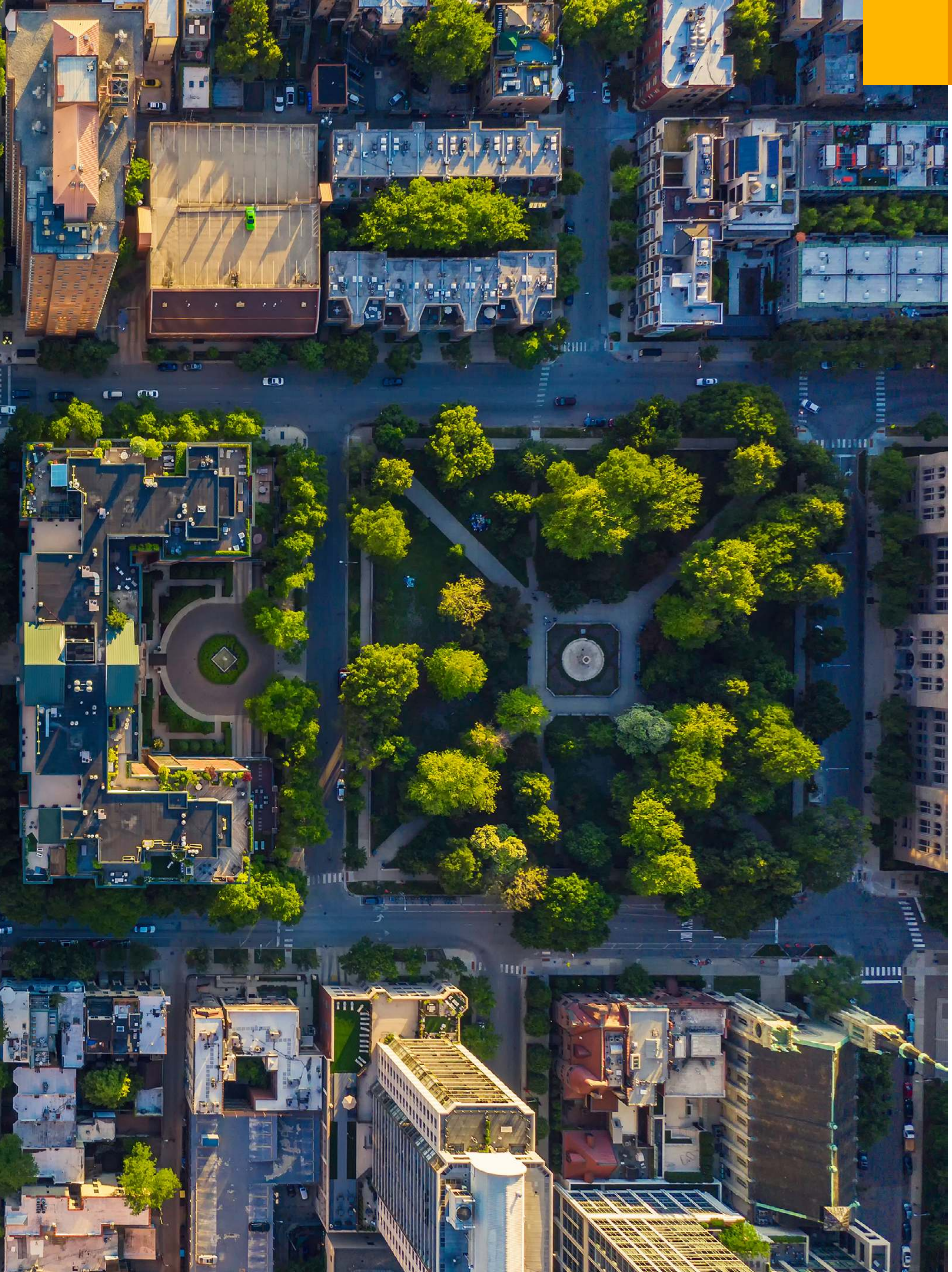
Net Zero Economy Index 2024

Incremental progress made, exponential change required



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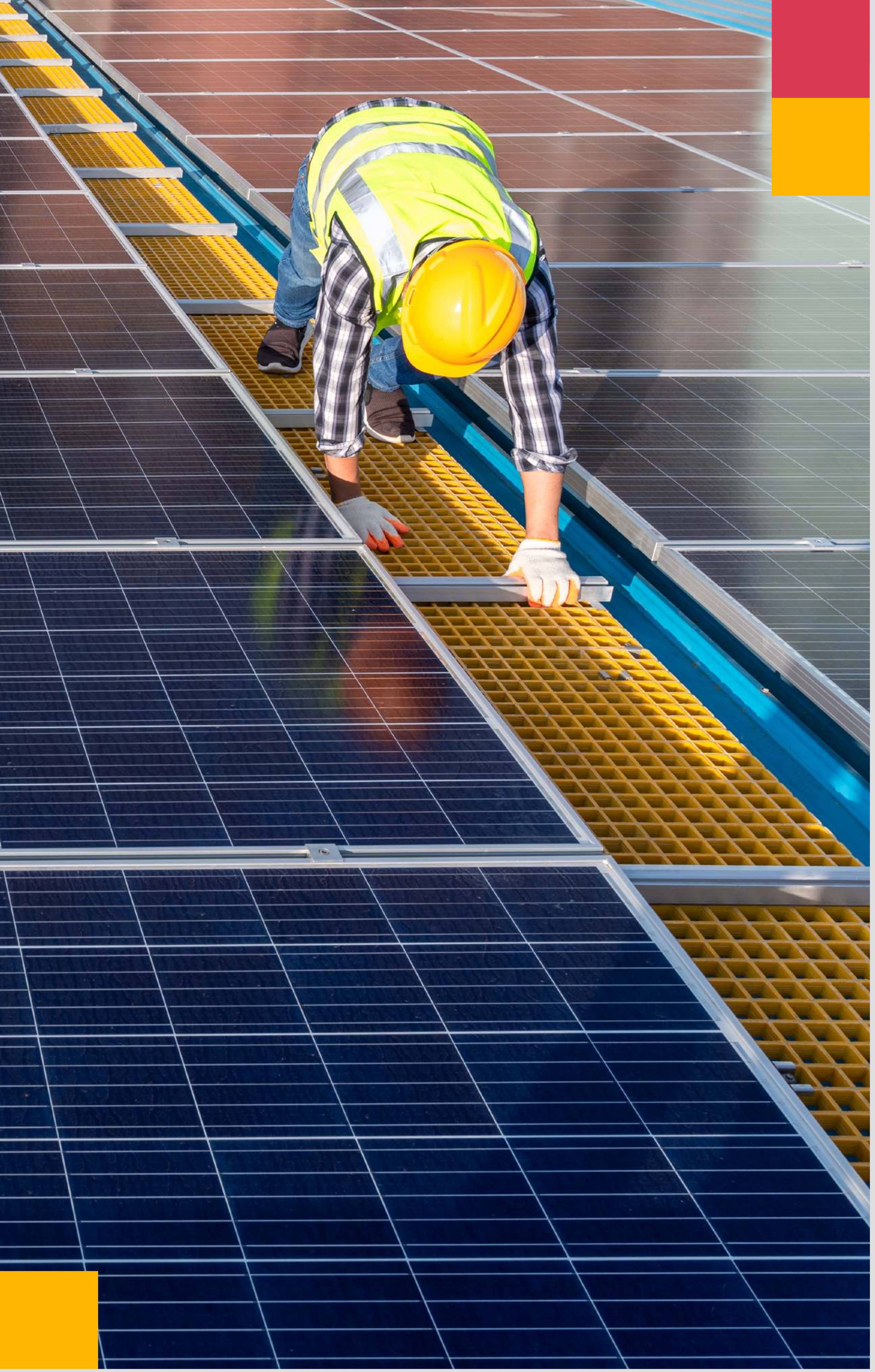


1 Executive summary

Reduction in carbon intensity stalls to lowest level in over a decade

A global decarbonisation rate of just 1.02% in 2023 reflects a troubling stall in the progress we have made in decoupling economic growth from emissions. This latest finding from our Net Zero Economy Index shows the smallest decrease in carbon intensity since 2011. Sluggish progress comes as global temperatures edge dangerously close to the 1.5°C threshold, with temperatures in 2023 averaging 1.43°C above pre-industrial levels.

