Baillie Gifford™

The Climate Scenarios Project

Risk factors

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Caroline Cook

Head of Climate Change

As Head of Climate Change, Caroline works across the firm to integrate our understanding of energy, climate and environmental issues into our investment practice. As these interlinked transitions compound, her aim is to improve outcomes for all our clients. She joined Baillie Gifford in January 2020, having spent the prior four years leading cross-sector energy transition research within Deutsche Bank's equity research business. Prior to that she focused on the oil and gas sector, both as an independent consultant and as co-head of Deutsche Bank's number one rated Global and European oils team. Caroline graduated from Cambridge with an MA in Modern History in 1989.

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Climate Analyst

Oliver is a climate and environment analyst in Baillie Gifford's Climate Team, where he has worked to develop the firm's understanding of the technological, social and physical elements of the climate transition. He has also been leading efforts to integrate nature-related risks and opportunities into the firm's work. He holds an BA in Natural Sciences from the University of Cambridge and an MSc in Environmental Politics from the University of Edinburgh.

Contents

Introduction

Baillie Gifford regards the climate and energy transitions as material investment factors. For some companies, the changes underway and yet to form will offer new growth opportunities. For others, there will be risks of straight obsolescence, unmanageable physical shifts and less clear-cut failures arising from a lack of anticipation and preparation.

Complicating our ability to assess these factors for companies and portfolios is the sheer complexity and pace of the transitions. The years ahead will be marked by dislocations, exponentials, tipping points and reinforcing feedbacks. These apply equally in the spheres of physical climate, technology, politics and social responses.

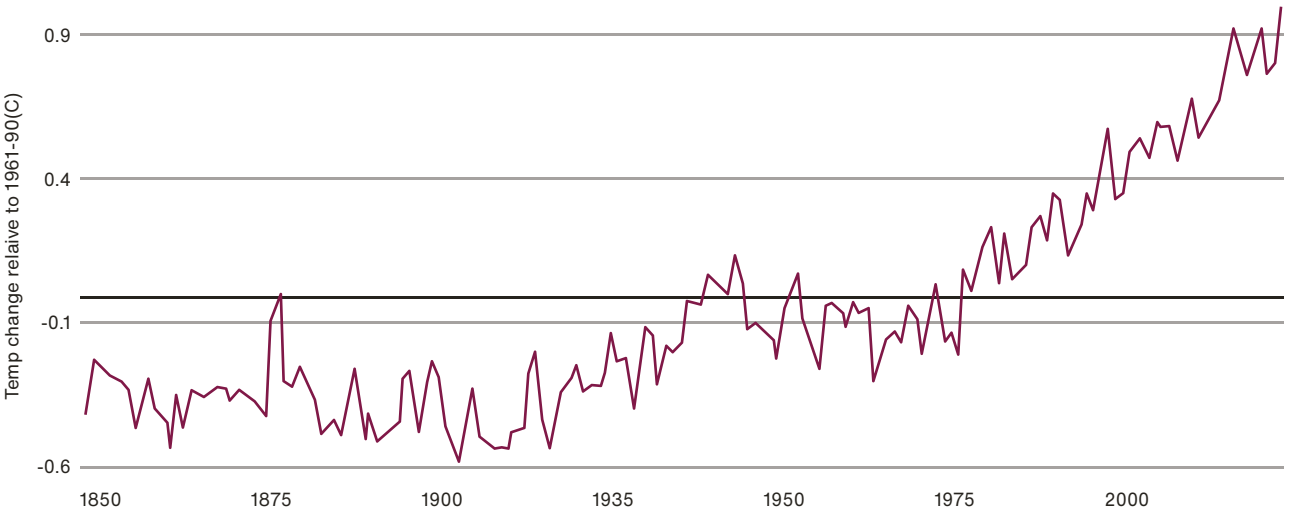
The Climate Scenarios Project aims to help our investors tackle these questions. Pushing us to reject the temptations of simply avoiding the issue or finding false comfort in narrow quantitative models.

The project has two aims. First, to challenge ourselves to explore varied but plausible futures. These are not forecasts, and the aim is not to average the conclusions: our future is not the middle of a bell curve. We are looking for new ideas and questions to ask, seeking the indicators that might tell us which pathway is emerging, and exploring the risk tolerances we (and our clients) need through the transitions. Second, to use this better appreciation of scenarios to develop our assessment of companies. This is not about reporting and disclosure but innovation and adaptability: people and strategies that can thrive even as the landscape (in the broadest sense) evolves around them.

We now have the resources to embark on the first task – scenarios – and, in so doing, bring new momentum to the second. Working alongside two academic partners, Deep Transitions and Independent Economics, we have created system-wide narratives across **three representative climate futures**. The following paper introduces these narratives and their implications for our investment activities.

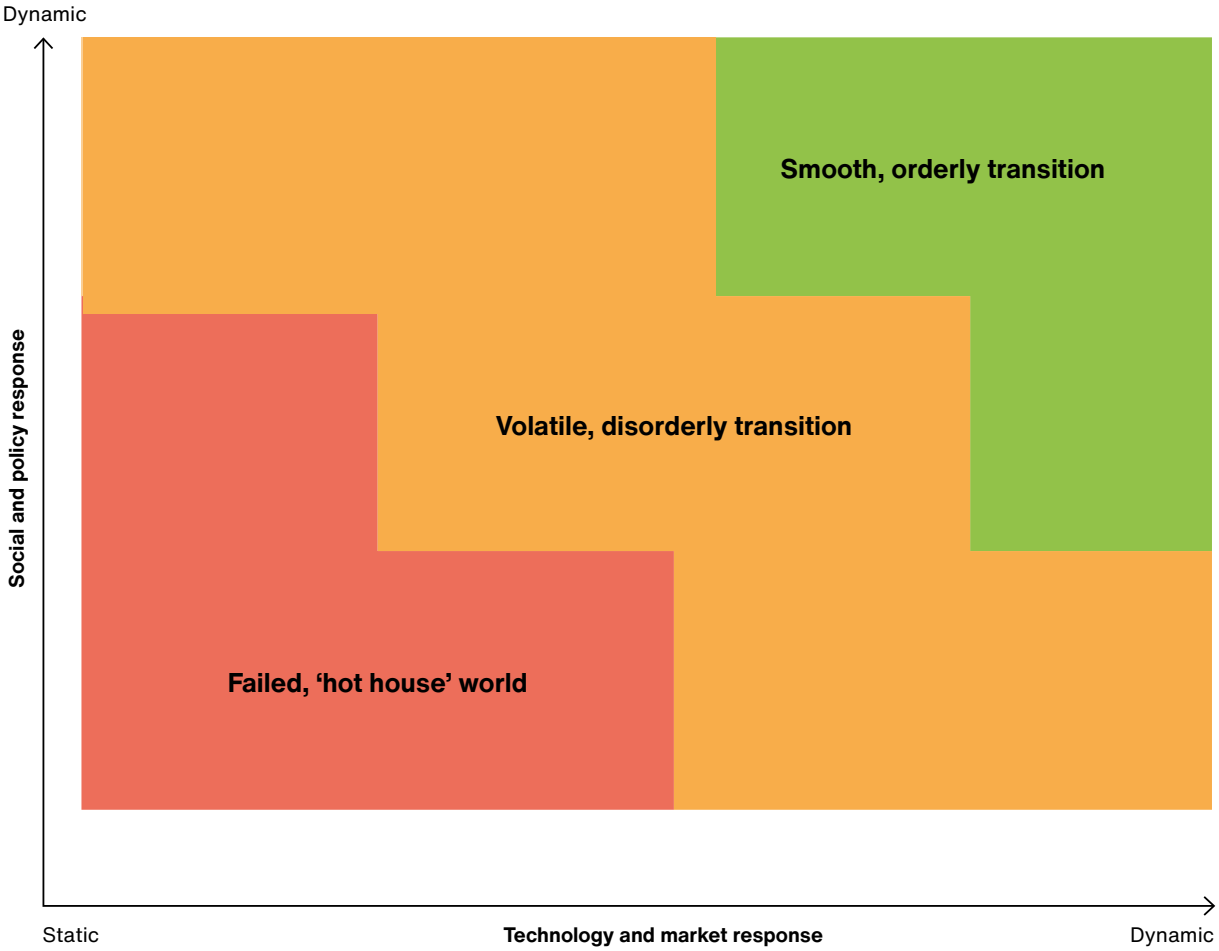
The following paper was the initial output shared with our investment teams to help them think through the implications for our investment activities. We share the unedited version with you as a conversation starter and an insight into how we incorporate climate considerations into our investment approach.

The global climate is changing and will continue to change
Global average temperature change relative to 1961-90 (C)



Source: Met Office Hadley Centre (2023) – processed by Our World in Data

Three climate transition scenarios



The more dynamic social and technological responses to climate change are, the greater the likelihood of a smooth and orderly transition

How to use the scenarios

This document

This paper provides headline summaries of the three scenarios created for the initial phase of this project. After a brief introduction to some of the overarching trends in the physical climate, it presents a series of more detailed 'scripts' that you can read as possible (and hopefully internally consistent) ways these alternative futures could unfold. Your views of these pathways may differ, just as you may have different opinions about the essential features of the world as it is today. But hopefully, a read-through will inform and provoke. It is also designed to form the basis of future work: whether by sector or regional deep dives, new questions for companies or new stock ideas, or entirely new scenarios.

Other resources

These scenario scripts reflect our integration of the work commissioned from our academic partners, with many different resources and perspectives on the transitions. For further reading, we'd particularly recommend:

- our **scenarios webinar** with Deep Transitions and Independent Economics,
- the Deep Transitions **paper** for the theory behind transitions,
- the Independent Economics **one-pager** on the strengths of qualitative scenarios.

Question Framework

An example framework for investment teams to consider after working through the scenarios:

Scenario baselining

01. Assumptions

    What scenario do we believe we are currently in? What variations in or deviations from this scenario might we expect in the future?

Company/thematic level

02. Sensitivities

    At the company, regional or industry level (whichever is most appropriate to the fund) are any of the variables in the investment case dependent upon specific scenarios? Do different scenarios introduce any significant risks or opportunities to the investment case?

Portfolio level

03. Alignment

    Aggregating the perspectives from Q2, to what extent is the portfolio 'hedged' for different transition outcomes, or is it mutually reinforcing in a particular direction? How does this align with assumptions made in Q1?

04. Opportunities

    Do the assumptions made in Q1 point to any new sectors, regions or technologies to focus future ideas generation?

Watch for

05. Indicators

    What might change that would make us change our verdict for Q1 or heighten risks/ opportunities for Q2 and Q3? Are there any indicators or trends we should track to confirm, challenge and monitor our assumptions over time?

Scenario summaries

Hot House World

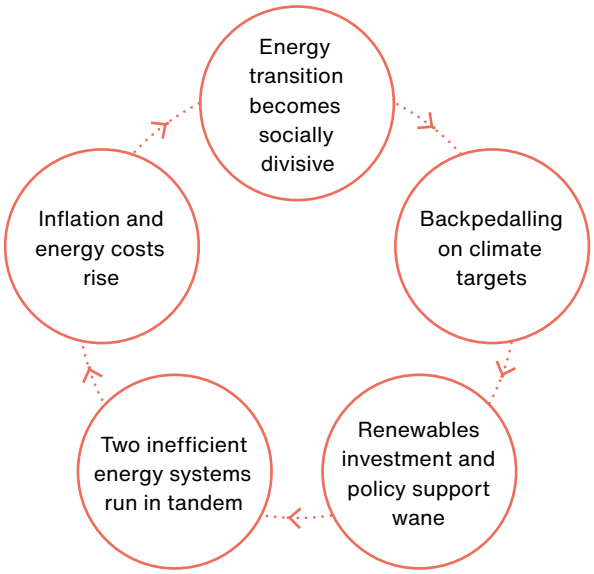
The Hot House World scenario depicts society's failure to contain the global average temperature rise to below 2C, with global warming exceeding 2.5C by 2100. The consequences of such changes are increasingly extreme:

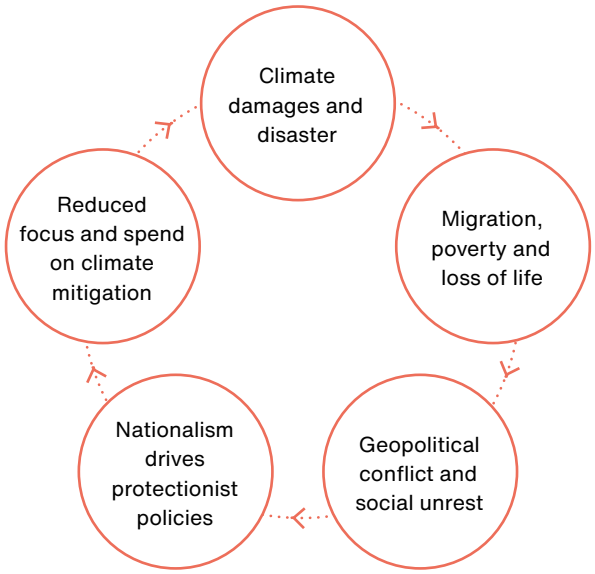
- severe physical damages lead to massive losses in lives and livelihoods;
- productivity and economic growth fall as supply-driven inflation rises;
- large swathes of land become uninhabitable and unsuitable for food production (inarable);
- migration towards more favourable climates drives conflict;
- and geopolitical divisions rise.

For many societies, the global climate impacts become simply unmanageable. This scenario aims to explore how humanity could become immobilised and unable to change course when facing such dire consequences.

Geopolitical hostility and conflict drive protectionist agendas, with globalisation going into reverse. The energy transition slows as nations vie for strategic positioning, seeking instead to invest in defence, support incumbent industries and protect national borders. A lack of predictable long-term investment results in poor technological progress, meaning cost and scale-based tipping points for vital technologies are not reached. The reliance on fossil fuels and high-carbon industrial processes is sustained. A Hot House World scenario produces a highly unequal world. Without the technological advancements or financial resilience to adapt globally, the wealthy and powerful thrive by exploiting the natural resources of the vulnerable.

Though climate risks accumulate gradually to begin with and do not trigger decisive climate action, impacts quickly unravel in a non-linear manner as extreme weather events become far more frequent and disruptive. The combination of physical damages, inefficient energy systems and geopolitical conflict results in a highly volatile and inflationary environment, leaving countries in a poor state to regain control. Importantly, though industry and politics are distracted by what is occurring, they are not passive. As climate impacts unfold, significant investment and innovation arise around adaptation – especially in agriculture, healthcare, disaster management and ultimately new energies.



