of electricity as more and more renewables connect to the system.

How would this work? Historically, power engineers treated electrical demand as a given, and worked to vary the supply in order to meet that demand. But in the era of smart devices and ubiquitous internet connectivity, that paradigm is fast growing outdated. With the right arrangements, power companies can send signals to customer equipment to manage the demand. For instance, you might load a dishwasher late at night, but instead of running immediately, that dishwasher could wait for a signal from your power company. Perhaps it does not run until 4am, when strain on the grid is at low ebb and demand is easily met. Your dishes would still be clean in the morning, but the appliance would have used cheaper power, caused lower greenhouse emissions or both. Similarly, thermostats could be turned up or down slightly, water heaters could be turned off when not needed, and so on.

This is not some mystical vision of the future: it is already happening. In fact in some places, including California, people are being paid significant sums by power companies to allow this kind of demand management inside their homes. The rapid development of these systems has helped California avoid blackouts during recent summers with high power demand. In a grid with more fluctuations from renewable energy, and more erratic weather straining our power supplies, we think this is the kind of smart thinking that must spread worldwide.

05
Industry



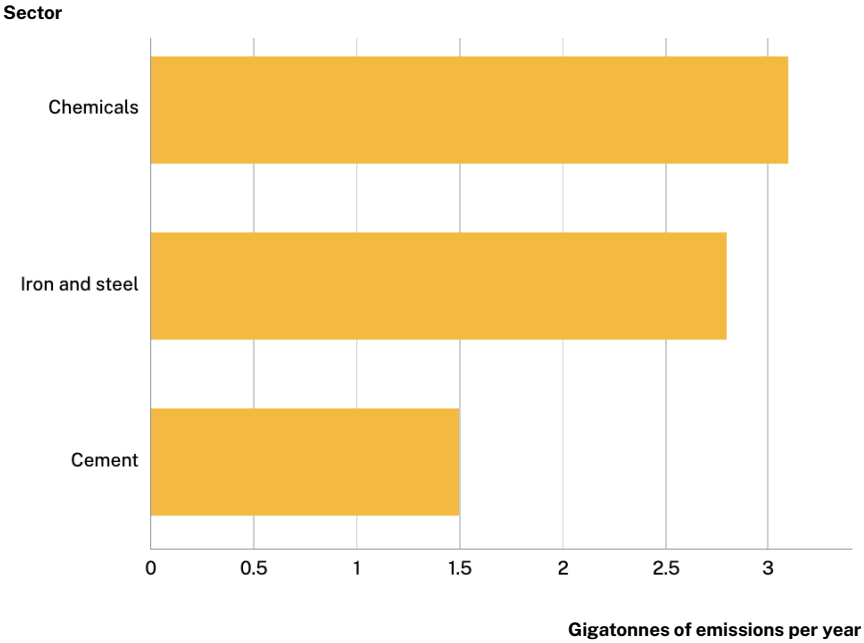
Share of direct global CO_2e emissions (IPCC)

Struggling for traction

Every time a pavement, a bridge or a skyscraper is built with modern methods, carbon dioxide escapes into the atmosphere. Many of the chemical transformations that create the materials of the modern world have a greenhouse footprint. Most of the food people eat was grown with chemical fertilisers made in part from fossil gas. Plastics typically start out as gas or oil, and they have a greenhouse footprint, too. Steel and cement, two of the fundamental building blocks of civilisation, are made by techniques that involve prodigious emissions.

Industry is not only one of the world's largest sources of greenhouse gases, it is proving to be one of the hardest to clean up. Scant progress has been made so far. In many cases, methods that would allow chemicals and building materials to be produced with low emissions are still in their infancy, with little information available on what they may cost to scale up. In other instances, lower-emissions methods have been developed but adoption is lagging. In principle it may be possible to reduce the environmental consequences of many industries by capturing their emissions and burying them underground, but only halting progress has been made on that approach.

Figure 32: Emissions of hard-to-abate sectors



Data reflects emissions in 2019

Source: WRI

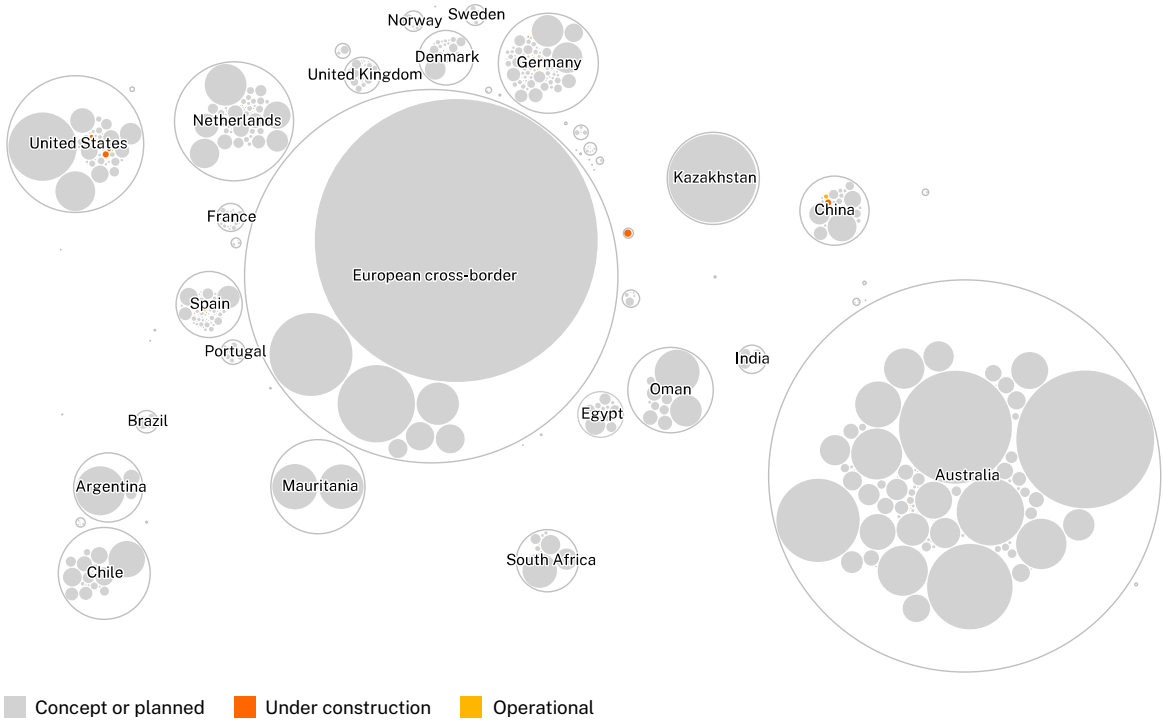
Still, the picture is not entirely bleak. Governments, responsible for most of the world's road and bridge construction, are starting to send market signals that they will be willing to pay for cleaner materials. They are beginning to pass laws and adopt targets designed to get industry moving in the right direction. In some jurisdictions, they are putting a price on industrial emissions, creating an economic incentive to find better methods. One promising approach is to electrify the production of heat that is now generated by burning fossil gas; to that end, efforts are under way to create immense, industrial-scale heat pumps that can run on clean power. This approach may be particularly useful in industries like food processing, which uses heat for operations like drying and cooking. Steel can be recycled using clean electricity, and some mills have already started adding solar panels to help power their operations.

Governments are beginning to push hard on one approach that promises to help clean up a slew of industries: the development of 'clean hydrogen.' Hydrogen is widely used in industry already, but it is made by dirty methods that involve significant carbon dioxide emissions. The clean variant of hydrogen can be four to five times as expensive as the dirty stuff.[1] It can be made in several ways. The simplest, but also the most expensive at the moment, is to use renewable electricity to split molecules of water into their constituent atoms of hydrogen and oxygen; the technology is similar to an experiment many people have run in high-school science lessons. Another approach would be to produce hydrogen by combining natural gas with steam; this is the method widely used in industry already, resulting in large emissions, but in principle those could be captured and buried in underground reservoirs.

1. These were the costs being cited for production in the United States in 2021, before the global run-up in natural-gas prices caused by the Ukraine war. See, for example, Hedreen, Siri, "Blue hydrogen runs 'significant risk' of becoming stranded asset — advisory firm," S&P Global Market Intelligence, 19 July 2022. Since fossil gas is the main feedstock for producing dirty hydrogen, prices will have changed with the recent price spike, but they are now falling and we assume this cost differential will likely apply for the better part of the coming decade, at least. The large subsidies in the Inflation Reduction Act will change production costs for green hydrogen in the United States, but that is not the same as a change in the unsubsidised economics.

It is still unclear what the various flavours of clean hydrogen are going to cost, how much of it society will be willing to produce, how large the market will be, or what the ultimate end uses might be, though there is no shortage of experts willing to guess at all those questions. So many hydrogen projects have been announced lately that, if all of them were completed, the world might well be supplied with more hydrogen in 2030 than anybody could use. Many of these projects are likely to die before companies make the final decision to build them, but that still leaves dozens, at least, on the drawing board and likely to get built.

Figure 33: Status of clean hydrogen projects worldwide



This chart shows that many 'green hydrogen' projects have been dreamed up around the world, but few of them have proceeded to final investment, and fewer still are completed and operating. The map includes only projects based on electrolysis, excluding those based on fossil fuels and biomass, even where the sponsors of the latter intend to bury their emissions. The Web version of this report provides additional detail.

Source: IEA Hydrogen Projects Database

In principle, clean hydrogen can be used to refine virgin steel without emissions, and several such steel projects are on the drawing board. Generation, through its Just Climate subsidiary, has invested in one of them, in Sweden.[2] Clean hydrogen could be used to displace the immense quantities of fossil gas now used to produce nitrogen fertiliser, essential to the global food supply. Hydrogen could become the heart of systems for storing electrical power: it would be created when renewable power is abundant, by using the electricity to split water, then stored and turned back into power when electricity shortages loom. In theory, clean hydrogen could be used to make synthetic jet fuel that would not exacerbate global warming. Hydrogen could be used to clean up a substantial fraction of the global chemical industry, one of the largest sources of emissions. And it could be burned to generate heat for high-temperature industrial methods that now rely on fossil gas.

With that all said, the hype about hydrogen has gone beyond reason. Claims by the gas industry that it can start sending hydrogen through its pipes for people to burn in their stoves and furnaces, in place of fossil gas, are dubious: heat pumps running on electricity will likely make more sense for heating homes, and induction stoves will probably make more sense for cooking.

