WORLD ENERGY COUNCIL

2025 GLOBAL ENERGY SCENARIOS COMPARISON REVIEW

Source: Unsplash, Susan Q Yin

ABOUT

WORLD ENERGY SCENARIOS

Scenarios are equally plausible but divergent stories of the future that serve as platforms for strategic conversations. While forecasts may try to project an “official future” built on the past, scenarios help leaders practice dealing with the unpredictable.

They are essential tools for navigating uncertainty - enabling energy leaders to explore choices, test assumptions, and make better-informed policy and strategy decisions.

The World Energy Council is committed to using scenarios to uncover opportunities for alignment and collaboration, supporting more equitable and inclusive energy additions and transitions.

WORLD ENERGY COUNCIL

The World Energy Council is the world’s oldest independent and impartial community of energy leaders and practitioners. Through our Humanising Energy vision, we involve more people and communities in accelerating clean and just energy transitions in all world regions. Formed in 1923, the Council has convened diverse interests from across the full energy ecosystem for a century and today has over 3,000 member organisations and a presence in nearly 100 countries. Our global network draws from governments, private and state corporations, academia and civil society, as well as current and future energy leaders. We effectively collaborate on impact programmes and inform local, regional and global energy agendas in support of our enduring mission: to promote the sustainable use and supply of energy for the benefit of all people.

Further details at www.worldenergy.org and on LinkedIn and Twitter.

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EXECUTIVE SUMMARY

The 2025 Global Energy Scenarios Comparison Review is not just a survey of futures methods and studies – it is a strategic lens into the unfolding realities of global energy for human development – i.e. energy additions and transitions. In a world shaped by compounding crises and rising fragmentation, scenario comparisons help leaders reveal and challenge assumptions, explore new possibilities and stress-test priorities under deep uncertainty.

This review synthesises insights from **13 leading global energy futures studies**, highlighting areas of convergence, divergence, and emerging blind spots. It goes beyond comparing models and methods to expose **six key insights** that matter now for making energy transitions happen.

WHAT WE'RE SEEING ACROSS THE 2024-2025 SCENARIO LANDSCAPE

- **Renewable power is rising faster than expected** – but not evenly. Pace and pathways vary significantly by region and sector.
- **Demand is becoming a disruptor.** AI, affordability, lifestyle shifts, and decentralisation are reshaping energy use in ways most models still underplay.
- **AI and digital infrastructure are missing from most outlooks.** Their impact on energy demand, grid design, and resilience will be profound – and poorly understood.
- **New dependencies threaten clean energy at scale momentum.** Critical mineral supply, tech access, and infrastructure constraints are the new battlegrounds of energy security.
- **Institutional trust and inclusion are underexamined.** Large scale systems change will fail without legitimacy. Yet few scenarios explore the social and governance risks of a more intermittent and fragmented energy future.

FROM INSIGHTS TO ACTION

This review offers tools to **activate insights**, not just absorb them. You'll find:

BREAKOUT BOXES highlighting demand shocks, Artificial Intelligence (AI) disruption, and fragile supply chains

ROLE-BASED ACTIVATION BRIEF guiding policymakers, CEOs, strategists, and regional leaders

INSIGHTS ACTIVATION TOOLKIT with reflection questions and decision-use prompts

ROCKS & RIVERS narrative archetypes to explore regionally grounded energy transformations i.e. additions and transitions logics

Use this review to explore big leadership questions and avoid being blindsided by relying on the ability to predict the future.

- How might modern energy societies better prepare for new energy security challenges - e.g. demand shocks, climate resilience, supply chain disruptions?
- What if tomorrow's advantage lies in trust – not technology?
- What are the Humanising Energy choices for a smart, rather than soft, energy system?

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INTRODUCTION

BACKGROUND AND OBJECTIVES

This report by the World Energy Council provides a comprehensive analysis and comparison of recent global energy scenarios produced by a diverse range of international organisations. The objective of this comparative review is to identify significant trends, divergences, and commonalities across these scenarios to enrich strategic thinking and inform decision-making in an increasingly uncertain global energy landscape.

In response to rapid changes and heightened global uncertainties, scenario analyses have become crucial for anticipating and navigating possible futures. By systematically examining and comparing scenarios and outlooks from various leading organisations, this report highlights critical insights, key areas of agreement, significant divergences, and emerging trends in global energy futures.