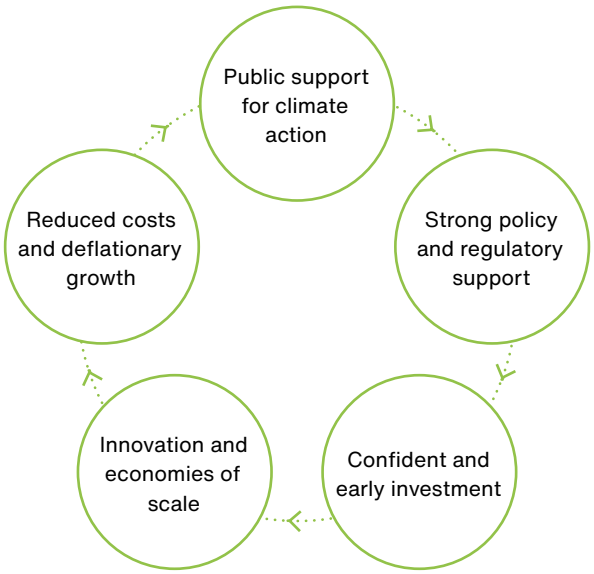


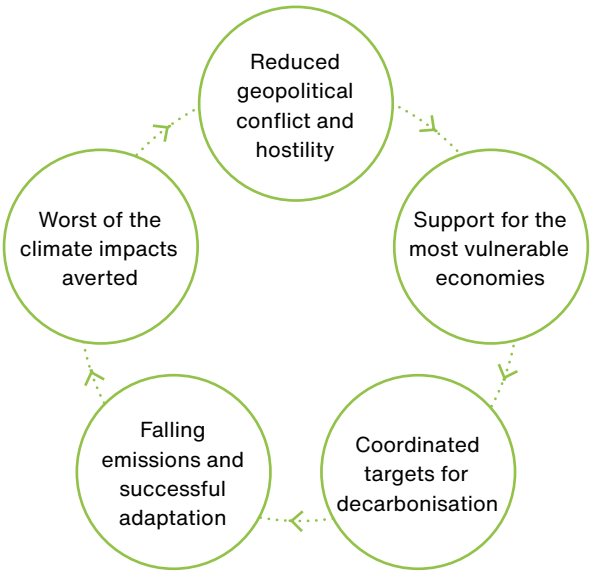
Orderly Transition

An Orderly Transition – containing the global average temperature rise to 1.5C by 2100 – assumes that climate policies are introduced early and become steadily more stringent. The scenario relies upon significant front-loading of policy and investment efforts to minimise climate damages in the long run. As a result, both physical and transition risks are relatively subdued. Fossil fuels are replaced rapidly by renewables and electrification. The strong policy support for the energy transition eliminates the inefficiencies of supporting old high-carbon systems. Energy efficiency and circularity are prioritised early and assisted by progress in AI, as well as pro-transition behavioural change. By 2050, both the geographies and industries of growth have been transformed – dominated by regions with relatively stable climates, favourable demographics and abundant access to renewables and transition materials.

Even at this level of warming, the physical realities society faces change: extreme weather events are more common and areas of the world are now unliveable and inarable. Adaptation requires significant investment but is largely successful: agricultural innovation and effective urbanisation counteract the worst of climate impacts. With land emerging as a yet more important asset class, natural carbon sinks are protected and restored, which in turn channels capital towards rural and emerging economies.

The orderly scenario is only feasible if powerful political and institutional feedback loops work together, driving rapid cost reductions, learning effects, economies of scale and technological tipping points. With the sheer scale, complexity, and interdependency of the needed changes, strong and undistracted policy support and global cooperation underpin this transition. Thus, geopolitical conditions must avoid conflict and favour free trade, investment flows and productive competition to benefit from the combinatorial effects of moving in tandem. Politics itself manages the transition's trade-offs, with public funds (expanded by carbon tax revenues) providing a pool of capital to buy 'losers' consent'.





Disorderly Transition

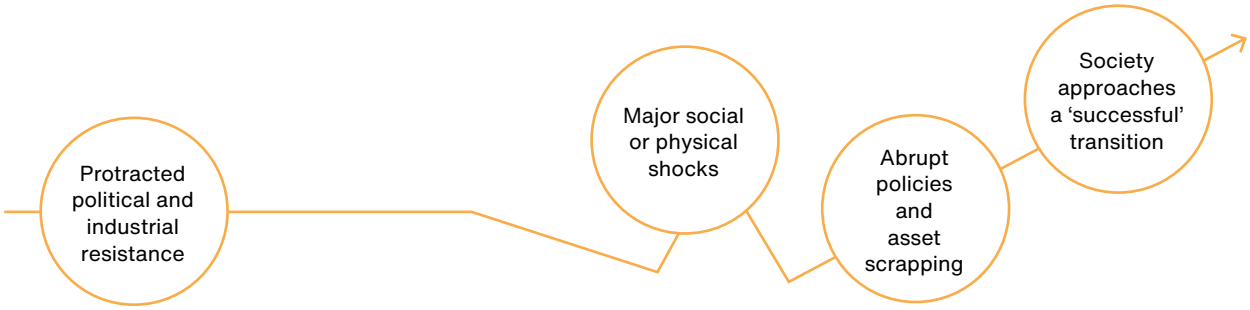
In the Disorderly Transition, the world initially follows an emissions trajectory on course for a Hot House World, driven by incumbent lobbies and political-economy resistance to the transition.

Contradictory policies and capital deployment provide incremental opportunities for new green sectors but still allow profits to accumulate for high-carbon incumbents. As time passes, the dire implications of the trajectory become more apparent, and pressure grows for a more ambitious response.

When the system is finally 'shocked' towards a successful transition, it is rushed and requires radical change and strong innovation to meet climate targets. The transition, therefore, relies on the rapid scaling of still relatively immature technologies and the scrapping of functional high-carbon assets. The transition is expensive because the world is not optimised for either energy system. Actual or shadow carbon prices are higher and more disruptive than they would have been if introduced earlier and more gradually. Inflation, too, is higher and more volatile as opportunities for an early energy transition are missed.

The transition is also less equitable and supportive of developing markets than the Orderly Transition. Within countries, fast scrapping of infrastructure and transitioning of sectors result in higher levels of unemployment. Between countries, the powerful seek to stabilise their economies by exploiting the materials, renewable capacity and natural resources of weaker nations.

Whereas the feasible pathways to an orderly and hot house transition are few[1], disorderly transitions come in many forms and are not preordained. Rather, they are the product of periodic forces, or shocks, that themselves are a reaction to the evolving situation. There is a near-infinite set of idiosyncratic disorderly scenarios. The one posed here is simply illustrative. That said, forces strong enough to materially shock the trajectory to success are probably limited in number[2]. Many future pathways might look initially like a Disorderly Transition, but efforts could ultimately prove 'too little too late' to prevent a Hot House World. In our scenario, as 1.5C and perhaps even well below 2C targets are initially overshot, a significant amount of remedial carbon capture (both technological and nature-based) is required to correct the overshoot and avoid unmanageable climate impacts.



[1] Partly because they rely on the extreme ends of political and industrial action, but also because the Orderly Transition requires relatively minimal physical impacts to materialise, whereas the Hot House World – in which the climate becomes quickly unmanageable – requires near-worst case physical impacts.

[2] Our Multi Asset Income Team is currently working with Independent Economics to explore the range of possible forces.

Scenarios comparison table

		Orderly	Disorderly	Hot House World
Climate	Short term	Impacts remain significant but localised and contained	Impacts remain significant but localised and contained	Extreme weather events begin to degrade societal resilience
	Mid term	Adaptation and resilience outpace the physical changes	Extreme events more frequent than expected – drives political change	Events compound, lives and livelihoods lost at significant rate
	Long term	Despite major risks, heightened resilience contains losses	Despite major risks, heightened resilience contains losses	Adaptation is weak and failing, the climate becomes unmanageable
Geopolitics	Short term	Tensions ease, global trade and markets reopen	Tensions remain high, countries protect important industries	Geopolitics is fractured and distracted
	Mid term	Coordination and free trade support transition	Physical shocks force the political powers to coordinate	Protectionism and conflicts increase across geopolitical blocs
	Long term	Developing geographies leapfrog into a transitioned system	Large divergence between lagging and leading economies	Each for their own, major migrations drive conflict
Society	Short term	Transition accepted as an opportunity, not cost	Society divided, intergenerational friction builds	Public support weak with the transition seen as too costly
	Mid term	Rapid shifts in behaviour reinforce political momentum	Public support accelerated in the face of physical impacts	Unemployment, physical stress and migration drives conflict
	Long term	Structural readjustment and retraining in labour markets	The abrupt policy changes cause inequality and loss	Inequality (between and within countries) rises significantly
Policy	Short term	Policies are well-signalled, predictable and proactive	Policies conflicting due to political resistance and incumbent lobbying	Public support weak with the transition seen as too costly
	Mid term	Policy becomes less important as clean technology spreads	Fast and abrupt policy interventions driven by physical shocks	Unemployment, physical stress and migration drives conflict
	Long term	Focus shifts towards adaptation plans and agriculture	Policies are high-cost and required for longer periods	Innovation is forced but costly in agriculture, energy and adaptation

		Orderly	Disorderly	Hot House World
Energy	Short term	Renewable price reductions are rapid, fossil fuels peak	Energy futures hedged, insufficient grid investment	Technological innovation and efficiency improvements slow
	Mid term	Tipping points for most green technologies reached	Rushed deployments now higher cost, stranding of assets	Markets and technological innovation fragmented
	Long term	Abundant renewables support CCUS[1] and green cement/ steel	Costly usage of negative emission technologies to avoid worst impacts	Energy shortages, reliance on long-shot technologies (CCUS / geoengineering)
Agriculture	Short term	Government subsidies prioritise diet changes and diversification	Slow transitioning of the food system, resilience drops	Failures in food system, falling yields[3] and isolated food insecurity
	Mid term	Major shift in diets and reductions in food waste decrease impacts	Failures in food system and falling yields drive innovation	Large swathes of land become inarable, driving conflict and unrest
	Long term	Breakthroughs in precision agriculture and genetic engineering	Diets shift, investment in adaptive techniques, resilience builds	Innovations (eg insect/vertical farming), but severe stress remains
Finance	Short term	Multi-lateral financial reform supports investment flows	Contradictory investment and significant greenwashing	Contradictory investment and weak emerging market flows
	Mid term	Inflation drops with decreasing energy costs	Market shocks driven by abrupt policy change	Crisis-driven investment in adaptation
	Long term	Land as an asset class supports development	Flows to late-stage innovation, minimal regard for ESG[2]	Exploitative investment flows into land and natural resources

[1] Carbon capture, usage and storage
[2] Environmental, social and governance factors
[3] A standard measurement of the amount of agricultural production harvested per unit of land area

Physical change: setting the scene

The near term: changes locked in

With the consequences of climate change already a physical reality[3], significant levels of damage are present in even the most optimistic scenarios. For the next 10-15 years, most climate change is locked in, meaning the direction and pace of the energy transition will have little impact on resulting physical impacts. On the other hand, the climate change that transpires could have a major impact on the transition path society chooses or is able to take. Should the physical impacts be worse than expected, the world might not have the economic resilience to respond at speed. Alternatively, if the impacts are highly conspicuous but well contained, they could galvanise faster action.

Types of direct impacts:

- Extreme weather events (acute)
  - Heatwaves, wildfires, rainfall and flooding, cyclones, storm surges, drought
- Slow-onset weather events (chronic)
  - Temperature rise, sea level rise, changing precipitation, disease spread, loss of natural capital

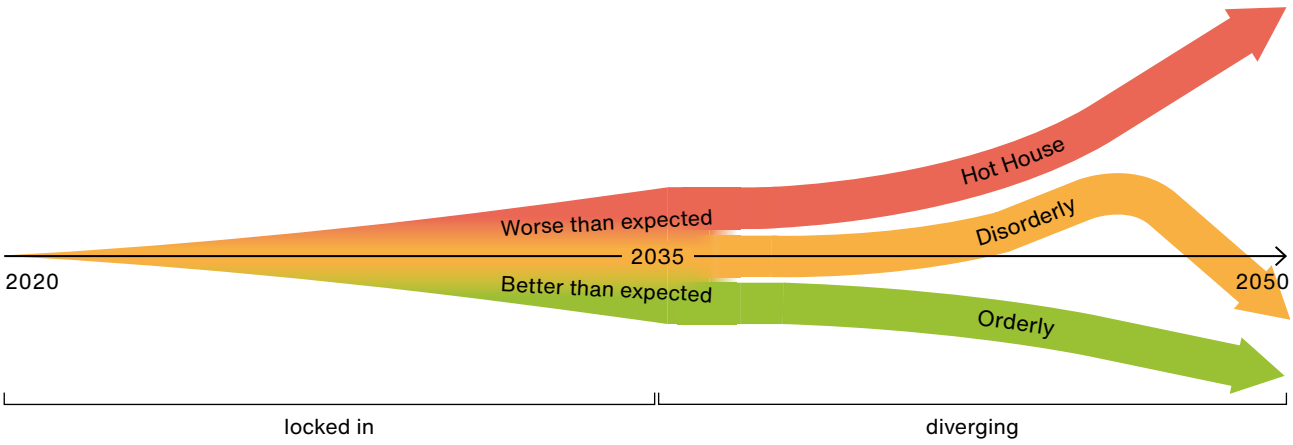
Though the physical risks may be locked in, they are by no means certain. Below are examples of potential worst and base cases for what is locked in – though these are not explicit predictions – followed by diverging outcomes for the different transition scenarios.

Indicative worst case (locked in): 2020-2035

The current El Niño is severe and permanently disrupts the global climate (perhaps triggering tipping points such as glacial melt and permafrost thawing, which lock in further damages). As we exit the current El Niño cycle, the frequency and severity of extreme events continue to increase. The events become frequent enough that impacts begin to compound, leaving little time for societies to respond, thus reducing overall resilience.

Indicative best case (locked in): 2020-2035

As we exit the current El Niño cycle, the major sea surface temperatures anomalies subside. It becomes clear that the frequency of extreme events observed in the early 2020s were – to some extent – cyclical. Though catastrophic weather events continue to occur across the globe, they are isolated and temporally separated, allowing time for society to build resilience. The global economy remains largely unimpacted.



Source: Baillie Gifford & Co

[3] 2023 saw: historic heatwaves across the world, with >50C in the US and China; the highest recorded sea surface temperature; Canada's worst wildfire; devastating floods in India, the Philippines, Korea, Malaysia, Brazil and China; and Europe's second-warmest winter. It was officially the hottest year on record. The top 10 hottest years have all occurred since 2010.

The longer term: diverging futures

In the mid-2030s, the results of our efforts to reduce emissions will start to emerge. Should society transition quickly and effectively, physical impacts could be largely contained (as shown in the following 'successful' Orderly and Disorderly scenarios). However, if society fails to decarbonise – from a lack of effort or ability – then impacts could quickly become unmanageable for many societies.

Despite innovations, in a failed scenario, humanity seems constantly to be 'playing catch up' – adaptation and disaster management are insufficient to contain the damages. Nations simply lack the financial fitness to respond proportionally. More tipping points are reached that accelerate and lock in further damages. By 2050, the global temperature surpasses 2C and continues accelerating towards 3C by the end of the century.

In a successful scenario, though the impacts are still significant, society is better able to respond: adaptative capacity is higher, and vulnerability levels are lower (thanks to heightened financial resilience, technological advancements and quicker global development). By 2050, global temperatures are contained to near 1.5C, or at least well below 2C.

Physical realities: current expectations

Though the half a degree between 1.5C and 2C may seem insignificant, it has a drastic impact on the climate and environment. The differences below are estimated by the Intergovernmental Panel on Climate Change (IPCC). If temperatures rise further (into the Hot House World scenario), the expected losses become greater and outcomes are complicated by the huge uncertainties regarding geophysical tipping points (Amazonian/boreal forest collapse, ice sheets, atmospheric circulations etc).

