The Economist

THE AGE OF CHAOS

Business

Photograph: Getty Images

S&P 500
1941-43=10

[Chart showing S&P 500 index from 2024 to 2025, values ranging from 5,000 to 6,000, with prices rising through 2024 to peak near 6,000 then declining sharply to around 5,000 at the end.]

Source: LSEG Workspace

Chart: The Economist

Stockmarkets rebounded on April 9th after Donald Trump announced a 90-day pause on his far-reaching punitive tariffs, clawing back some of their earlier losses. The S&P 500 jumped by 9.5%, adding about $4.2trn to its value. Earlier in the week global markets had gone into meltdown; $5trn was wiped off the S&P 500 in two days. The tech-heavy NASDAQ Composite also soared, having its best day since 2001. It had hit bear territory earlier, having plunged by 23% from its most recent peak. Markets in Europe and Asia also recovered. Asian stocks had endured their worst sessions in decades, with Hong Kong's Hang Seng index plunging by 13% in a day.

The prices of America's government bonds were battered in the market turmoil. Usually Treasuries do well in a stockmarket rout, but investors such as hedge funds were said to be cashing out of them under duress. The yield on ten-year Treasuries had jumped over a few days from 3.9% to 4.5%, increasing the cost to the government of servicing its already mighty debt.

Wall Street and business titans voiced their criticisms of Mr Trump's trade policy, which may have been a factor in pushing him to pause his tariffs. Bill Ackman, an investor who once described the administration as the "most pro-growth" he'd seen, said he'd assumed that "economic rationality would be paramount. My bad". (He then said he was "totally supportive of Mr Trump" and described him as "tough, but fair".) Larry Fink warned of a "real downturn". The share price of BlackRock, the firm he leads, is down by 12% this year. Jamie Dimon, the boss of JPMorgan Chase, said America First risked turning into America alone. Even Elon Musk was critical, calling Peter Navarro, Mr Trump's trade guru, a "moron".

Earlier in the week the dollar fell amid fears of a recession. Speculation swirled about how far China would go in allowing the yuan to weaken in order to boost its exports. The Chinese central bank, which manages the exchange rate at which the currency is traded, had let the yuan fall to 7.2 to the dollar, its supposed soft red line. In Japan the yen rallied against the dollar as investors piled into safe-haven assets, though the greenback rebounded on Mr Trump's tariff reversal.

How the mighty fell

Companies that are most exposed to tariffs saw their market value slump. Among them, Apple's share price dived by 22% over five days before bouncing back. The iPhone is assembled mostly in China and subject to the extra trade levies. Nike, which makes its sports shoes in Vietnam, saw an 18% decline in its stock. Its share price surged when Mr Trump suspended his tariffs and the Vietnamese government announced that it would hold trade talks with America.

Reports emerged about the immediate effect of tariffs on the car industry, which remain in place at 25%. Jaguar Land Rover, a carmaker based in Britain, suspended its exports to America. American ports were filling up with cars as manufacturers held their vehicles there to stop them from becoming subject to the levy.

In Britain the government slightly softened its rules surrounding the phasing-out of petrol cars. It said the ban on sales of new petrol and diesel car sales would still come into effect in 2030, but that new hybrid vehicles could continue to be sold until 2035. And small manufacturers, such as Aston Martin and McLaren, will now be exempt. The car industry's association responded that given America's car tariffs, which were not included in Mr Trump's wider pause, more action would be needed.

Oil prices sank to their lowest point in nearly four years, as traders bet that demand would fall amid a possible global recession. Brent crude sagged below $60 a barrel before snapping back to $65. It started the year at $75.

India's central bank cut its benchmark interest rate by another quarter of a percentage point, to 6%. It also indicated it would be more open to further cuts to maintain growth amid economic turmoil.

The share price of global drugs companies fell sharply, after Mr Trump hinted that the pharmaceutical industry would be his next target for tariffs. They were not included in his recent broadside. Stocks in European and Indian drugmakers were particularly hard-hit. About a third of India's exports of generic versions of popular drugs go to America.

Deluded

Mr Trump signed another 75-day extension to find a way to allow TikTok to continue operating in America. The president suggested a deal had been close but fell apart over China's objections to tariffs. He claimed that if he had cut China's trade duties it "would have approved that deal in 15 minutes, which shows the power of tariffs".

Image: The Economist/Getty Images

After the terror, the euphoria. When, on April 9th, President Donald Trump postponed for 90 days the most illogical and destructive of his tariffs, after a meltdown in financial markets, the s&p 500 index of American stocks rose by 9.5%, its fastest daily rise in nearly 17 years. The darkest scenarios for the world economy that had been envisaged by investors until that moment are now unlikely. It seems

there is some limit to the market falls the president will tolerate on his watch. After the chaos that had followed Mr Trump's announcement of "reciprocal" tariffs a week earlier, that is no small source of comfort for the world.

But do not mistake the consolation of having avoided disaster for good fortune. The scale of the shock to global trade set off by Mr Trump is still, even now, unlike anything seen in history. He has replaced the stable trading relations which America spent over half a century building with whimsical and arbitrary policymaking, in which decisions are posted on social media and not even his advisers know what is coming next. And he is still in an extraordinary trade confrontation with China, the world's second-biggest economy.

Investors and companies everywhere have been put through the wringer. Global markets crashed in response to Mr Trump's first tariff announcement. The S&P 500 fell by about 15%. Long-dated Treasuries sold off, as hedge funds were forced to unwind their leveraged positions. The dollar, which is supposed to be a safe haven, fell. After the tariffs were delayed, stockmarkets enjoyed a vertiginous climb. Between its low and high on the day, Nvidia's value fluctuated by over $430bn.

Even after the tariff pause, however, Treasury yields remain elevated. Global stocks are 11% below their highs in February—and justifiably so. Mr Trump has still raised America's average tariff rate to over 25% since January, with the promise of more levies, including on pharmaceuticals imports, to come. The president's advisers display a jaw-dropping insouciance about the damage tariffs can do to the economy. In their view, foreigners foot the bill for tariffs and market declines hurt only rich investors. Yet the dollar's fall all but guarantees that tariffs will cause American consumer prices to surge, hurting households' real incomes. The knock-on hit to consumer spending, including on goods made in America, is likely to be substantial, compounded by the blow to confidence from volatile stocks.

A similar blow will be dealt to capital spending. More than the precise level of tariffs, firms crave certainty that the rules of global trade will remain stable, so that they can plan their long-term investments. For example, although China's accession to the World Trade Organisation (WTO) in 2001 led to an explosion of trade, it did not involve materially lower trade barriers with America. Instead, businesses gained the confidence that there would not be a trade war, an effect that economists later estimated as being worth a staggering 13-percentage-point reduction in duties.

Mr Trump has now put that confidence effect into reverse, for both America and its trading partners— especially since his tariffs have disregarded America's past trade deals, including those he signed in his first term. It is still unclear what Mr Trump really wants to achieve in his 90-day holding period: his apparent goals of extracting concessions from other nations and reshoring manufacturing jobs

contradict one another. If tariffs are lowered, reshoring will not happen. Yet if trading partners suspect he is committed to protectionism, why would they offer concessions? And even if all the tariffs are rolled back, the memory of "Liberation Day" will linger in the minds of any company building a supply chain.

In any case, Mr Trump remains in an open stand-off with China from which it could be hard to back down. As we published this leader, America's new tariff on Chinese imports had reached 125%; China's levies, including in retaliation, came to 84%. These tariffs are high enough to devastate goods trade between the world's two largest economies, which have hitherto been deeply intertwined even as tensions have ratcheted up between the superpowers.

Mr Trump says that "China wants to make a deal". But, as with America's allies, only he knows what such a deal might be. For more than a decade there has been no shortage of Western complaints against China's approach to trade. The country has long violated at least the spirit of the WTO. Its model of state capitalism, in which its exporters are supported by an opaque system of subsidies and state-backed finance, can be hard to square with a transparent, rules-based order. And China's manufacturing surpluses have been so large in part because its own consumption is too low. None of this makes America poorer in aggregate, but it does mean that trade with China is not perceived to be fair—especially by those workers who have been displaced by it.

Superpower showdown

Yet a destructive and unpredictable tariff war was never the right way to approach these problems (which were in any case poised to improve as China stimulates its economy). Both sides' tariffs are causing deep economic harm; they may also raise the risk of a military showdown. A more promising route for America was to marshal its allies into a free-trade bloc large enough to force China to change its trade practices as the price of admission. This was the strategy behind the Trans-Pacific Partnership, a trade deal that Mr Trump binned in his first term. Scott Bessent, the treasury secretary, talks of doing a trade deal with allies and approaching China "as a group". But now that it has bullied its allies and reneged on its past deals, America will find they are less willing to co-operate.