2. Hallstan, Karin. "Just Climate announces its investment in H2 Green Steel's Series B equity round." Press release, H2 Green Steel, 1 February 2023.

Sea-borne hydrogen

Japan and Australia are working together to develop an international trade in liquified hydrogen. This newly built ship, the Suiso Frontier, has already carried hydrogen between the two countries; it is a prototype for a potential fleet of hydrogen tankers. Image: The Asahi Shimbun via Getty Images

In the short run, the goal is to scale clean hydrogen up and drive the costs of producing it down. With that goal in mind, the new American climate law offers generous tax breaks for the production of clean hydrogen. Europe is pushing on the technology, too, but no country is pushing harder than Japan, which has been investing in hydrogen for decades. The country is still convinced that future cars will run on hydrogen, though few other countries believe it makes sense in vehicles, with the possible exception of the heaviest lorries. One of the German states tried running trains on hydrogen, but recently abandoned the experiment after realising that direct electrification would make more sense.[3]

Governments must navigate this situation carefully. The fossil-fuel industry sees the rising interest in hydrogen as one of its few avenues to carve out a big role in the energy transition. A lot of the current hydrogen hype is paid advertising from fossil interests, designed to make them appear to be doing more for the transition than they actually are.[4] Subsidies make sense as a way to scale an infant industry, but the fossil producers have proven masterful at keeping overly generous subsidies on the books forever. Governments have to be careful about subsidising hydrogen too much; the uses that make true economic sense need to be discovered, and the others cast aside.

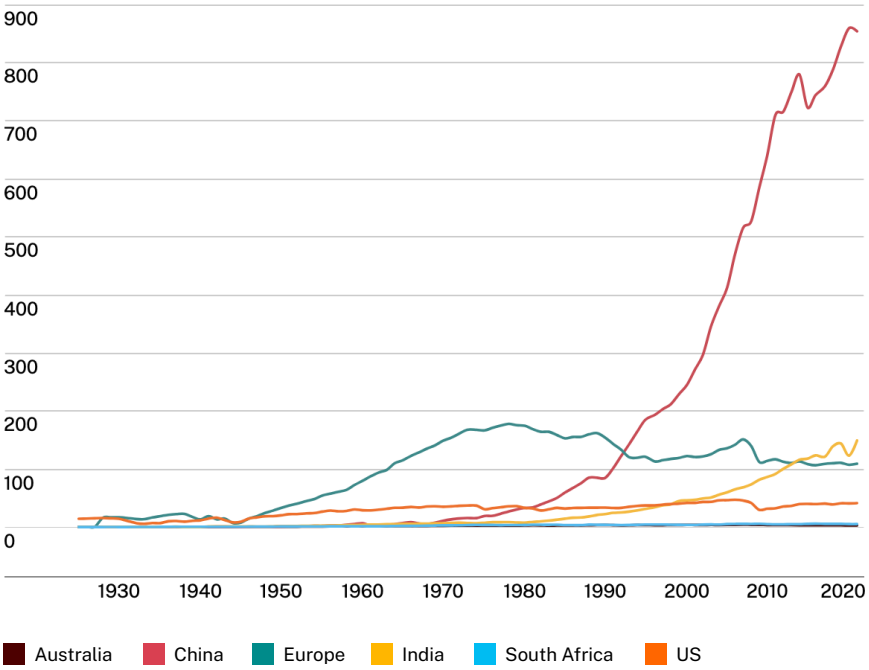
For too long, the missing ingredient with regard to dirty industry was the lack of any signal in the marketplace that low-emissions products would be welcomed, or that buyers would pay a premium for them. But we are starting to see 'buy clean' policies from forward-leaning governments. Their role is potentially critical in jump-starting the market, especially in the cases of steel and cement, where government infrastructure projects constitute as much as half the sales in some countries.

3. Bhattacharya, Ananya. "The dream of the first hydrogen rail network has died a quick death," Quartz, 7 August 2023.

4. In countries that enforce strong advertising standards, fossil-fuel companies have sometimes been reprimanded for excessive claims about their achievements in producing and distributing green hydrogen. See a Netherlands case, for instance, in "Advertising watchdog: Shell misleads with ads about green hydrogen," Advertising FossilFree, 11 February 2022. The decision against Shell is available in Dutch at reclamecode.nl/uitspraken/hydrogen/vervoer-2021-00561/347639/.

Figure 34: Annual CO_2 emissions from cement, 1925–2021

CO_2, in megatonnes



Cement emissions soared in China as that country underwent its own accelerated version of the Industrial Revolution.

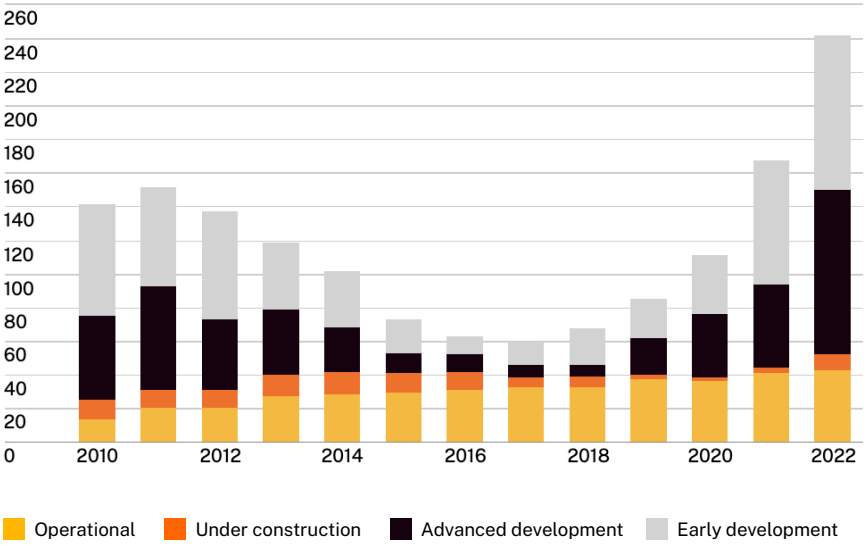
Source: Our World in Data

Cement, the binder used to make concrete, is an enormous emissions problem, responsible for as much as 4 percent of the human-produced carbon dioxide entering the atmosphere.[5] The majority of this does not come from energy use; most of it comes directly from the chemical process needed to convert the raw material, limestone, into cement. Cement products with reduced emissions have become available, but in this hidebound, low-tech industry, none of these alternative approaches has yet achieved significant penetration in the marketplace. Partly this is because the technical standards governing cement have been slow to change. Governments need to push cement makers, construction companies and engineering associations much harder on this issue.

5. Friedlingstein, Pierre et al., "Global Carbon Budget 2022." Earth System Science Data 14, pp. 4811–4900, 2022.

Figure 35: Rising interest in carbon capture

CO_2 capacity of CCS facilities, in megatonnes per annum



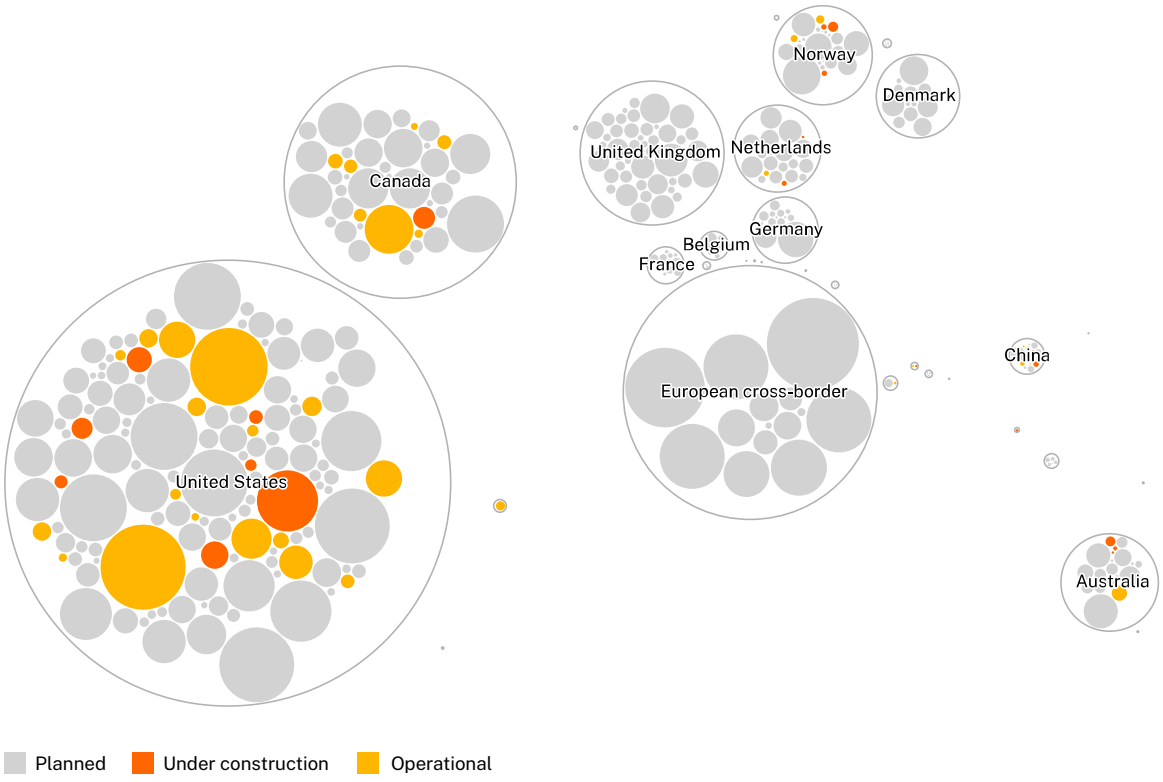
Source: Global CCS Institute

One potential method of reducing cement emissions, as well as emissions from steel and various other industrial techniques, is simply to bury them in impermeable underground reservoirs. This approach, known as carbon capture and storage, has been long discussed, but with relatively little investment. It is likely to be costly, involving extensive drilling and long-term monitoring of the underground reservoirs. Recent years have seen a rising number of projects, but the ultimate role of this approach compared to alternative methods remains unclear. In the case of cement, one company has decided to go forward with a full-scale capture plant near the German city of Hanover, after a successful test at pilot scale.