	Population exposed to extreme heat	Species loss (insects)	Species loss (plants)	Decline in marine fisheries	Arctic permafrost thawing	Loss of coral reefs	Loss in tropical maize	Land area that will change biome
1.5C	14%	6%	8%	1.5Mt	4.8 million km^2	70-90%	3%	7%
2C	37%	18%	16%	3Mt	6.6 million km^2	99%	7%	13%

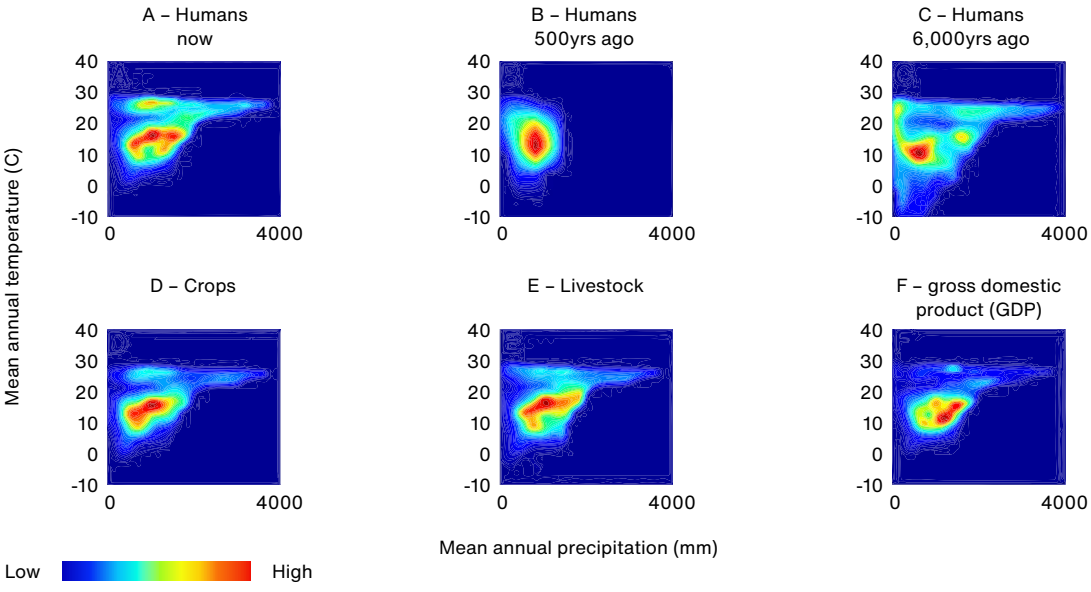
Source: IPCC, 2018. **Special Report: Global warming of 1.5°C**

The human climate niche

For over 6,000 years, humans have settled in a remarkably limited range of Earth's climates, with populations generally grouping in regions with an average annual temperature of around 13C. As with all living organisms, humans have evolved and adapted to a set range of environmental conditions, representing our 'climate niche'. Though technological adaptation allows for a slight broadening of this niche (with energy being the key adaptive ingredient), the fundamental challenges of extreme heat, cold, aridity and precipitation limit our geographic expansion.

Climate change is unique in that unlike other crises – such as the Covid-19 pandemic – it is not just a shock to the systems that support society. It is the fundamental loss and degradation of the systems we depend upon. Even if temperature rise is contained to 1.5C, by 2100, roughly two billion people could live outside the 'human climate niche'. At 2.7C, however, this figure could rise to around four billion[4]. Further adaptations – in technology and lifestyle – should partly manage these changes. However, the migration of whole societies and shifts in industrial and agricultural geographies are likely unavoidable. (NB this gets to one of the key distinctions of the climate debate: the planet will clearly carry on, the question is its carrying capacity for stable human societies at their current scale, absent further dramatic technological innovation: see James Lovelock's **Novacene).**

Distribution of human societies

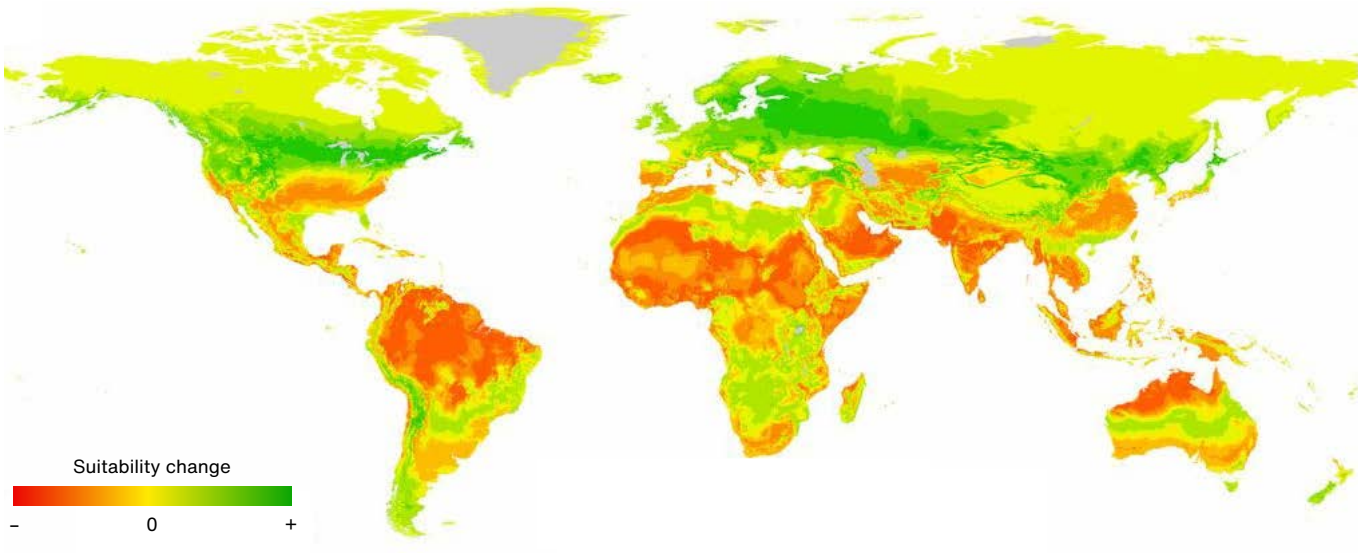


The above graphs show the geographic distribution of humans – detailing our densities according to both annual temperatures and annual precipitation levels. Graphs A-F are current distributions, whereas B-C are historical. Human societies group around a remarkably small niche and have done for thousands of years. The only noticeable change is an increase in humans surviving in a high temperature zone (the upper yellow blip in graph A) – perhaps explained by the expanding populations in the Middle East, aided by advancements in temperature management.

Source: Xu, C., Kohler, T. A., Lenton, T. M., Svenning, J., & Scheffer, M. (2020). **Future of the human climate niche**. Published by Proceedings of the National Academy of Sciences (PNAS).

[4] See article by Prof Tim Lenton, whom we are collaborating with on physical risks and scenarios: **Quantifying the human cost of global warming | Nature Sustainability**

Plausible gains and losses for the human climate niche (2070, heading towards +3C)



Source: Xu, C., Kohler, T. A., Lenton, T. M., Svenning, J., & Scheffer, M. (2020). **Future of the human climate niche**. Published by PNAS.

The map above shows changes in climatic suitability under a business-as-usual scenario in 2070. Further adding to migration pressures, the most severe changes are due to occur in regions experiencing rapidly expanding populations, especially Nigeria, Ethiopia, Pakistan and the Democratic Republic of the Congo. The UN International Organisation for Migration has cited estimates of as many as one billion environmental migrants in the next 30 years.

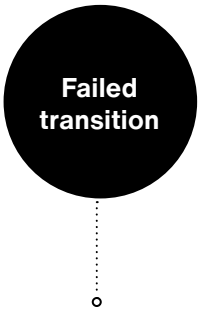
In the most smooth and successful scenarios, not only is migration curtailed by quick and effective decarbonisation, but that which remains is seen as a solution, not a problem. With much of the global north-facing 'top-heavy' demography crises, migration is embraced as an opportunity to rebuild workforces and transition industries. Cities across the world may begin to compete for migrants. This would, however, require a complete reversal of current societal and political discourse on migration.

In failing transition scenarios, migration is likely to exacerbate social and geopolitical tensions. Current anti-immigrant sentiments intensify, driving more nationalistic and protectionist policies that prioritise self-interest over global climate action.

Lived experiences: imagining futures

The work provided to us by the Deep Transitions team, a multi-disciplinary collaboration between the universities of Sussex and Utrecht, includes various 'narrative vignettes' to help move beyond the data and imagine what different futures might look like on the ground. Two vignettes that highlight the physical realities of a successful and failed transition appear on the following page. For further immersion, you can engage with the Deep Transitions project **here**.

Narrative vignettes from the Deep Transitions team

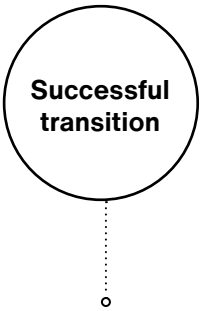


Pearl River Delta, China, 2050

Xia stood on the banks of the Pearl River Delta, gazing across the murky, polluted water. She remembered how, year after year, towering skyscrapers and sprawling factories had risen until the pressure of serving a soaring population drove the fisheries to collapse. The once-bustling factories and ports were now eerily quiet, the streets empty of the usual throngs of people.

This year's floods were the worst ever after having been extenuated by years of mining in the area. Xia had lost count of the times she had waded through floodwater to get to work. The diseases that came with the floods were a constant threat – Xia had already lost several family members.

She remembered how the government had responded to droughts and crop failures inland that had caused food shortages and riots in the Delta. The war for Taiwan had only brought more suffering, with millions of people displaced and badly needed funding being diverted away from climate mitigation and adaptation. Xia now worked long hours in a small factory, making goods for export to the countries that still traded with China after the international sanctions were imposed.



La Pampa, Argentina, 2050

After generations of his family farming in La Pampa, Franco watches rising temperatures destroy his cattle ranch. Many of his old friends and neighbours in the community have left after years of irregular precipitation and crop failures. Those failures affect local ranchers' feed supply and land productivity, exacerbating food insecurity.

Franco himself thinks of abandoning the family business. But solutions are emerging – researchers and engineers are introducing heat- and drought-resistant plants in La Pampa. Searching for alternatives to cattle ranching, Franco reads a news article asking, "Is Insect Protein the Future?". He shocks his family by signing a franchisee contract with an industrial insect-farming company. As insect farming is heavily [artificial intelligence] AI-controlled, his work now consists of overseeing automated systems. He rescues his family from poverty but feels alienated from his local community.

Franco is no longer in need of large tracts of pastureland. Energia Verde, a Brazilian-Argentinian renewable energy company, has offered to buy Franco's surplus land. A local council gathers, where Franco and his remaining neighbours discuss the proposal. They decide the net benefits outweigh the minor impacts and approve the sale to Energia Verde. It is one more step towards Argentina becoming the green energy supplier for Latin America.

The narratives

The scenarios presented below are not forecasts. Nor are they necessarily probable outcomes. They are constructed to explore the likely characteristics of the transition: to understand the driving factors involved, be they technological, social, political or physical.

The Orderly Transition and Hot House World are deliberately chosen as edge cases. They present futures in which nearly all systems either support or work against each other. The Disorderly Transition, on the other hand, represents the messy middle of plausible pathways, of which there is an infinite set of variations.

If – like most of the investment teams who have engaged so far – you conclude that smooth success and utter failure are improbable, then the most likely futures resemble some form of Disorderly Transition. In this case, the Orderly and Hot House World scenarios should act as illustrative guides to test company and portfolio sensitivities against more accelerated and more decelerated variations of the Disorderly. Disorderly transitions will combine some elements of success and some of failure, so the Orderly and Hot House World scenarios can be used to construct, stress and manipulate different disorderly futures.

Where are we now: 2024

A prelude to a discussion of plausible futures is some agreement (or agreement to disagree) on the key features of our current state. By way of example, we've set out our view below.

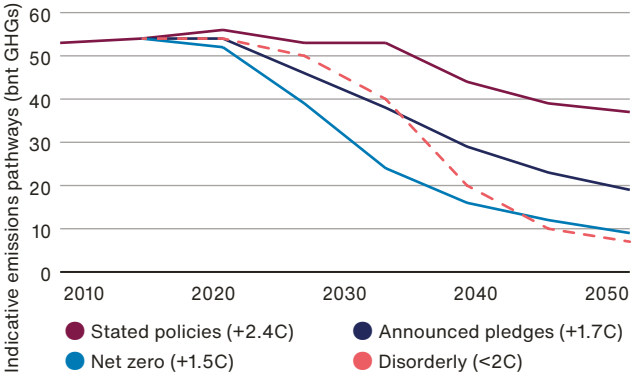
What is yours? How might that set up a different perspective on the unfolding narrative arcs?

- **Geopolitics:** multipolar and fragile; increasing numbers of 'local' **conflicts**; US and China tensions; Russia; and Middle East maverick actors.
- **Domestic politics:** declining **democracies**; tendency to nationalism and populism resulting in short-termism; a massive election year: Taiwan, India, Indonesia, Pakistan, US, UK, South Africa, Algeria, Tunisia and more; maybe the Paris Olympics will bring a dose of optimism for all?
- **Economics:** interest rates are beginning to turn, and there is room for higher investment spending if governments act **strategically**; re-shoring maintains some inflationary pressure.
- **Finance:** volatility and interest rates are truncating investment horizons; insufficient policy clarity to support strong flows to transition or adaptation funding.
- **Climate:** acute weather events are compounding, with El Niño uncertainties to come in 2024; pressure is building in food and migration.
- **Fossil fuels:** fragile normality with Ukraine at stalemate but Gaza is still unfolding; global coal use is at a new high; long-term oil and gas resources are geographically concentrated, but The Organization of the Petroleum Exporting Countries (OPEC) is cutting to balance the oil market; and an excess of new gas export projects.
- **Green technologies:** despite recent supply chain pressures, there are proven exponentials for cost reduction and deployment in solar, wind, battery, electric vehicles (EV), heat pumps; significant intellectual property (IP) building in industrial solutions (steel, cement, heavy transport); further opportunities in AI-enabled energy and grid efficiencies are ready with the right incentives. But food is lagging.
- **Energy transition:** running late as numerous delay tactics in politics, economics, technology and permitting are well played by the incumbents; Conference of the Parties (COP) process still alive and edging forward; two major coal economies (China and India) are well positioned in domestic renewables; unresolved perspectives on the importance of justice/equality (the 'S' in ESG) versus climate and economic growth; social confusion over the urgency and trade-offs inherent in the transition.

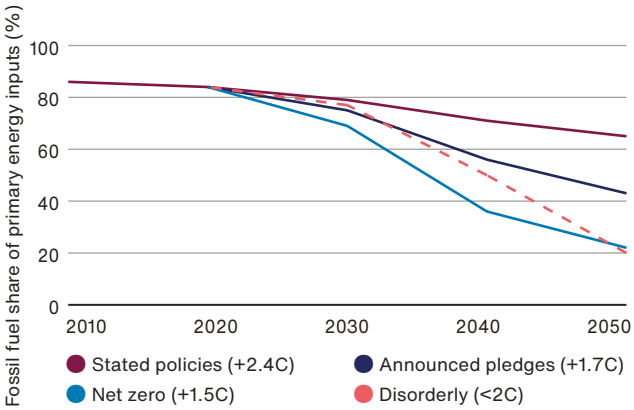
Biggest known unknown: the speed and societal impact of generative AI developments.