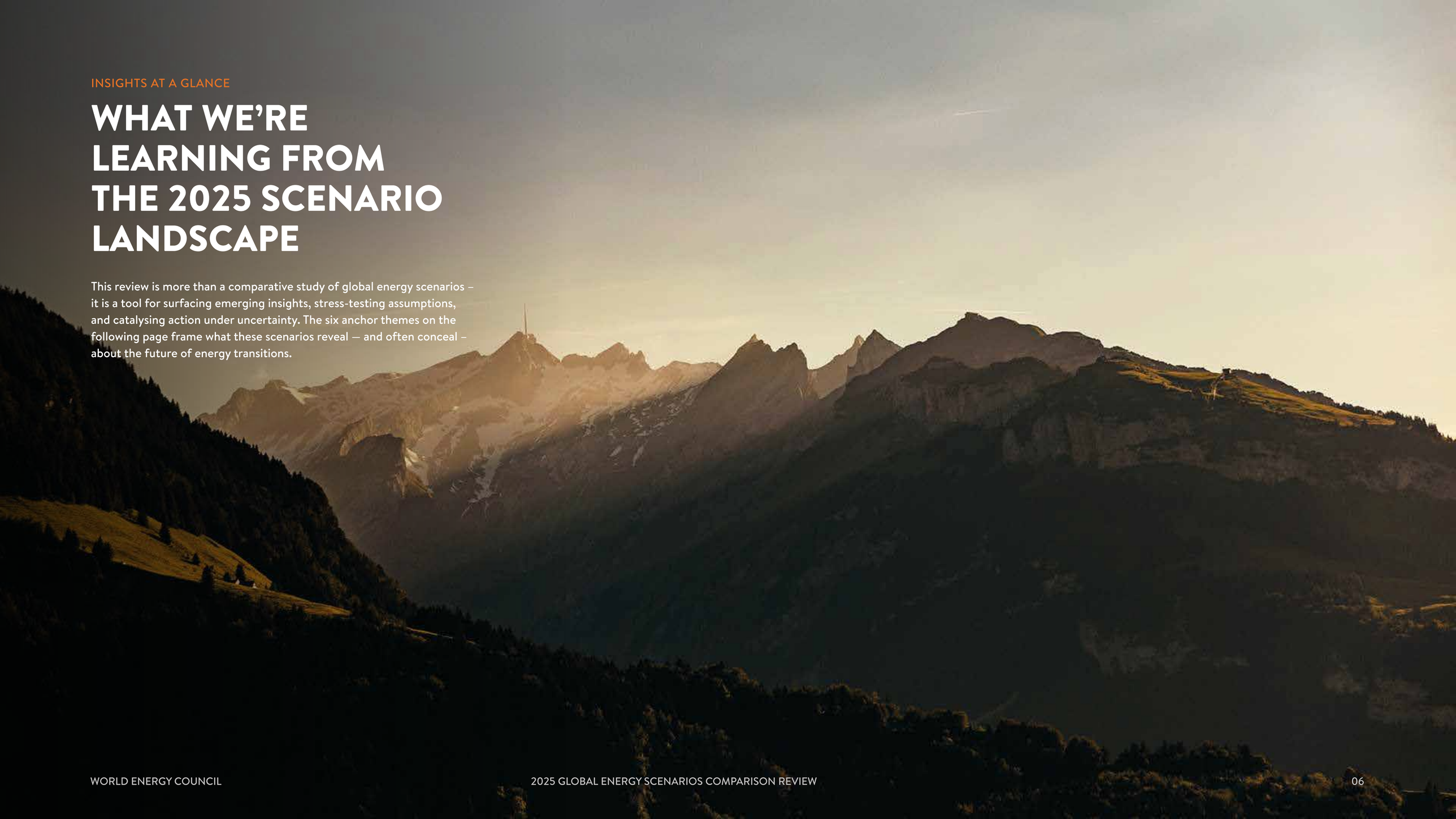
The findings from this comparison serve multiple purposes. Primarily, they validate and challenge the current understanding captured within the **World Energy Scenario Foundations: Rocks and Rivers,** ensuring their continued relevance and rigour. Additionally, this comparative analysis offers an impartial foundational framework from which stakeholders across sectors and regions can develop more detailed, customised scenarios tailored to their specific contexts and strategic needs.

Ultimately, the objective of this global scenarios comparison is to facilitate better-informed, collaborative dialogues among energy leaders worldwide. It supports stakeholders in proactively adapting strategies, exploring innovative pathways for energy transitions, and seizing opportunities for cooperation that can contribute to sustainable, resilient, and inclusive global energy systems.

INSIGHTS AT A GLANCE

WHAT WE'RE LEARNING FROM THE 2025 SCENARIO LANDSCAPE

This review is more than a comparative study of global energy scenarios – it is a tool for surfacing emerging insights, stress-testing assumptions, and catalysing action under uncertainty. The six anchor themes on the following page frame what these scenarios reveal — and often conceal – about the future of energy transitions.



ONE

FRICTION OVER SPEED: IS THE TRANSITION FAST ENOUGH – OR TOO FAST FOR STABILITY?

Despite growing ambition in many scenarios, implementation timelines are uneven, especially across developing regions. The speed of change is colliding with system inertia, equity concerns, and political volatility.

Insight Activation

Are your expectations of scale-up pace grounded in delivery capability – not just technology potential?