Another major source of industrial emissions is the processing of fossil fuels, including oil refining, coal mining and the 'fugitive emissions' involved in these activities. The latter includes a great deal of fossil gas, mainly methane, that leaks into the air from activities like digging up coal, the seams of which contain considerable trapped methane. It acts as a significant greenhouse gas. Some, but not all, of these emissions could be offset by capturing and burying them, or even potentially by the use of green hydrogen in oil refining. The better route, of course, is to reduce our reliance on fossil fuels in the first place, so that these emissions never occur.[6]

6. Alert readers may realise that the 'fugitive emissions' discussed in this paragraph were attributed, in last year's Sustainability Trends Report, to power production. This is the category that the Intergovernmental Panel on Climate Change labels as 'other energy.' While it is true that many of these emissions are incurred to produce coal for power generation, that is not the case for all the emissions. This year, we have chosen to allocate these emissions to the industrial sector rather than the power sector in our description of the categories.

Figure 36: Status of carbon capture projects worldwide



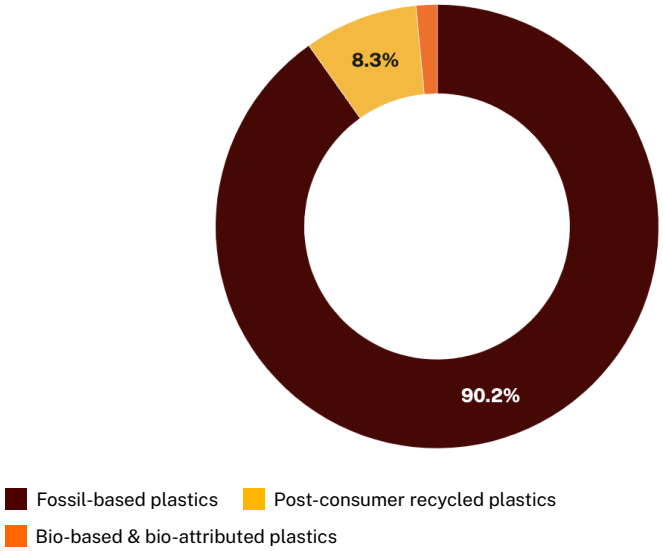
This chart shows announced carbon-capture projects across the world, but as the colours indicate, the final decision to invest has been made for relatively few of them. The size of each circle shows the relative capacity of the projects.

Source: IEA

Perhaps nothing better illustrates the overlapping nature of modern environmental issues than the problem of plastic. People of a certain age will recall a movie from 1967, "The Graduate," in which the young character played by Dustin Hoffman is fretting about finding a career. An older man pulls him aside. "I just want to say one word to you," the fellow declares. "Plastics! There's a great future in plastics. Think about it."

Who in 1967 could have imagined that plastics, far from being a "great future," would actually turn out to be one of the worst human assaults on Planet Earth? But that is exactly what happened. The horrifying gyres of plastic garbage in the ocean are by now world famous. Plastics are pervasive in the environment, from the top of Mount Everest to the deepest trenches in the ocean. In microscopic form, they enter human bodies through food and water, with unknown consequences. Wild animals the world over choke to death on plastic garbage. The plastic industry's supposed solution to this problem, recycling, has turned out to be deeply problematic and, in its current form, largely unworkable.

Figure 37: World plastics production, 2021



Includes plastics production from polymerisation and production of mechanically recycled plastics.

Source: Plastics Europe

Plastics are also a huge emissions problem. The feedstocks that become plastic originate as fossil fuels, and the production of plastic is responsible for at least 3 percent of global greenhouse emissions.[7] Many countries, unable to recycle plastic effectively and with few other options for disposing of it, simply burn it to recover the energy, typically using it to generate electricity. In that instance, the plastic is simply another increment of fossil fuel that took a brief detour, perhaps through your refrigerator, before ending up in the atmosphere. The incineration of plastic comes with a nasty little chaser: it can produce dioxins, polychlorinated biphenyls and other compounds that are directly harmful to human health. Somehow, the incinerators that burn plastic tend not to end up in wealthy neighbourhoods, either; they are imposed on poor people, and so are the health effects from the burning of plastic.

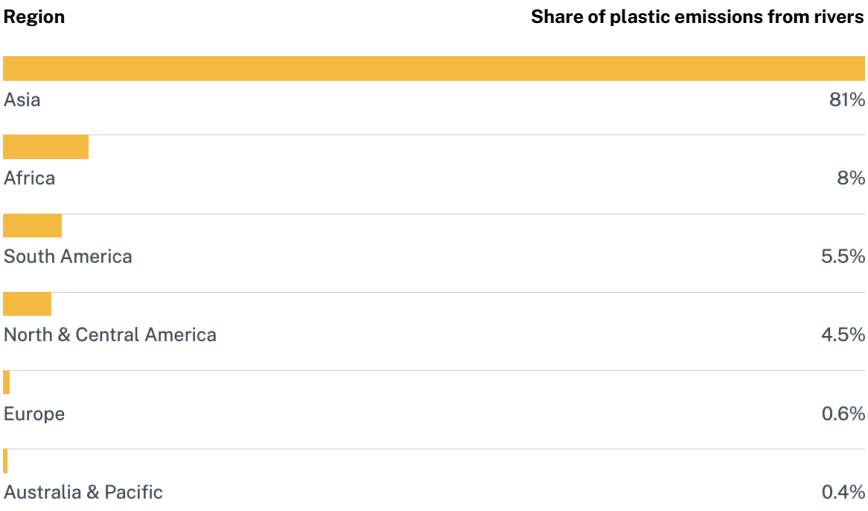
This is yet another problem that is not going to be solved without a heavy dose of public policy. No country, to our knowledge, has put together a truly comprehensive and successful strategy for dealing with the problem of plastic, but around the world, we are starting to see elements of what such a policy might look like.

7. Across various papers, the calculated range of plastics' contribution to greenhouse emissions varies from below 2 percent to nearly 5 percent. The difficulties include the need to take conflicting estimates of electricity consumption by plastics producers into account, as well as variability in how much credit recyclers get for reducing emissions by offsetting the production of virgin plastics. Here we rely on Zheng, Jiajia and Sangwon Suh: "Strategies to reduce the global carbon footprint of plastics," Nature Climate Change 9, pp. 374–378, 2019. They calculate that if recycled plastic is assumed to fully offset virgin polymer production, then worldwide plastic production and use over its entire life cycle amounted to 3.5 percent of global greenhouse emissions in 2015.

The first and foremost strategy needs to be to reduce the production of plastic in the first place. Banning certain single-use plastic items, like plastic shopping bags, plastic cutlery and many others, is a good place to start. But plastics are undeniably convenient and, in certain medical applications, life-saving, so wholesale bans will not be practicable. The most powerful policies are likely to be those that put the true cost of dealing with plastic waste onto the manufacturers that create it. This approach is known as 'extended producer responsibility,' and it can take several forms. The 'bottle bills' that many countries and some American states adopted in the 20th century, requiring deposits on bottles that are repaid when the container is returned, were a precursor. The more modern approach, however, is to charge a disposal fee that must be paid directly by the producer of the plastic article, set high enough to cover the true cost of recycling or disposing of it properly. Widespread adoption of this approach would inject large amounts of money into the recycling system. It should be coupled with legally binding requirements that companies making plastic packaging use a rising percentage of recycled plastic, thus creating a stronger market for types of waste plastic that are now essentially stranded.

Germany and South Korea are examples of countries that have effectively implemented many of the policies described above. They have also managed to embed recycling as a cultural norm. In South Korea this has been encouraged through celebrity and corporate endorsement. For example, K-pop megastars BTS collaborated with Samsung to produce a video highlighting issues of plastic waste in the oceans. In both countries households are meticulous in sorting their waste into recyclable and non-recyclable items before the point of collection, enabling higher recycling rates.

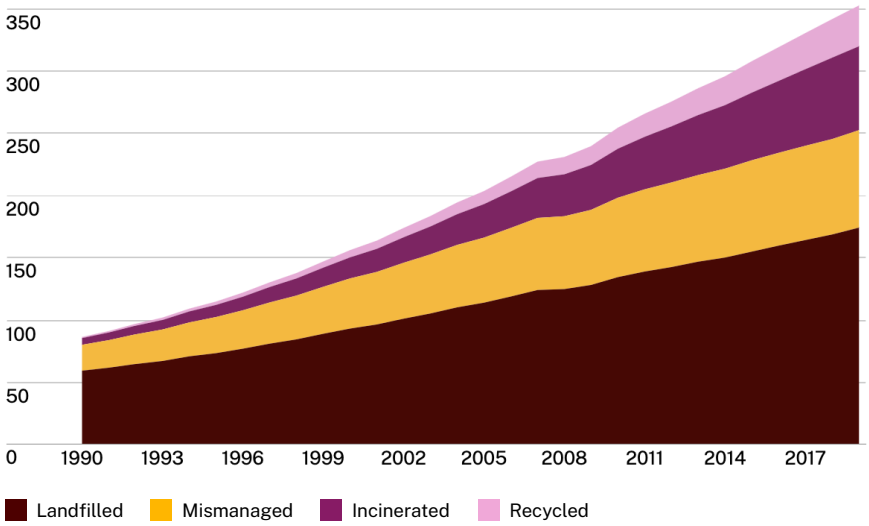
Figure 38: Plastic into oceans



Source: Meijer et al, 2021

For years, Western countries dealt with their plastics problem by exporting shiploads of plastic waste to developing countries in Asia, where only the most valuable plastics were recovered. Unsurprisingly, more than 80 percent of the plastic in the world's oceans got there after being dumped into rivers in Asia. But Asian countries have started to push back, with China largely banning plastic imports in 2018, and some other countries starting to crack down, too. That has forced Western countries to reconsider their approach.

Figure 39: Fate of plastic waste



Worldwide recycling rates are rising but remain low. 'Mismanaged' waste is plastic that was produced and sold, but not recovered and disposed of properly; much of it is presumed to have ended up in the environment.