The findings suggest the decarbonisation rate required to keep global warming within 1.5°C has surged to 20.4% per year. For context, the largest annual rate of decarbonisation achieved by any G20 country in the history of our analysis is 11.08%, by France in 2014. There's a growing consensus: overshooting 1.5°C is a likely reality[1]. Limiting warming to 2°C - the lowest end of the Paris Agreement's ambition - would also require a step change from the incremental annual progress we are seeing, with an annual decarbonisation rate of 6.9% needed.

Consequences of collective inertia

The consequences of overshooting 1.5°C are not abstract. They translate into real losses: of lives, property, and livelihoods. In the five years to 2022, climate-related events such as heat waves, floods and storms, caused over $192 billion in economic losses in the EU alone, over twice as much as the previous five year period from 2013 to 2017[2].

The greater we overshoot 1.5°C by, the more severe the likely impact. Limiting global warming to 1.5°C instead of 2°C by mid-century is projected to save $8.1–11.6 trillion in avoided damages[3]. Any overshoot heightens the risk of triggering climate tipping points. These critical thresholds, once crossed, can cause significant and irreversible damage. Between the range of 1.5ºC to 2ºC, estimates show six climate tipping points become likely.

These include the collapse of the Greenland and West Antarctic ice sheets, die-off of low latitude coral reefs, and widespread abrupt permafrost thaw[4]. The exact point at which these tipping points will be triggered is uncertain, underscoring the urgency of limiting global warming as close to 1.5°C as possible.

1 IEA (2023), Credible pathways to 1.5°C; UNEP (2022), Emissions Gap Report 2022; IPCC (2021), Sixth Assessment Report; WBCSD insights (2023), Carbon removals: why a portfolio approach is key to achieving climate goals.
2 Eurostat (2022), Climate related economic losses - EU Losses from climate change between 2013 - 2017 were $95 billion (Conversion €1 = $1.11); UNEP (2023), About Loss and damage
3 IPCC (2019), Global warming of 1.5°C - Avoided damages includes costs related to both direct economic impacts and the need for adaptation
4 Science (2022), Exceeding 1.5ºC global warming could trigger multiple climate tipping points

Renewable energy capacity up, but fossil fuels still dominant

COP28 resulted in an agreement to triple global renewable energy generation capacity to at least 11,000 GW by 2030 and to double the annual rate of energy efficiency improvements from 2% to over 4% until 2030. Last year saw another record increase in renewable energy capacity with total installed capacity rising 14% from 2022 to 2023, to 3,870 gigawatts (GW)[5,6].

This uptake in renewable energy has been driven by supportive policies and continued reductions in the cost of solar and wind technologies. Sustained momentum could see renewable energy capacity nearly double in the next five years and surpass coal as the largest source of electricity globally by 2025[7]. Despite this progress, fossil fuels remain the dominant source of energy, with consumption growing by 1.5% last year to 16,007 GW[8].

This trend is reflected in our findings that the global fuel factor - the emissions released per unit of energy consumed - also increased slightly by 0.07% in 2023, indicating a small rise in the proportion of fossil fuels relative to renewables in the energy mix.

Surging energy demand risks undermining gains from growth in renewables

Growth in energy demand continues to outpace the adoption of renewables, leading to a persistent increase in fossil fuel consumption. Economic challenges such as inflation, geopolitical tensions, and rising interest rates further complicate the shift away from fossil fuels. Urgent action is needed in energy efficiency and demand management, alongside energy supply improvements, to ensure sustained progress in global decarbonisation. Despite electrification and digitisation generally being less energy-intensive, escalating energy requirements for emerging economies, transport systems, artificial intelligence (AI), data centres, and climate adaptation efforts, such as increased cooling and water desalination, are driving higher energy demands.

Public-private partnerships offer a powerful tool for effectively managing energy demand. The private sector can lead in deploying energy efficiency technologies, adopting circular business models, and implementing advanced manufacturing processes, potentially unlocking $2 trillion in annual savings by 2030[9]. Governments can enhance this effort by focusing on energy demand reduction in revised Nationally Determined Contributions (NDCs)[10] and investing in critical sectors like the built environment, industry, and transport. Public investments, tax incentives, and dynamic electricity pricing can stimulate private sector investments in energy efficiency. Strengthening building standards, incentivising retrofitting and electrification, and supporting transport electrification through shared infrastructure are crucial public initiatives. Aligning public policy with private innovation is essential for a secure and sustainable energy future.

Financial and technological support are essential for a just transition

The disparity in decarbonisation rates between developed and developing nations highlights the challenges of achieving a just transition. In 2023, G7 countries managed a 5.31% reduction in carbon intensity, while the E7 saw an increase of 0.04%[11]. Fossil-fuel-intensive, highly industrialised, or quickly urbanising countries face significant challenges in balancing emissions reductions with economic growth and climate adaptation.

The Paris Agreement enshrines 'the principle of equity and common but differentiated responsibilities and respective capabilities, in the light of different national circumstances'[12]. Developed countries must lead in reducing emissions and provide financial and technological support to help developing nations transition away from fossil fuels. COP29 will be crucial in finalising the New Collective Quantified Goal (NCQG) on Finance, setting financial targets for developed countries to aid developing nations in their climate action. Ambitious financial commitments are essential for empowering these nations to enhance their climate strategies.

The window for action is closing. Immediate and sustained efforts are crucial to turn the incremental progress made to date into exponential change and ensure a sustainable and resilient future for all.
It's time to act.

5 IEA (2024), Massive expansion of renewable power opens door to achieve global tripling goal set at COP28
6 IRENA (2024), Renewable Energy Capacity Tracker
7 IEA (2023), World Energy Outlook 2023, IEA, Paris
8 Energy Institute (2024), Statistical Review of World Energy
9 World Economic Forum & PwC (2024), Transforming Energy Demand
10 Nationally Determined Contributions (NDCs) are commitments made by countries under the Paris Agreement to reduce greenhouse gas emissions and adapt to climate change impacts, reflecting each country's specific circumstances and capabilities.
11 G7 countries include Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. The E7 country group refers to Brazil, China, India, Indonesia, Mexico, Russia and Turkey.
12 UNFCCC (2015), Paris Agreement

2 Our 2024 analysis

Our metrics

The table below sets out key metrics used in this report. For further details, see our metrics and methodology section.

Carbon intensity

The primary purpose of the Net Zero Economy Index is to calculate national and global **carbon intensity (CO_2e / GDP)**, and track the rate of change needed by 2050 to limit average global warming to 1.5°C.

To do this, we use the IPCC carbon budget to calculate how much emissions need to be reduced in the future, and divide this by the projected increase in GDP. This allows us to see the amount emissions must reduce to maintain projected GDP growth, providing insight to the scale of efforts required to decouple emissions from economic growth.

Fuel factor

The **fuel factor (CO_2e / energy)** measures how much CO_2e is emitted per unit of energy consumed. Put simply, how green the energy consumption is.

It indicates a country's shift in energy mix towards renewable energy sources and can reflect movements away from the most highly emitting fossil fuels (such as coal). For each fossil fuel type, a differing amount of CO_2 will be released per unit of energy consumed. For each unit of energy consumed from a renewable source, emissions will be reduced to negligible, or zero, therefore reducing the fuel factor towards zero.

Energy intensity

Energy intensity (energy / GDP) measures the energy consumed per unit of GDP generated. It shows how much energy is needed to generate a given amount of GDP.

Energy intensity is impacted by factors including: energy efficiency, in the form of energy efficiency policies or technological advances enabling efficiency; energy pricing mechanisms; shifts in regional population and demographics; changes in the composition of an economic sector's output; maximising economic output per unit spend on energy usage; investment in new, more efficient technology and infrastructure; and climatic influences on energy usage.