THREE

THE RISE OF MULTIPOLAR AND MULTI-SPEED ADDITIONS AND TRANSITIONS PATHWAYS

Fragmentation is a consistent theme. Instead of a single global trajectory, we are entering a world of multiple, sometimes incompatible, transition pathways shaped by regional priorities, values, and capabilities.

Insight Activation

How does your strategy adapt to a future where alignment is partial and plural, not global and unified?

FIVE

CLEAN TECH DEPENDENCIES ARE THE NEW ENERGY SECURITY FRONTIER

While fossil fuel geopolitics is well-covered, many scenarios underplay new dependencies – minerals, supply chains, IP control – that could derail clean tech rollout or create new vulnerabilities.

Insight Activation

Are you actively stress-testing your strategy for green supply chain risks and chokepoints?

TWO

DEMAND IS NO LONGER PASSIVE

Most scenario sets treat demand as a derivative of economic growth. But real-world shifts in consumer behaviour, affordability, AI, and distributed solutions are disrupting traditional patterns.

Insight Activation

What assumptions about energy demand are at highest risk of being wrong in your country or sector?

FOUR

AI, DATA, AND DIGITAL INFRASTRUCTURE AS EMERGING ENERGY ACTORS

Only a few scenarios explore the energy implications of AI, digitalisation, and data centres. Yet their impact on demand growth, grid design, and resilience is already unfolding.

Insight Activation

Are energy models in your organisation treating AI as a marginal force – or a structural gamechanger?

SIX

LEADERSHIP LEGITIMACY WILL SHAPE ENERGY TRANSFORMATION OUTCOMES

Whole systems changes depend not just on policy but on trust, inclusion, and institutional legitimacy. Few scenarios consider how contested narratives, social divides, or governance gaps may delay, disrupt and derail pathways.

Insight Activation

What mechanisms are in place to ensure your transition plans are perceived as fair, inclusive, and future-fit?

SCENARIO PRACTICE

Scenario practice encompasses a rich diversity of methods, tailored to context, purpose, and resources. There is no single “correct” way to explore possible futures – different methods serve different strategic needs.

Scenario thinking differs fundamentally from outlooks, forecasts and projections. Outlooks, forecasts and projections typically assume a relatively predictable future, relying heavily on historical data and trends extrapolated forward. In contrast, scenarios embrace uncertainty, explicitly exploring diverse plausible futures without predicting any given one, to support more resilient and adaptive decision-making under deep uncertainty.

The World Energy Council’s latest comparison of a global peer group of published energy outlooks and sets of scenarios provides a refreshing starting point for exercising better quality leadership judgement in a context of shifting geopolitics, climate and social risks, and regional divergence.

The World Energy Council remains committed to using scenarios to surface shared challenges and enable alignment, supporting more collaborative and equitable energy additions and transitions.

This diversity of approach is critical given today’s increasingly fragmented and contested global energy landscape.

CHOOSING WISELY AMIDST DISRUPTIONS

Energy system additions and transitions do not occur in a vacuum – context matters. The risk of disorderly world energy developments is growing as multiple and diverse regional visions and technology pathways unfold.

Whilst the global goal of a net-zero emissions energy system by 2050 is broadly shared, there is no such thing as THE global energy system nor a silver or green technology bullet. Single issues agendas and one-size-fits-all policy prescriptions have proven to be recipes for disaster and derailment. No country, company, or community can manage to change a whole world energy system alone. Securing energy for billions of lives and a healthy planet involves complex coordination challenges. This presents a so-called ‘wicked problem’ in terms of energy policy making. Despite the increasing availability of data, the exercise of better quality leadership judgement depends on dialogue and decision making in an era of non-linear and disruptive innovation can’t rely on technology forecasting alone.

So we must ask:

- Are global energy scenarios fulfilling their potential to catalyse action?
- What can we learn from comparing the Council’s Foundations with the diverse energy futures published by others?

This review distils insights from leading global energy scenarios – Exploratory Scenarios, Outlook/Projection, and Normative Scenarios – and invites ongoing dialogue on enhancing their practical impact. It encourages broader engagement on how scenarios can be more actively integrated into strategic decision-making, policy development, and collaborative action to navigate uncertainty.

Table 1 – Three Global Energy "Scenarios" Approaches

OUTLOOKS	EXPLORATIVE SCENARIOS	NORMATIVE SCENARIOS
Data rich projections – **the future we expect/assume** on a business-as-usual projection of current trends	Plausible pathways of alternative futures contexts that **might happen** whether we want them or not	Technically possible and **preferable future towards a target**
Quantitative led	**Qualitative based – narrative-led**, supported with **illustrative numbers**	Focus on achieving a **specific goal** aligned to a global vision agenda
Focus on **techno-economical elements**	Explicit about **societal and political elements** in addition to techno-economic elements	**Values and identity-based approach**
Provide a **sensitivity analysis & enable cost-benefit analysis** for decision makers to compliment the baseline projection with new policies	Provide a **clear and enabling pre-decision framework** for leaders to engage with uncertainty	Generated by starting from a clear **objective/target** and back-casting to identify the pathway for making progress (i.e. road mapping)
FACTS **A model** ↓ Conditional projection of the expected future ↓ Upper/ best case · Reference/ baseline · Lower/ worse case	ASSUMPTIONS **Stories** ↓ Futures already emerging whether we want them or not ↑ ↑ ↑ Plausible future · Plausible future · Plausible future	CAPABILITIES & VALUES **Organisation/System today** ↓ What has to be done to close the gap and achieve specific goals? ↑ [GAP] ↓ Preferable future · Business as usual