Getting your eye in: some basic characteristics of plausible energy system pathways

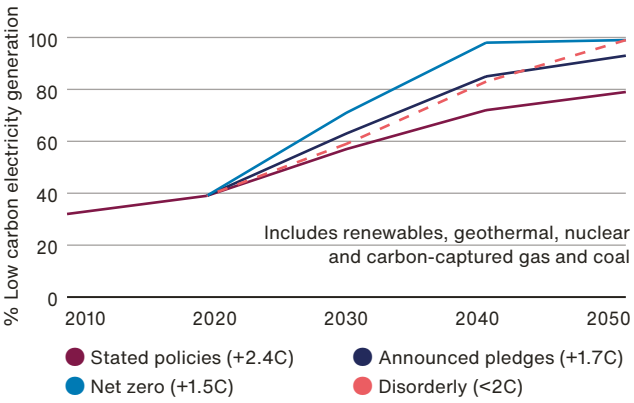
Emission pathways/temperature outcomes



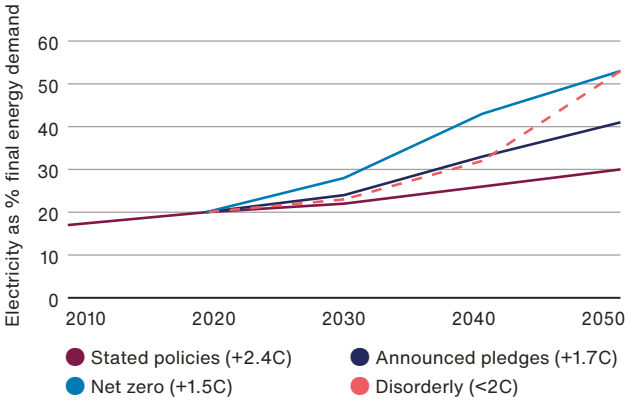
Fossil fuel share of primary energy inputs



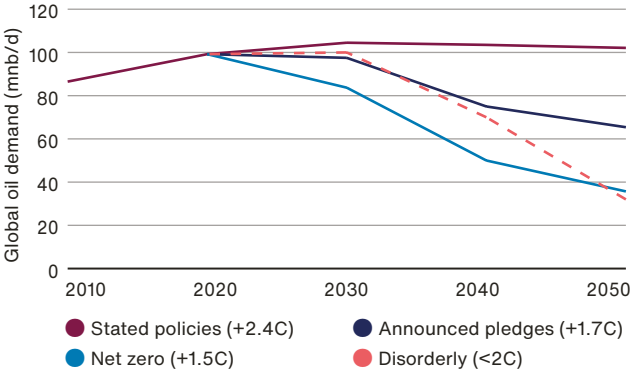
Low carbon electricity generation



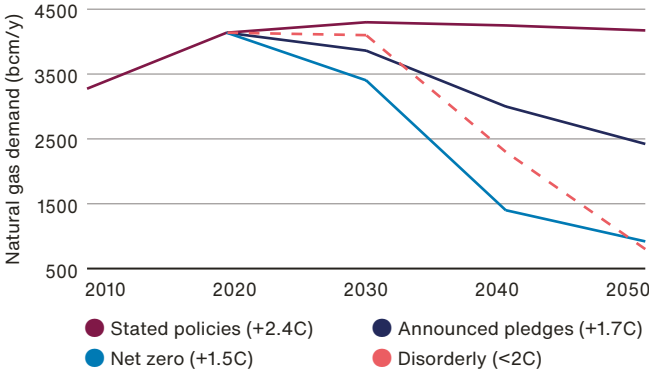
Electrification of final energy demand



Prospective global oil demand

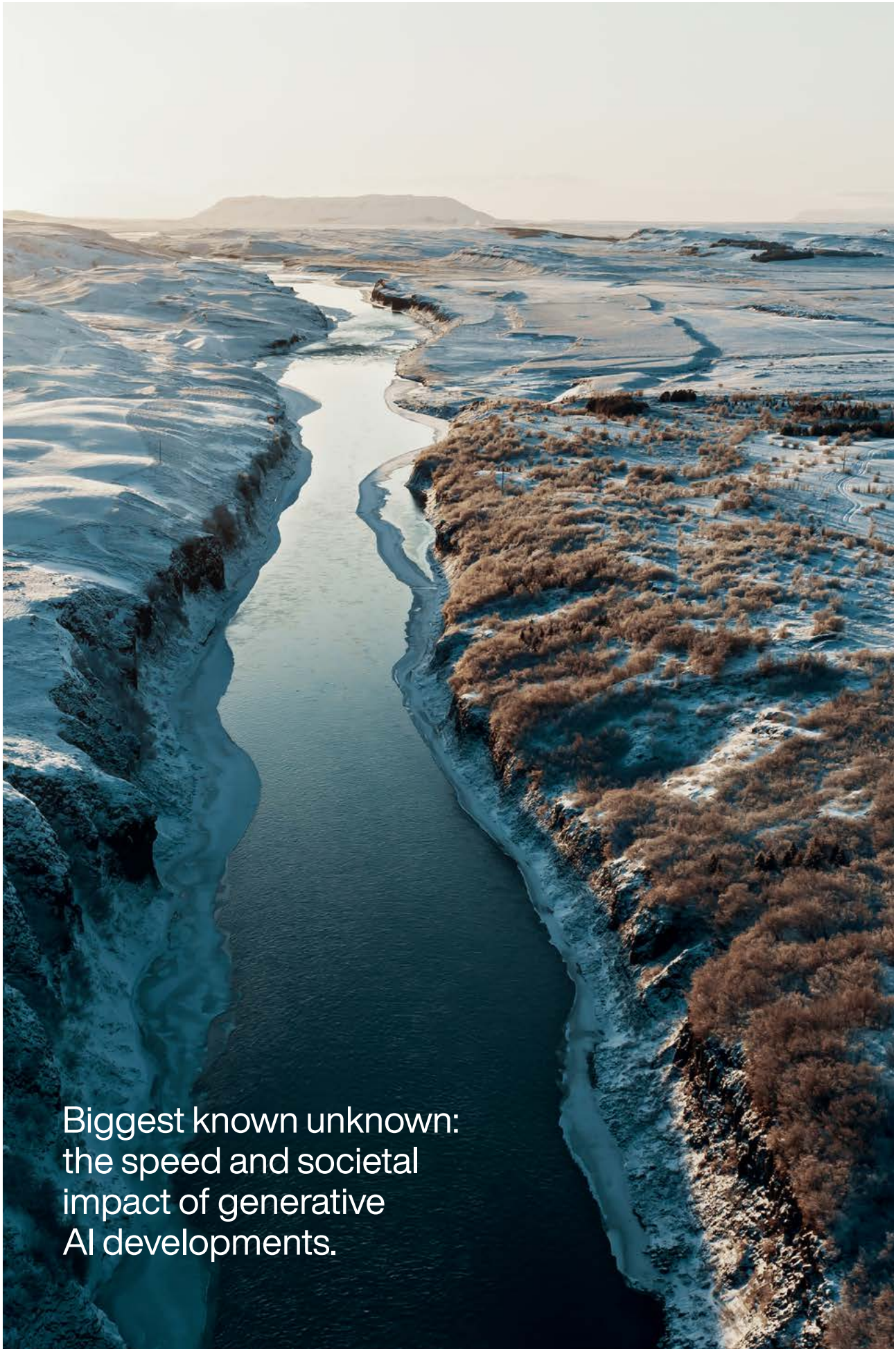


Prospective global gas demand



Source: International Energy Agency (IEA) World Energy Outlook, Network for Greening the Financial System (NGFS) Scenarios and UN Gap Report. Adapted by Baillie Gifford & Co.

'Stated policies' reflects the IEA's interpretation of current policies and likely implementation; 'Announced pledges' reflects all climate-related commitments and aspirations announced by governments; 'Net Zero 2050' is the IEA's normative pathway consistent with restricting temperature rise to 1.5C to 2100; 'Disorderly' (greater than 2C) is our interpolation of a rapid shock shift that succeeds in keeping temperatures well-below 2C.


Biggest known unknown:
the speed and societal
impact of generative
AI developments.

Hot House World Narrative

The Hot House World scenario is summarised **here**.

Near-term horizon
(three to five years, to 2026-28)

The Ukraine war and an associated spike in inflation resets the global energy map. The hopes that 2019 would have marked a peak in fossil fuel use are confounded as coal jumps 10 per cent above its 20-teens plateau of 8 million tonnes per annum (mtpa), oil adds a steady 1-2 per cent per year above 2019's record 100 million barrels per day (mbd), and there's a rush of new gas projects to fill the gap left by Russia's aggression.

- The attractions of domestic coal over imported gas are reinforced - most importantly for coal-titan China (>4.6mtpa), but also India (>1mtpa) and Indonesia (0.8mtpa produced).
- European countries particularly dependent on Russia for their energy needs rush to diversify their gas supplies, put more coal power on standby and invest in new liquefied natural gas (LNG) terminals and pipelines. Japan, Korea and Taiwan follow suit.
- Domestic policies cite national security concerns to extend fossil fuel infrastructure and promote investment in whatever new production and exploration can be eked out of mature provinces.

As global but fragmented conflict persists, the world moves away from the relatively well-integrated, cooperative spirit of past decades, and climate action moves down the agenda. The short-for-long-term trade-offs and the support required for emerging economies are just not seen as plausible or affordable. There is no money to buy losers' consent for an accelerated transition. *[Watch for: only a few new nationally determined contributions (NDCs) are being presented at Baku's COP29, and the UN-orchestrated process beginning to fade if no solution emerges to 'differentiated responsibilities']*.

International relations become more fractious, and countries turn inwards. Large geopolitical blocs form, with strategic autonomy becoming a key force in national and corporate decision-making. As a result, some of the 'green policy space' created by technological progress and evident physical risks is not taken up. Instead, public capital is diverted to defence, (often panicky) adaptation, short-term electoral bribes and healthcare. *[Watch for: election results across the world in 2024]*

Protectionist 'each to their own' attitudes dominate: supply chains are moved closer to home ('near-shoring'), and resource security concerns increase (eg food, water and energy). Supply (not demand)-led inflationary pressures build on traded goods. *[Watch for: proliferation of import/export bans – covering finished goods and/or re-export of batteries for recycling]*

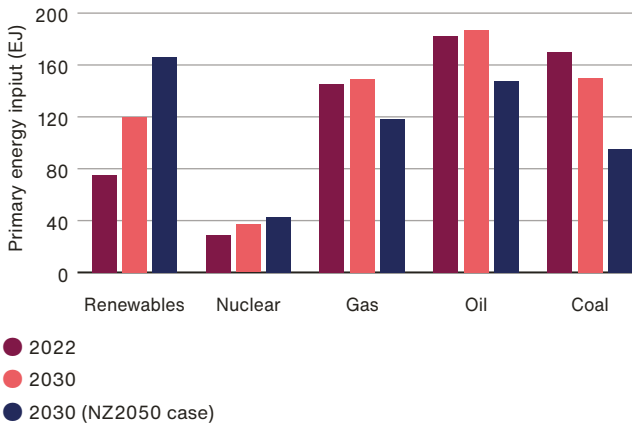
The World Bank is kept on the sidelines: multilateral financial reform does not emerge to 'crowd in' green private investment. Inflation and interest rates remain volatile, constraining investment flows to new infrastructure and renewable capacity. Markets in nature-based solutions for carbon and biodiversity remain nascent and prone to fraud. There's no sudden flourishing of multi-asset/ blended finance.

Without a clear policy backdrop, energy innovation is slower, incumbents remain strong, and the transition is left to the market. Renewed growth in compute led by advancing AI adds to overall electricity demand while not yet making any contribution to efficiency or radical solutions.

- Supply bottlenecks sustain energy prices. In addition to slower renewables, a decade of constrained investment in oil and gas production outside the Middle East/Russia leaves the 2020s with a rolling tightness.
- Natural gas production and exports stay high as the US and Middle East fill the energy demand gaps in India, China (and elsewhere) unmet by renewables. Oil demand remains strong for a personal vehicle fleet that stays hybrid and benefits from weak public transportation.

- Energy price volatility saps global economic growth, while wealth continues to concentrate with the big fossil fuel exporters (including the US), simultaneously constraining options for importers (such as China, India and the EU, as well as the vast number of poorer economies).
- However, wind and solar still show the strongest growth of any energy source, with electricity continuing to take share from other carriers. Renewables are already the cheapest source for additions in most markets.

2020s energy mix in a slow-progress case (versus accelerated net zero)



Source: Source: International Energy Agency (IEA), 2023

High energy prices push efficiency innovation more than expanding regulatory frameworks, but deployments are slow without interventions that manage the financial switch from low capital expenditure/high operating expenditure to high capex/low lifetime opex. It's the incremental gains of LEDs, insulation, variable motor drives and combined heat-and-power that make progress rather than the game-changers of electric transportation and smart grids.

Similarly, inter-bloc competition does create the friction needed for innovation, but markets are more fragmented, and scaling is sub-optimal. For example, energy-short Europe pushes ahead with heat pumps, India tries for domestic biofuels, while gas-rich America exploits Inflation Reduction Act (IRA) tax credits for blue hydrogen (hydrogen that is manufactured by natural gas) and blue carbon capture and storage (CCS). Meanwhile, some renewable assets and early-adopter electric vehicles (EVs) become stranded by a lack of supporting infrastructure and skills. *[Watch for: stalling EV sales due to perceived lack of support infrastructure]*

Industrial decarbonisation slows in the face of weakening economies and concerns over national security of supply. Steel, cement and long-distance transport remain stuck as hard-to-abate, with slow movers left reaping high cashflows. There is no regulatory intervention against oil and gas producers. *[Watch for: stock market valuations of high carbon sectors]*

The geopolitical reconfiguration of battery and semiconductor supply chains does begin to stimulate new manufacturing, processing and mining hubs beyond China, albeit slowing cost advancement for applications like electric vehicles and stationary storage.

With capital and policy looking for easier wins, offshore wind deployment remains weak, beaten by cheap gas exports from the US and Qatar. *[Watch for: offshore wind* **additions** *remain less than 25 gigawatts (GW) per year to 2027]*

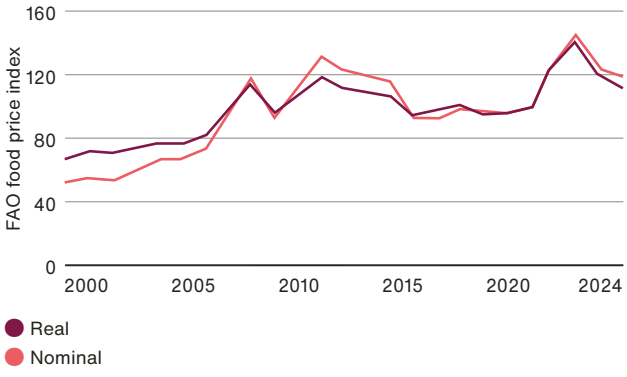
Carbon capture, both technological and nature-based, is presented as the future solution to still-high emissions. The narrative of Saudi Arabia's **Circular Carbon Economy** takes hold, but there is little investment to make it a plausible reality in the 2020s.

Volatility favours short investment horizons for financial markets. Pragmatic hedge funds win out over sustainability/ESG mandates (confounded by squabbles over definitions of fiduciary duty and purists whose fight against greenwashing allows 'perfect to become the enemy of the good'). Pensions remain fragmented, and personal finance models remain geared to high/repeat consumption.

Negative surprises at the extremes of physical impacts increase as low-probability, high-impact climate events become increasingly frequent and destructive. National, regional and city adaptation plans become an essential norm as authorities seek to protect citizens from hurricanes, cyclones, flooding and heat bombs. Demand increases for steel, cement, water management infrastructure, early-warning weather detection and air conditioners.

Global food supplies are damaged regularly by unpredictable and extreme weather, increased pests, disease, and the changing distributions of pollinators. Some regional crop yields begin to fall, more land becomes inarable and human productivity struggles with rising temperatures. Need creates innovation, and price spikes (not values) shift diets away from meat. The race between assuring food security or risking more migration has begun.