Such is the short-sightedness of Mr Trump's reckless agenda. In a mere ten days the president has ended the old certainties that underpinned the world economy, replacing them with extraordinary levels of volatility and confusion. Some of the chaos may have abated for now. But it will take a very long time to rebuild what has been lost.

Finance & economics
The tariff madness of King Donald, explained

As his policy turns on a dime, pity those tasked with justifying his actions
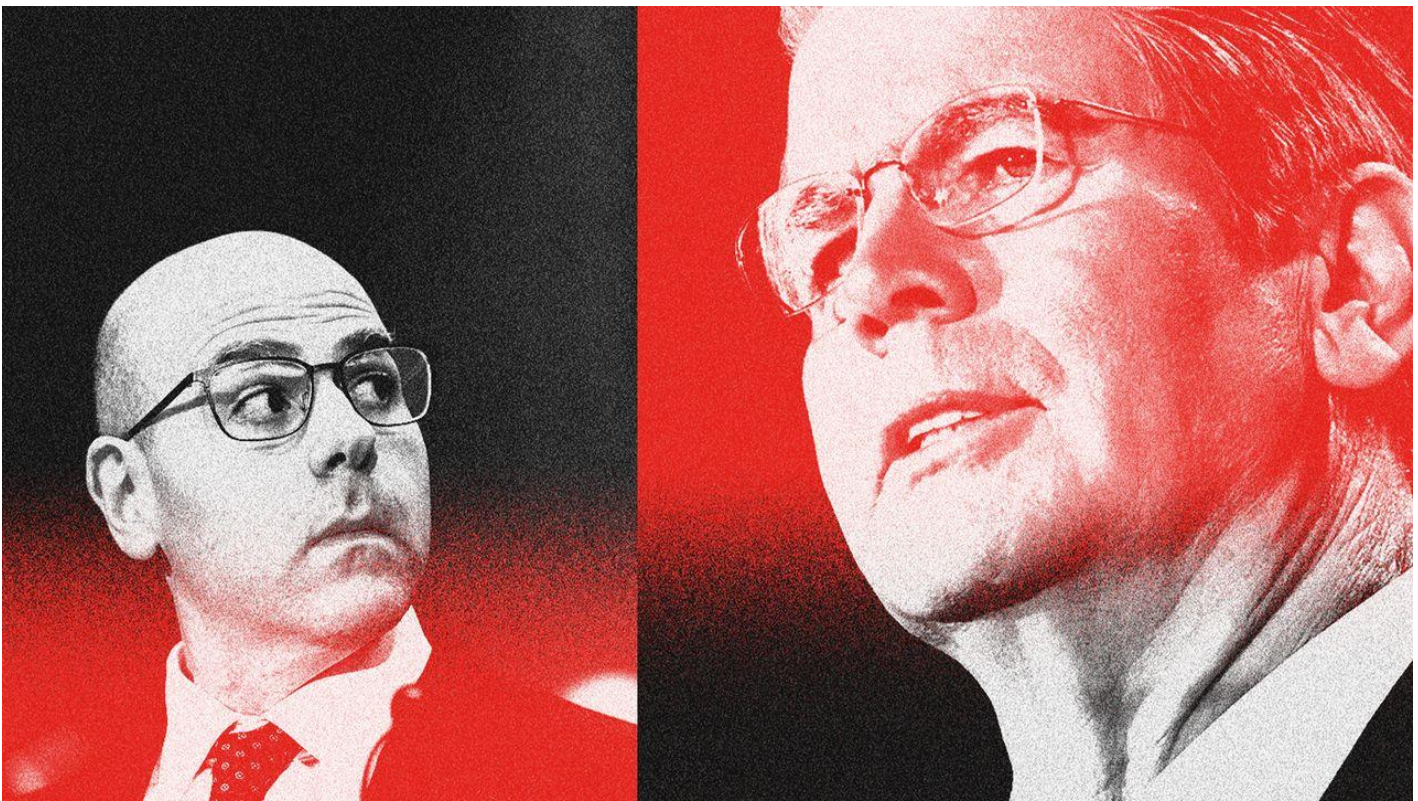

Illustration: The Economist/getty images/picture alliance

For people who believe themselves to be autonomous individuals possessed of their own free will, the past week has been a bracing corrective. Everyone, down to the most rugged individualist, is a pawn in Donald Trump's grand caper, bouncing between his threats of economic chaos and acts of mercy. On April 9th all it took was a few dozen words from him, delaying some of his most extreme tariffs for 90 days, to transform a spreading panic in financial markets into a full risk-taking frenzy.

Given this volatility, it might seem hopeless to ascribe any strategy to Mr Trump's on-again, off-again tariffs. But the rewards are such that bosses, diplomats and investors must try their best. Over the past week two members of Mr Trump's economic team have offered contrasting justifications for his

"Liberation Day" tariffs, helping to shed light on the thinking behind his protectionism. At the same time, though, they have exposed its flaws.

Stephen Miran, chairman of the Council of Economic Advisers, in effect a small think-tank within the White House, has provided the most complex rationale for the trade war. Shortly after Mr Trump's election victory, Mr Miran wrote a paper for an investment firm in which he laid out the potential for a "Mar-a-Lago Accord". Under its terms, other countries would strengthen their currencies against the dollar and provide low-cost financing in exchange for America's security umbrella.

Since entering the White House, Mr Miran has been at pains to say that the "Mar-a-Lago Accord" reflected his own musings, not administration policy. But on April 7th he used a speech in his official capacity to lay out a watered-down version of his paper. The imposition of tariffs was, Mr Miran said, a form of "burden sharing".

In his analysis America has paid a heavy cost in providing the dollar and Treasuries to the world as reserve assets that support the global trading and financial systems. As a result of doing so, it has suffered from currency distortions, which have led to unsustainable trade deficits and a hollowing-out of domestic manufacturing. In Mr Miran's view, countries could share the burden in other ways: buying more from America, investing in its factories or simply sending cheques to the Treasury. It is just that tariffs stand out as the most readily available tool to fix the problem.

A royal pain

The market ructions of the past week have pointed to a weakness in Mr Miran's thinking. Reserve-currency status may have strengthened the greenback, but it has also suppressed yields on dollar assets, allowing America's government and firms to enjoy cheaper financing. On top of this, it has given America the power to monitor global transactions and target people or regimes it does not like with sanctions. This is what made a surge in Treasury yields during the market chaos alarming: it carried a whiff of American markets losing their reputation for good governance, foretelling a possible decline in the dollar's standing.

Scott Bessent, Mr Trump's treasury secretary, attempted to set the record straight. In an interview with Tucker Carlson, a right-wing podcaster, released on April 4th, Mr Bessent said that only he and the president spoke for the administration on dollar policy. He insisted that both were pursuing a strong dollar, "putting in all the ingredients" to keep it that way for the long run. In other words, there are important benefits to issuing a reserve currency, and these outweigh the burdens.

9

Mr Bessent offered a more refined version of Mr Trump's view that America's success depends on the revival of its factories. In Mr Bessent's telling, this is about shoring up America's industrial base. "One of the few good outcomes from covid was we had a beta test for what a kinetic war with a large adversary could look like, and it turned out that these highly efficient supply chains were not strategically secure," Mr Bessent argued. With slight exaggeration, he says America could no longer make its own medicines, semiconductors or ships. Expressed in those terms, that might sound like a national emergency befitting tariffs.

Yet on closer scrutiny Mr Bessent's logic is also wanting. In nearly the same breath as describing the threat to American security, he says the solution for getting away from Mr Trump's tariff wall is to bring factories to America, including from Mexico. Although it is understandable that America wants to lessen reliance on Chinese supply chains given the two countries' rivalry, Mr Trump's willy-nilly tariffs have risked undermining America's relations with its allies and neighbours, a folly that leaves it more isolated.

Moreover, Mr Bessent appeals to deregulation as a way to unleash growth. But the one thing that has restrained businesses in recent months has been Mr Trump's radical tariff agenda, which is itself a form of regulation—one that attempts to dictate where companies invest. Hence the massive relief rally in financial markets when Mr Trump announced his pause.