The following criteria have been used to select a benchmarkable set of global energy 'scenarios' for comparison:

- Breadth of **input parameters** used
- **Scope:** representing the global energy system
- **Geographical focus:** global scenario sets beyond any single regional focus
- **Minimum time horizon:** ending no earlier than 2050
- **Quantification and illustrative numbers:** no limitation to models used
- **Release date:** recent reports published no earlier than 2022

This resulted in a peer group of 13 sets, as listed in Table 2.

Table 2 – Peer Group for Comparison Review

	OUTLOOKS	EXPLORATIVE SCENARIOS	NORMATIVE SCENARIOS
World Energy Council Scenario Foundations (2024)		Rocks Rivers	
Bloomberg NEF New Energy Outlook (2024)	Economic Transition Scenario		Net Zero Scenario (1.75°C)
BP Energy Outlook (2024)	Current Trajectory		Net Zero
DNV Energy Transition Outlook (2024)	Base Scenario		1.5°C Scenario
EIA International Energy Outlook (2023)	Reference Case		
Enerdata Global Energy Scenarios (2024)	EnerBase EnerBlue		EnerGreen
Equinor Energy Perspectives (2024)		Walls	Bridges
IEA World Energy Outlook (2024)	Stated Policies Scenario (STEPS) Announced Pledges Scenario (APS)		Net-Zero Emissions (NZE)
IEEJ Outlook (2024)	Reference Scenario	Advanced Technology Scenario	
IRENA World Energy Transitions Outlook (2023)			1.5°C Scenario (1.5C)
OPEC World Oil Outlook (2024)	Reference Case	Technology-Driven Equitable Growth	
Shell Energy Security Scenarios (2025)		Archipelagos Surge	Horizon
TotalEnergies Energy Outlook (2023)	Momentum		Rupture

Insight Gap: Demand-Side Disruptions Are Underplayed
Most scenario sets still treat energy demand as a derivative of economic growth, overlooking the complex shifts underway in behaviour, digitalisation, distributed energy solutions, and affordability concerns. This limits foresight on non-linear demand shocks and user-led transitions.

Insight Activation

- Where are bottom-up shifts (e.g. prosumers, lifestyle changes, AI-driven energy efficiency) already disrupting demand assumptions in your context?
- How are national or corporate energy models adjusting — or not — to account for these changes?

CHAPTER ONE

GLOBAL SCENARIOS COMPARISON

Recent trends of significance for energy scenario development and comparison.

1. GLOBAL AND REGIONAL CRISES

Recent years have seen two major dips in global energy demand—during the 2008 financial crisis and the 2020 Covid-19 lockdowns. Yet **the long-term trend remains upward,** driven largely by rising demand in Asia, particularly China and India, which continues to outweigh efficiency gains elsewhere.

The energy crisis triggered by Russia's invasion of Ukraine had mostly **regional effects,** sparking price spikes, supply fears, and a deep reassessment of Europe's energy security. Although the impact beyond Europe was limited, the crisis refocused global attention on **independence and resilience over lowest-cost supply.**

Ongoing tensions in the Middle East, particularly around critical oil-producing regions, pose persistent risks to **global energy trade and supply chains.** Perceived threats trigger speculative trading and infrastructure bottlenecks – reminding scenarios to stress-test exposure to geopolitical shocks.

2. NEW POCKETS OF POWER AND INFLUENCE ARE EMERGING

The expansion of BRICS into BRICS+ marks a **structural shift in global influence.** As of 2025, BRICS+ represents nearly half of the world's population and surpasses the G7 in purchasing power.

From an energy lens, BRICS+ includes both major fossil exporters and key transition resource holders (minerals, hydrogen). But **internal diversity in priorities** – between growth, security, and climate – could make coordinated decarbonisation harder. This multipolar dynamic is increasingly reflected in **scenario fragmentation and divergence in pathways.**