UN Food and Agriculture Organization (FAO)'s food price inflation index:
almost 20 years of upward creep



Source: FAO, 2024. World Food Situation.
FAO weighted basket of meat, dairy, cereals, vegetable oils, sugar.

Global food supplies are damaged regularly by unpredictable and extreme weather

As the years pass, the early-2020s' insurance protection gap of around 55 per cent globally and 90 per cent in poorer countries starts to rise again as damages increase in frequency and intensity. Insurance coverage becomes increasingly problematic in high-hazard areas and begins to shrink financial markets. Geography becomes an ever-more important element of asset allocation.

Despite strengths in energy production and export, and compute/AI, significant numbers in the US are feeling the weight of increasing physical stress. Land and buildings are being lost, some farming is becoming untenable and automation is eating jobs. The 'winner-takes-all' culture is pitting state against state. It's a strain to hold the country together peacefully.

Global inequality remains high. In an uncertain world, narcissism rules. Luxury and financial services to high-net-worth individuals do well, while much of the population finds escapism in online gaming.

Despite rising climate damages and fervent campaigning by certain regions and industries, nations fail to act upon climate change. ***Emissions did seem to peak in 2025 but have barely changed since then***. Geopolitical conflict, cost of living, economic growth, and protectionist policies dominate the political agenda.

Medium-term horizon
(five to ten years, to 2028-2033)

Fragmentation and conflict are damaging overall economic momentum at a global scale, and without strong growth from renewables and electrified technologies, access to energy remains a critical divide. The still-high fossil share (above 70 per cent), with reserves ever more geographically concentrated, leaves producers strong (albeit riding markets made volatile by swings in politics and weather).

Europe's attempt to break from energy import dependency has faltered, adding to its economic decline. The US has shrunk back into mercantilism, doing deals rather than building alliances. At the other end of the spectrum, emerging economies in Africa and parts of Asia seek aid by aligning with oil and gas-rich Middle Eastern powers or renewable-rich China.

China itself is under internal pressure from lost export markets for its renewables technology, weakening demography and more extreme weather. Perceiving little to lose in a low-growth, climate-pressured world, it envelops Taiwan (and/or eastern Russia). This reinforces global tension, breaks supply chains and again distracts from productive innovation.

With the global temperature rise established at >1.5C, heatwaves, droughts and forest fires become more frequent and severe, tending to the negative side of the probability distribution.

- Damaging heatwaves reach higher-latitude regions in North America, Europe and Asia which have little experience or preparedness. Lack of cooling at night becomes a primary driver of deaths during heatwaves. Droughts oscillate with deluges. The occurrence of deadly wet-bulb temperatures – taking account of both the air temperature and the amount of moisture it holds – increases, particularly in Pakistan, India, a large part of Africa and the UAE.
- Insurance markets continue to fail. This further reduces investment overall, especially in emerging markets, compounding the slow pace of adaptation and mitigation spending.

Despite efforts to adapt to the changing weather patterns through alternative crops and new technologies, food supplies come under ever more duress as yields and distribution suffer.

People move increasingly to urban centres that are already overcrowded and where infrastructure is under strain. With some 50 per cent of the world's population already living in cities, of which a third are in slums, heat exposure proves deadly. A divide forms between those who have the luxury of protecting themselves and those who cannot and between those who live in wealthy adapting **cities** (from simple green roofs to insulated and cooled mega-malls) and those who do not.

Under increasing physical pressure, India starts to run out of adaptation space. With initial hopes for developed-market support for Modi's Made-in-India renewables charge dashed in the mid-2020s, the new manufacturing base has failed to scale. The fiscal drain of escalating food imports and subsidies is becoming untenable. Meanwhile, internal migration is rising, borders challenged, and even Gujarat, Chennai and Delhi are struggling.

The divides in the US worsen between regions and between industries. Wealth is becoming increasingly concentrated among those in energy production and advanced computing. Outright conflict is avoided for now, but internal migration is becoming problematic. Will Texas, California and other adapting states bail out the rest of the country?

More positively, a few global regions with low population densities, more hospitable climates, strong resources (energy, minerals, food and water), and united politics begin to advance. Canada, Australia, and parts of South America can attract the brightest and the money they bring. Not so Russia, which once again is its own worst enemy, failing to recognise its geographical resource advantages faces pressure from larger populations to the west, east and south.

By the early 2030s, not only is the reality of current climate stress apparent, but the science is now unequivocal on some major tipping points. Timelines for glacial melt make plain the risk of conflict over water sources. At the same time, sea level rise and increased storm activity place end-dates on the habitability of some coastal regions (global real estate was worth more than $300tn in 2020[6], with two-thirds of the largest cities on the coast). Worse still, global forests, from the Amazon to the northern boreal, release increasing amounts of carbon and methane from fires, drought and permafrost melt.

The need to invest in adaptation, even in the developed world, has drained capital from advancing conventional renewable energies. The focus begins to switch to apparently cheaper but higher-risk options for end-of-pipe emissions control: public funds for carbon capture, for localised atmospheric interventions (also known as geoengineering, mainly sulphur spraying) and the (sometimes forced) takeover of land in other countries for fast-growth forest, mangrove and algae. Concerns about human rights, just transitions and neocolonialism are second order.

In 2033, global greenhouse gas emissions are still in excess of 50 billion tonnes per year (the 2010 global total).

Land area below annual flood level projected for 2030: US Gulf, China, Gujarat and north-west Europe

Click to see map

Source: **Climate Central | Land projected to be below annual flood level in 2030**

6: **The total value of global real estate | Savills Impacts**

Long-term horizon
(10+ years, beyond 2033)

Despite increasingly poor economic outlooks, countries do what they can to cope with the increasingly adverse weather conditions (eg flood defenses, radical building design, insulation, air-conditioning, desalination technologies, place-specific geoengineering).

New technology and increased diversification of crops bring back some agricultural resilience, alongside a relocation to the extended growing season of newly temperate regions (southern Russia, parts of Canada).

- New crop varieties are created that are more heat- and drought-resistant and able to cope with increased salinity (eg innovations in rice production). Global acceptance of genetically modified (GM) and AI-led advances in bioengineering are the key **unlocks**.
- Price realities further force dietary change towards more vegetables and insect farming (we still lack sufficient cheap power for cultured meat).

Water shortages resulting from increasing heat and shifts in rainfall patterns begin to cause mass closure of coal-fired power, providing new momentum for diversified energy investment. Renewables and transition metals finally get a real boost, and there is widespread state-backing for a nuclear expansion. An Apollo-mission mindset is also applied to fusion, where success finally seems plausible given the massive advances in machine learning. The reorientation of advanced computing from encouraging consumption to solving basic industrial problems (from grid management to smarter catalysts and optimised recycling) finally finds sufficient incentive in this poorer, more resource-constrained world.

In the mid-2030s, grid connections and energy price volatility are still major problems for many.

This creates innovation in local solutions for independent micro-tech and off-grid economies. Some regions of the world become very isolated and insular.

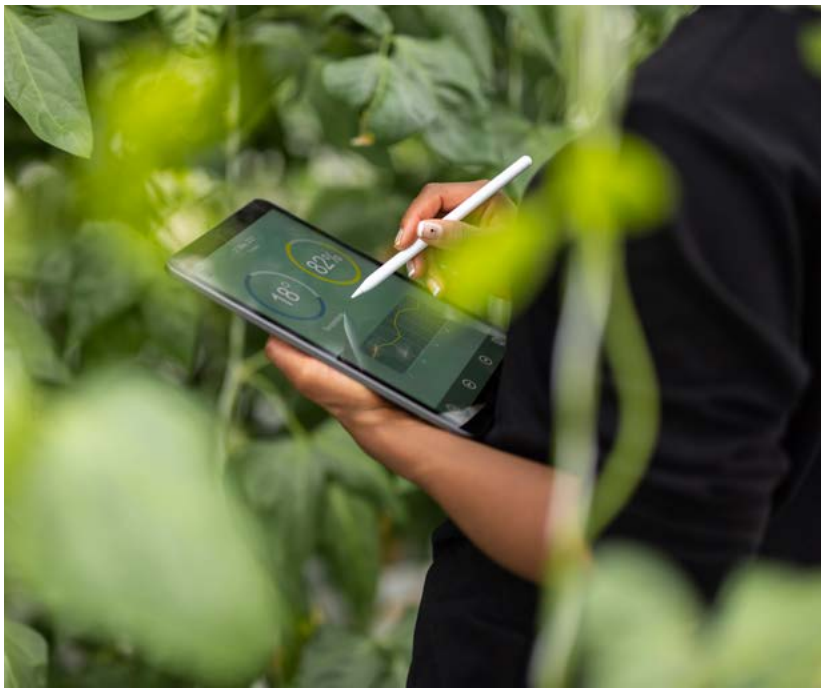
In the long-awaited fulfilment of the **transition models** promoted by the oil majors in the 20- teens, land and oceans are recruited at scale as carbon sinks. The accompanying economics are exploitative, with ownership (and rents) accruing to land-buying (-taking) richer countries and mega-corporations. The climate-related failures of some states support such expansions.

Holding back the negative impacts on human health of a hotter, more disordered world advances and reshapes the healthcare sector. The very wealthy continue to access extraordinary medical interventions while managing repeated **threats of new pandemics** becomes a requirement for state security. Conversely, there is less scope for advanced provision for the middle class, and euthanasia becomes more common.

While waiting for the grid rollout for new fusion reactors, geoengineering scales (through atmospheric injection and later vast space-mirrors). This creates yet another reason for conflict between some neighbouring countries, but the major powers of the 2030s (China, the Gulf Cooperation Council and the US) eventually force a global deployment regime.

The rate and severity of natural disasters – and their compounding impacts – result in the climate being simply unmanageable for much of society. Adding to this pressure, chronic shifts in temperature and sea level decrease global productivity, further reducing the capacity to recover and respond. Unable to shield whole populations from the changes, inequality continues to increase.

- The megadrought seen in California in the 2020s is now a reality for large swathes of the planet in any given year (including much of Europe, South America, and south-east Asia)[7]. Dustbowl-like conditions and record-breaking fires appear across the globe as water supply for consumption, sanitation, and irrigation is limited.
- The likelihood of a heatwave capable of wiping out the southern Chinese rice crop each year rises from 1 in 100 to 1 in 10 under 2-3C of warming. With food supply chains failing, the progress in the early 2000s towards tackling global hunger begins to unwind.
- Floods like those seen in Pakistan in 2022 become increasingly common across Asia, particularly. The 2022 floods caused $15bn in damages and $15bn in economic losses. As the frequency of such disasters increases, losses begin to compound.
- Human health risks rise with the combination of urban pollution, heatwaves, zoonotic diseases (those transmitted from animals to humans or vice versa) and malaria spreading to northern latitudes.



By 2040, still generating annual greenhouse gas (GHG) emissions of nearly 40bn tonnes per year (versus 55bn in 2023), the world reaches 2C and is on track for over 2.5C of warming later this century. This will bring average planetary temperatures not seen for over three million years. Without significant re-location, some four billion people will be living outside the conventional human climate niche and many others alongside extreme environmental damage. The pressure to promote innovation is huge, but the big known unknowns are how to resolve the challenges of mass migration and how to integrate new technologies.

[7] One-in-ten-year heatwave events are now four times more likely than in pre-industrial times and one-in-ten-year droughts twice as likely.

Orderly Narrative

The Orderly Transition scenario is summarised **here**.

Near-term horizon

(three to five years, to 2026-2028)

The Ukraine war causes temporary expansion in fossil fuel capacity but mostly drives an accelerated energy transition. Policies reinforce both the supply side (renewables) and the adoption of demand-side responses (technological and social). COP29, at the end of 2024, delivers the deeper and more comprehensive nationally determined contribution (NDC) updates agreed to by all countries at COP28.

In China and India, the attractions of local coal over imported gas are reinforced, but a potent policy and technology combination ensures that base-load coal starts to fall back rapidly from its 2023 peak. Instead, solutions are developed that enable coal plants to offer some of the peaking services required to support a renewable grid (low-utilisation firing and carbon capture).

Leadership changes enable geopolitical conflicts to ease and global markets to reopen. International competition (for minerals, materials, technology, etc) remains but is productive and enables rapid scaling. *[Watch for: US/China high-level summits: eg **Sunnylands**]*

Ambitious policy targets and instruments continue to be deployed[8]. These receive public support, are credible, strategic, long term and increasingly driven by new industrial lobbies. They incentivise deep and prolonged infrastructure and capital equipment investment cycles.

Carbon prices and carbon-aware trade systems are introduced with the help of coordinated global agreement (achieved at COP30 in Brazil end-2025 and enacted through the World Trade Organisation (WTO)). Free-riding is mostly eliminated. Funds begin to flow to land-based solutions that absorb carbon (especially forestry). *[Watch for: EU carbon-border mechanism, China and India carbon prices]*

Fossil fuel subsidies fall away as revenues from carbon taxes are effectively redistributed to support a just transition (within and between countries).

The World Bank, supported by the wealthiest nations, leads a reinvigoration of multilateral **development financing for mitigation and adaptation investment**. Risk premiums drop, inducing significant private investment[9]. Capital investment increases by 2 to 3 per cent/GDP.

Mainstream financial products follow the first movers in sustainable/ESG finance. This includes pension reforms that focus on aggregation (more 'supers') and duration (risk metrics set to longer horizons). Blended and multi-asset finance shows strong growth.

[8] Current policies, which combine incentives and finance with legal and regulatory support include: the US Inflation Reduction Act (IRA) and Bipartisan Infrastructure Law (BIL), which directs more than $400bn in federal funding and lowers financing costs for key climate technologies by 40 per cent on average; China's 14th Five-Year Plan on Modern Energy System Planning; the EU's Green Deal and Carbon Border Adjustment Mechanism (CBAM); India's Union Budget, 500GW renewables target, Energy Access and Green Hydrogen policies; Japan's Green Transformation (GX) Strategy.

[9] The Energy Transitions Commission estimates that $1 of multilateral development bank (MDB) financing currently crowds-in $0.4 of private capital, but that this could be increased to $2 by the kind of policies already in place to encourage private infrastructure expansion in some western economies.

Regulatory solutions are found to enable the steady wind-down of oil and gas production: tightly managing financial returns, incentivising brownfields and eliminating new exploration. Key to the global breakthrough is the agreement at COP26 in Australia to fossil fuel phase-out pathways in exchange for OECD countries bringing forward their net zero dates to 2040. Current buyers of its oil support the Middle East in shifting to solar-based technologies and attract the relocation of energy-intensive industries[10]. By the end of the period, there's a glimmer that post-Putin Russia also acknowledges its transition advantages.

Investment drives further rapid price reductions in renewables, batteries and energy efficiency. A sense of pride in national and global rejuvenation overcomes NIMBY (not in my back yard) objections to new infrastructure, mines and factories to allow rapid deployment and integration. *[Watch for: by 2025, grid connection times in the US return to the 2002/03 average of six months. By 2025, exploration spend for key **transition metals and minerals** doubles from 2021's $5bn[11]]*

The timeline for connecting to the grid averaged 4.4 years for new facilities in service in 2023, up 2x from the mid-2000s, and highest for wind and solar.

Tipping points for some critical green technologies are met across the next three to five years.