Listen to this story
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In the end, intellectual justifications are only worth so much. As everyone in the administration acknowledges, the only person whose opinion really matters is the president. Advisers say that his views are, at their essence, quite straightforward: he wants manufacturing jobs back in America and believes high tariffs are needed to induce that. Still, with the latest shifts in his policy, he is stumbling into a strategy that, while unkind to most of the world, is harshest by far on China. For those tasked with explaining his actions, it is at least an easier story to tell.

America's financial system came close to the brink

Chaotic markets threatened to trigger a full-blown crisis
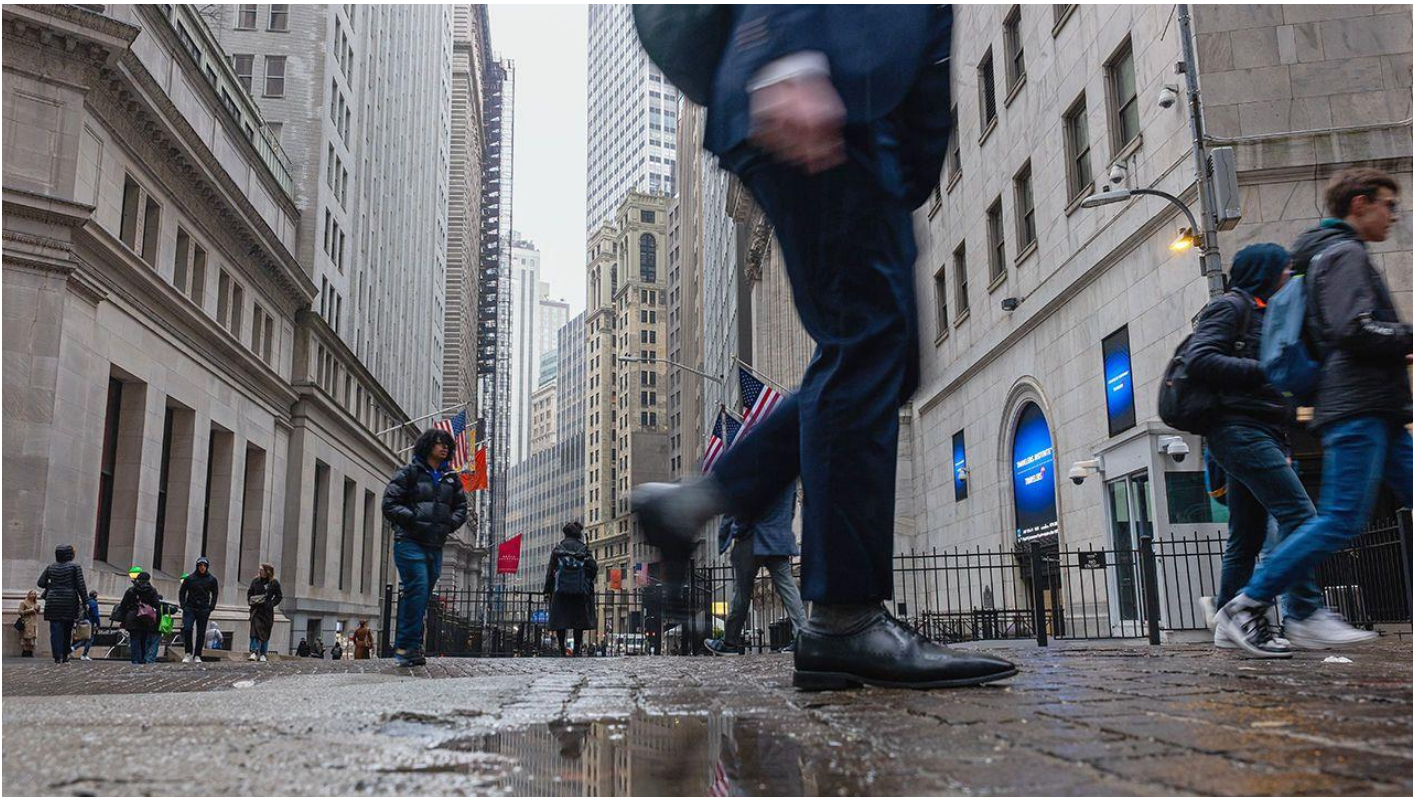
Puddles so far avoidedPhotograph: Getty Images

For a good few hours on April 9th, disaster beckoned. Share prices had been falling for weeks. Then the market for American Treasury bonds—normally among the safest assets available—started convulsing, too. The yield on ten-year Treasuries leapt to 4.5% (see chart 1), up from 3.9% days earlier. That meant bond prices, which move inversely to yields, had cratered. The failure of both risky and supposedly safe assets at once threatened to destabilise the financial system itself.

That should not have happened

US, ten-year government-bond yield, %

4.50

4.25

4.00

3.75

Apr 7th 2025   8th   9th

Source: Bloomberg

Chart: The Economist

Then everything changed. Late in the day, Donald Trump blindsided investors by saying he would delay many of the tariffs that had sparked the panic, for 90 days. Share prices surged: America's S&P 500 index closed up 10%, marking its best day since 2008. Treasury yields remain elevated, but as the chaos elsewhere subsides, that has less potential to cause damage.

The financial system came perilously close to the brink, and it is important to understand why, since the turbulence may well return. Warning bells have been ringing everywhere. Volatility gauges, derived from the insurance premiums traders pay to protect themselves from wild swings, have soared, though after Mr Trump's announcement they fell back somewhat (see chart 2). For risk managers at banks and hedge funds, such moves can be a prompt to tell trading desks to offload risky positions, lowering the chances of a big loss. If this happens at many institutions at once, the selling can make markets even wilder. The dash for cash even sent the gold price down for a time.

Vix up, look sharp

United States, implied-volatility measures
January 2nd 2025=100

Stockmarket
VIX index

Interest rates
MOVE index

$ per €

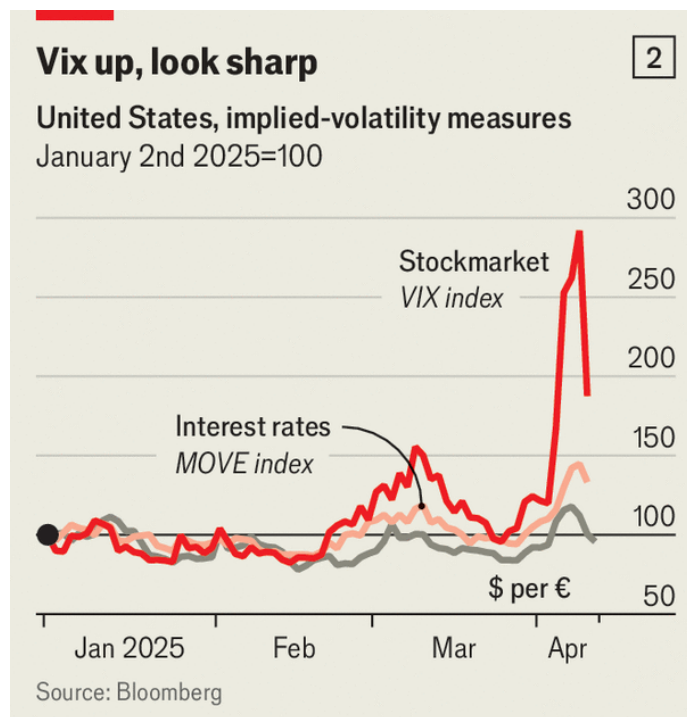Jan 2025   Feb   Mar   Apr

Source: Bloomberg

Chart: The Economist

Such stresses are deeply uncomfortable because they recall the last time the Treasury market seized up, at the onset of the covid-19 pandemic. Back then, heavy trading led to a liquidity shortage, meaning the difference between "buy" and "sell" offers widened sharply and the market became much less able to absorb large orders. Trades that could take place moved prices far more than they normally would have done, adding to the volatility. Eventually the Federal Reserve had to buy large quantities of bonds to stabilise the market.

"Swap spreads" suggested a similarly alarming dynamic was in play this week. These measure the gap between Treasury yields and interest-rate swap rates, which are the average of the overnight rates traders expect. The two usually move together, since an alternative to buying a Treasury bond and receiving its fixed yield is to deposit money in the overnight market and earn a rolling interest rate there instead. But on April 9th yields on ten-year Treasuries rose to a record-breaking 0.6 percentage points higher than the rate on equivalent swaps. The growing gap suggested that usual customers were reluctant to buy, given the enormous uncertainty haunting markets, according to Martin Whetton of Westpac, an Australian bank.