Carbon intensity:

At 1.02%, we have stalled to the lowest reduction in over a decade

Decoupling economic growth from emissions remains a significant challenge

No country is moving quickly enough to decouple economic growth from carbon emissions[13]. In 2023, the world managed only a 1.02% reduction in carbon intensity, down from 2.5% in 2022, and the smallest decrease in carbon intensity since 2011. To limit global warming to 1.5°C by 2100, an average year-on-year global decarbonisation rate of 20.4% is required, up from 17.2% last year. This also falls short of the 2°C threshold - the lowest end of the Paris Agreement's ambition - which requires a decarbonisation rate of 6.9%.

Required decarbonisation rates are informed by the concept of a carbon budget (see Figure 1). Keeping within the critical thresholds of 1.5°C or 2°C of warming means we cannot exceed certain levels of cumulative greenhouse gas emissions, outlined by the Intergovernmental Panel on Climate Change (IPCC). However, recent research suggests that if we keep to current decarbonisation rates, we are now just five years away from exhausting the carbon budget for 1.5°C[14].

What is the carbon budget?

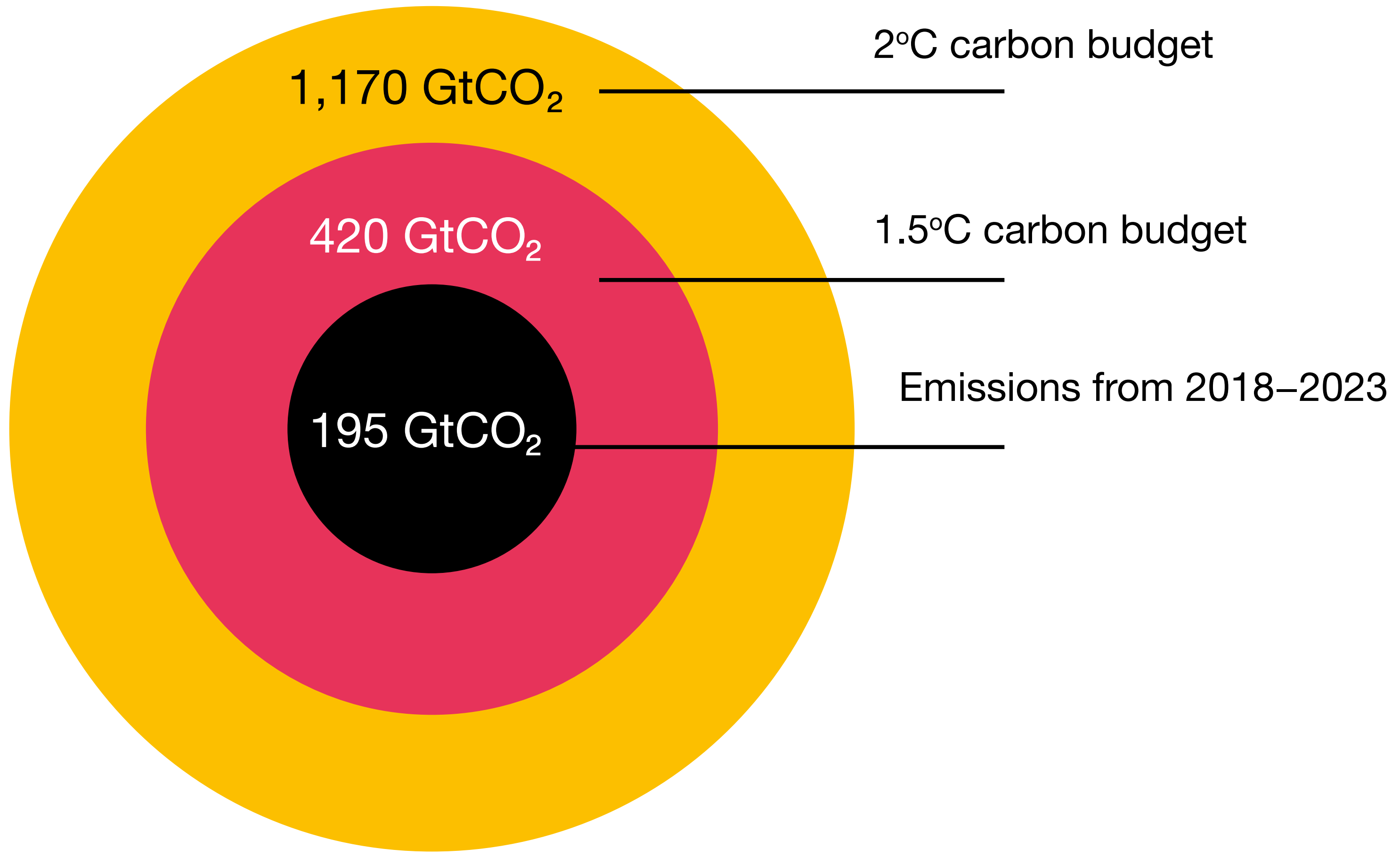
The carbon budget is the maximum cumulative greenhouse gas emissions allowed for a given chance (33%, 50% or 67%) of staying beneath a certain level of global temperature rise by 2100[15].

For a 67% chance of staying beneath 1.5°C, the Intergovernmental Panel on Climate Change (IPCC) gives a carbon budget of 420 $GtCO_2$ from 2018 up until 2100.

To stay under 2°C, the carbon budget is 1170 $GtCO_2$.

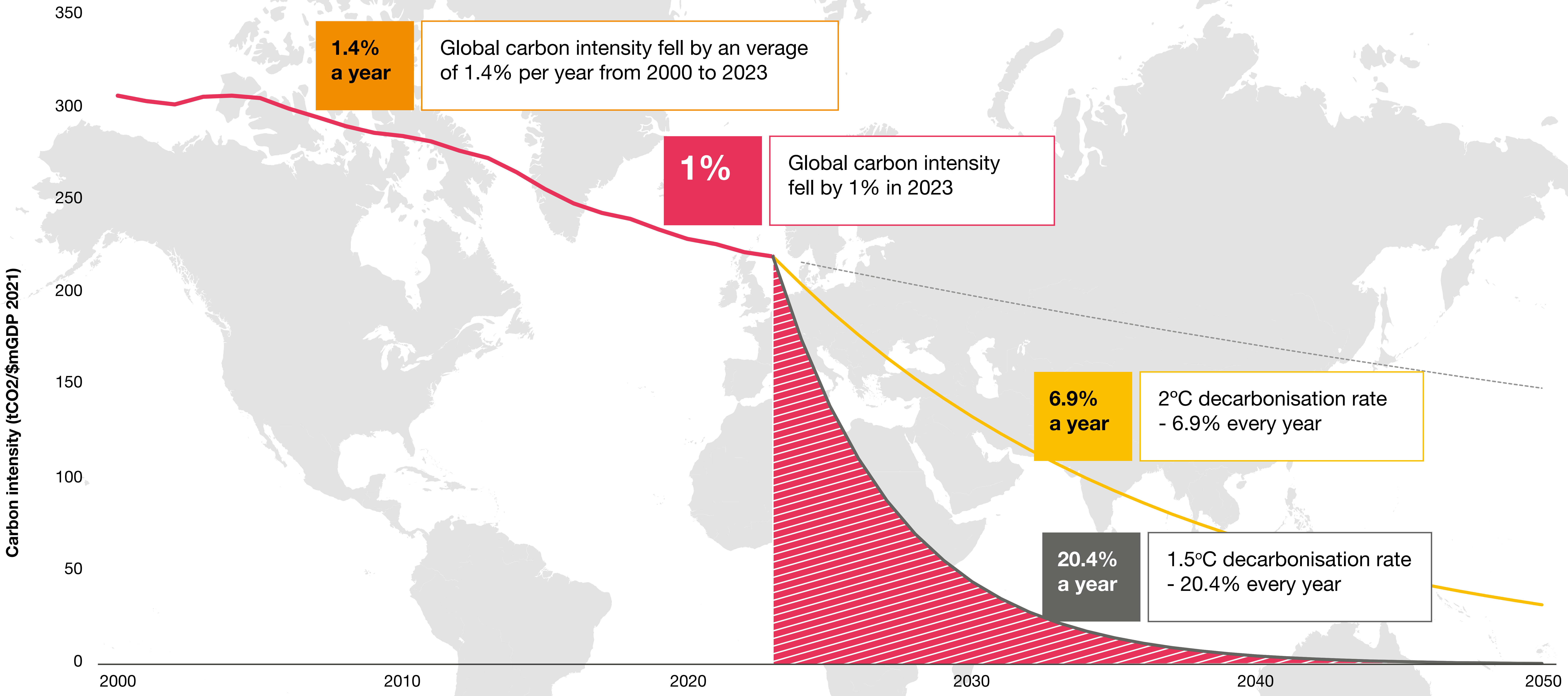
As set out in more detail in the methodology, our analysis focuses on the more ambitious 67% chance, and specifically on the decarbonisation required from fossil fuels and industry.