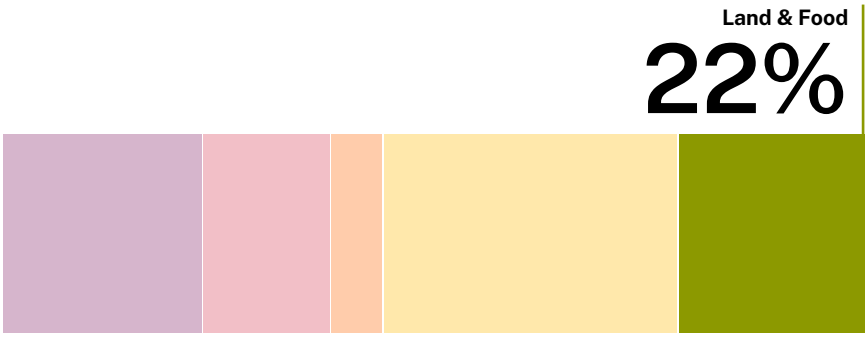
Source: OECD

In the United States, the plastic problem has largely been managed at the state and local level, with no effective national policy. Recently, President Joe Biden announced a goal of displacing 90 percent of today's plastics with materials based on biological feedstocks. This would hugely benefit farmers, a key politicial constituency in the United States, if it were feasible, but many experts believe it is not. It would require a 154-fold scale-up in the production of bio-based plastics in that country.[8] The European Union is taking a much different approach, considering mandates that would require recycled content in plastic products and packaging, as well as obligating companies to reuse and refill some types of packaging. This measure has a long legislative road ahead before it might become law, however.

8. Vasta, K., Tang, Y., Attwood, J., "Q2 2023 Sustainable Materials Market Outlook," BloombergNEF, 12 May 2023.

The best news of the past year is that the plastics problem is about to become the subject of an international negotiation. In early 2022, the United Nations agreed to devise a global treaty to deal with the root causes of plastic pollution. Many questions about this proposed treaty remain unanswered, including the critical issue of whether it will be legally binding on member states. The fossil-fuel lobby can be expected to push for the weakest possible treaty, seeing plastic as one of their few growth industries. Without a strong agreement, there is a real possibility that plastic production could triple by 2050, as could the greenhouse emissions associated with plastic use. Citizens need to push their governments hard to find better ways of dealing with this vexing problem.

06
Land & Food



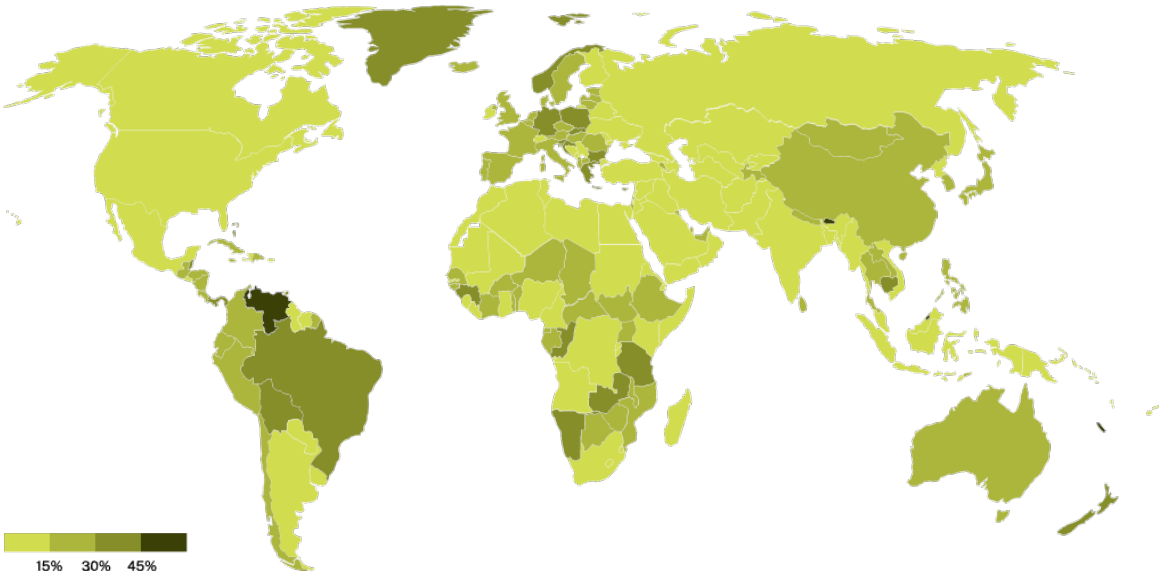
Share of direct global CO_2e emissions (IPCC)

Two steps forward

The international goals to combat global warming, reached at a negotiation just outside Paris in late 2015, were adopted under the auspices of a treaty called the United Nations Framework Convention on Climate Change. Many people who are aware of the outlines of that treaty are unaware that it has a close cousin whose goal is to preserve the richness of the world's plants, animals and other organisms. The two treaties both came into existence at the Earth Summit in Rio de Janeiro in 1992. And the biodiversity treaty is like the climate treaty in another way: the track record in carrying it out so far is one of failure. While the destruction of forests has slowed somewhat from its all-time highs, the loss of species seems to be accelerating, in part due to the overheating of the planet. Many scientists believe human activity has precipitated the sixth mass extinction in the Earth's history.

The good news is that 2022 saw a major breakthrough in the effort to turn the Convention on Biological Diversity into a meaningful set of commitments. At a large meeting of the parties in Montréal, delegates who negotiated under the leadership of China agreed on a new framework embodying grand global goals meant to slow and ultimately stop the extinction of species and the loss of natural habitat, including the world's remaining forests. This deal commits the signatories to bring 30 percent of the world's land and 30 percent of its oceans into protected status by 2030. If carried out, this '30 by 30' commitment would nearly double the amount of land held in protected reserves like national parks, and it would triple the area of the ocean covered as protected reserves.

Figure 40: National commitments to land protection



The map shows each country's commitment to protecting its lands, as a percentage of all land. These legal commitments are not always effectively enforced.

Source: The World Bank

Most of the world's nations are signatories to the underlying treaty and endorsed the Montréal deal. The United States is the major holdout, having never ratified the treaty because of opposition among Republicans in the United States Senate. However, the United States helped to negotiate the deal in Montréal and encouraged other nations to sign it. President Joe Biden is pursuing a policy consistent with the treaty, attempting to preserve 30 percent of lands and oceans in the United States, though anything he puts in place by executive order is subject to reversal by a future president.

Just as with the climate treaty, the big question now is whether these goals can be achieved. Even some of the lands and waters currently under protected status are not *truly* protected, with governments often lacking the money or the political courage to enforce their own conservation laws. The biggest problems are in the world's three main tropical forest basins: the Amazon, the Congo and Southeast Asia, including the islands of the Indonesian archipelago. These maps show how deforestation has proceeded in each basin over the past 20 years.

Figure 41: Forest loss in the Amazon

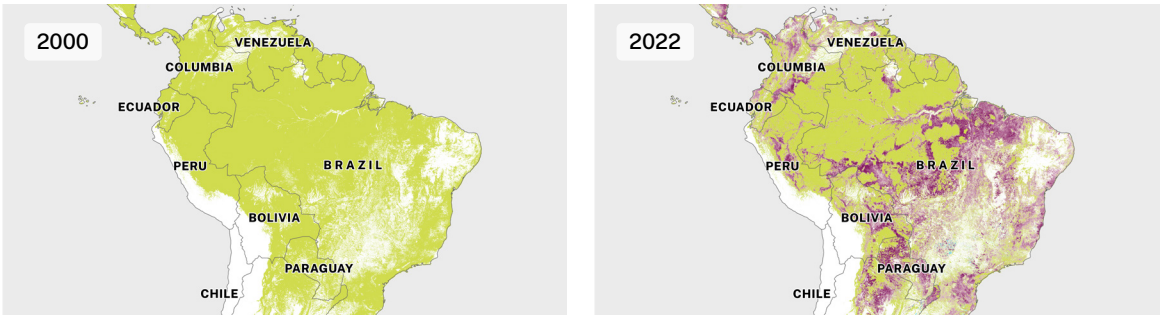


Figure 42: Forest loss in the Congo Basin

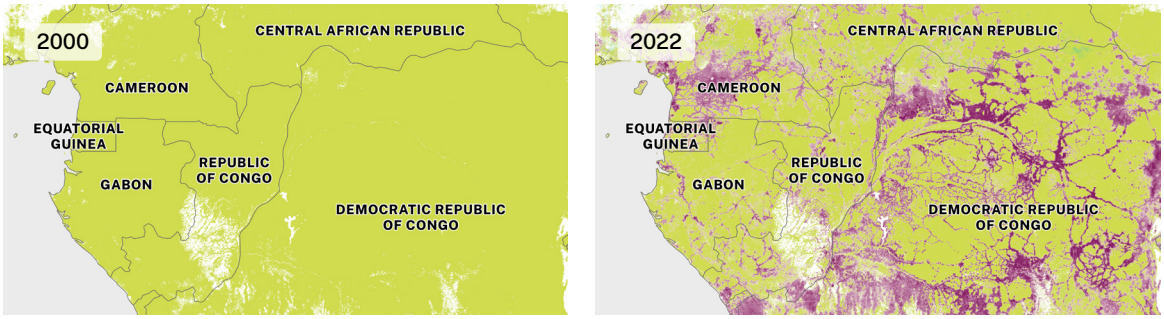
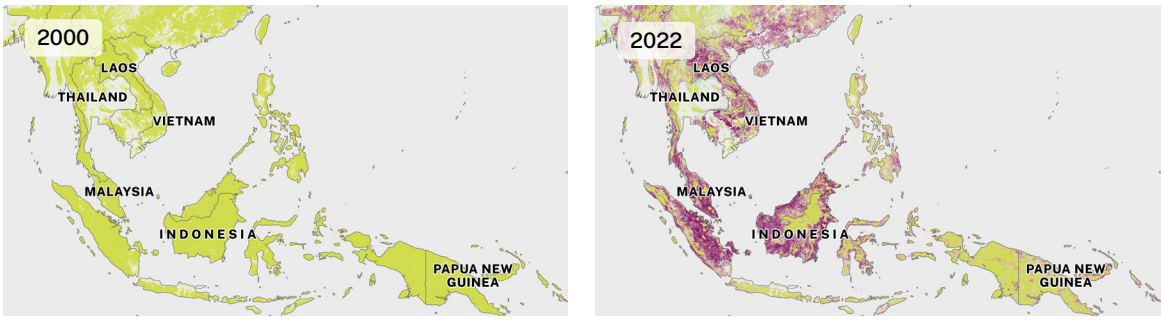


Figure 43: Forest loss in Southeast Asia



Tree cover Tree cover gain Tree cover loss

Data showing change in forest cover since 2000.