3. DOMESTIC INDUSTRIAL POLICIES – RIPPLE EFFECTS

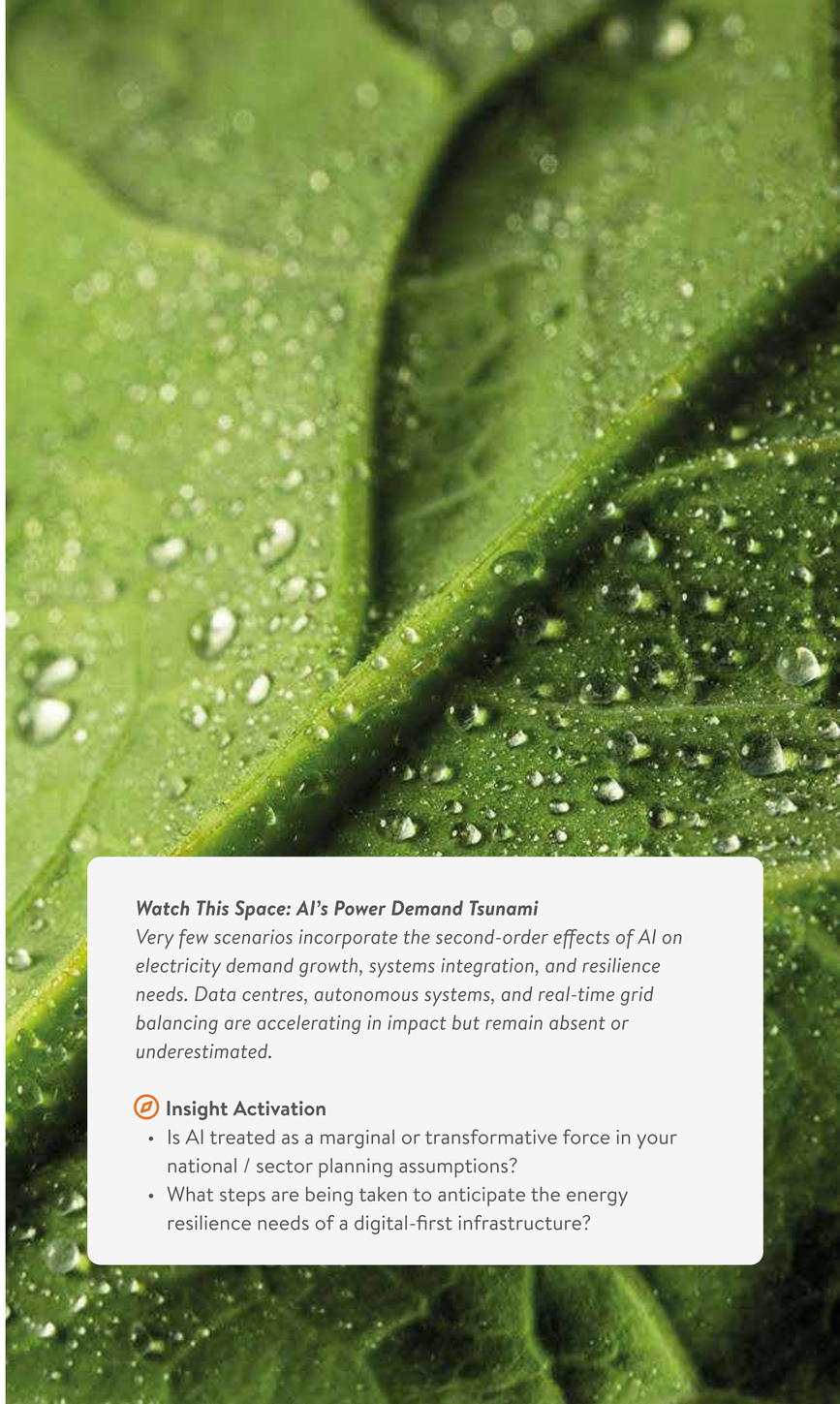
The U.S. Inflation Reduction Act (IRA) and the European Green Deal initially outlined clear pathways toward renewable energy and decarbonization, shaping global investment flows. Recent shifts under the new U.S. administration, however, have reintroduced uncertainties, complicating U.S. participation in these pathways, while other nations, including China, Australia, and Canada, reaffirm their commitments.

Still, **industrial strategy remains a powerful transition lever.** The interplay of U.S., Chinese, and EU policies is producing ripple effects far beyond national borders – impacting supply chains, innovation cycles, and energy scenario assumptions across the world.

4. ARTIFICIAL INTELLIGENCE, HYPERSCALERS, AND THE POWER DEMAND TSUNAMI

A new disruptor is emerging: **explosive electricity demand from AI and hyperscale data centres.** Generative AI, digitalisation, and automation are rapidly increasing baseload consumption, particularly in the U.S., China, and parts of Europe.

Hyperscalers are no longer just consumers – they're becoming **strategic actors** in power procurement and grid design. Yet few scenarios have adequately modelled this surge. Forecasts suggest AI-driven power demand could **more than double** by 2030, posing major questions about system reliability, affordability, and resilience.



Watch This Space: AI's Power Demand Tsunami

Very few scenarios incorporate the second-order effects of AI on electricity demand growth, systems integration, and resilience needs. Data centres, autonomous systems, and real-time grid balancing are accelerating in impact but remain absent or underestimated.