Figure 1: Representative sizes of 1.5°C and 2°C carbon budgets



13 United Nations Environment Programme (2023), Nations must go further than current Paris pledges or face global warming of 2.5-2.9°C.
14 Carbon Brief (2024), Tracking the unprecedented impact of humans on climate change
15 IPCC (2022), Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development

Figure 2: Net Zero Economy Index 2024: Global decarbonisation rates required for 1.5°C and 2°C levels of warming



* Global carbon budgets refer to the global estimated budget of fossil fuel emissions taken from the IPCC Special Report on Global Warming of 1.5°C. A series of assumptions underpin these carbon budgets, including the likelihood and uncertainties of staying within the temperature limits, and the use of carbon dioxide removal (CDR) technologies.

Sources – bp, World Bank, OECD, IPCC, National Government Agencies, PwC data and analytics

Notes – GDP is measured on a purchasing power parity (PPP) basis. The NDC pathway is an estimate of the decarbonisation rate needed to achieve the targets released by G20 countries. NDC's only cover the period to 2030, we extrapolate the trend in decarbonisation needed to meet the targets to 2050 for comparison.

Decarbonisation takes a backseat as geopolitics and macroeconomic factors gain focus

Wider geopolitical and macroeconomic factors have combined to create a challenging environment for sustained decarbonisation. G7 countries[16], while leading the charge, still have a long way to go to close the emissions gap. Over the last five years, these nations have managed a decarbonisation rate of just 3.45%. The period is marked by considerable volatility in the metric which reflects the broader external circumstances influencing global energy dynamics. The COVID-19 pandemic initially led to a temporary reduction in emissions but this was followed by a rebound as economies reopened. Subsequently, the geopolitical upheaval caused by the conflict between Russia and Ukraine spurred an increased reliance on fossil fuels in many regions in 2022, with 11 of the G20 countries experiencing a deterioration of their fuel factor.

2023 saw a greater push towards lower carbon energy, as carbon intensity across G7 countries fell by 5.31%, the greatest single year decrease since the aftermath of COVID-19 in 2020 (6.51%). Further advancements in the push for energy security through scaling and facilitating rapid rollout of renewable energy would allow nations to sustain and enhance their climate ambitions, ensuring long-term resilience and deeper emissions reductions[17].

Balancing emissions reduction and responding to climate risks poses a unique challenge to energy security, particularly in developing economies. As decarbonising economies look to transition from fossil fuel to renewables, they also face energy security challenges when the rain doesn't fall, the sun doesn't shine and the wind doesn't blow. In 2023, drought in many parts of Asia has significantly reduced hydropower outputs, notably in both China and India.

16 G7 countries include Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States. The E7 country group refers to Brazil, China, India, Indonesia, Mexico, Russia and Turkey.
17 IEA (2024) G7 ministers draw on wide range of IEA recommendations to strengthen energy security and accelerate clean energy transitions

Table 2: Carbon intensity comparison between G7 and E7

	G7	E7
Change in carbon intensity in 2023	5.31% decrease	0.04% increase
Change in carbon intensity in 2022	1.3% decrease	1.6% decrease
Average annual change in carbon intensity 2019-2023 (including COVID-19 period)	3.45% decrease	1.17% decrease

Despite exceptional growth in renewables like wind and solar, falling hydropower outputs led to an increased use of coal in 2023, leading to a 4.7% rise in carbon emissions in China. At the time of writing in 2024, heavy rainfall in China has replenished their dams, and power generation from coal will likely drop in 2024 when we rerun the Net Zero Economy Index[18]. Similarly in India, despite growth in wind and solar, changing weather conditions required greater dependence on fossil fuels which contributed nearly 60% of the increase in the country's electricity sector emissions. A weak monsoon season resulted in significant loss of hydropower resources and a four-fold increase in electricity demand for agriculture and cooling, compared to non-monsoon months[19]. The impacts of climate change are now also affecting our ability to decarbonise – and its impacts vary around the world, making it more difficult for developing economies to fully decouple from coal and other fossil fuels as they remain a key lever to maintain overall energy security.

Ambitious climate policy and financial support pave the way forward

The collective effort to combat climate change can be accelerated if underpinned by more ambitious and targeted policy intervention. While the G7 nations have taken steps forward, their current policies fall short of the significant reduction needed to keep global warming below 1.5°C. Currently, G7 emissions are projected to decrease by 19 - 33% by 2030 compared to 2019 levels, far below the required 58% reduction to align with the Paris Agreement targets. To close this gap, the G7 could accelerate the phase-out of coal by 2030, end fossil fuel subsidies and scale up investments in renewable energy and energy efficiency[20].

In addition to bolder policy initiatives, the complexity of the task for E7 countries requires robust international cooperation and targeted financial support. Initiatives such as the Just Energy Transition Partnerships (JET-P), which aim to support an increasing number of emerging economies - including South Africa, Indonesia, Vietnam and Senegal - to transition away from fossil fuels, suggest that international collaboration may be able to drive meaningful change.

COP29 presents a crucial opportunity to enhance countries' Nationally Determined Contributions (NDCs). NDCs are essentially national climate strategies as they are commitments made by countries under the Paris Agreement to reduce greenhouse gas emissions and adapt to climate change impacts. Countries are due to submit more ambitious NDCs by early 2025 that account for the recommendations from the first Global Stocktake at COP28 - which highlighted the critical role of finance, technology and capacity-building in enabling effective climate action globally[21]. COP29's success will in particular be judged on the outcomes of negotiations regarding the New Collective Quantified Goal (NCQG) on Finance. This mechanism, which succeeds the $100 billion target established in 2009 at the Copenhagen Climate Summit, is designed to provide financial support for developing countries to scale up their climate action, a key factor in achieving a just and equitable transition.