Fire-sales probably exacerbated the damage. Wall Street banks have hit their hedge-fund clients with the steepest margin calls since 2020, meaning they must stump up cash to cover their lossmaking

15

positions across asset classes. Government bonds are among the easiest things to sell to raise the necessary funds (as is gold). Yet if it is losses on these positions that triggered the margin calls in the first place, selling can make things worse. It pushes prices down further, creating a self-reinforcing "doom loop" in which margin calls prompt sales, which prompt yet more margin calls. This is what happened in 2022 when British pension funds rapidly offloaded holdings of gilts to meet margin calls, sending prices down and yields up even faster. Eventually the Bank of England had to step in to break the spiral.

A particular worry in the Treasury market is that a doom loop could arise from the "basis trade". This is popular with hedge funds and has minted fortunes at some of America's largest. It attempts to profit from the difference in price between Treasury bonds and Treasury futures contracts, caused by high demand for the futures from asset managers. Traders exploit this by buying Treasuries and selling futures contracts. To amplify the returns, they borrow using the Treasuries they have bought as collateral, then recycle the cash into even more Treasuries. Thanks to this procedure, hedge funds are short some $1trn-worth of Treasury futures.

The trade is profitable for as long as the cost of borrowing, and meeting margin calls, remains lower than the difference between Treasury bonds and futures. With lots of leverage, it can generate vast returns. But "it is like picking up nickels in front of a steamroller", bristles one hedge-fund manager. Funds can get squashed when markets plummet, either because credit dries up and leaves them unable to renew their borrowing, or because they must suddenly meet large margin calls on positions that have plunged into the red.

Crack of doom

When the bet is unwound, perhaps because yields have moved sharply and unexpectedly, funds are forced to sell Treasuries fast—compounding the selling to meet margin calls in other asset classes. In 2020 dealer banks were overwhelmed by the volume of Treasuries being sold, meaning that liquidity dried up. Something similar may have happened this time, too. Before the ructions, banks' inventories were already stocked full of Treasuries, giving them little capacity to handle more selling.

Should trading seize up once again, the Fed would have to intervene, acting as buyer of last resort and offering emergency loans to systemically important firms in need. Today's political backdrop would put central bankers in an invidious position, however. It was one thing for policymakers to backstop Treasuries when the problem they faced was a liquidity crunch brought on by covid lockdowns. This time, it is anyone's guess how much of the move in Treasury yields was down to the system malfunctioning, and how much reflects a loss of faith by investors in the bonds themselves. After all, Mr Trump's assault on the global trading system has dented confidence in American policymaking. It

16

is only natural to conclude that the country's sovereign debt has become less safe, and that Treasury yields should accordingly incorporate more of a risk premium.

Were the Fed to intervene in markets, in other words, it would prompt questions over whether it was simply protecting financial stability or also trying to suppress such a risk premium. Then there is the question of how far central bankers can use monetary policy to ease financial conditions and reduce the risk of systemic damage. Under other circumstances, they might opt for rapid rate cuts. Yet even though Mr Trump delayed his tariffs, investors are still betting inflation will rise. They fear stagflation—a nasty combination of inflation and stagnant growth—that would constrain any doves at the Fed.

The greatest threat surely still comes from politics. Even as some trade barriers have been postponed, those between America and China have been ratcheted to ludicrous levels. And it would be reckless to assume the shocks are over, or that foreign investors' faith in American assets, now shaken, can be magically restored. How much more can the system take before something really does break?

Despite the pause, America's tariffs are the worst ever trade shock
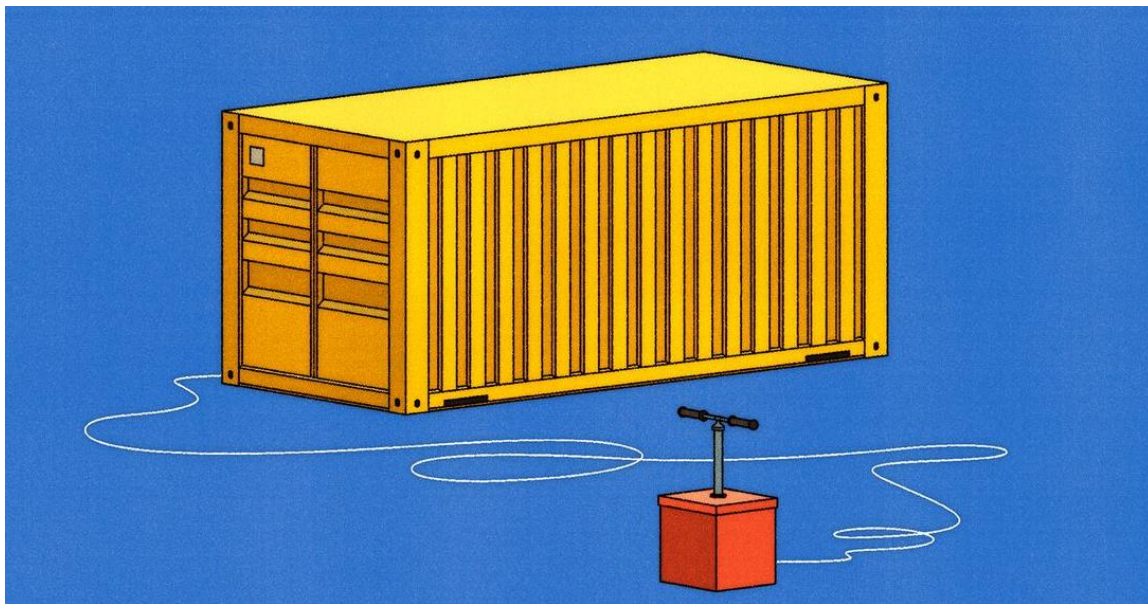
Reed Smoot, eat your heart out

Illustration: Álvaro Bernis

The announcement on April 9th that America would pause sky-high reciprocal tariffs sent stockmarkets soaring around the world. Countries that had faced crippling levies, such as Cambodia and Vietnam, celebrated. But do not lose sight of the bigger picture. The announcement excludes China, leaves in place all earlier tariffs and implements the universal 10% minimum portion of the reciprocal tariff. America's "effective tariff rate"—total tariffs paid as a share of total imports—may still rise by 15-20 percentage points. Even after the about-face, the incoming levies represent the most disruptive policy in the history of global trade.

If that sounds exaggerated, consider how disruptions typically look. American presidents of all stripes have imposed tariffs to protect favoured industries. In 1977 Jimmy Carter put tariffs on sugar. Joe Biden raised duties on Chinese electric vehicles. Even Ronald Reagan, the free trader's best friend, did similar. In 1983 lobbyists for Harley-Davidson persuaded him that they needed protection from Japanese manufacturers, so he slapped a 45% tariff on imports of big motorbikes. Yet the economic consequences of these policies, being so narrowly defined, were slight.

Many countries outside America have imposed transformative trade policies of their own. North Korea, for instance, has taken an off-again-on-again approach to engaging with the outside world. In the mid-20th century Argentina turned decisively from being an open trading nation to one that embraced protectionism. Britain's vote for Brexit in 2016 raised trade barriers between it and the European Union. In the end, however, none of these events had much impact on the world economy. After all, even Britain accounts for only 3% of global gdp.

Although America, which accounts for 25% of global gdp, has in the past embraced wholesale changes to its trade policy, pundits tend to overestimate how much damage they caused. Take Richard Nixon's 10% across-the-board tariff, imposed in 1971 in an attempt to boost exports. The policy sounds bad, but it was only in force for a few months and it excluded lots of imports. From 1970 to 1972, America's effective tariff rate actually declined.

It is a similar story with William McKinley. Those in the White House today are fans of this president, who was in office from 1897 to 1901 and, like many in the Republican Party, believed at the time that tariffs would nurture American industry. Yet McKinley the "tariff man" had less impact on America's trade stance than many believe. The Dingley Act of 1897, which McKinley signed into law, gave the president power to cut tariffs if trading partners acquiesced to America's demands. By comparison with today's policies, McKinleyism was weak tea. From the start to the end of McKinley's presidency the effective tariff rate on America's imports rose from 21% to 29%. Today's administration is overseeing an increase of twice the size.