- Wind and solar made 12 per cent of global generation in 2022, having passed the critical 5 per cent threshold in 2016. Germany, California and Texas are over 30 per cent; China is more than 10 per cent and is set to meet its 2030 capacity tripling target by 2025.
- Electric light vehicles passed the 5 per cent threshold in 2019 and achieved greater than a 15 per cent global sales share in 2023, with China at 25 per cent. Three-wheeler adoption in India shows the fallibility of linear forecasts: now cheaper and better, it's just jumped to 60 per cent. Similar inflection points are delivered for most four-wheelers across major economies this decade.

[10] Further deals along the lines of the China/Saudi summit that established payment for crude in yuan and the transfer of Chinese tech.

[11] In 2013, Shell spent more than $5bn on oil and gas exploration; Petrobras has just set its annual exploration budget for oil and gas at $1.5bn/yr to 2028.

- Batteries are gaining scale from buses to cars to stationary storage. **The last 20-year learning rate** has been a 19 per cent/yr fall in costs/kilowatt hour (kWh); the last decade has seen an even more interesting 18 per cent/yr gain in energy density.
- In their varied ways, **Bill Gates**, Rolls Royce, China and India begin to win the argument for new nuclear. Mega-projects start to come in on time and on budget; modular units are supported by governments for planning and waste management. Microsoft has the first 'private' nuke under construction by 2026.
- Appliances, heating, and cooling are supported by policy and finance to deliver greater efficiency at lower lifetime costs, helping unlock a sustained doubling of recent improvements in energy efficiency per unit of GDP to 4 per cent/yr.
- New grid 'hard tech' (long-distance cables, transformers and frequency regulators) combines with AI-led grid 'soft tech' (especially in demand shift, sensors and variable speed motors) to deliver integrated smart grids across geographies. Transmission line additions double to 300,000km/yr by 2026.

Digital and AI-based technologies begin integrating into production and distribution systems, optimising energy needs, materials efficiency and reducing waste. *[Watch for: further growth in cloud computing with AI solutions focused on enterprise customers]*

The increasing ease of car and appliance sharing and smarter electricity use, enabled by advanced digitisation, begins to make apparent energy 'frugality' a positive social trait for city-dwellers. This helps constrain rebound and leakage effects that can plague transitions.

The growing combination of renewable supply and electrified demand technologies stops the growth in our overall primary energy inputs. This helps wind and solar rise from 2 per cent of total energy in 2022 to pass through the critical 5 per cent threshold by 2026 and speed to 10 per cent by 2030, alongside gains for nuclear, hydro and modern biomass. *[Watch for: total clean energies on track to double their 2022 share of primary energy to exceed 30 per cent by 2028]*

Policy support and preferential financing kickstart the emergence of integrated hydrogen and carbon capture, usage and storage (CCUS) hubs to drive tipping points for scale and costs at some industrial megaports with the right mix of existing attributes (eg Saudi, US Gulf Coast, Guangzhou, Gujarat and Rotterdam).

During Brazil's G20 presidency in 2024, Brazil and India lead a trans-continental collaboration in biofuels that combines the former's technology expertise with the latter's agricultural might. This channels new funds into their land sectors, creating new momentum in biorefining.

Policies to encourage clean investment are initially inflationary but are manageable given global excess savings with low real interest rates. The pressures begin to subside as global capacity expands, revenues are redirected and energy costs start to fall.

Asset market valuations follow the policy signals and begin to price expectations of a steadily accelerating, rather than failing, shift to low-carbon technologies. Asset stranding and premature scrapping are minimal.

The increasing frequency of extreme weather events across the globe reinforces ambition. Impacts are well managed by international finance flows and adaptation innovations. Insurance remains (mostly) effective and available. COP29 in 2024 delivers a financing framework for 'loss and damage' alongside 'national adaptation plans' coordinated by the World Bank programme.

Adaptation and improved resilience prevent migration from becoming a major threat to global peace. National political budgets are not diverted to unproductive protectionism, populist responses or defence. *[Watch for: US Presidential election 2024]*

Society and political institutions view the energy transition as an opportunity, not a cost. The social narrative reinforces and rewards pro-transition behaviours (resource efficiency, shared usage and circularity). Decarbonisation and sustainability are table stakes for consumer brands.

By 2028, global GHG emissions have shown five years of sequential and accelerating reduction. The decline was never going to be linear, but technology deployments are now of a scale to drive increasing year-on-year shifts. ***CO_2 emissions from energy have dropped more than 15 per cent from the 2022/23 peak (to 31 billion tonnes (bnt)), with annual reduction now exceeding 2bnt/year.***

Medium-term horizon

(five to ten years, to 2028-2033)

The Orderly Transition is 'just': there is gradual retraining, no mass unemployment and limited instances of social unrest, strikes, protests and conflict. The transition is also just from a global distributional perspective in that it relies on rapid decarbonisation in the global north and financial assistance for mitigation and adaptation in the global south. These elements of justice help mitigate shocks, unrest and overwhelming migration, keeping the transition on course. *[Watch for: UN COP process for international climate action continues to function, increased government spending leads to an increase in private investment (crowding in action) through mediated trade-offs and the threatened isolation of laggards]*

As the world transitions away from fossil fuel-based sectors, structural shifts in the labour markets accelerate. The International Energy Agency (IEA) estimates that although 13 million high carbon jobs will be lost by 2030, 30 million will be created through higher capital investment into new manufacturing, high- value mining, recycling and equipment servicing. China halved employment in coal mining 2000-20; both China and India are on track to do the same again by 2035. *[Watch for: India doubles its gross value added (GVA) share from manufacturing to 30 per cent by 2030]*

Nature and land emerge as a substantial asset class: their carbon capture/storage, water and biodiversity services are increasingly remunerated. This enables capital flows to emerging economies, supporting their resilience through infrastructure and development. A new wave of agricultural innovation accelerates in Africa and Asia.

The Orderly Transition is 'just': there is gradual retraining, no mass unemployment and limited instances of social unrest, strikes, protests and conflict

Financial products structured to fund climate-aligned services become commonplace: shared-use consumer goods, efficiency retrofits, grid-capacity markets and extended ownership models with high recycling-based end-of-life valuations (as opposed to rapid turnover consumption).

Policy changes continue to be well signalled and anticipated – systemic financial risk remains in check. Business and trade union lobbies for expanding new industries play a role in strengthening the policy support for emerging technologies.

As renewables move to **real scale in use, not just installation,** the second-order solutions enabled by lower-cost energy become increasingly commercial: green hydrogen for fertilisers and steel, electric industrial furnaces, process carbon capture, synthetic fuels and chemicals. By 2025, there is line-of-sight to 1bnt of capture for 2030, and by 2030, credible plans for more than 3bnt by 2040.

Materials recycling is similarly underpinned by lower-cost energy but really enabled by the tracking and predictive powers of accelerating AI. Revolutionised waste sourcing stimulates a new stream of innovation in machines that extract and purify metals, minerals and compounds. [Watch for: Amazon buys Redwood Materials to become the goliath of 2030s circularity!]

The relative quantities of food waste also start to drop significantly. Currently, about one-third of food produced globally is wasted. A combination of a more sustainable global mindset, the pricing of carbon emissions, and technological innovation optimise flows from field to fork.

By the early 2030s, the huge efficiencies in primary resource needs enabled by renewable generation, electrified demand, AI and urbanisation begin to suggest a new period of ‘abundance’. Countries must no longer become richer to afford energy: they become richer through the development enabled by low-cost energy.

The world’s industrial geography and trade patterns begin to change to reflect the location of more benign climates and cheap renewable energy sources. South America, Canada and Russia have a mix of both. The Middle East, parts of Africa, central Asia and Australia use their very abundant energy resources to manage increasing heat while attracting relocating energy-intensive industries.

Shifts in demography bolster changes to the geographies of growth: rapidly ageing populations in the developed world face competition from growing populations such as India, Pakistan, Philippines, Ethiopia, Nigeria and Tanzania. The threat and management of climate-related migration is a constant influence on global policymaking but is managed by the rapid deployment of new technology (for mitigation) and new wealth (for adaptation).

By 2033, clean energies, including nuclear, are providing over 40 per cent of primary energy inputs, so coal and oil are now in clear decline:

- Coal volumes have halved since 2022, and oil is falling towards 70mb/day, losing more than 3mb/day per year. While OPEC's market share has risen towards 60 per cent, the political risks of concentration have been managed by integrating the Middle East (and Russia) into the renewable economy.
- The natural gas decline has come later, buoyed by its cheapness in the US and the late transition of rich liquefied natural gas (LNG) importers, including Japan, Taiwan and Korea.
- Some of the last entrants to the early 2020s post-Ukraine LNG export boom (Mozambique and Tanzania) are exploring World Bank-funded hydrogen-ammonia retrofits.

Although global GHG emissions have almost halved (to <35bnt carbon dioxide equivalent (CO_2e)by 2030, the threats of physical climate change do worsen. Increased frequency of extreme events results in supply chain disruptions and asset losses. Productivity in heat-exposed industries must be defended through high levels of adaptation spending and innovation in more vulnerable locations (from agricultural activities in India to mining in northern Australia).

With decarbonisation increasingly seen as a collective responsibility and food under price pressure from the more volatile climate, dietary changes pick up pace. High-GHG foods, such as meat and dairy, are replaced with vegetarian diets and cultured meats. Carbon prices have entered the food chain as agriculture competes with carbon sequestration for land.

The international order is multi-polar: 'orderly 1.5' is by no means a utopia, and cooperation is both tense and hard-won. It is important not to underestimate the level of disruption the transition causes, though outright conflict is avoided by adept political management of the tradeoffs.

Long-term horizon

(10+ years, beyond 2033)

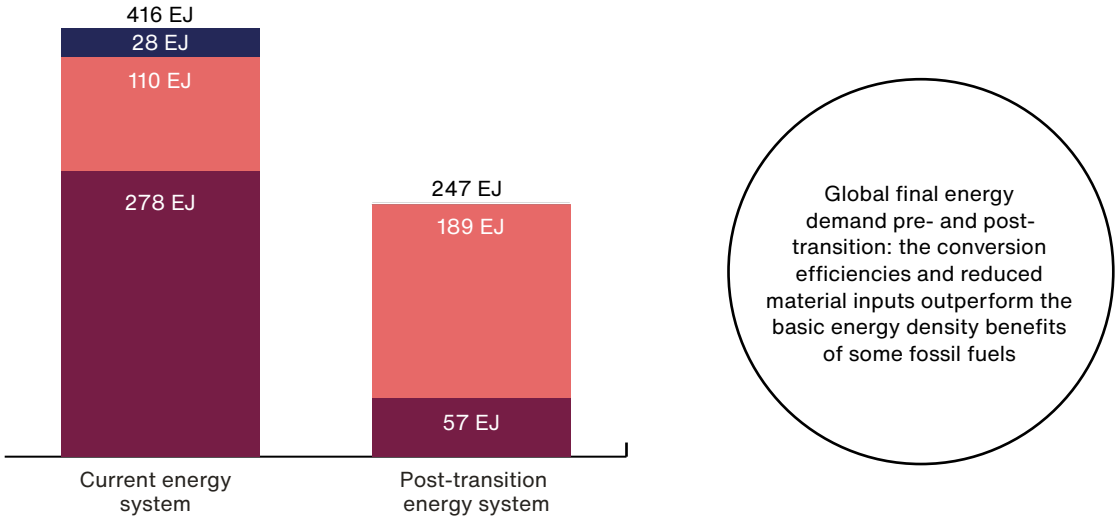
Structural and systemic change continues: the 'frontloading' of the transition has sown the seeds of much that will follow. This applies not only to the technologies but also the enabling cultural values of circularity, shared-use, environmental sustainability, human rights, and a rebalancing between consumption and contentment. Free-riding is countered as digitally-enabled transparency limits the 'tragedy of the commons'.

AI-based environmental and climate monitoring form an integral part of the rollout of smart distributed energy grids and the management of extreme weather events.

Growing deployment of AI-assisted technologies across multiple sectors increases economies of scale, driving down costs. As prices fall, new use cases and technologies become commercially viable, strengthening the feedback loops and generating further exponential change[12]. We pass technological tipping points in fusion (or orbital solar?), quantum computing, alternative proteins and waste management. New markets emerge from the subsequent derivatives of cheaper energy. An innovation-led wave in global equities succeeds the asset-finance wave of the 2020s.

[12] Recent estimates suggest that AI technologies could increase global GDP by $15.7tn by 2030.

A world of devices powered by electrified renewable energies needs less primary energy: conversion losses fall, less inputs are required



*exajoule (EJ) = 1×10^18 joules.

Source: Hannah Ritchie and Nick Eyre: **From using heat to using work: reconceptualising the zero carbon energy transition | Energy Efficiency (springer.com)** (see also Tesla MasterPlan).

The ever-expanding renewable energy system develops resilience through a variety of place-specific solutions that mixes the micro (prosumers) with the macro (giant energy parks and vast cross-region grids).

As +1.5C becomes the new normal, the need to adapt drives continual innovation to constrain food insecurity and commodity price volatility – and manage human migration. Population relocations are steady rather than rapid, find some newly benign regions and aid the rebalancing needed for industrial transitions and ageing demographics.

The geography of industrial production is redrawn for energy-intensive trade-exposed but relatively low-skill industries such as steel, aluminium and chemicals. The availability of low-cost, low-volatility renewable power alongside carbon capture in these difficult-to-fully-decarbonise sectors is critical. Conversely, the high-skill energy-intensive sectors, such as semiconductors, prove more geographically sticky and can support the cost of imported power.

The global population is on course to rise to 9.7 billion by 2050, over half of which is concentrated in eight countries: the Democratic Republic of the Congo, Egypt, Ethiopia, India, Nigeria, Pakistan, the Philippines and Tanzania. The world copes by being highly urbanised, enabling maximum energy efficiency and preserving nature-based solutions.

With the energy and industrial transitions accelerating towards a decarbonised state, transforming the agriculture system remains the most pressing challenge. The system faces a dual challenge: reducing impacts on climate and adapting to changing climatic conditions[13].

[13] Globally, each 1C rise in mean temperature will reduce yields of wheat by an estimated 6 per cent, rice by 3.2 per cent, and maize by 7.4 per cent. Further pressure will be placed on food production by increases in pests, weeds and diseases.

Economic development and support from the wealthiest countries are critical to success.

- Reduction of impacts: progress already made through dietary changes and food waste reduction is bolstered by technological and ecological innovations applied in a location-specific manner (eg precision agriculture, vertical farming, organic farming and meat substitutes).
- Adaptation to climate change: new crops that are more heat- and drought-resistant and able to cope with higher salinity increase resilience in areas facing testing climates. Production also expands into newly temperate regions (Canada, Russia, Scandinavia and Northern China). This requires a complete redrawing of agricultural supply chains.

Though natural disasters are more common, societies are – as a whole – better able to prepare and respond. A combination of climate-resilient planning, early warning systems, and adaptation measures (water management, irrigation and air-conditioning) has seen losses from natural disasters decline since the 2020s.

- Despite advances in adaptation, extreme events in vulnerable areas (eg Central Africa and south-east Asia) still cause significant suffering and loss. The planned relocation of infrastructure is also costly in the short term, though it saves stranding in the long run.
- Water scarcity and the depletion of non-renewable groundwater remain the most pressing issues and threaten agricultural yields. This continues to drive the innovation seen through the 2030s in water capture, storage and efficient usage.
- As we enter the latter half of the 2040s, the global temperature reaches +1.5C: one-in-ten-year heatwave events are now four times more likely than in pre-industrial times and one-in-ten-year droughts twice as likely.