Insight Activation

- Is AI treated as a marginal or transformative force in your national / sector planning assumptions?
- What steps are being taken to anticipate the energy resilience needs of a digital-first infrastructure?

WORLD ENERGY COUNCIL SCENARIO FOUNDATIONS

ROCKS AND RIVERS

The Rocks and Rivers scenario foundations explore alternative, plausible futures as opposed to forecasted outlooks or normative scenarios that reflect specific values or preferred outcomes.

While these scenarios include associated quantitative analysis, the numbers are not the most important focus. The quantitative metrics are only intended to demonstrate the plausibility of the scenarios and to illustrate how far these scenarios are from meeting normative targets.

The important, distinctive characteristics of Rocks and Rivers are their qualitative storylines that help explore the critical uncertainties and their impact, specifically around different modes of cooperation in an ever-increasing fragmented world.

Find out more here: 2024 World Energy Scenario Foundations: Rocks and Rivers

Table 4 – Summary Characteristics of the Rocks and Rivers Scenario Foundations

	ROCKS	RIVERS
Geopolitics	Blocs	Shifting alliances
Trade	Blocs with leaky barriers	International in principle, but with security carve-outs
Energy Systems	A long tail of fossil fuel use with deep electrification and decarbonization in some blocs	Turbulent but swift fossil fuel substitution (electricity, hydrogen, biofuels) and cross-border connections enabled by technology
Agents of change	Mission-oriented governments energy leaders collaborating to design policy for national interests	Entrepreneurs, CEOs, policymakers, and consumers with aligned emerging interests
Modes of cooperation	Policy convergence and deliberate collaborations among like-minded powerful actors with common interests; community collaborations at multiple levels	Emerging alignments driven by common pressures, market opportunities, and innovation

OVERVIEW

ROCKS

Rocks represent structural constraints and inertia in energy systems – such as geopolitical tensions, legacy infrastructure, and vested interests – that can slow or reshape transitions. In this world, global climate ambitions face rising pressures from national self-interest, leading to policy fragmentation and delayed fossil fuel phase-outs.

Nationally Determined Contributions (NDCs) fall short, with subsidies often reinforcing populist and protectionist agendas. Cleaner technologies struggle to scale as technology transfer and collaboration fragment. Wealthier nations prioritize energy security, while less-resourced regions rely on higher-emission pathways, deepening global inequality.

Collective action emerges mainly through transactional alliances among “actors like us” – nation-states or businesses sharing narrow, short-term interests. Energy transitions persist in pockets where they serve domestic agendas, but the broader vision of shared global progress fades.

Rocks aligns closely with Shell Archipelagos, IEEJ Reference, and to some extent, BP’s Current Trajectory scenarios marked by slow innovation, high emissions, and limited global coordination.

Insight Activation

If your region is moving in a Rocks-like direction, what trade-offs between industrial competitiveness and decarbonisation are emerging in your national debate?

OVERVIEW

RIVERS

Rivers symbolizes dynamic change led by digitalisation, innovation, shifting consumer behaviours, and evolving supply chains. While geopolitical “rocks” still exist, they are increasingly bypassed by powerful market currents and new alliance.

In Rivers, powerful currents flow over and around the “Rocks” that still emerge, for example in the geopolitical arena. These currents prove more significant in shaping the future energy landscape.