Perhaps the Smoot-Hawley Act of 1930, the most famous protectionist measure in history, takes the crown? Hardly. Even under that law, many American imports came in duty-free. From 1929 to 1932 America's effective tariff rate therefore rose by only six percentage points. The bill provoked just a 5% decline in imports. Historians agree the measure was not sufficient to have provoked or even have done much to exacerbate the Depression. Did it prompt other countries to embrace protectionism, creating knock-on damage? Perhaps. Then again, other countries had been busy raising tariffs before America. Reed Smoot, the co-sponsor of the bill, may have had a point when he wrote in 1930 that "Only the purblind egotist can suggest that the world turned to protection in retaliation against the American tariff."

If the current administration wants a rival for truly protectionist policy, it must look to the civil war. From its birth in 1854 the Republican Party, largely in the north of the country, had favoured high tariffs in order to benefit manufacturers. The Democrats, in the South, liked free trade, so that they could sell their cotton abroad. As hostilities between North and South rose, the Republicans struck. From 1861 to 1868 America's effective tariff rate rose by 32 percentage points. Now you're talking.

Radical, yes. Unreasonable? It is harder to say. Desperate times call for desperate measures: America needed to fund its war quickly. And the Southerners hated tariffs, meaning that imposing them was a stick in their eye. Good for the Unionists! The wartime government also raised tariffs more slowly than the government is doing today. And the context is crucial. The American economy of the 1860s was half as dependent on imports as it is in 2025, and supply chains were far less complex. A given rise in the effective tariff rate had far less of an impact than it would do today.

William McKinley, your boys took one hell of a beating

The tariffs of the 1860s were, nonetheless, a bad idea. Just look at the accounts of people on the inside, including David Wells, who was appointed in 1866 to oversee America's levies. A long-standing protectionist, Wells ultimately came to favour free trade. He despised the cronyism that the tariff system engendered. In his view, the provision of cheap raw materials was "essential to the prosperity of the manufacturing industry of the United States", a principle that was "almost entirely disregarded under the existing tariff". Recent accounts by economic historians have tended to side with Wells. By raising costs, protectionism impeded rather than assisted America's industrial development.

Pause notwithstanding, the pain is just beginning. The administration is quick to punish trading partners that have fought back, notably China. And because it believes that the benefits of tariffs, such as they are, will take months or years to emerge, it may keep levies high for a long time. All of which means there is no precedent for what the world is about to experience.

Technology
The tricky task of calculating AI's energy use

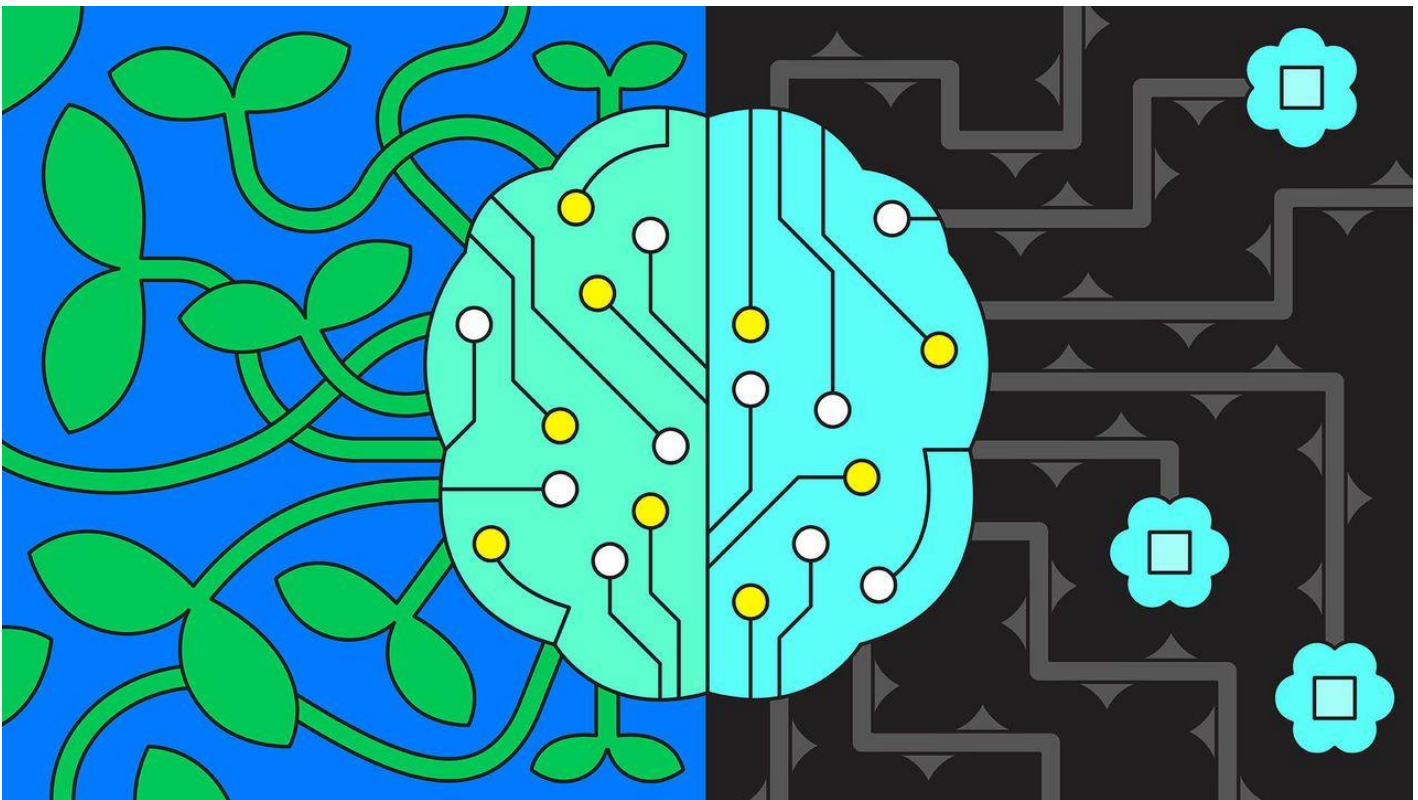**Making models less thirsty may not lessen their environmental impact**

Illustration: Rose Wong

Afifth of all electricity used in Ireland is spent powering the country's data centres, more than is used by its urban homes. With one data centre for every 42,000-odd people, Ireland has one of the highest per-person concentrations of computing power in the world. Loudoun County, just outside Washington, DC, beats it: its 443,000 residents rub shoulders with scores of data centres—more than the next six biggest clusters in America combined. In 2022 their peak energy usage was almost 3 gigawatts (GW), a power draw that, if maintained year round, would approach Ireland's total annual consumption.

Around 1.5% of global electricity is spent on powering data centres. Most of that is for storing and processing data for everything from streaming video to financial transactions. But artificial intelligence (AI) will make up much of future data-centre demand. By 2038 Dominion, a power company, expects the data centres in Loudoun County alone to need more than 13GW. The International Energy Agency, a forecaster, estimates that global data-centre power demand could increase by between 128% and 203% by 2030, mostly because of AI-related energy consumption.

Big tech is confident that the environmental benefits justify the costs. "AI is going to be one of the main drivers of solutions to the climate situation," says Demis Hassabis, the boss of Google DeepMind. Others disagree. This week's special section explores the arguments in detail. It examines the ways in which AI can help clean up some of the most polluting industries, including energy production and heavy industry, and discusses the possibility of moving data centres off Earth altogether. It will also examine why AI's energy footprint is so hard to quantify, and what its true environmental impact might be.

Tech firms are generally unwilling to share information about their AI models. One indirect way to estimate the environmental impact of building and deploying AI models, therefore, is to look at the firms' self-reported carbon emissions. Google's greenhouse-gas emissions rose by almost half between 2019 and 2023, according to the search giant, primarily because of increases in the energy consumption of data centres and supply-chain emissions. Microsoft's emissions jumped by roughly a third in 2023, compared with three years earlier, partly due to its own focus on AI.