Source: Global Forest Watch

The motives for deforestation are generally simple: to convert the land into farms to supply commodities to overseas markets, or sometimes, to sell tropical hardwoods into those same markets. The governments of middle-income countries have often been left to their own devices in trying to enforce their forest-protection laws, even though the market pull was coming mainly from rich countries in the global North. Finally, however, this is beginning to change, which brings us to another big development from the past year.

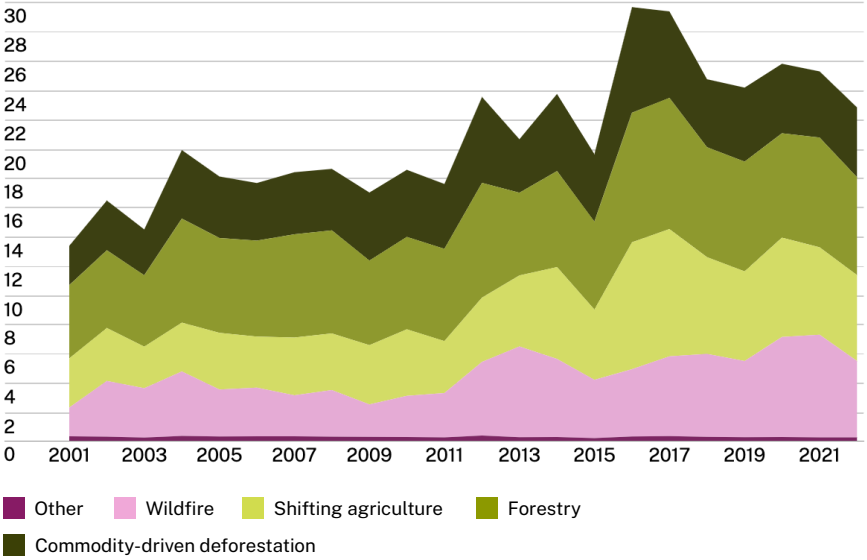
After long and difficult negotiations, the European Union has finally agreed on a law to block the importation of products of deforestation into the 27 nations of the union. This is another major breakthrough, for it puts law enforcement in some of the world's richest countries on the side of preserving forests. The EU has an arduous task ahead in setting up effective mechanisms to catch violators and enforce the policy, but at least the legal structure is now in place. A similar law has been introduced in the United States, with sponsors from both political parties, but it has not yet progressed in the American Congress. The United Kingdom is also considering stronger legislation to eliminate products of deforestation from supply chains.

Aside from these steps in consumer countries, we are also seeing serious efforts by forest countries to find a way to protect their natural resources consistent with their development objectives and with improving the livelihoods of their people. In Brazil, voters in late 2022 threw out the government of Jair Bolsonaro, a far-right figure who had essentially declared open season on the Amazon, and reinstalled a past Brazilian president, Luiz Inácio Lula da Silva, who has a strong track record of fighting deforestation. Under his leadership, Brazil has already reduced deforestation to the lowest rate in six years. Lula, as he is universally known, also cultivated fellow heads of state to develop the Belém Declaration, a bold new vision and commitment for protecting the rainforest and supporting its people.[1]

1. Andreoni, Manuela and Bearak, Max. "Amazon Countries, Led by Brazil, Sign a Rainforest Pact." The New York Times, 8 August 2023.

Figure 44: Why forests are lost

Million hectares



Urbanisation, encompassed by the 'other' category, and commodity production are considered permanent drivers of deforestation. The other categories shown here are not considered permanent by Global Forest Watch.

Source: Global Forest Watch

Pressure for action is also being applied through climate commitments by investors and corporations. The Glasgow Financial Alliance for Net Zero announced that transition plans that "don't eliminate and reverse deforestation are incomplete," and another organisation pushing corporate action, the Science Based Targets Initiative, has made clear that firms wanting its seal of approval will have to develop ambitious plans to eliminate forest destruction. An organisation called Global Canopy that tracks deforestation has expanded its efforts to hold corporations to account for their promises. Investment managers are also beginning to lean in, with the formation of the Financial Sector Deforestation Action Initiative, comprised of members with USD 9 trillion of financial assets under management; they have committed to tackling deforestation in their portfolios by 2025. Generation is a signatory to this initiative. Some consumer-goods companies, including Nestlé and Unilever, are reporting steady progress in cleaning up their supply chains.

Unfortunately, those positive developments from the past year were accompanied by bad news. The market for 'carbon offsets,' projects designed to limit forest destruction or otherwise keep carbon dioxide out of the atmosphere, was thrown into turmoil over the past several years, culminating in declines last year in both the traded volume and the prices of certain types of offsets. These offsets are traded in a voluntary global market in which promoters undertake activities designed to halt or limit emissions, then create credits that can be sold to corporations or individuals who want to 'cut' their emissions without actually cutting them. This market, with many permutations, has grown to approximately USD 2 billion a year, relatively small in the scheme of things, but large enough to underpin some bold claims by corporations that buy the offsets.

Emissions claim made by Delta Air Lines

Delta is being sued by consumers who allege that its carbon-neutrality claim was fraudulent. The company denies any ill intent but is shifting its focus to other strategies for cutting emissions. Image: Montgomery Taylor

For example, if you happened to take a seat on Delta Air Lines, an American carrier based in Atlanta, within the last few years, you might well have had a napkin put on your tray table proclaiming Delta to be “carbon neutral since March 2020.” Of course, like every other airline, Delta was still burning jet fuel and emitting carbon dioxide into the atmosphere. But it was also buying carbon offsets from projects like a Cambodian wildlife sanctuary and an Indonesian wetland. The marketers of the offsets asserted that carbon dioxide was being kept out of the air by their activities, allowing Delta to make the claim that it was offsetting 100 percent of its emissions.

Lawyers in California smelled blood, filing suit this spring on grounds of fraud, and seeking to have the suit certified as a class action on behalf of all Delta fliers. “Nearly all offsets issued by the voluntary carbon offset market overpromise and underdeliver on their total carbon impact due to endemic methodological errors and fraudulent accounting on behalf of offset vendors,” wrote the attorneys for the plaintiff, one Mayanna Berrin. Responding to the suit, Delta assured the public that it planned to stop relying on carbon offsets and would seek to cut its emissions directly. The company outlined a plan to run its fleet on sustainable aviation fuel made from climate-friendly biological feedstocks by 2050, with an interim target of 35 percent of its fuel coming from climate-friendly sources by 2035.

Whatever the merits of the lawsuit against Delta, it illustrates the magnitude of the controversy swirling around the market for carbon offsets.

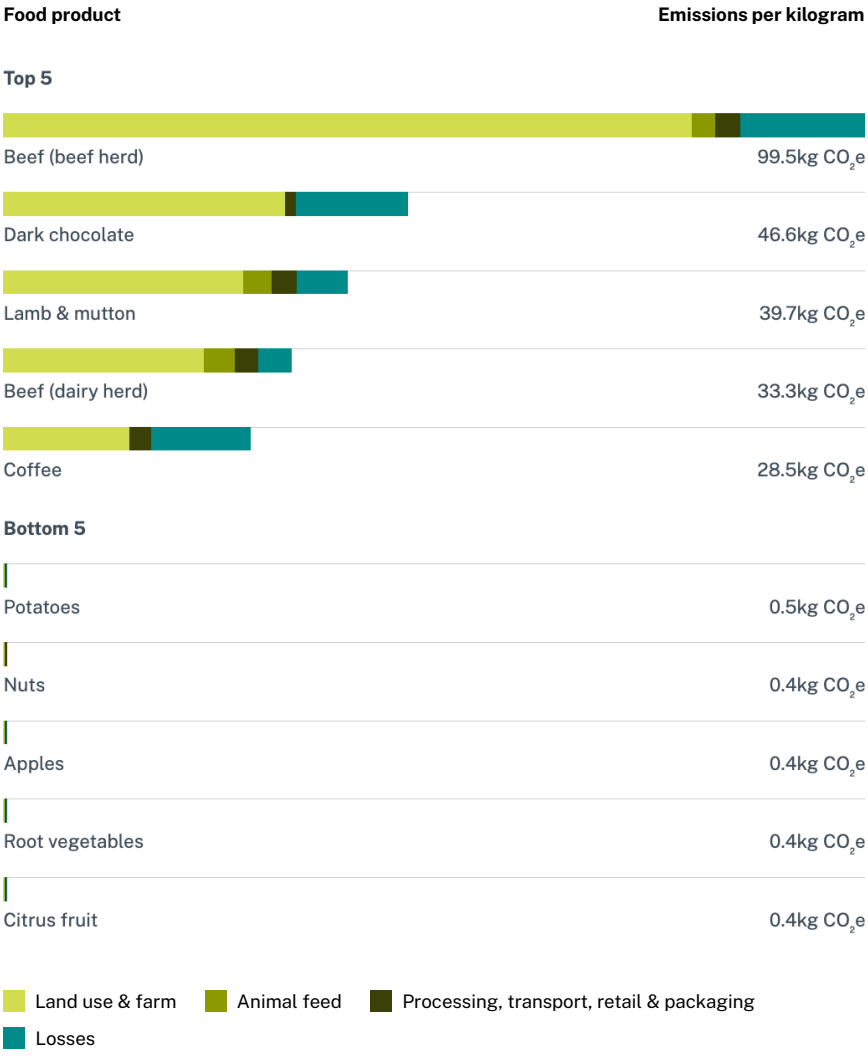
It has been a Wild West of a marketplace, rife with conflicts of interest. The offsets are supposed to be certified by third-party verifiers, but they are paid for the certifications by project sponsors, giving them an obvious incentive to pump up the business. The promoters of carbon offsets range from deeply sincere environmental or indigenous organisations, trying to spend the money wisely, to fraud artists with criminal records. 'Avoided emissions' projects require constructing hypothetical scenarios that cannot always be verified: "Without our project, Forest X would have been cut down." But would it really have been?