18 Reuters (2024), China's hydropower generation surges and coal ebbs
19 IEA (2023), CO2 emissions in 2023
20 Climate Analytics (2024), What good looks like: G7 climate policy 2024 update
21 UN (2023), Global Stocktake reports highlight urgent need for accelerated action to reach climate goals

Fuel factor and energy intensity:

The drivers of carbon intensity

The Net Zero Economy Index examines two drivers of carbon intensity:

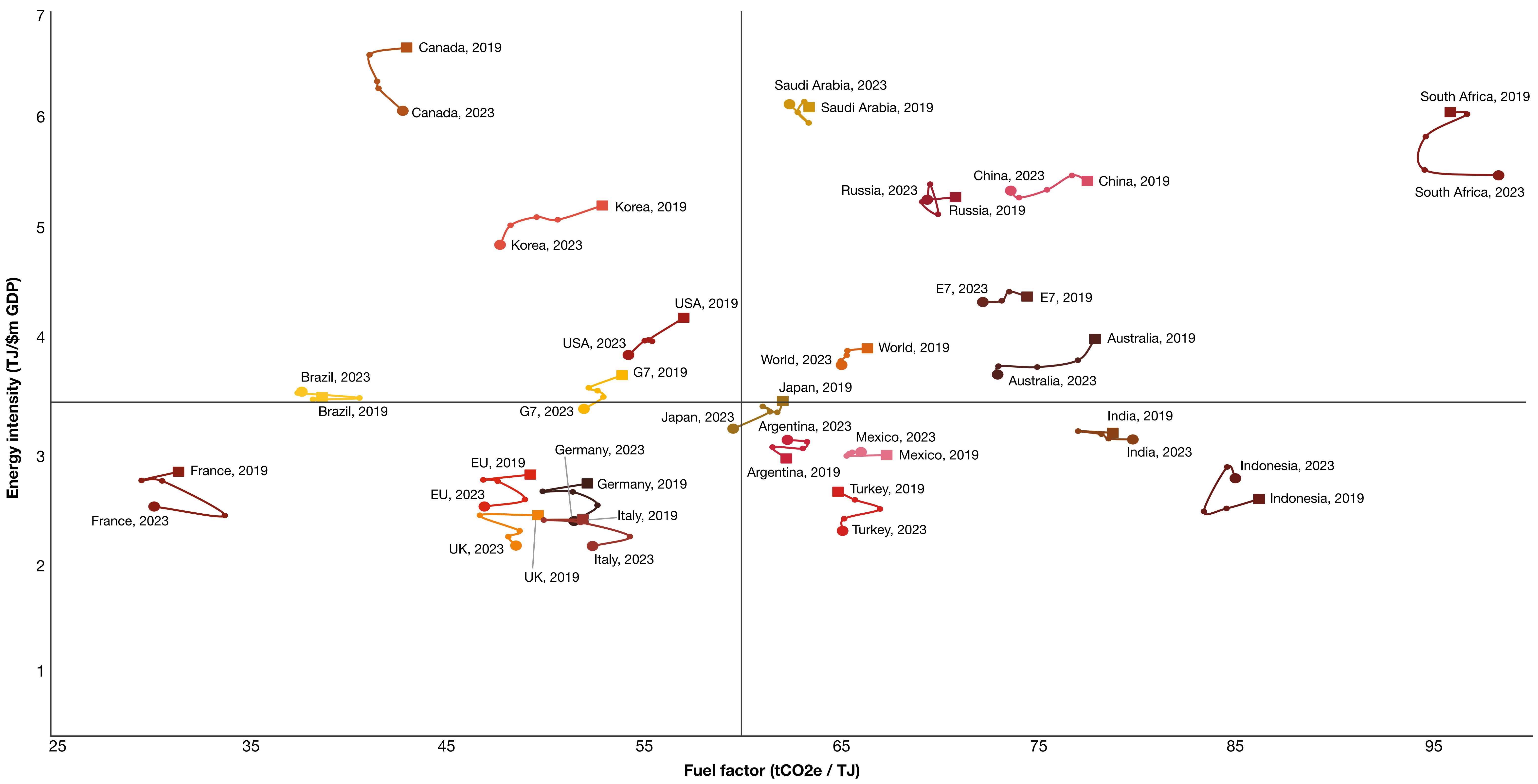
1 **The carbon content of the national energy mix (fuel factor: CO_2e / energy).**

2 **The amount of energy consumed per unit of economic output (energy intensity: energy / GDP).**

Figure 3 uses the relationship between these drivers to show the decarbonisation positions of every G20 member state by revealing the variability in fuel factor and energy intensity for the G20 countries over the five year period since the release of the carbon budget for 1.5°C in 2018[22].

The graph shows that there has been limited consistent progress on decarbonisation, with external factors such as COVID, Russia's invasion of Ukraine and other macroeconomic considerations driving countries' trajectories. Over time, countries need to shift towards the bottom-left quadrant as they reduce the share of fossil fuels within their energy mix (decreasing along the x-axis) and reduce the energy intensity of their economies (decreasing on the y-axis). Countries already in this quadrant are those with the lowest carbon intensities in our index - but even they have a long way to go in reducing their fossil fuel dependence. Countries in the top right quadrant are those with the highest carbon intensities in our index.

Figure 3: Change in fuel factor and energy intensity between 2019 and 2023 (raw values)



22 IPCC (2018), Special report: Global Warming of 1.5°C

Fuel factor

The fuel factor metric calculates the emissions released per unit of energy consumed. It reflects the carbon intensity of energy consumption by assessing the balance of fossil fuels and renewables in the energy mix.

Fossil fuels still dominate despite renewable energy surge

2023 experienced the highest uptake of renewable energy to date, surpassing the previous record set in 2022. Global renewable capacity additions achieved its fastest growth rate for the past two decades, having increased by almost 50% to nearly 510 GW in 2023[23]. Three quarters of this growth was achieved by solar PV[24], however, the majority of renewable energy is still attributed to hydroelectricity (35%)[25]. The significant growth of renewables is primarily concentrated in specific countries and regions, especially the APAC region as well as USA, Europe, Brazil and in particular China which accounted for almost 60% of new renewable energy capacity installed in 2023[26]. This uptake in renewable energy has been driven by supportive policies and significant reductions in the cost of solar and wind technologies. The IEA expects this annual trend to continue, with 2025 estimated as the year renewables surpass coal to become the largest source of electricity generation[27].

France (10.55%) and Italy (3.47%) saw the largest reduction in 2023 fuel factors among the G20, with the EU as a whole seeing a 4.18% reduction. This follows an increase in their fuel factors in 2022, partially driven by the supply shock resulting from Russia's invasion of Ukraine[28].

This demonstrates how geopolitical tensions and associated international fuel shortages can encourage a shift towards renewable energy to provide energy supply security. The EU Green Deal, the REPowerEU Plan and a series of emergency legislative measures ensured that the EU avoided energy supply disruptions, eased pressure on energy markets, prices and consumers; and pursued structural reform to energy systems[29].

Despite these trends, fossil fuels still continue to dominate the energy mix - as highlighted in Figure 4. The global fuel factor increased by 0.07% in 2023; within this the fuel factor among the G7 decreased by 1.84%, whereas the E7 countries saw an increase of 0.02%. In the G7, oil and gas now account for 37% and 30% of the energy mix respectively, while coal leads in the E7 countries (46%). Despite agreement at COP28 for countries to transition away from fossil fuels in the energy system, in a just, orderly, and equitable manner, accelerating action in this critical decade, the world continues to rely heavily on fossil fuels[30].