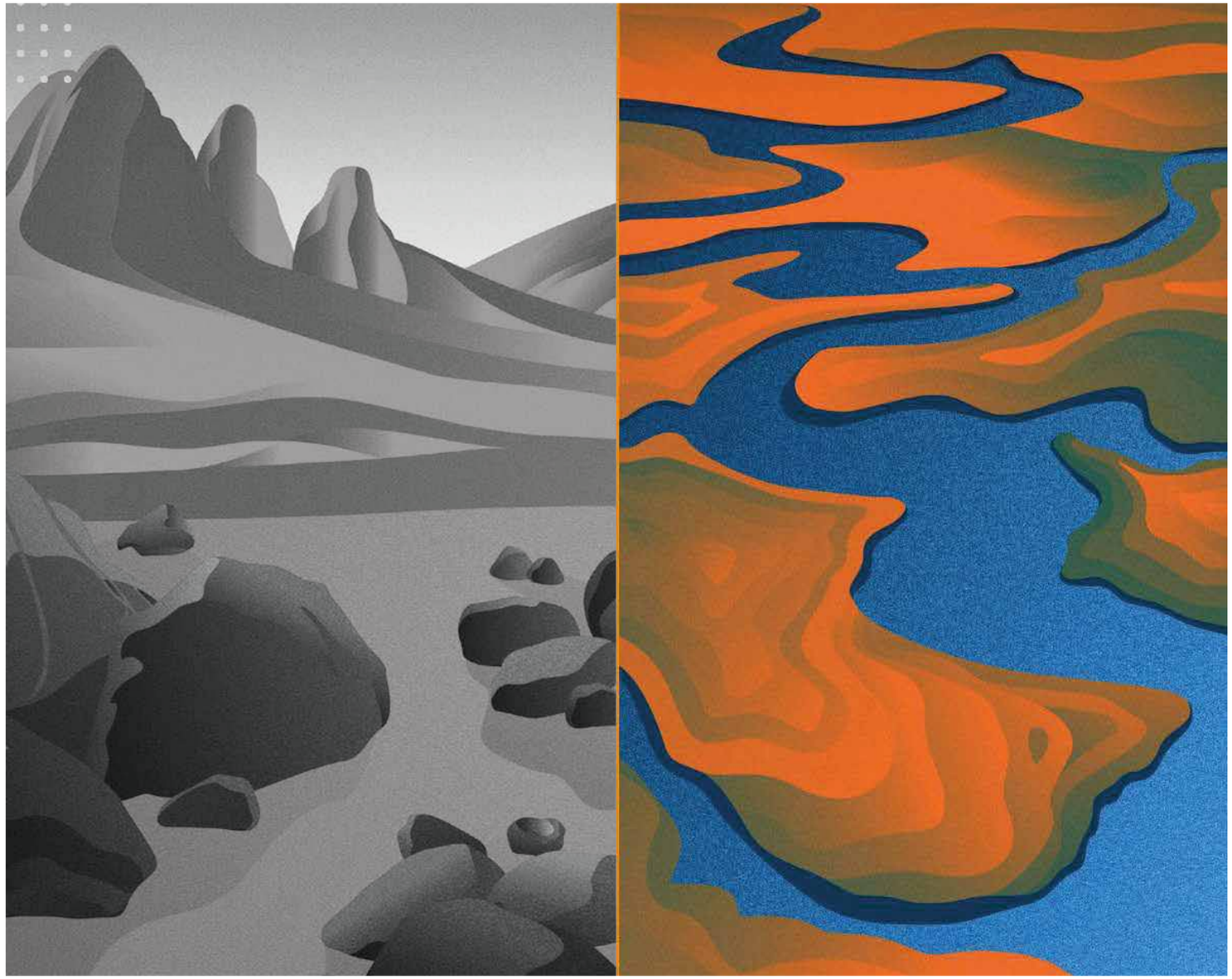
Technological advances, digital transparency, and consumer-driven shifts reshape both demand and supply. Innovation moves in bursts, rewarding actors who align early with emerging opportunities. Instead of top-down coordination, new forms of cooperation arise – from citizen movements to carbon clubs and private-sector-led coalitions.

The prevailing ethos is longer-term and more collective, shaped by “actors with us” rather than “like us.” In wealthier economies, demand-side signals (e.g. consumer standards) accelerate action; in developing regions, local innovation and targeted investment in grid and renewables infrastructure drive transformation.

Rivers echoes scenarios like IEEJ Advanced Technology, Shell Horizon, and IEA APS – though with greater emphasis on societal dynamics and non-state actors as levers of change.

Insight Activation

If your region is moving in a Rivers-like direction, what tipping points could trigger acceleration – or regression – in your national or regional energy transition?



HOW DO ROCKS AND RIVERS COMPARE WITH THE PEER GROUP?

Rocks and Rivers explore broader societal and geopolitical dynamics than many peer scenarios, framing energy transitions through the lens of governance, institutional trust, and the shifting balance between cooperation and self-interest.

Rocks describes a fragmented world where national self-interest, geopolitical tensions, and legacy infrastructure delay transitions. It aligns with Shell Archipelagos, IEEJ Reference, and Equinor Walls scenarios that feature state-driven, slower-moving systems with patchy innovation and high emissions.

Rivers, in contrast, envisions a fluid, adaptive world shaped by market-driven innovation, digitalisation, and evolving social norms. It mirrors aspects of Shell Horizon, IEEJ Advanced Technology, IEA APS, and Enerdata EnerBlue, which show faster innovation, bottom-up cooperation, and more dynamic policy responses – though not always a clear path to net-zero.

Normative scenarios like IEA NZE, Equinor Bridges, and Shell Horizon go further, combining strong global cooperation, structured long-term policies, and deep decarbonisation aligned with Paris targets. Rivers shares some features with these – but driven more by emergent alignment than centralised planning.

Compared to many peer models focused primarily on techno-economic forces, Rocks and Rivers bring in the deeper layers of social transformation, trust, and institutional change, making them powerful tools for stress-testing regional strategies.

The geopolitical shifts since February 2025 highlight the need for adaptive frameworks and regionally responsive approaches. While the scenario sets reviewed remain fundamentally insightful, some elements require reframing to stay contextually relevant. The Council's Rocks and Rivers scenario foundations emerge notably robust and relevant due to the flexible narrative structure that already anticipates geopolitical volatility.

Join the Conversation at the World Energy Congress 2026

The Council will continue evolving its scenario foundations and insights with Member Committees, partners, and communities worldwide. Your feedback, applications, and provocations are essential to shaping the next wave of shared foresight.