High demand

World, CO_2 emissions from electricity generation for data centres, megatonnes

*Faster AI growth and fewer energy bottlenecks
†AI-adoption and energy-supply trends continue
‡Same AI growth and improved energy efficiency
§Slower AI growth and energy bottlenecks persist
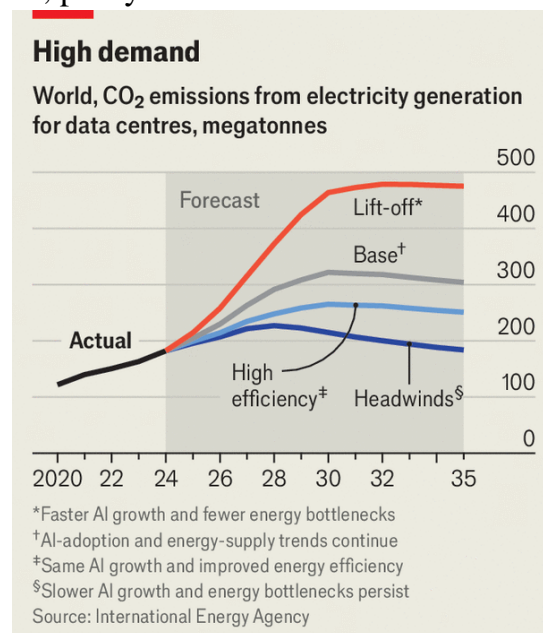Source: International Energy Agency

Chart: The Economist

Another approach to estimating AI's environmental footprint is to add up the energy use of the infrastructure used to build the models themselves. Meta's Llama 3.1, a large language model (LLM), for example, was trained using chips from Nvidia which can draw 700 watts of power each, around half that of a fancy kettle, and it ran those chips for a cumulative 39.3m hours. The resulting energy used, 27.5 gigawatt-hours (GWh), is enough to supply 7,500 homes with a year's worth of power.

Tech companies, perhaps unsurprisingly, are keen to argue that this energy bill is not nearly as outlandish as it might appear. The immediate climate impact of the final Llama 3.3 training run, Meta estimates, is emissions worth 11,390 tonnes of CO_2—about the same as 60 fully loaded return flights between London and New York. Those are the emissions, at least, of the power grid that supplied the company's data centre. But Meta argues that, since electrons are fungible, if enough renewable energy is bought on the opposite side of the country—or even at another time altogether—the true emissions fall to zero.

Put to good use

Focusing on the energy impact of training models, however, may be a distraction. Boris Gamazaychikov, who is in charge of AI sustainability at Salesforce, a software company, compares it to trying to estimate the carbon footprint of a flight by including the impact of building the plane itself. Not only is that construction cost tiny compared with the fuel used over a typical lifetime in service, it's also impossible to calculate the per-passenger impact until the aircraft is finally retired.

Instead, he says, it is best to focus on the energy impact of using AI, a process called inference. Brent Thill of Jefferies, an analyst, estimates that this stage accounts for 96% of the overall energy consumed in data centres used by the AI industry. Mr Gamazaychikov is trying to put hard numbers on that side of the industry, working with HuggingFace, an AI cloud provider, to systematically test the efficiency of hundreds of AI models. The results show the difficulty of generalising: the difference between the most and least power-hungry models is more than 60,000-fold.

Some of that difference arises from the AI models' varying purposes. The most efficient model tested, called BERT-tiny, draws just 0.06 watt-hours (Wh) per task—about a second's worth on an exercise bike—but is useful only for simple text-manipulation tasks. Even the least power-hungry image-generation model tested, by contrast, requires 3,000 times as much electricity to produce a single image.

All the same, says Sasha Luccioni of HuggingFace, concrete figures are not always available. Her company could test only the models it could download and run on its own hardware. "OpenAI has not released a single metric about ChatGPT," Ms Luccioni says, even though such data exist.

Another difficulty in calculating energy use is the fact that AI models are rapidly evolving. The release of DeepSeek V3 in December, a top-tier AI model made by a lab spun off from a Chinese hedge fund, initially looked like good news for those concerned about the industry's energy use. A raft of improvements meant that the final training run was more than ten times faster than that of Meta's Llama 3.3 model just a few weeks earlier, with a roughly proportionate reduction in power used. Inference also became less power-hungry.

In January, as the implications of that improvement became clear, the stock prices of chipmakers crashed. But Satya Nadella, the boss of Microsoft, predicted the upset would be brief, citing the Jevons paradox, a 19th-century observation that the rising efficiency of steam engines opened up new economic uses for the technology and thereby raised demand for coal.

For AI, the rebound effect arrived in the form of "reasoning" models, including DeepSeek's follow-up model, R1. If normal chatbots exhibit what Daniel Kahneman, a psychologist and Nobel economics laureate, called "type one" thinking—prioritising speedy responses—reasoning models display "type two": structured replies that attempt to break a problem into its constituent parts, solve it with a variety of approaches, and check their answer is correct before settling on it as the final response.

Training a reasoning model is not much harder than training a normal AI system, especially if you have pre-existing models to learn from. But running it requires significantly more power, since the "reasoning" step, in which the problem is thought through before a final answer is reached, takes longer. The efficiency improvements DeepSeek pioneered in V3 were more than eaten up by the extra thinking time used by R1 a couple of months later.

If models become more efficient still, there are yet more uses to which they can be put. In recent months, several AI labs have launched "Deep Research" tools, combining reasoning models with the ability to search the web for information and set themselves follow-up tasks. The tools are one of the first mainstream examples of what the AI industry calls "agents", quasi-autonomous AI systems that can carry out many tasks sequentially. And because it takes them between five and 30 minutes to give a response, running such an agent uses more energy than asking a simple query.

Such efficiency gains leave some wary of the Jevons paradox popping up in other industries. Lynn Kaack, who leads the AI and Climate Technology Policy Group at the Hertie School in Berlin, worries that, by increasing efficiency and reducing costs in areas like shipping, AI will incentivise companies to increase their activity.

Those concerned about the trajectory of AI's environmental costs are looking for ways to alter it. Mr Gamazaychikov, for instance, hopes that his effort to rank various AI models will allow users and businesses to find the most efficient one for any given task, rather than always using the "best".

But the closed nature of the biggest labs complicate things. OpenAI, for instance, gives away access to its top-tier models below cost, according to Sam Altman, its boss; Google and Amazon charge less for access to their own AI systems than the cost of the electricity alone, insiders claim. That means users have less motivation to hunt for the most efficient model than they would if they had to pay the true cost of their use. And greater transparency around efficiency and emissions may not result in meaningful behavioural change: after all, there is little evidence to show that growing awareness of the carbon cost of flying has stopped people taking flights.

Coming clean

Many observers think that the best way forward is through tighter regulation, both of AI itself and of the energy it consumes. The first has had limited success in Europe—from the summer of 2026, developers of "high risk" AI will need to tell regulators about the energy it consumes—and is struggling to get off the ground almost everywhere else. In America the Trump administration's bonfire of red tape means voluntary efficiency drives are more likely than new regulations.

That said, trying to regulate the development of AI specifically is not the only option: broader policies meant to motivate emissions cuts, such as carbon pricing, can help too. Arguably the most important change will come from speeding up the transition to clean energy, and boosting the amount available so that demand for greener AI does not gobble up the low-carbon electricity also needed to decarbonise other sectors, from transportation to construction. Figuring out how to do that shouldn't require Deep Research.