Figure 4: Global energy consumption (in EJ) by fuel type (%) in 2023

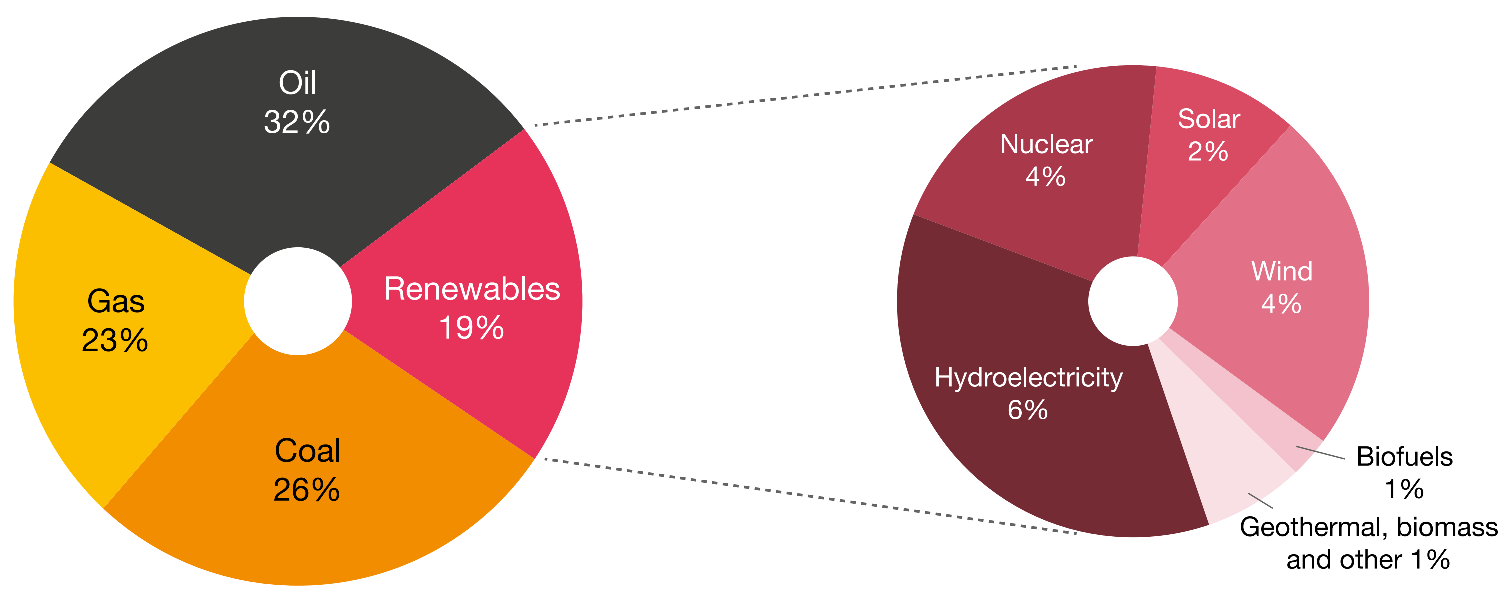


Table 3: Fuel factor comparison between G7 and E7

	G7	E7
Change in carbon intensity in 2023	1.84% decrease	0.02% increase
Change in carbon intensity in 2022	0.56% increase	1.32% decrease
Average annual change in carbon intensity 2019-2023 (including COVID-19 period)	1% decrease	0.77% decrease

Last year's fuel factor was 65.23 tCO_2e/TJ, representing a reduction of just 2.76% since 2000. Since the Net Zero Economy Index's first year of data in 2000, there has only been one year where the reduction of the global fuel factor was greater than 1% (1.53% in 2020). While there has been significant expansion in renewable energy capacity, the progress is far from keeping up with demand, with the impact on the energy mix being offset by rising energy demand and fossil fuel consumption.

23 International Energy Agency (2023), Renewables 2023
24 International Energy Agency (2023), Renewables 2023
25 PwC analysis of Energy Institute's Statistical Review of World Energy (2024), Renewable energy mix: biofuels (4%), geothermal, biomass and other (8%), hydroelectricity (35%), nuclear (21%), solar (13%), and wind (19%).
26 International Energy Agency (2023), Renewables 2023.
27 International Energy Agency (2023), Renewables 2023
28 EU council (2024), Where does EU's gas come from?
29 IRENA (2023), World Energy Transitions Outlook 2023: 1.5°C Pathway,
30 UNFCCC (2023), Outcome of the first global stocktake.

Energy intensity

The energy intensity metric provides a high level view of the energy requirements for economic output. A lower energy intensity indicates an economy is using energy more efficiently due to advances in technology, energy efficiency policies or underlying economic structures - for example, economies which are more reliant on the services sector tend to have a lower energy intensity. Higher energy intensities are indicative of inefficient systems, limited policies focused on energy efficiency or a high reliance on energy-intensive processes such as metal production, manufacturing and other similar industries.

Rapid and sustained action is needed to meet energy efficiency targets set at COP28

Last year, global energy intensity decreased by only 1.09%. This reduction is well below the levels needed to align with the IEA Net Zero by 2050 scenario, which suggests a 4.2% annual reduction in energy intensity is needed through to 2030[31]. In positive news, the G7 countries saw a significant improvement in energy intensity, with a decrease of 3.53%. This reduction reflects ongoing efforts to enhance energy efficiency through greater capital allocation, policy measures and technological advancements. E7 nations, however, saw a slight increase in energy intensity by 0.01% in 2023, underscoring the difficulties with improving energy efficiency while balancing industrialisation and urbanisation.

The trend of increased energy intensity in several key economies - such as China and Saudi Arabia - coupled with a slower rate of global improvement, highlights the need for more ambitious energy efficiency measures and greater coordination between countries to facilitate the flow of technical and financial support.

At COP28, global leaders committed to doubling the average annual rate of energy efficiency improvements from 2% to 4% by 2030, aligning with the IEA's Net Zero pathway. G20 nations have made significant steps towards improving energy efficiency, with 75% of countries having exceeded or come close to the 4% target at least once within the period of 2012 to 2021. Notably, China, France, Indonesia and the United Kingdom have sustained an average improvement of 4% or more over a continuous five-year period in recent years[32]. However, no major economy has been able to achieve such improvements over an entire decade, indicating that while short-term gains are achievable, maintaining momentum needs to be a priority.

The disparity in energy intensity among E7 and G7 countries can be attributed to several factors. Economic structures, levels of electrification and the prevalence of energy efficiency policies and technologies play significant roles. Notably, countries with strong regulatory frameworks and technological innovation, such as the European Union's Energy Efficiency Directive, show more consistent progress. Leadership and prioritisation of energy efficiency are also critical. For instance, China has demonstrated strong leadership through national and sectoral target setting, allowing for observed improvements in previous years. Additionally, the degree of de-industrialisation significantly affects the energy intensity metric. Developing economies face the challenge of balancing growth and efficiency while struggling to secure international finance.

Investment and financial support is gaining momentum. Global investment in energy efficiency has surged since 2020, with a 45%

Table 4:
Energy intensity comparison between G7 and E7

	G7	E7
Change in carbon intensity in 2023	3.53% decrease	0.01% increase
Change in carbon intensity in 2022	1.82% increase	0.31% decrease
Average annual change in carbon intensity 2019-2023 (including COVID-19 period)	2.50% decrease	0.40% decrease

increase driven by growth in sectors like electric vehicles and heat pumps. Nearly $700 billion has been invested in energy efficiency initiatives globally, with the majority concentrated in the United States, Italy, Germany, Norway and France[33]. The U.S. Inflation Reduction Act of 2022 alone earmarked $86 billion for energy efficiency measures, underlying the scale of the commitment required[34]. While these show a positive uptick in capital for energy efficiency, it is unlikely that the full extent of these investments will be reflected in the 2023 data due to time lags in policy implementation and market take up. While investment has increased, the IEA estimates overall energy efficiency investment would need to triple by 2030 to keep in line with a 1.5°C scenario[35].

31 International Energy Agency (2021), Net Zero by 2050: A Roadmap for the Global Energy Sector
32 IEA (2023), What does doubling global progress on energy efficiency entail?
33 IEA (2023), Energy Efficiency
34 IEA (2023), Energy Efficiency 2023
35 IEA (2023), World Energy Investment 2023

Energy demand and consumption

Risk of complacent consumption threatens progress

In 2023 global energy consumption rose by 2.02%, continuing the rebound in energy demand post-pandemic. With the focus of the energy transition largely on the supply side issue, efforts towards reducing energy intensity have been more limited[36]. For example, some countries (four of the G20) showing a decrease in fuel factor have simultaneously seen an increase in energy consumption.

This, coupled with the "rebound effect[37]" - a phenomenon which suggests that efficiency gains from modern technology could lead to increased energy use in other areas - has the potential to erode the benefits of renewable energy expansion.

By 2050, GDP is expected to double and the global population is forecast to reach 9.7 billion, with most of this growth anticipated in emerging economies. This will result in even greater pressures on energy supply[38,39], as countries face the challenge of meeting the energy requirements of an expanded population, along with their decarbonisation commitments. Emerging economies will need low cost, low carbon and abundant energy to grow sustainably.