Dateline 2050: transforming the world's energy landscape

The scenario work produced for us by Deep Transitions included a series of conversational narratives. The one included below illustrates a 2050 lookback at 25 years of accelerating the energy transition. For more like this see the **Deep Transitions report:**

From 2025 to 2050, our world embarked on an unprecedented journey towards combating the environmental crisis. Ambitious climate and net zero policies became the driving force behind a wave of innovation and technological advancement. The urgency to find novel solutions propelled the development of cutting-edge technologies that would forever reshape our energy landscape.

Investment in renewables and nuclear power soared, fuelling the rapid growth of clean energy production, storage and distribution. In the mid-2030s, we witnessed the emergence of place- specific renewable energy systems tailored to harness the unique potential of each region. From the mighty rivers generating hydropower to offshore wind farms harnessing offshore wind, our planet's energy needs were met with ingenious solutions. Green hydrogen, solar and sand energy, and battery parks became common features of our renewable energy infrastructure. Furthermore, small modular nuclear reactors gained prominence, revolutionising how we think about atomic energy.

A critical aspect of this transformation was the establishment of intercontinental energy grids. 'Ultra-high voltage energy grids' connected regions and facilitated the efficient distribution of energy across borders. This cross-regional connectedness not only enabled the sharing of renewable resources but also paved the way for collaborative efforts in combating the climate crisis.

The energy-as-a-service model took centre stage in the global economy. With this shift, consumers no longer needed to own energy infrastructure but could access sustainable energy sources seamlessly. This pattern led to economies of scale for small nuclear reactors, but it also created an unintended consequence: a global oligopoly of suppliers due to high entry barriers. Recognising this, a focus on 'just investment' emerged, striving to develop alternative technologies that avoided justice issues, such as using child labour in mining rare earth resources.

As environmental consciousness deepened, demands for transparency and ethical markets soared. Calls for supply chain transparency and fair resource trading gained momentum, placing pressure on businesses to adopt sustainable practices. Moreover, legal mechanisms were put in place to ensure that local communities reaped the benefits of new energy production ventures. Wind and solar parks, as well as nuclear plants, were obligated to prioritise the welfare and empowerment of nearby communities.

Governments worldwide gradually imposed a 'carbon takeback obligation' on businesses, holding them accountable for their carbon emissions. Explicit agreements between nations were forged, aiming to prevent carbon and pollution from shifting from one region to another. Community energy initiatives flourished, empowering local neighbourhoods to take control of their energy sources and reduce their carbon footprint.

In this greener world, flexible energy consumption became the norm. Enabled by advanced information technology, energy consumption automatically adjusted to optimise efficiency and minimise waste. Energy efficiency was no longer viewed as an individual obligation but as a collective responsibility of the state, enterprises and citizens alike.

As we reflect on the momentous changes that unfolded from 2025 to 2050, it is clear that our world underwent a remarkable green revolution. The synergy between ambitious climate policies, technological advancements and a growing societal consciousness brought us closer to a sustainable future. It is now our responsibility to carry this momentum forward, ensuring that the triumphs of this era become the enduring legacy of generations to come.

Disorderly Narrative

The Disorderly Transition scenario is summarised **here**.

Near-term horizon

(three to five years, to 2026-2028)

In 2023, fossil fuels still supplied 84 per cent of global energy inputs (down 2 per cent since 2010) and 60 per cent of electricity generation (down a more encouraging 7 per cent since 2010). Global GHG emissions again edged higher, as global CO_2 from fuels and cement hit a new record of 37bnt and methane continued to climb, driven by coal, gas and agriculture, alongside spreading wildfires.

Perceptions of the global energy system have been reset by Russia's invasion of Ukraine and the general deterioration of the geopolitical environment.

- The attractions of domestic coal over imported gas are reinforced – most importantly for coal-titan China (greater than 4.6m tonnes per annum), but also India (more than 1mtpa) and Indonesia (0.8mtpa produced). There is continued investment in coal mining and power in these states.
- There is an initial rush to secure new long-term gas supplies for import in Europe, Japan, Korea and Taiwan, but also policies to promote nuclear as well as continued support for renewables and energy efficiency.
- With key tipping points in the cost and deployment of wind, solar and EVs passed in 2022/23 and more in sight for batteries, heat pumps and grid tech, 'going green' is gaining traction as a viable route to energy independence.
- Oil demand edges up post-Covid but starts to disappoint – perhaps underestimating the pace of the transport transition in China and the accumulating impact of efficiency gains in backup power, aviation and shipping. OPEC has to cut to balance its market.
- Citing national security concerns, some governments revert to being more overt in maintaining fossil fuel infrastructure and promoting investment in whatever production and exploration can still be eked out of mature provinces. Conventional 'western' finance remains cautious of this opportunity, but international/private money takes a chance.
- In the US, the green headlines of the Inflation Reduction Act and Bipartisan Infrastructure Law are real but also mask an 'anything goes' drive for energy abundance. American oil and gas producers are encouraged and are further emboldened by OPEC price support and global LNG excitement.

Beset by various tensions, countries are increasingly protectionist, and governments prioritise nationally-important industries – onshoring/nearshoring becomes increasingly central to industrial strategy.

- While manufacturing starts to reshore, adding to costs, energy transition metals struggle to diversify in the face of opposition from an accidental alliance of fossil-fuelled NIMBYism and concerned environmentalists. There are opportunities to be had in government support for new mines and metals processing, but many countries remain heavily reliant on China for critical materials for batteries, solar and wind.
- The pursuit of green technologies is regionally fragmented, raising subsidy costs and slowing effective scaling. Energy-short Europe pushes ahead with heat pumps, India tries for domestic biofuels alongside its own wind and solar tech, while gas-rich America exploits IRA tax credits for blue hydrogen and blue CCS. Struggling for integrated global scale, deeper and/or floating offshore wind disappoints.
- Policies are somewhat misdirected for this point in the transition. Instead of a clear focus on the early, easy wins, some capital is 'wasted' trying

to build later-stage solutions like hydrogen and carbon capture (that fit the strengths of the lobbying oil and gas incumbents) when the basic ingredient of abundant, cheap power is still missing.

The deployment of transition technologies runs slow relative to their potential but is significant nonetheless:

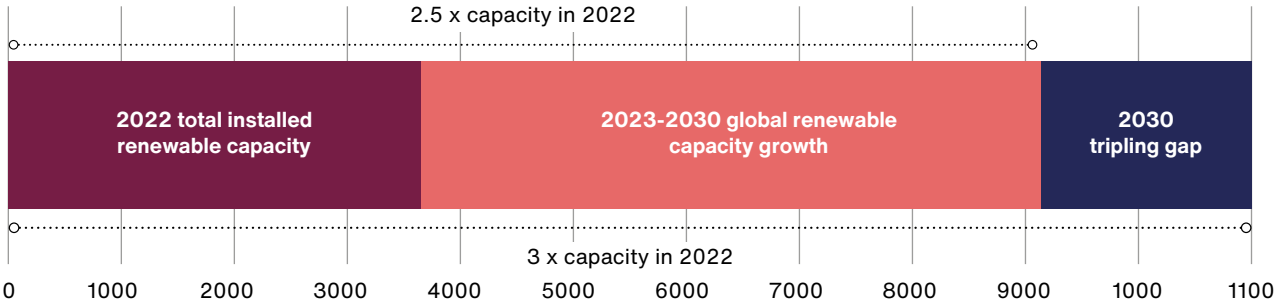
- Electrified end-use technologies (EVs, heat pumps and variable motor drives) increasingly show their advantages, wind and solar can meet significant portions of demand at the lowest cost, and energy (and resource) efficiencies become easier to realise as AI advances.
- The COP28 pledge to triple renewables and double the pace of energy efficiency gains by 2030 is seen as plausible and sets the background for specific references to 2030 emissions reductions and a transition away from all fossil fuels.

Nonetheless, political wrangling and positioning within and between countries limits actual hard commitments at a global scale. Country NDCs for emissions reduction remain unaccountable.

- There is no resolution of 'fair share' contributions to the required pace of global emissions reduction. An agreement on global carbon pricing – and the trading of international offsets remains elusive
- The carbon border mechanism introduced by the EU is contested, and debates get purposely sidelined into an ineffective WTO. That said, it does at least stimulate the introduction of (admittedly low-priced) emissions tax regimes in India and elsewhere.
- At COP30 in Brazil at the end of 2025, there is some progress on a framework for nature-based solutions, and a few states (led by oil producers Norway and the Saudis) step forward to fund a pilot inter-country scheme.

In 2023, advanced economies finally met their promise to funnel $100bn/yr to emerging and developing countries for mitigation and adaptation and began to fund a World Bank-run 'loss and damage' programme. But without the clear cross-border policy signals noted above and the refusal of the US to accept past responsibility, further expansion is slow despite the pleas of climate-vulnerable states.

Latest IEA forecast for renewables additions: COP28 goals for 2030 within reach



Source: International Energy Agency: Renewables 2023

In among this general volatility, the finance sector remains short term. Pension reforms that could extend horizons become lost in a plethora of committees and review groups. 'Sustainable' finance struggles to grow caught between attacks by the libertarian right and environmental perfectionists.

With two energy systems trying to run in parallel, the world is optimised for neither. Polices are often contradictory, and the risks of stranding (on both sides) are real. Innovations stay in niches, lacking the broad support to flourish (see the **Deep Transitions report** for more on critical enabling conditions). Inflation too is higher and more volatile as opportunities for early energy transition are missed, reducing the non-inflationary rate of sustainable growth.

Meanwhile, new records for the hottest year continue to be set. Extremes of rain and heat disrupt the food chain, residential insurance and tourism – but remain just about manageable: physical change is clearly present but still not viewed by most with real economic agency as an imminent emergency.

Geopolitical tensions, weak economic growth and a myopic view of the price volatility across many commodities dominate political agendas and fiscal policy. Although the fossil fuels-based energy system is seen as increasingly unsustainable, the public at large is not fully behind the energy transition, which the wealthy incumbents portray, quite effectively, as costly and unjust. The food system is beginning to show signs of stress, but there is little coordinated promotion of lower-carbon, lower-resource intensity diets.

That said, clear divides are emerging: between the young and the old, the poor and the rich, vulnerable versus better located states and regions, green energy growth versus fossil fuel fade.

For corporates, this is a complex world to navigate. There is no clear advantage to being a transition first-mover or pro-climate advocate. There can be high cashflows to reap from yesterday's high carbon but fully depreciated capital stock. Financial outcomes remain dependent on local circumstances and technology readiness.

By the end of 2028, however, global GHG emissions have fallen (albeit marginally) for the second year in a row. While the +1.5C carbon budget looks bust and even +2C somewhat implausible, the annual emissions peak truly seems past.

- Global economic growth has been suboptimal, limiting top-line energy demand. At the same time, uptake of still-improving renewables and more efficient electrified technologies has eaten into the fossil share (trickling down to 75 per cent of primary energy and 40 per cent of electricity, with EVs now making up almost 40 per cent of global sales).
- There have been some important structural shifts: new manufacturing and mining capacities for green technologies have been established in the US, India, Indonesia and Australia, with potential in Brazil and Chile; China has taken advantage of a mini gas glut and accelerated nuclear to drive its coal demand back down to 2015 levels; business application of AI is beginning to hint at transformations in energy efficiency for industrial applications (catalysts and motor drives), as well as for batteries and grid integration.
- Despite the disorder, the growth and flow of investment are towards low carbon, electrification and efficiency.

Medium-term horizon
(five to ten years, to 2028-2033)

In the late 2020s, this scenario encounters a breakpoint. Something(s) provokes or suddenly enables a change in society's approach to the transition. In the following narrative, this is set up as the response to a rapid accumulation of physical tragedies creating the space for a clear global policy intervention that drives the world back to at least well-below +2C, if not quite +1.5C. There could be many other triggers: a truly extraordinary technology breakthrough (fusion?); a multitude of varied gains across many electrification technologies that accumulate into a step change in real-world deployment around the turn of the decade; or some geopolitical change that ramps up the flow of capital to emerging economies (be that multi-source or driven by a few rich neocolonial states); and so on....

Equally, this narrative assumes that the trigger can drive the world back to something approaching climate success at scale. It is, of course, quite possible that this is not possible. Disorder may continue, or we might just be physically too late to regain control of the climate for most of the world's population.

In late 2028, after a La Niña interlude, the El Niño effect returns with a vengeance to drive a rapid increase in the frequency and severity of global weather events. The next two years are rolling continuum of floods, droughts, heatwaves and wildfires around the globe as the warmed, more energetic, atmosphere kicks off.

- A massive drought in China causes major crop failure. One knock-on is a massive increase in demand for seafood that pushes the regional fisheries into collapse.
- Extreme heat events roll around the globe, starting in India in March with temperatures beyond the deadly wet bulb[14] maximum, into the southern US in August/September and ending with a boiling Christmas in Australia.
- Floods on the scale of Pakistan in 2022 feature in all continents. Americans and Europeans already experiencing a contracting property insurance market find valuable real estate lost to waves and rivers from Florida to the Rhineland.

The physical disruption is unbearable for the global food system and causes a wave of price inflation, draining government coffers. Despite having money, industry can't buy water when populations are thirsty and the wealthy can't take all the food when so many are at risk of starving.

Mass migration is the other increasing threat. There is a realisation that individual countries can't manage this alone: more protectionism, higher walls and more conflicts won't stem the potential movements. Public pressure on politicians reaches a tipping point.

With a sudden but growing realisation that 'time is running out', new policy measures (carbon prices, regulations and subsidies) are introduced abruptly and haphazardly.

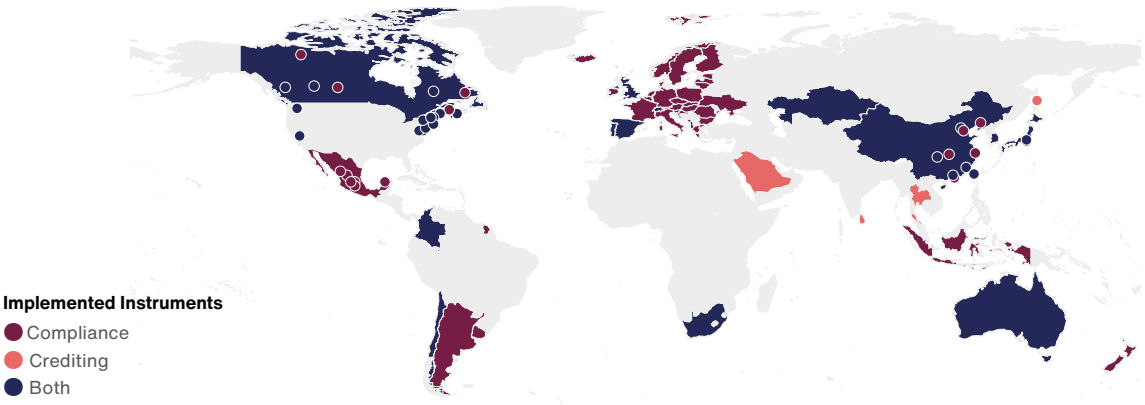
- The frameworks for (generally ineffective) carbon prices already in place are suddenly jacked up. The economist William Nordhaus's global Carbon Club finally comes into being, with those countries lacking punitive carbon regimes now ostracised from international trade. Where necessary, emergency legislation funnels some of the government carbon revenues to the poorest, while the rest goes to accelerated build-out of nuclear, renewables and electrifying demand.

[14] Wet-bulb temperatures take account of the air temperature and the amount of moisture it holds. You can learn more via **this Fortescue presentation**.