The recent controversy has led some potential corporate buyers to sharpen their pencils and look more closely at where their money is going. Companies like Microsoft,[2] Stripe and others have gained a reputation for closely scrutinising any offsets they buy, and for being willing to pay extra for high-quality projects. Instead of 'avoided emissions' credits, many of these meticulous buyers have shifted their focus to 'removal' credits that draw carbon directly from the atmosphere. These include projects that restore native forests and others using new approaches like enhanced rock weathering on agricultural land, a technique that is capable of absorbing carbon dioxide from the air. Credible buyers have begun disclosing the prices, volumes and sources of all the credits they buy, an essential step to build trust in the market. The claims that these corporations make are also evolving to become less expansive and more accurate. Ultimately, we think governments will need to regulate this market if it is to contribute meaningfully to global climate goals; we need tough, legally binding standards governing how these projects are created and certified, as well as prohibitions on dubious marketing claims by the corporate buyers of offsets.

While governments are beginning to develop legally binding policies to protect biodiversity, they are making less headway in cutting the demand for meat and commodities that is the fundamental driver of deforestation. Global meat demand continues to rise sharply. Voluntary efforts to shift diets away from meat and toward plants have had modest success in some countries, but governments have been too afraid of consumer backlash to try policies — such as taxes on meat consumption — that might make a serious difference. Yet the mix of people's diets has radical implications for greenhouse emissions.

2. Generation holds shares in Microsoft Corp., in its Global Equities Fund, and Microsoft is an investor in our new subsidiary, Just Climate.

Figure 45: Greenhouse implications of dietary choices



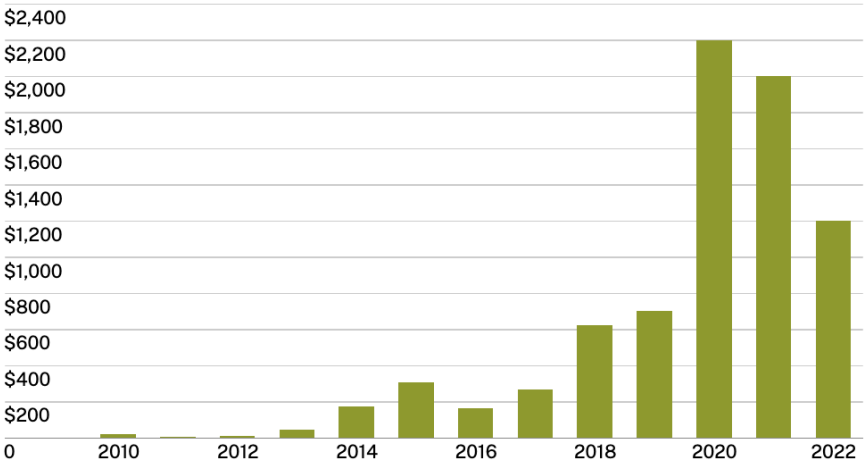
In the online version of this report, the chart gives the emissions footprint for each of more than 40 food items. Beef is by far the most damaging food from an environmental perspective. People can contribute to solving the climate crisis by eating diets based largely or exclusively on plants.

Source: Our World in Data

In the face of rising food demand and the need to shrink the global footprint of agriculture, the only choice is agricultural intensification — producing greater yields on a given amount of farmland. This means bringing modern agricultural inputs like fertilisers to the small farmers, many of them women, who work modest plots of land across the developing world. Doing this in a way that does not worsen the environmental crisis is a major challenge. For instance, the production of nitrogen fertiliser, while essential to modern food production, has its own greenhouse footprint. Generation has invested in an alternative approach pioneered by Pivot Bio of Berkeley, California, in which the roots of cereal crops are inoculated with microbes that can pull nitrogen out of the air, cutting or eliminating the need to apply nitrogen fertiliser.

Figure 46: Investment in plant-based meat alternatives

Invested capital, in millions



Sales of plant-based meat alternatives have declined recently as consumers have come under pressure from high inflation. The chart shows that investors have lost some of their enthusiasm for the sector.

Source: Good Food Institute

Another way to cut the environmental footprint of food production is to substitute meat alternatives for meat. Unfortunately, companies like Impossible Foods and Beyond Meat appear to have stalled at a relatively modest market penetration, perhaps because their products remain more expensive than meat itself. As the chart above shows, investors have been losing some of their enthusiasm for the plant-based meat alternatives as the difficulties these companies face have come into sharper focus. Still on the horizon are 'cultured meats' produced by growing actual meat cells in vats, though the environmental footprint and the consumer acceptance of these products — to say nothing of the cost — are still largely unknown.

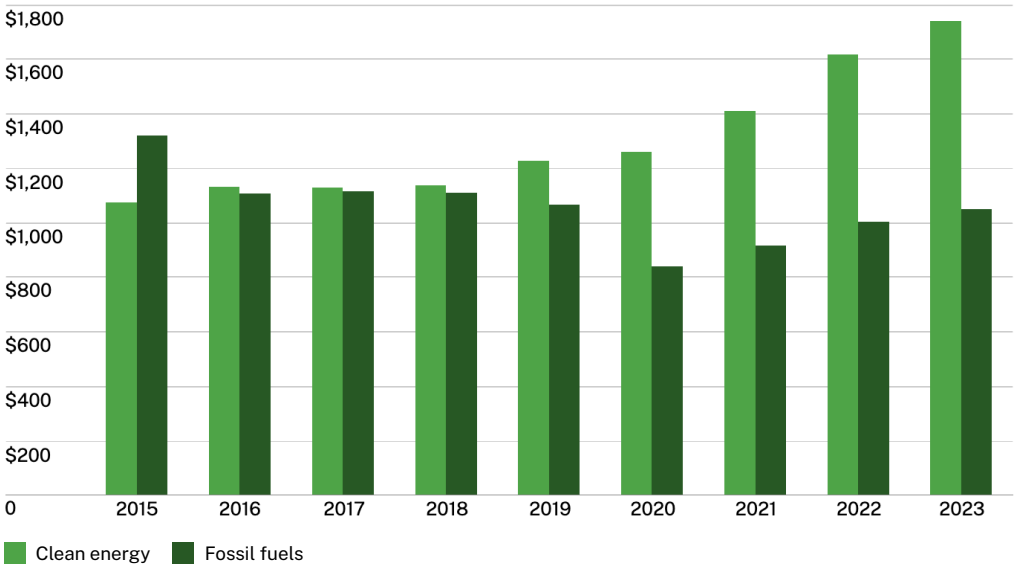
07
Financing the Transition

Trillions more needed

Investment in the energy transition is rising rapidly. The annual flow of investment funds into clean energy is now 70 percent larger than the flow into fossil fuels. The capital going into certain sectors, like the roll-out of renewable energy, is encouraging, and so are the capital flows into certain technology-driven, asset-light businesses that are aligned with the goals of a clean economy. However, the flows of capital are still not large enough overall, nor are they going everywhere they need to go.

Figure 47: Clean vs dirty

Investment, in billions



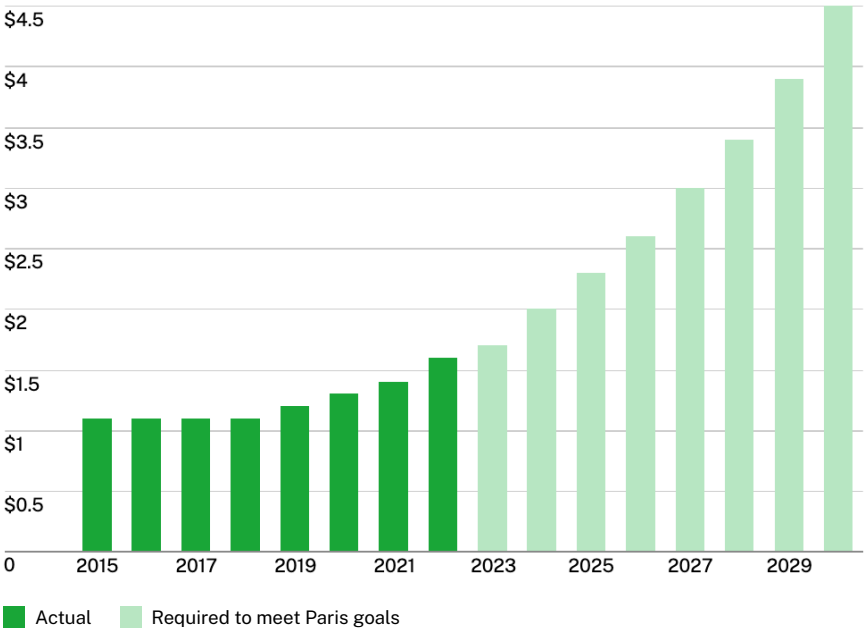
Investments in clean energy compared to investments in discovery and production of fossil fuels.

Source: IEA

The gains since 2019 are certainly encouraging. And yet — this will be a familiar refrain by now — they are not enough. The International Energy Agency calculates that by 2030, clean-tech investment will need to approach USD 5 trillion a year if the most ambitious goals of the Paris climate agreement are to be met. This means the annual sums invested in clean-tech need to rise much faster than they are doing.

Figure 48: Historical and required investments

Clean energy investment, in trillions



This chart shows historical trends in clean energy investment and, for future years, the investment requirements out to 2030 if the most ambitious goals of the Paris climate agreement are to be met. The historical trends are from the International Energy Agency, and the forecast future needs are Generation's interpolation of the requirements to meet the IEA's net-zero scenario.

Source: IEA, Generation analysis

A major part of the problem is that the energy transition is still largely confined to a handful of markets: the United States, the European Union and China, primarily, with a notable role for solar power in India, Australia and a handful of other countries. The transition must broaden to encompass the entire world. In the next section, we will discuss the problem of developing countries and the risk that many of them will be left behind as the clean economy takes off.