36 IRENA (2023), Investment Needs of USD 35 trillion by 2030 or successful energy transition
37 University of Strathclyde Glasgow (2021), Energy Savings and the ups and downs of rebound
38 World Economic Forum & PwC (2024), Transforming Energy Demand
39 The United Nations, Population

Low cost solutions that optimise energy supply and demand systems are poised to attract foreign investment, reduce carbon intensity and boost productivity, while simultaneously improving energy security[40]. Emerging economies also have the potential to leapfrog inefficient systems that are deeply embedded in developed countries. For instance, India has launched a series of preemptive policies and projects to address anticipated increases in energy demand for cooling. The Gujarat International Finance Tech (GIFT) City is India's first district cooling system designed to eliminate the need for individual air conditioning units by using a centralised plant for residential, public and commercial buildings[41].

Modern technology, in particular AI, can unlock energy efficiency and emission reductions when integrated with efficient and greener energy systems

Technology is reshaping how we produce and consume energy; through innovations like smart grids, advanced solar and wind power, electric motors and AI-driven energy management systems. High-efficiency electric motors with International Efficiency ratings (IE3 and above[42]), which are increasingly required by regulators, have the potential to reduce energy intensity by up to 90% in an industrial process, or 29% if implemented widely across industries[43].

Artificial Intelligence (AI) is emerging as another transformative force when faced with the challenges of net zero. By using the advanced analytics capabilities of AI, better insights can be gathered across organisations and grid components to both optimise electric grid performance and inform grid planning[44]. Through machine learning, AI can also improve electricity supply and demand forecasts, minimising the reliance on battery storage and standby power and facilitating real-time balancing of electricity grids[45].

In transport, AI supports fuel-efficient routing processes by examining real-time traffic data and optimising route recommendations to minimise idle time and detours. Google has included AI features in Google Maps to suggest routes with lower emissions, such as fewer hills, less traffic, and constant speed with the same or similar ETA for drivers. The company estimated that between October 2021 and September 2023, more than 2.4 million metric tons of CO_2e emissions have been avoided[46].

However, it is also important to note that AI uses significantly more energy than other forms of computing. The IEA estimates that the electricity consumed by data centres, AI and the cryptocurrency sector is set to double by 2026 to more than 1,000 TWh, roughly equivalent to the electricity consumption of Japan. While AI is undoubtedly poised to be pivotal in mitigating climate change through improving the efficiencies of systems worldwide, it will also require a more efficient and greener energy system to run on to prevent its own energy use from exacerbating the problem.

40 LSE, Grantham Research Institute on climate change and the environment (2022), Financing a big investment push in emerging markets and developing countries for sustainable, resilient and inclusive recovery and growth
41 IEA (2023), Energy Efficiency
42 Electric motors are classified into efficiency standards, ranging from IE1 (lowest efficiency) to IE4 (highest efficiency)
43 World Economic Forum & PwC (2024), Transforming Energy Demand
44 Google & BCG (2023), Accelerating Climate Action with AI
45 Google & BCG (2023), Accelerating Climate Action with AI
46 Google (2023), New ways we're helping reduce transportation and energy emissions

Climate adaptation can lead to higher energy consumption

There is a risk that our efforts to adapt to the changing climate will escalate energy demand, due to energy-intensive solutions. For example, desalination processes that remove salt and other minerals from seawater to produce freshwater require significant energy. This can further exacerbate emissions if connected to a fossil fuel-powered grid[47]. As global temperatures rise, electricity consumption for space cooling in residential, commercial and industrial spaces has also increased. While space cooling is an adaptation strategy for rising temperatures, it already accounts for almost 20% of the electricity used in buildings, and is the fastest-growing source of energy demand in buildings globally, with projections indicating a threefold increase by 2050[48]. Countries should therefore also focus on reducing the energy intensity of solutions, through policies which stipulate the procurement of the most efficient products or innovations in adaptive responses, to avoid maladaptation and increased exposure to climate risks in the long term.

Demand transformation: A significant opportunity for business

In a recent collaboration with the World Economic Forum, we found that tackling global energy demand could result in a 31% reduction in energy intensity and $2 trillion in annual savings if actions are implemented before 2030[49]. However, we can only realise this potential through a combined effort, with interventions from both the public and private sector. Companies should not only adopt energy efficiency measures, but also engage in broader collaborations that span industries, supply chains, and the public sector, to raise awareness and promote the need for policies that incentivise energy intensity reduction.

The International Business Council (IBC), a group that together represents 3% of global energy use, finds that collaborative initiatives with key stakeholders are essential for sustainably and efficiently managing energy demand. This needs to be both inside an organisation, and out. Collaboration across functions - from finance to technology - to gather data and insights can unlock much needed change. Outwardly looking, organisations can participate in industrial clusters to adopt circular business models or advocate for energy companies to lower their energy and emission intensities. Enhanced value chain collaboration and initiatives such as demand substitution, demand consolidation and flexible demand response have the potential to significantly reduce energy intensity in the long run. Companies can also work with smaller enterprises in their supply chains to reduce energy consumption and emissions, as they often lack the resources and technologies needed to develop and execute sustainability initiatives.

Strong signals such as these, can inform policymakers on critical areas for support - leading to reduced barriers to participation, more competitive markets, greater incentives and tax reliefs. These initiatives have the potential to significantly reduce operating costs and enhance productivity: creating a win-win situation for people and the planet.

More progress needed in the decisive decade

“ If we don't take bold action, we risk exceeding 1.5°C of warming and the greater the overshoot, the more severe the impact. Despite these warnings, the gap between goals and actions is growing. Without global cooperation, the possibility of keeping warming within safe limits will disappear. To achieve the necessary changes, we must expand the use of renewable energy, manage energy demand better, and increase financial and technical support for a fair transition."

Emma Cox
Partner, Global Climate Leader, PwC UK

47 CO,balance (2022), Adapting to Water Stress Through Desalination
48 UNEP (2023), Air conditioners fuel the climate crisis. Can nature help?
49 World Economic Forum & PwC (2024), Transforming Energy Demand

3 Our metrics and methodology

The Net Zero Economy Index tracks the decarbonisation of energy-related CO_2 emissions worldwide

The analysis is underpinned by the Energy Institute's Statistical Review of World Energy, which reflects energy consumption per fuel type per country and CO_2e emissions based on the consumption of oil, gas and coal. Emissions are calculated by using consumption data and applying Default CO_2 Emission Factors for Combustion from the list of IPCC emission factors. Non-combustion activities, such as the use of oil products and natural gas in the petrochemicals industry, or oil used in the production of bitumen for road construction, are not included in the analysis. Estimates of the proportion of non-combusted fossil fuels are subtracted from the total consumption of fossil fuels before applying the relevant emission factors.

The analysis does not consider emissions from other sectors (e.g. Agriculture, Forestry and Other Land Use). Data for methane emissions associated with fossil fuel production, transportation and distribution from the IEA are included in the Energy Institute's Statistical Review of World Energy and in our analysis. Carbon emissions are included from natural gas flaring and from industrial processes (which refer only to non-energy CO_2 emissions from cement production). No carbon sequestration is accounted for in the Net Zero Economy Index analysis. As a result, this data cannot be compared directly with national emissions inventories.

We use the IPCC global estimated carbon budget data on fossil fuel emissions taken from the IPCC Special Report on Global Warming of 1.5°C (SR15), to estimate the energy-related CO_2 emissions associated with limiting warming to 1.5°C and 2°C by 2100. We have elected to not use the updated global carbon budget from the IPCC's Sixth Assessment Report (AR6), as it is similar to the total budget attained from SR15 and AR6 does not provide interim emissions targets for specific years between the present-day and 2100, which are used in the model underpinning this analysis.

For GDP data, our analysis draws on the World Bank historical data. The GDP PPP dataset from the World Bank was updated in 2024 from constant 2017 international $ to constant 2021 international $, which results in slight variations in our calculated real GDP figures compared to figures stated in previous Net Zero Economy Indexes. For long-term GDP projections, our analysis draws on two different banks of OECD forecast data. The first dataset assesses 2022 and 2023, accounting for the impacts of current world events such as COVID-19, which was updated in June 2022. The second dataset consists of 2024-2060 forecast data, updated in October 2021. World GDP projections for 2061-2100 have been updated based on PwC analysis (decreasing by 0.1% from last year's forecast growth rate).