Geographies with, or considering, carbon price regimes 2023

Carbon pricing instruments around the world, 2024

Map shows jurisdictions that have implemented Direct Carbon Pricing Instruments - Compliance instruments (Emissions Trading Systems (ETS) and Carbon taxes) and/or domestic carbon crediting mechanisms, subject to any filters applied. The year can be adjusted using the slider below the map.



Source: The World Bank. **State and Trends of Carbon Pricing Dashboard: Carbon pricing instruments around the world, 2023**.

- Many high-carbon assets face stranding through high carbon prices or direct regulatory bans. There's a rapid shake-out that is ruthless for the inefficient – be they power stations, cement plants, airlines or combustion engine vehicles. Gas is supplanted faster than oil.
- Despite years of climate debate, these policy changes are neither well signalled nor anticipated.
- Many businesses are unprepared for the rapid shift in policies and regulation, as well as the sudden changes in consumer and investor preferences.
- There is a lot of blame, so not only are high carbon industries weakened but companies deemed to have slowed or diverted the transition are shunned.
- Relative prices adjust abruptly and disorderly, with quick repricing of fossil fuel assets leading to premature scrapping. Supply-driven inflation is high from food to new energies.
- The policy risk premium is high, and volatility and systemic financial market risk rise sharply. This is a period of economic shocks with weak general consumption.

There is a 'race to the top' by green technology companies to meet the sudden sharp increase in renewable energy demand and gain market share in rapidly evolving markets. In still quite immature technologies, with still quite concentrated supply chains, production bottlenecks and price spikes are common. There is little regard for human rights or wealth-sharing in the rush for low-carbon materials. With grid connections insufficient, deployment initially struggles to meet energy demand in many regions.

This backdrop favours the consolidation of new oligopolies to replace the old. Perhaps surprisingly, some names are the same. Some of the key Middle Eastern oil and gas exporters, buoyed by revenues from 2020s price volatility and with the right ingredients of sun, space, labour and customer relationships, emerge as major new investors in the transition.

The US and Russia also resolve their own internal factions. Moving past Putin, Russia learns from the Middle Eastern states and wakes up to its tremendous potential in wind, hydro, forestry and metals, pulling in new workers from the south and east. While inspirational (youthful!) leadership in America creates a true Green New Deal to unite behind tech and energy advantages.

Carbon capture is the industry that now needs to move up the development curve fastest. Several different pathways emerge. Point-of-emission capture is publicly funded and creates a new competitive edge for those regional hubs where industry, cheap power and storage reservoirs coexist (perhaps Saudi Arabia, US Gulf Coast, Guangzhou, Gujarat and Rotterdam). Direct air capture and nature-based solutions (forestry, mangroves and algae) quickly tend to the exploitative. Best suited to the land of emerging markets, outsiders (countries and mega-corps) take control with little regard for local populations. Meanwhile, advanced AI models are put to work on exploring the potential for localised geoengineering interventions.

The fossil fuel share of primary energy inputs is under two-thirds, with only 25 per cent of electricity generation still coming from a mix of coal and gas

It takes adept government to contain the multitude of social pressures created by disrupted food prices, volatile energy supplies, stranded businesses and the need for workers to reskill at pace. In some regions, this is enabled by a combination of 'wartime' togetherness and the revenues extracted through tax or appropriation from the declining high-carbon industries. In others, through top-down force and control.

With policy direction set and new streams of revenue emerging, finance is quick to step forward. First comes infrastructure, then lease-based to enable the upfront capital expenditure to deliver lifetime operating expense savings, and then, as the immediate disruption starts to abate, equity for a new round of low-carbon (and captured-carbon-using) innovations.

This is a very messy period. There are losers within and between countries. Some fail, others leapfrog. But there is enough unity of purpose across the major powers to keep outright conflict at bay.

Heading into the mid-2030s, global GHGs are now falling: down almost 30 per cent from 2023 to 40bnt. The fossil fuel share of primary energy inputs is under two-thirds, with only 25 per cent of electricity generation still coming from a mix of coal and gas.

Long-term horizon

(10+ years, beyond 2033)

With pressing climate targets to deliver and physical impacts still compounding, China and India oversee the first large-scale stratospheric aerosol injections. Though Europe objects, much of the world is supportive, and the UN begins work on an international deployment regime.

Somewhat protected by effective weather forecasting and geoengineered climate control, new technology and increased diversification of crops begin to build back agricultural resilience. This is ultimately a slow process and net importers of food still struggle to secure supply (Africa, east Asia and southern Europe). While demand for nature-based carbon sequestration has added to pressure on land availability, the food system is supported by:

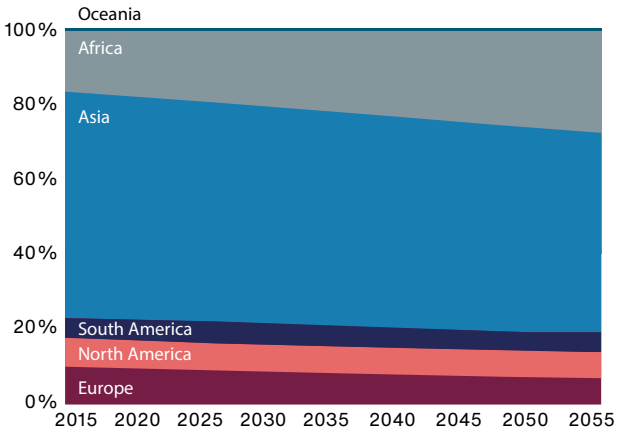
- The advancement of new crop varieties that are more heat- and drought-resistant and able to cope with increased salinity (eg innovations in rice production).
- Precision and regenerative practices that optimise yields and reduce ecological pressures.
- Growth in insects as protein, and later, as energy supplies increase, cultured meat and vertical farming.

The geography of industrial production is steadily reset – especially for energy-intensive, trade-exposed industries, such as steel, aluminium and chemical feedstocks. The availability of reliable, low-cost, low-volatility renewable power, as well as carbon capture in sectors that are difficult to decarbonise, is critical. South America emerges as a relative winner given its still benign climate and capacity in mining, renewables and biofuels.

As a whole, migration pressures are lower than feared a decade earlier. Strong adaptation and proactive (albeit often aggressive) routing of migration to geographies with expanding industries and climate niches reduce the number of chaotic climate migrants. Interestingly, the integration of ‘green’ Russia into the European Union gives this region the geographic space (as well as natural resources) to accept migration (mostly from Africa) for sustained growth.

Long-term shifts in demography also bolster changes to the geographies of growth: ageing populations in the developed world cede some of the economic pie to growing populations in now (renewable) energy-rich India, Pakistan, Philippines, Ethiopia, Nigeria and Tanzania.

Trend to 2050 is already set: Africa will dominate population growth



Source: Our World in Data. Data sources: HYDE, 2017; Gapminder, 2023; UN, 2022.

But the disruptive rush to decarbonise and control the climate has still left the world fragmented. Solutions are often place-specific, with less potential for global collaboration and scaling to really drive down the costs of a few winning options. Access and control are critical, and the inequalities created by the physical and transition shocks persist.

Eventually, the growing deployment of AI-assisted technologies into urgent industrial challenges increases economies of scale, driving down costs. As prices and interest rates fall, new sectors and technologies become commercially viable, strengthening the feedback loops and generating rapid exponential change. In addition to breakthroughs in the food chain, AI revolutionises:

- Industrial catalysts to transform the thermodynamic efficiency of materials production, including energy vectors, superalloys and synthetic compounds
- Solar cell efficiency, battery solutions, grid balance and the optimal matching of electricity supply with demand
- Modular nuclear fission and achievable tipping points in the commercialisation of fusion

As the 2040s begin, a successful climate outcome that holds overall warming this century to less than 2C is still not assured – but it is plausible with the right mix of carbon capture deployment across industrial and nature-based systems.

Advances in energy and resource efficiency (through synthetic chemistry, desalination and recycling) might yet generate genuine abundance – which in turn could allow a reset in global equality and opportunity. The younger generations begin to find reasons for optimism.

The global climate roughly resembles that described in the Orderly Transition. However, the resounding difference is the higher vulnerability levels and adaptive burden. The higher costs and duration of this transition have afforded less time and investment for development.

Accordingly, the human impact of natural disasters remains higher, water and food scarcity are more prevalent, and larger amounts of infrastructure become uninsurable.

- Different disorderly scenarios may show a wide range of physical changes. In this scenario, they trend to the less-severe end of the spectrum, allowing societies to focus predominantly on decarbonisation and adaptation planning. In others, impacts may look much more like the Hot House World, constantly threatening to derail the transition efforts (and in the worst case, dragging the world back into the Hot House scenario).
- ***As we enter the latter half of the 2040s, the global temperature surpasses +1.5C albeit hopefully set to be constrained to less than +2C***. One-in-ten-year heatwave events are now four times more likely than in pre-industrial times, and one-in-ten-year droughts are twice as likely.

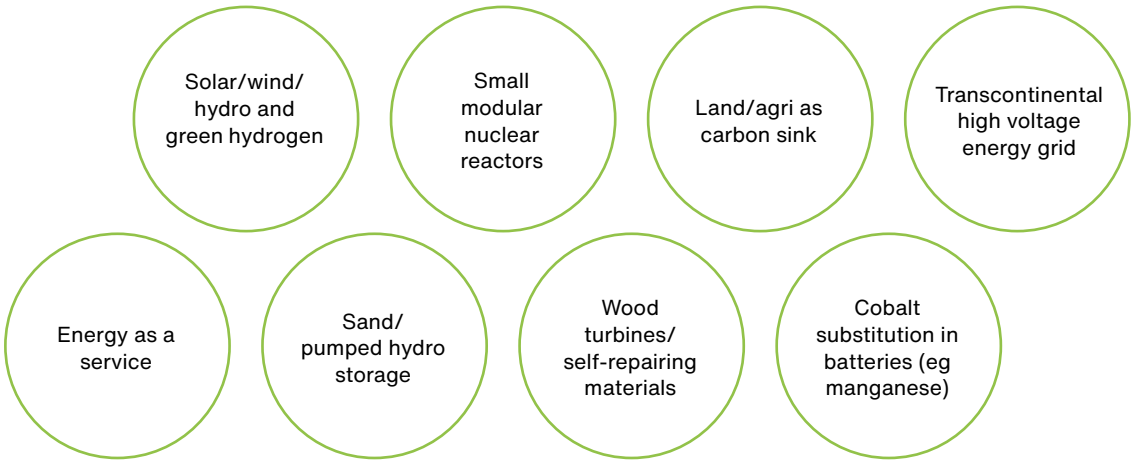
Appendix: the energy system

The following graphics were prepared by the Deep Transitions team to explore how future shocks and emergent niches/opportunities may reshape the energy system.

01 Orderly Transition

Energy system	2025	2035	2050
Social-technical system regime	**Policy as the main driver** rapid policy action provides a decisive boost to mature niches, including both renewables and nuclear global coordination	**Dual transition** fossil fuel based energy generation declines, centralised grid less so, justice, sharing, circularity	• **Tech:** place-specific renewable systems, electrifed industry, cross-region grids • **Economy:** energy as a service technology winners/ oilgopolices • **Policy:** carbon takeback • **Everyday life:** flexible energy consumption a new routine • **Culture:** energy efficiency framed as a collective repsonsitility

Emergent niches



Shocks

Global supply chain disruption: economic shocks

Heatwave, droughts lead to crop failures, mass cattle die-offs

Local-global ownership conflicts; nationalist-private debates

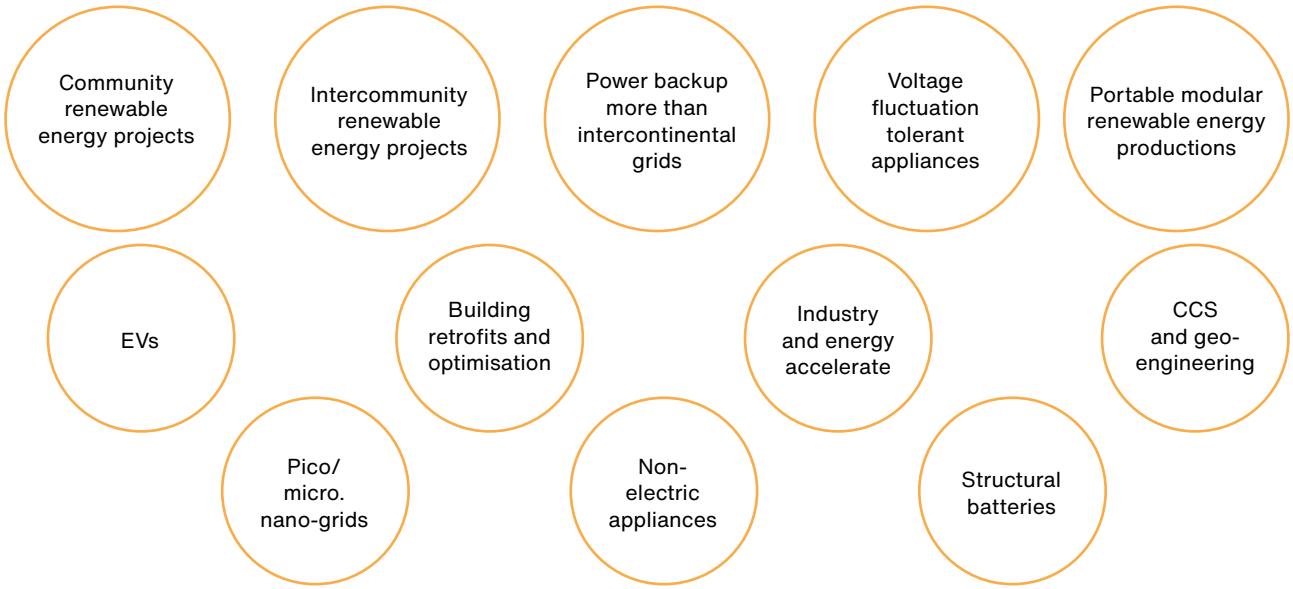
02 Hot House World

Energy system	2025	2035	2050
Social-technical system regime	**Survival first** Fossil fuel dominated energy mix with some renewable but the coalition of nation policy makers and large fossil fuel companies remains very influential	**Reconfiguration** Stepwise changes in system architecture through successive optimisation attempts	• **Tech:** end-of-pipe solutions dominate renewables remain a niche • **Economy:** carbon rush for markets • **Policy:** subs for CCS support for geoengineering • **Everyday life:** inequality, food stress • **Culture:** securitisation of energy provision
Emergent niches	Carbon capture, storage and utilisation Solar geo-engineering CCS and coal-fired power generation Specialised carbon storage enterprises Solar and heat pumps for cooling Off-grid as tech of defiance Direct air capture		
Shocks	Fisheries collapse: 1-in-100 year flooding	Conflict over Taiwan	Major global economic disruption

03 Disorderly Transition

Energy system	2025	2035	2050
Social-technical system regime	**DIY** Fossil fuel based energy production start to decay but state actions are not decisive enough to provide a sufficient boost to renewable; citizen cooperation steps in and fills the void	**De-alignment and re-alignment** Existing system starts to destabilise before niches have matured = high costs and stranded assets	• **Tech:** place-specific solutions optimised for transport and buildings • **Economy:** uneven development, inequality • **Policy:** international extractivisim continues **Everyday life:** 24 hour availability of electricity no assumed • **Culture:** energy-saving framed as individual responsibility

Emergent niches



Shocks

Multi-year droughts; crop failures

Violent extremist attacks on aid workers

1-in-100 year flooding in coastal areas & food stress

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