AI models can help generate cleaner power

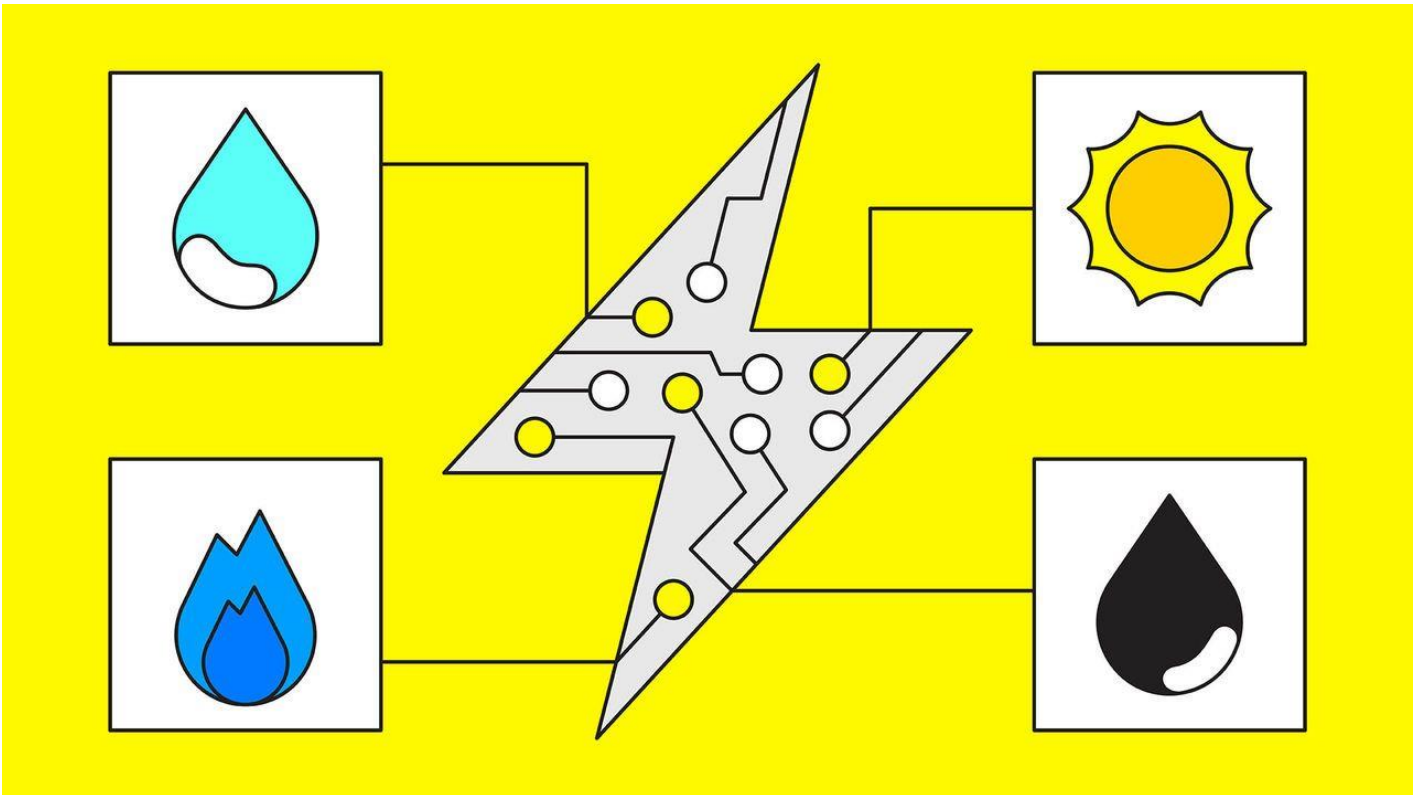## Energy companies are using them to increase efficiency and spot problems

Illustration: Rose Wong

ROLL UP in a BYD Seal to the leafy entrance of a small housing block in Walthamstow, in east London, and the first thing that strikes you is the quiet. The stylish Chinese saloon is all electric, so you hear no mechanical grind or combustion groan, but so too are the innards of these unusual homes. The hyper-insulated units are powered using solar panels, warmed by electric heat pumps and served by whizzy digital appliances, all tracked remotely with smart electricity meters. Ask a homeowner how the heat pump in his yard works and he says he has no idea and frankly does not care. "Zero bills means zero cost!" he says with a broad smile.

These homes, and others like them around Britain, are part of an innovative deployment of clean-energy technologies controlled by artificial intelligence (AI) tools developed by Kraken, the software arm of Octopus Energy. The utility, which serves roughly a quarter of the country's households and is

25

one of the energy world's most valuable unicorns, is offering customers free heat and power for five years in those toasty "Zero Bills" homes in return for allowing it to control, within comfortable parameters, when and how devices are operated. A separate scheme provides cut-rate electric-vehicle (EV) tariffs if customers agree to let the firm charge cars during fallow periods rather than when the grid is overloaded.

Kraken's AI manages roughly 8bn data points a day from nearly half a million devices across the country to allow real-time price and energy arbitrage. By shifting when these loads consume energy from peak periods to fallow times, the firm earns a profit and helps keep the grid from overloading. Amir Orad, Kraken's chief executive, reports that his firm's distributed assets, which include half of Britain's grid-scale battery capacity, exceed 1.6GW (roughly the output of two nuclear plants). Its AI optimisation avoided the emission of over 16m tonnes of CO_2 in 2024. Customers in those nifty homes save a fortune in avoided heat and power bills, and EV-owners saved an average £375 ($480) a year versus unmanaged charging and £750 a year versus the petrol alternative.

"A tidal wave of change is coming to this industry," insists Mr Orad. AI is often overhyped, but for the conservative energy industry that prediction seems plausible. Utilities have long resisted change, typically reinvesting low shares of revenues in research and innovation, but AI promises to change this rapidly. Climate-tech companies around the world are coming up with novel energy equipment, from nuclear power to renewables, to speed development and deployment. The range of potential applications is vast: even the hydrocarbon business is deploying AI to surprisingly green ends.

Start first with the grid. The Kraken example gives an idea of how AI can transform a top-down, centralised system of distant power stations into a distributed network of agile producers and consumers. Companies are also using AI techniques to boost throughput on power grids without going to the effort of building new power lines. LineVision, a startup which counts Microsoft as an investor, uses non-contact sensors to monitor temperature, sag and environmental conditions on transmission lines. By analysing these data in real time and combining them with weather forecasts, its algorithms calculate the lines' true carrying capacity.

A report released by the International Energy Agency (IEA), a global forecaster, on April 10th calculates that very-high-voltage transmission lines "can safely carry 20-30% additional capacity above their maximum rating for around 90% of the time". Britain's National Grid has used this approach to "unlock" an extra 600MW of offshore wind capacity per year.

Tapestry, an offshoot of Google's experimental X laboratory, has developed a forecasting tool for Chile's electrical grid that allows planners to anticipate congestion, better locate green-energy projects

and, eventually, accelerate the phase-out of coal by ten years. On April 10th Tapestry announced a deal with PJM Interconnection, the largest regional grid operator in America, to use its AI tools to help speed up the connection of energy sources.

The Electric Power Research Institute (EPRI), an industry body, points to the success machine-learning models have had in identifying dangerous fluctuations in voltage or frequency on power grids that can damage equipment or lead to blackouts. In one case, what would have taken analysts weeks was done in a day.

In March Nvidia and EPRI announced the Open Power AI Consortium, a project to build multimodal AI models that will be trained on energy and electrical-engineering data, academic research and industry regulations. The models could help utilities improve their grid operations and streamline the paperwork required for permits to build new infrastructure.

AI can also make using green energy more profitable and desirable: in 2018 Google DeepMind began using machine learning to manage some of the wind farms the company buys energy from. By combining weather forecasts and historical turbine data, the system was able to predict the farms' energy output up to 36 hours in advance, and to select how much to send to the grid and when. A year later, this both boosted the value of the energy by 20% and meant it was easier for grid operators to make use of.

Traditional big power plants are also seeing benefits. Hydrogrid, an Austrian firm, helps dam operators globally to generate more power by applying AI. Because inflow patterns vary at hydro-electric plants with multiple parallel turbines, the system optimises water flow to maximise electricity output, yielding up to 10% increases in power generation.

Inspecting existing nuclear sites is an extremely complicated task. Done the old-fashioned way, with ultrasound, an inspection produces a mountain of data (4.4 "miles", jargon reflecting the distance a small probe travels over the reactor vessel component), and takes several experts days to plough through. With AI managing the inspection, that mountain became a molehill of 463 "feet" of data, and one expert did the job in four hours.

Terra Praxis, a non-profit outfit, uses AI to cut through the red tape involved in the application process for new nuclear plants. By dramatically reducing the complexity of producing draft applications, it promises to help projects reduce the cost (typically $25m-40m) and take years off the conventional waiting time.

AI is even making big oil a bit more environmentally friendly. ADNOC, an Emirati state energy giant, applies AI tools to spot leaks of methane, a potent greenhouse gas, at its assets so that they are tackled quickly. It also uses software to predict emissions sources up to five years in advance. In 2023 its new approach helped abate around 1m tonnes of CO2-equivalent emissions, roughly the same as taking 200,000 petrol-powered cars off the road.

It helps that, thanks to AI eyes in the sky, polluters can no longer hide. Working out which companies are responsible for methane emissions is hard. Methane plumes, invisible and odourless, can be spotted only by using specialised infrared or spectroscopic equipment. The geographic areas over which they might occur, at any time of day or night, are immense. Quantifying them reliably requires the onerous collation and cross-validation of multiple data sets, from satellites, aircraft, ground sensors and industry reports. It was only with the advent of AI that doing this at a global scale became feasible.The IEA's new report calculates that replacing periodic inspections with AI-enabled continuous monitoring and repair would avoid 2m tonnes of methane emissions a year.

Saudi Aramco, the world's largest oil company, is using AI-powered "digital twins" and LLMs to help squeeze more oil out of existing fields without consuming a lot of dirty energy, boosting hydrocarbon production by 8.4% while reducing emissions per barrel by 8.2%. The firm has also used AI to reduce flaring of methane by more than 50% since 2010. All this may seem perverse to environmentalists, but as long as the world continues to consume fossil fuels—which still provide some 80% of primary energy—AI can at least help make their production less polluting.