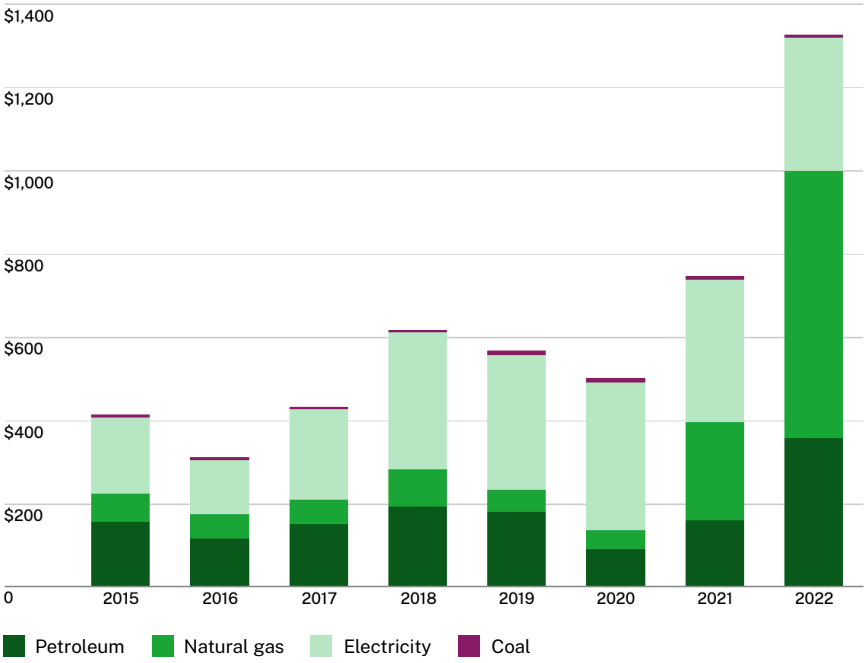
Given the urgency of the situation, the pipeline of investment funds flowing into the transition is still too constrained. Unfortunately, a new political development in the United States is compounding the challenge. For years, investors had increasingly been embracing a money-management approach that promised to take environmental, social and corporate-governance factors — so-called ESG factors — into careful account. But state and federal politicians are now attacking this movement, and in some cases have passed laws ordering pension funds under their control not to invest in ESG funds. We believe the ESG trend certainly warranted some criticism: people were using conflicting definitions of the concept, the terminology was often confusing, there was an over-reliance on checklists and the field has been plagued by a lack of rigour and accountability. But these valid criticisms do not mean that sustainable investing and the ESG approach are failed concepts. Instead the criticism, where valid, will help to ensure that sustainable investing and ESG concepts are carefully defined, clearly understood and effectively practised.

The American political attacks, motivated by far-right ideology, have gone beyond any reasonable criticism. Climate change is having, and will continue to have, devastating effects on people and nature. Investors who do not consider the physical realities with which we are living are putting their clients' capital at risk and failing to fulfil their fiduciary duties. You only have to look at the recent fires in Canada and California, and their implications for insurers as far away as Zurich, to realise that the climate crisis has large consequences for business, and those will continue to grow.

The ESG backlash has not been the only setback of recent years. Generation has long been concerned about subsidies for fossil fuels, a category of government spending so perverse that we refer to it as anti-climate finance. The Organization for Economic Cooperation and Development, the club made up of 38 rich countries, has been pushing since 2009 to reduce these subsidies. And for several years they did fall, but the energy crisis that followed the Ukraine war has seen a dramatic reversal. Western governments, in particular, opened the floodgates and spent immense sums to shield their consumers from higher energy bills. Remarkably, direct energy subsidies have nearly tripled in two years, as the chart below demonstrates.

The political impulse that led to this sudden jump was certainly understandable, given the public outcry that followed a tripling or quadrupling of household energy bills in some European countries. The smarter way to have done it would have been to concentrate the subsidies on households too poor to bear the increased costs, while exposing those who could afford to pay to the real market realities of fossil fuels, encouraging conservation, home retrofits and smaller cars. But this would have required considerable political courage and it is not what happened. Now governments have a lot of work to do to peel back these subsidies and get back to where they were only a few years ago.

Figure 49: Global fossil-fuel subsidies



Data reflect explicit subsidies only. Implicit subsidies — that is, the failure to put a price on emissions reflective of the damage they cause — are substantially larger.

Source: IMF

Perhaps the most worrisome aspect of the investment situation is that the flow of funds into clean alternatives remains constricted for entire sectors of the economy. The industrial sector, the buildings sector and the land sector must undergo transformations in the coming decades that are just as dramatic as those already taking hold in power and transportation. But we are not seeing capital flows remotely commensurate with the scale of the task.

We will not attain a sustainable economy unless the stewards of capital consciously allocate the funds to help create it. If the investment industry is to deliver against its climate commitments, it will need to seriously reconsider how and where capital and engagement efforts are needed. Investors should adopt a new framework for capital allocation that expands what capital markets value. A good example is an approach that we call climate-led investing.

The idea is to identify climate solutions with the highest potential impact, defined as avoidance or removal of greenhouse emissions at scale, in a way that is timely, as well as consistent with a just economic transition and a sustainable end state. Climate-led investing then seeks to allocate capital to climate solutions that can both address these emissions while also generating attractive risk-adjusted financial returns for investors.

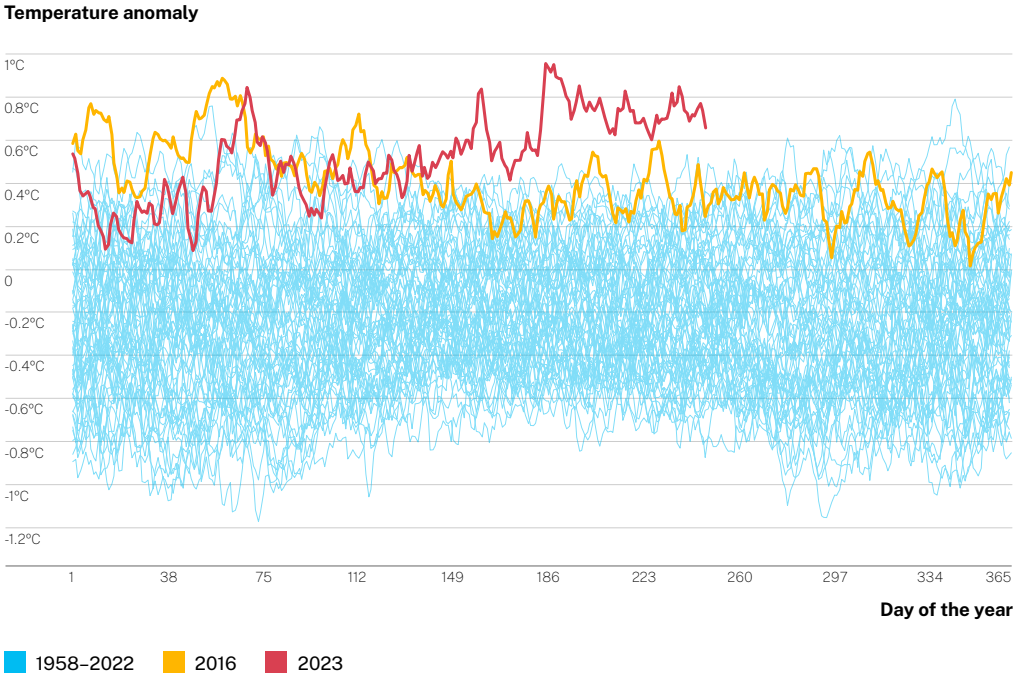
These will be difficult goals to meet. Governments have yet to pass the necessary laws, adopt the right rules or establish the right conditions for the clean economy to flourish. They are still too much under the influence of fossil-fuel interests, it is true, but the sheer power of human inertia may be just as important. One of the roles investors must play is to help governmental leaders see that change can no longer wait.

08 Looking Ahead

Stark realities

The rich countries of the world have been digging up fossil fuels and burning them prodigiously since the late 18th century. They are, as a group, largely responsible for the high levels of carbon dioxide in the atmosphere today. Those emissions are already having profound effects on the climate, and the situation is rapidly getting worse. This year, with an El Niño weather pattern riding atop the human influence on the climate, is blowing away all historical temperature records.

Figure 50: Running away



This year appears likely to beat 2016 as the warmest year in the historical record. The graph shows daily global mean surface temperature anomalies, using a 1991–2020 baseline period. The pale blue lines show temperature each day since the beginning of the record in 1958, with the previous record warm year, 2016, highlighted in yellow and the current year, 2023, highlighted in red.

Source: Analysis of JRA-55 data

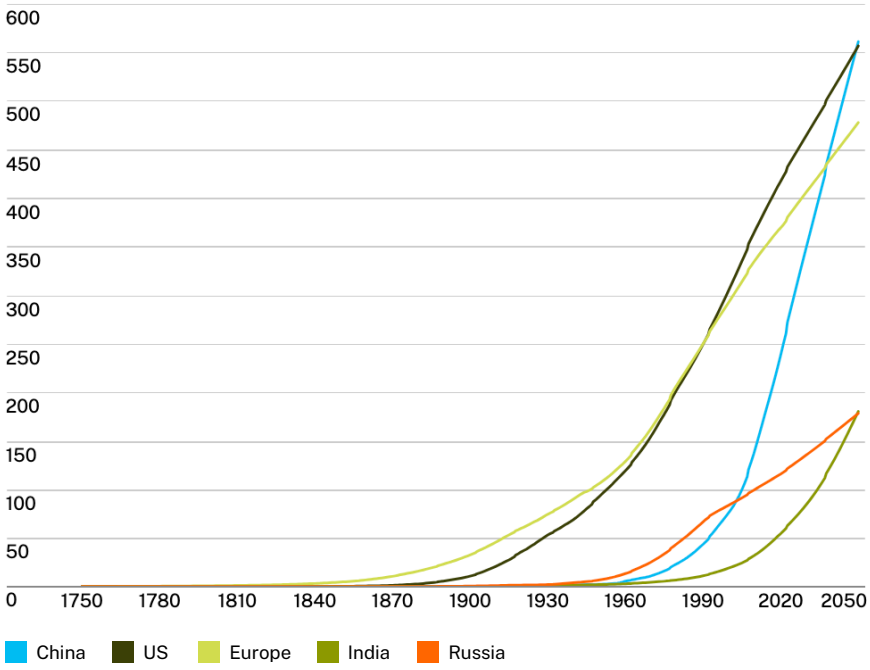
The big breakthrough of recent years was that the countries most responsible for where we are today finally committed themselves to the energy transition. Much more remains to be done, but nearly all of them are moving in the right direction. The United States, with its high consumption of all fossil fuels and its particular thirst for oil to power large automobiles, is responsible for more historical emissions than any other country. It was by far the most important holdout, but with the passage of two major climate and infrastructure bills in two years, the United States is finally on board with the global salvage effort.

What about the developing world?

China's economic growth of recent years has been so rapid that it is overtaking the rich countries of the West. It became the largest single emitter of greenhouse gases in 2006, and its emissions are now more than double those of the United States. Its total historical emissions will exceed those of the 27 countries of the European Union within the next few years, and its emissions per person already exceed those of the EU. If China continues on its current trajectory, it will surpass the United States as a cumulative historical emitter by 2050.[1] The country has pledged that its emissions will peak by 2030 and begin to fall, but it is not committed to reaching net-zero emissions until 2060.