The countries our analysis focuses on are individual G20 economies, as well as focusing on world totals. The G20 is portioned into three blocks: G7 economies (US, Japan, Germany, UK, France, Italy, Canada), E7 economies which covers the BRICs (Brazil, Russia, India and China), and Indonesia, Mexico and Turkey and other G20 (Australia, Korea, EU, South Africa, Saudi Arabia, Argentina).

The primary purpose of our model is to calculate national and global carbon intensity (CO_2e / GDP), and the rate of carbon intensity change needed by 2050 to limit warming to 1.5°C above pre-industrial levels. We use the IPCC carbon budget to calculate the required quantity of emissions reductions in the future, and then divide this by the projected increase in global GDP, providing us with a required rate of carbon intensity reduction to limit warming to 1.5°C. This allows us to see the amount emissions must reduce to maintain projected GDP growth, providing insight to the scale of efforts required to decouple emissions from economic growth.

Carbon intensity is the product of two factors that are explored separately, allowing for greater insights in our analysis.

Carbon intensity = **Fuel factor** × **Energy intensity**

$$\frac{CO_2}{GDP} = \frac{CO_2}{Energy} \times \frac{Energy}{GDP}$$

The **fuel factor** (CO_2e / energy) measures how much CO_2e is emitted per unit of energy consumed. It serves as a performance indicator for a country's shift in energy mix towards renewable energy sources, and can reflect movements away from the most highly emitting fossil fuels (such as coal). For a given unit of energy consumed, different fossil fuels will release differing amounts of CO_2 emissions. For a given unit of energy consumed from a renewable source, emissions will be reduced to negligible, or zero, thus reducing the fuel factor toward zero.

Energy intensity (energy / GDP) measures the amount of energy consumed per unit of GDP generated. It illustrates how much energy is required to generate a given amount of GDP. Energy intensity serves as a performance indicator for a country for factors including: energy efficiency, in the form of energy efficiency policies or technological advances enabling efficiency; energy pricing mechanisms; shifts in regional population and demographics; changes in the composition of an economic sector's output; maximising economic output per unit spend on energy usage; investment in new, more efficient technology and infrastructure; and climatic influences on energy usage.

To calculate the required percentage reduction in global fuel factor to maintain the world's course for a 1.5°C world, we use the IEA's values for percentage reduction of energy intensity presented in their Net Zero Emissions by 2050 Scenario (NZE) in the IEA's World Energy Outlook 2021. The scenario projects a 4.2% reduction in energy intensity year-on-year to 2030, followed by an annual reduction rate of 2.7% from 2030 to 2050. We divide the raw values of carbon intensity from our analysis by the raw values of global energy intensity we calculate using the IEA's NZE to calculate the necessary reduction in fuel factor.

Using the energy consumption data provided in the Energy Institute's Statistical Review of World Energy we have compared the proportions of different energy sources in the G20's fuel mix with that of the average fuel mix of the world, and observed how these have changed over time as the proportions of fossil fuels and renewables consumed has changed. Changes to the fuel mix affect the fuel factor, as a country increases the proportion of renewable energy in its fuel mix its fuel factor will decrease.

G20 performance across our key metrics

This table presents the data underpinning our analysis and findings

Country	Carbon intensity (tCO_2e/ $m GDP) 2023	Change in carbon intensity 2022-2023	Annual average change in carbon intensity 2000-2023	Fuel factor (tCO_2e / TJ) 2023	Change in fuel factor 2022-2023	Annual average change in fuel factor 2000-2023	Energy intensity (TJ / $m GDP) 2023	Change in energy intensity 2022-2023	Annual average change in energy intensity 2000-2023	Change in energy related emissions 2022-2023	Real GDP growth (PPP) 2022-2023
World	219	-1.02%	-1.43%	65.23	0.07%	-0.12%	3.36	-1.09%	-1.31%	2.10%	3.15%
G7	154	-5.31%	-2.37%	52.16	-1.84%	-0.51%	2.96	-3.53%	-1.86%	-3.75%	1.65%
E7	284	0.04%	-1.42%	72.39	0.02%	-0.27%	3.92	0.01%	-1.15%	5.28%	5.24%
China	364	0.71%	-2.63%	73.82	-0.55%	-0.77%	4.93	1.27%	-1.87%	5.95%	5.20%
US	187	-5.07%	-2.67%	54.41	-1.49%	-0.64%	3.45	-3.64%	-2.05%	-2.66%	2.54%
EU	98	-7.03%	-2.71%	47.11	-4.18%	-0.78%	2.08	-2.98%	-1.94%	-6.61%	0.45%
India	215	1.27%	-1.30%	80.01	1.57%	0.07%	2.68	-0.29%	-1.37%	8.95%	7.58%
Japan	166	-8.10%	-1.57%	59.73	-3.03%	0.18%	2.78	-5.23%	-1.75%	-6.33%	1.92%
Germany	101	-8.94%	-2.75%	51.65	-2.25%	-0.72%	1.95	-6.85%	-2.04%	-9.22%	-0.30%
Russia	337	-3.01%	-2.15%	69.58	-0.20%	-0.07%	4.85	-2.82%	-2.08%	0.48%	3.60%
Indonesia	199	-3.76%	-0.72%	85.21	0.50%	0.20%	2.33	-4.23%	-0.92%	1.10%	5.05%
Brazil	118	0.93%	-0.48%	37.84	0.59%	-0.44%	3.11	0.34%	-0.03%	3.86%	2.91%
France	63	-7.00%	-2.87%	30.35	-10.55%	-0.65%	2.08	3.97%	-2.24%	-6.35%	0.70%
UK	84	-3.69%	-3.80%	48.71	0.81%	-1.00%	1.73	-4.47%	-2.83%	-3.59%	0.10%
Italy	91	-8.07%	-1.94%	52.59	-3.47%	-0.59%	1.72	-4.77%	-1.36%	-7.22%	0.92%
Mexico	170	0.76%	-0.41%	66.22	0.69%	-0.36%	2.57	0.07%	-0.05%	4.01%	3.23%
Turkey	121	-5.73%	-1.71%	65.28	-0.12%	-0.45%	1.86	-5.62%	-1.26%	-1.47%	4.52%
Korea	213	-4.89%	-2.39%	47.90	-1.10%	-0.84%	4.44	-3.83%	-1.57%	-3.60%	1.36%
Canada	243	-0.61%	-1.71%	42.97	2.97%	-0.14%	5.65	-3.47%	-1.57%	0.45%	1.07%
Saudi Arabia	357	1.46%	0.05%	62.59	-1.52%	-0.55%	5.71	3.03%	0.60%	0.70%	-0.75%
Australia	239	-2.31%	-2.17%	73.15	-0.05%	-0.54%	3.27	-2.26%	-1.64%	0.64%	3.02%
Argentina	167	-0.94%	-0.22%	62.48	-1.56%	-0.14%	2.68	0.62%	-0.09%	-2.48%	-1.55%
South Africa	499	2.94%	-1.41%	98.56	3.96%	0.17%	5.07	-0.98%	-1.57%	3.56%	0.60%

Note that countries have been ordered in terms of percentage of global GDP, PPP (current international $).
Numbers in the table are based on energy-related CO^2 emissions only and do not include other greenhouse gases including non-CO^2 energy-related emissions. At the time of publication 2020 national inventory GHG emission data is available: https://di.unfccc.int/time_series.
No carbon sequestration is accounted for in the Net Zero Economy Index analysis. As a result, this data cannot be compared directly with national emissions inventories.
The changes in carbon intensity figures reflect the movement of both country level GDP and energy-related CO^2 emissions.
G7: Canada, France, Germany, Italy, Japan, the United Kingdom and the United States. E7: China, India, Brazil, Mexico, Russia, Indonesia and Turkey.

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