AI models are helping dirty industries go Green

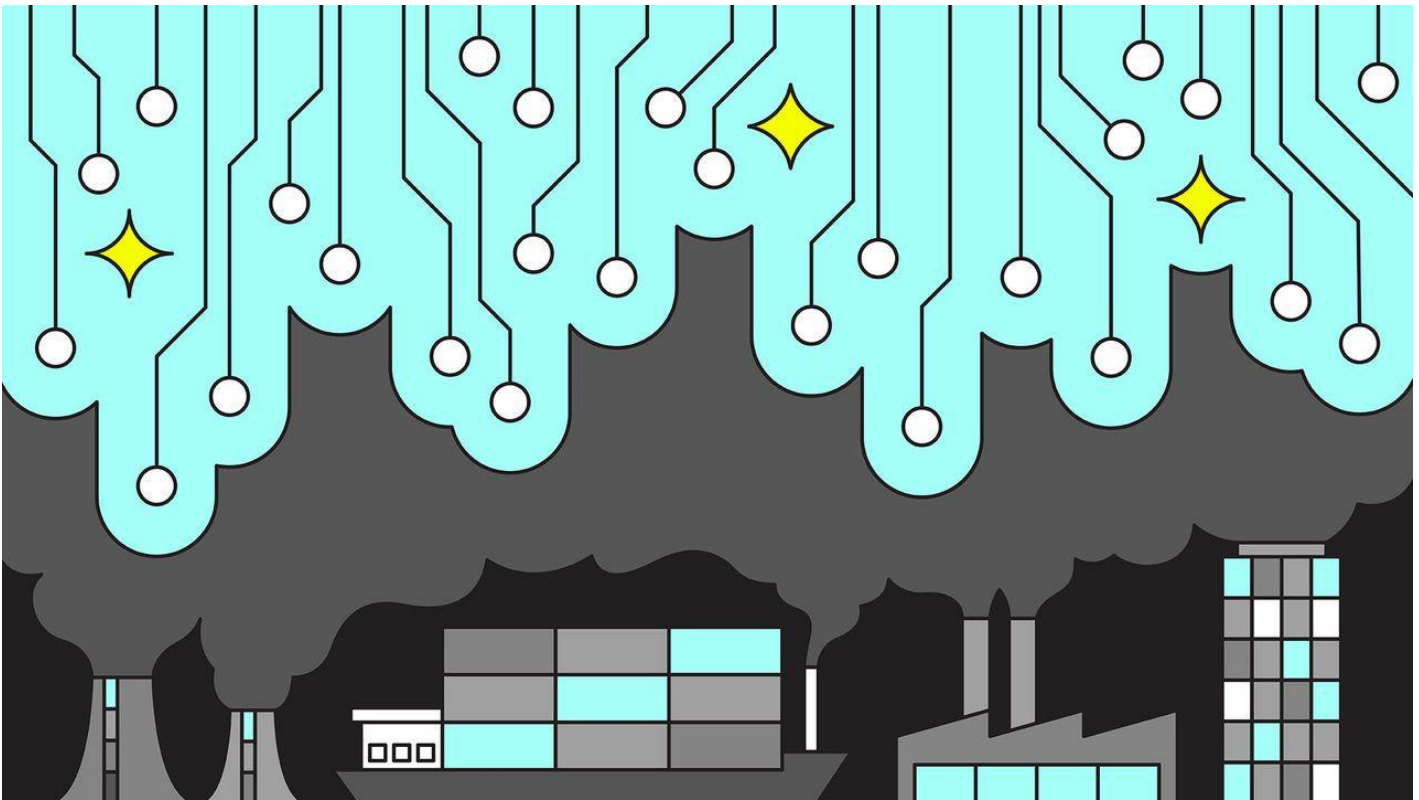## Mining companies and steelmakers are feeling the benefits

Illustration: Rose Wong

OVER A CENTURY ago, ships leaving Rotterdam's harbour were among the earliest to be equipped with wireless telegraphy and submarine signalling. Now, Europe's busiest port is pioneering the use of artificial intelligence (AI). PortXChange, developed by the port and spun out as an independent entity, uses AI to analyse several dozen factors tracking vessels, port emissions and estimated arrival times. A huge source of wasted fuel is the "hurry up and wait" common among ships rushing to arrive at congested ports. This platform helped Shell, an oil giant, reduce "idle time", affecting departures of barges and bulk shipments across all ports, by 20%. The tool is now being used by companies and ports around the globe.

The Dutch are hardly alone. Companies worldwide are applying AI tools like machine learning (ML) to cut energy use and emissions. Examples abound even in asset-heavy, fossil-intensive industries like steel, building maintenance and transport that account for a huge chunk of anthropogenic greenhouse gas (GHG) emissions.

Consider the steel industry, responsible for roughly a tenth of CO_2 emissions. It is hard to decarbonise when steel is made from virgin iron ore in conventional blast furnaces, because coal is used both as fuel and a reducing agent. A more promising path involves making steel from scrap metal in electric-arc furnaces powered with clean energy. The snag is that scrap comes in batches with varying impurities, which can make these mills more complex to operate and increase their energy use.

This is where Gerdau, a big Brazilian steelmaker with global operations, is applying ML. Fero Labs, a software company, analysed years of production data from a Gerdau facility in North America to work out how different "recipes" of input materials affect the quality of outputs. Its system measures the contents of each batch of scrap and uses AI to suggest the minimum quantity of alloys that will be needed to then produce metals that meet required standards. This saves time and overuse of additives. In 2024, with no change in hardware, these efforts cut GHG emissions associated with making a commonly used grade of steel by 3.3%.

In a report released on April 10th, the International Energy Agency estimates that widespread industrial application of such AI tools could save eight exajoules (EJ) of energy demand by 2035, as much energy as Mexico uses today. Widespread adoption in non-industrial sectors could save another 5EJ or so.

Mining is another dirty business where AI is making inroads. Fortescue, an Australian giant, is applying AI in designing current systems and redesigning future mining and energy operations with an eye to eliminating fossil fuels. Its algorithms automate tasks such as calculating how energy is used and the routes that autonomous heavy vehicles take. If the weather forecast is for rain, meaning solar output will fall, the company brings forward energy-intensive tasks while it can still use clean solar power. The software enabling this sort of load flexibility, the firm reckons, has allowed it to cut the required capacity of the power system it built by 9%, saving nearly $500m.

Buildings are responsible for perhaps a fifth of all man-made GHGs, and because they last a long time their climate impact can be hard to reduce. Happily, AI can help here too. BrainBox AI, a Canadian tech firm recently acquired by Ireland's Trane Technologies, has helped Dollar Tree, an American discount retailer, deploy autonomous heating, ventilation and air-conditioning in over 600 stores. Combining internal data with weather forecasts, the new systems cut electricity use by nearly 8GWh in a year, saving the firm over $1m.

Predictive maintenance shows promise too. Using AI-powered software supplied by AVEVA, a British company, Ontario Power Generation, a utility, found some $4m in efficiency savings in two years while reducing risks. Sund & Baelt, a Danish firm, used IBM's AI (in tandem with camera-toting drones) to cut expenses by 2% year on year. The approach is so superior that the company expects to double the lifespan of its assets, in effect avoiding 750,000 tonnes of CO_2 emissions.

Shipping and logistics companies have taken to applying AI with gusto. UPS, a package-delivery giant, recalculates delivery routes throughout the day as orders, pickups and traffic conditions fluctuate. It estimates that its smart software has improved on-time delivery while cutting 16-22 kilometres from drivers' daily trips, saving hundreds of millions in fuel costs. Cargill Ocean Transportation, the logistics arm of an agribusiness goliath, uses AI enabled by Amazon's AWS to reduce the time ships spend loading and unloading in port, saving up to 2,800 working hours, and their associated CO_2 emissions, per year.

Denmark's Maersk, one of the world's largest container-shipping lines, uses AI to analyse variables from engine performance to ocean currents and weather to avoid rough seas and waiting time. Making even its older ships smarter has reduced fuel consumption by over 5% across its fleet, saving $250m and reducing CO_2 emissions by perhaps 1.5m tonnes.

That example points back to Rotterdam. Routescanner, a route-optimisation platform developed by the port, uses terminal and company data to offer shippers real-time alternatives on routes, modalities (barge versus lorry, say) and environmental impact. The platform is now used by leading global forwarders and ports from Houston to Singapore. Slowly but surely, AI is helping turn brown to green.

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