Figure 51: China is catching up

Cumulative CO_2 emissions, in gigatonnes



Figures beyond 2022 are forecasts based on current economic trajectories.

Source: Washington Post

China's development aspirations are shared by many other countries, of course. India has recently surpassed China in population to become the largest country in the world.[2] Its emissions are only a quarter of China's, but they are rising. And billions of other people in the developing world aspire to higher living standards, too, which means they need the benefits of modern energy. Nearly 800 million people are still not connected to the electrical grid at all, concentrated in South Asia and in Africa south of the Sahara Desert.[3]

1. Stevens, Harry. "The United States Has Caused the Most Global Warming. When Will China Pass It?" Washington Post, 1 March 2023.

2. Hertog, Sara, Patrick Gerland, and John Wilmoth. "India overtakes China as the world's most populous country." United Nations Department of Economic and Social Affairs, 2023.

3. The International Energy Agency tracks the number of people lacking electricity and its latest estimate is 770 million. See iea.org/reports/sdg7-data-and-projections/access-to-electricity.

If all these countries were to replicate the high reliance on fossil fuels that powered the Industrial Revolution in the West, any hope of maintaining an equable global climate would be lost. This means the fate of the planet will be decided in the developing world. If these countries can leapfrog the fossil era and go straight to clean energy, the goals of the Paris climate agreement may yet be achievable.

China stands alone as a powerhouse in both manufacturing and deploying clean energy equipment. No other country comes close to its achievements, even though it is also burning more coal than any country in the world. Clean energy and dirty energy are thus in a race in China, running neck and neck at the moment, but if China makes the decision to speed its deployment of clean energy, it has the capacity to do so.

The developing world outside of China presents a far more worrying picture. Now is the time, we think, to consider the broad implications of this picture. The rich countries have both the capacity and the moral responsibility to help the developing countries make the energy leapfrog. If they fail to do so, all humanity will suffer for it.

Paying the price

Decades ago, scientists predicted heavier rainfalls as a result of global warming, and now they are upon us. Heavy rains triggered flash floods and wreaked havoc across much of Pakistan in 2022, killing nearly a thousand people and displacing tens of thousands. Here, a displaced family seeks dry ground in Jafarabad, a district of Pakistan's southwestern Baluchistan province. Image: Zahid Hussain/AP Photo via Alamy

The problem that most urgently needs solving is that clean-energy projects are still difficult to finance in the developing countries. Interest rates for projects like wind farms and solar panels can be two to three times as high as they would be for identical projects in the developed world.[4] Investors perceive risks in, say, South Africa or Nigeria that they do not perceive to apply in Britain or America, and they demand compensation for running those higher risks. To a degree this is merely perception, but some of the excess risks are real: the potential for political turmoil in poor countries, the possibility that projects will be nationalised, the chance of currency gyrations that raise the carrying costs of a project, and others.

4. For a full exposition of this problem, see the International Energy Agency's Cost of Capital Observatory project at iea.org/reports/cost-of-capital-observatory.

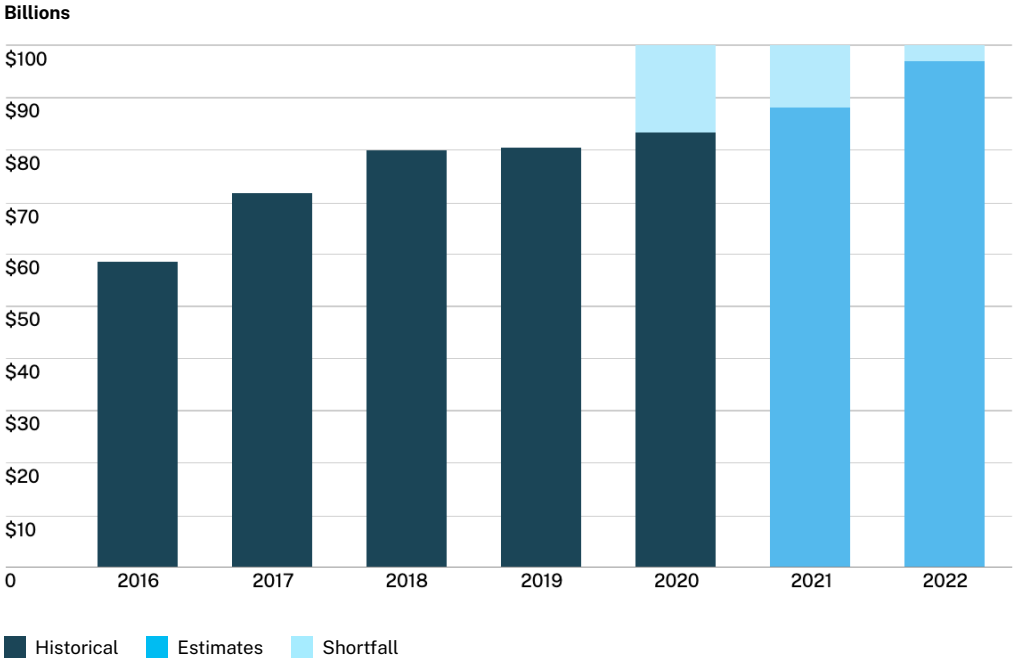
These higher interest rates badly undercut the economics of clean energy in developing countries. An urgent effort is needed to correct the situation. We are pleased that the World Bank, under fresh leadership, is considering how to use its vast resources on this problem, but it has yet to come out with a plan commensurate with the scale of the task.

The most promising effort so far involves special partnerships between the West and developing countries seeking to move forward on energy development, with Western money used to offset some of the risks and, effectively, buy down the interest rates of clean-energy projects. So far, such deals have been completed or are in the works for South Africa, India, Indonesia, Vietnam and Senegal. But we fear this approach is too piecemeal, and too slow.[5] A much bolder international effort is needed to create conditions that favour clean-energy investment across the developing world. That might involve creating some kind of standard financing package that countries could sign up for if they meet certain conditions.

5. The most ambitious of these deals, for Indonesia, is already in big trouble less than a year after it was announced. See Suhartono, Harry et al. "Money and politics put world's biggest climate deal at risk." Bloomberg, 4 September 2023.

Another longstanding promise to the poor countries may finally be on the verge of fulfilment. In 2009, the Western countries promised that by 2020, they would mobilise USD 100 billion per year in public and private capital to help poor countries cope with the effects of the climate crisis. They broke that promise, with the sum hitting only USD 83 billion per year by 2020, but it appears likely the promise will finally be kept three years late, by the end of 2023. Unfortunately, the climate emergency is accelerating so rapidly that it is becoming clear that USD 100 billion a year is not enough.

Figure 52: Climate finance delivered from richer to poorer countries



In 2009, the rich countries of the world promised that by 2020, they would mobilise $100 billion per year in public and private money to help poorer countries adapt to climate change. They broke this pledge, but may now be on the verge of fulfilling it three years late.

Source: OECD

The discussion about how to help the developing countries is likely to come to a head late this year, in Dubai, as the United Nations convenes the 28th conference of the parties of the Framework Convention on Climate Change. Controversy has swirled around the plans for this meeting for months: it is being chaired by the head of the United Arab Emirates' national oil company. Lawmakers from Europe and the United States tried, and failed, to get him fired from the job. The chairman, Sultan Ahmed Al Jaber, has made clear that his top priorities include new financing arrangements for the energy transition in the developing world, so there is some prospect that a major new deal could emerge from the discussions.

In other respects, it is likely to be a sobering meeting. The countries of the world are due to complete a 'global stocktake' of the commitments they made in 2015 in the Paris Agreement, meaning a detailed review of whether they are on track to meet their own promises. They are not, so the question becomes whether they will have the courage to admit it, and the boldness to try to get back on track.

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Global Carbon Budget 2022 (Friedlingstein et al., 2022b, *Earth System Science Data*)

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IEA (2023), The State of Clean Technology Manufacturing

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2023 Russia Fossil Tracker by Centre for Research on Energy and Clean Air, accessed Aug 31, 2023

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Global Coal Plant Tracker, Global Energy Monitor, July 2023 release

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IEA Solar Heating & Cooling Programme, Solar Heat Worldwide 2023

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Global CCS Institute 2022 Status Report

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Plastics Europe, “Plastics — the Facts 2022”, October 2022

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Meijer LJJ, van Emmerik T, van der Ent R, Schmidt C, Lebreton L. More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean. *Science Advances* 2021 Apr 30;7(18): eaaz5803. doi:10.1126/sciadv.aaz5803. PMID: 33931460; PMCID: PMC8087412

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OECD Global Plastics Outlook — plastics waste by region

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Curtis, P.G., C.M. Slay, N.L. Harris, A. Tyukavina, and M.C. Hansen. 2018. "Classifying Drivers of Global Forest Loss." *Science*. Accessed through Global Forest Watch on 23/08/23. www.globalforestwatch.org.

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Black, Simon, Antung Liu, Ian Parry, and Nate Vernon, 2023. "IMF Fossil Fuel Subsidies Data: 2023 Update." Working paper, IMF, Washngton, DC.

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Washington Post, "The United States has caused the most global warming. When will China pass it?", March 1, 2023

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Acknowledgements

Generation and Just Climate would like to thank our partners at Applied Works, one of London's great digital design firms, for their hard work under deadline in helping us to compile this report and present it in a readable form. Mandy Doran, Joe Sharpe, Callum Strachan, Richard Males and Radhita Jain provided invaluable assistance. We thank Rebecca Keys for proofreading the manuscripts.

We also thank the organizations whose work and data sets we drew on heavily, including Ember, the International Energy Agency, Our World in Data, Bloomberg New Energy Finance, the Intergovernmental Panel on Climate Change, Climate Trace, the Energy Institute and others. We thank the Global Carbon Project for its annual Global Carbon Budget, including the modeling groups around the world that contribute to that invaluable series of reports. At the IEA, we especially thank Curtis Brainard and Jon Custer for help locating data from the vast archives of that organization, so indispensable to understanding the world energy landscape. At Ember, we thank Matt Ewen for tolerating so many queries. We thank WindEurope for its close tracking and intelligent commentary in regard to the energy situation in Europe.

Critiques and errata notices are most welcome and can be sent to: str@generationim.com

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