Find out more: World Energy Congress 2026 Website

IMPORTANT TAKE AWAYS FROM REVIEWING THE LANDSCAPE OF SCENARIOS

GENERAL OBSERVATIONS

Despite their differences, the scenarios reviewed share deep commonalities when viewed through a techno-economic lens. Across nearly all pathways, **five core building blocks of energy transition consistently emerge:**

ONE

Significant improvements in energy efficiency across the economy, reducing overall demand growth even as services expand.

TWO

Massive scaling of renewable energy, especially solar and wind, as primary energy sources displace fossil fuels.

THREE

Widespread electrification of end-use sectors, with electricity rising from around one-fifth to well over half of final energy consumption.

FOUR

Continued use of liquid and gaseous fuels where electrification is impractical – such as in aviation, shipping, or heavy industry – paired with a shift from fossil fuels to net-zero-compatible fuels like sustainable biofuels, hydrogen, and synthetic fuels.

FIVE

Carbon dioxide removal, using both natural sinks (e.g. reforestation) and technological solutions (e.g. carbon capture and storage), to neutralize residual emissions and support net-zero goals.

These five transition blocks are remarkably consistent across global scenarios. However, **how they come together in practice varies greatly by context** – depending on regional resources, policy frameworks, institutional capacity, and public preferences. Technical differences also emerge between scenarios, such as the expected role of nuclear power or sector specific pathways such as decarbonisation of maritime fuels or other hard-to-abate industries. However, the foundational pillars remain stable.

The time dimension is the most important difference across the scenarios how quickly transition technologies can be deployed at sufficient scale to reduce emissions – ultimately determining whether the world reaches net-zero by 2050, 2070, 2100, or later. This uncertainty has enormous consequences for global warming and climate volatility.

What shapes the pace of change is not only technical capability, but human behaviour – expressed through decisions at international, national, community, and individual levels. Most critically, it depends on how self-interest is perceived and how quickly actors align around shared goals.

Once key stars align, competitive dynamics in business and policy can trigger tipping points – propelling progress far faster than anticipated. The open question is: *will those stars align soon enough?*

Exploring these dynamics is central to the Rocks and Rivers narratives. They offer valuable lenses for navigating uncertainty and shaping strategic decisions in real time.

AFRICA AND THE FIVE TRANSITION BUILDING BLOCKS

Africa's energy transition is characterized by a dual imperative: **expanding access** to modern energy while **pursuing climate-aligned growth.** Unlike other regions, the transition here is not about substitution, but additions, **building from low baselines** -with over 600 million people still lacking electricity access and many reliant on traditional biomass.

While Africa shares the same five building blocks of global transition, their application looks different:

- **Efficiency** is about leapfrogging inefficient systems entirely through distributed renewables and smarter planning.
- **Renewables** offer immense potential – especially solar and wind – but require investment in grids, financing, and local capabilities to scale.
- **Electrification** focuses first on **access and affordability,** with decentralized solutions (like mini-grids) playing a central role.
- **Fuels** include **natural gas as a pragmatic bridge** – supporting industrialization and reliability where renewables are not yet viable.
- **Carbon removal** is more about protecting and enhancing natural sinks, while also navigating land-use trade-offs with development needs.

Africa also holds strategic assets for the global transition, including critical minerals and a **young, growing workforce.** But realizing this potential hinges on closing infrastructure and financing gaps – and aligning energy policy with broader goals like health, education, and economic empowerment.

SOUTHEAST ASIA'S ENERGY TRANSITION CROSSROADS

Southeast Asia sits at the crossroads of development, energy security, and climate ambition. With growing energy demand and continued reliance on coal, the region's emissions are still rising. Yet, momentum is building toward cleaner systems – driven by falling technology costs, external financing, and growing public pressure.

While the five global transition blocks apply, the regional emphasis differs:

- **Efficiency** efforts are often linked to grid modernisation, building standards, and managing growing urban demand.
- **Renewables** are gaining ground, especially in Vietnam, Indonesia, and the Philippines – but grid integration and fossil subsidies remain major hurdles.
- **Electrification** focuses on urban transport and industrial clusters, with rising interest in electric vehicles and heat pumps.
- **Fuels** include a transitional role for gas and emerging discussions on ammonia and hydrogen for power and industry.
- **Carbon removal** leans heavily on **nature-based solutions** (e.g., forest and peatland protection), with limited current deployment of engineered removals.

The region's success will hinge on balancing energy access, affordability, and emissions reduction – requiring stronger regional collaboration, reforms to fossil fuel subsidies, and scalable financing for clean energy deployment.

REFLECTIONS ON SIMILARITIES

Energy efficiency is a consistent priority, with nearly all scenarios identifying it as a low-cost decarbonization lever. Substantial gains are expected through structural improvements — such as integrated urban planning and multi-modal transport systems. Several scenarios, including Shell Horizon, EnerGreen, and IEA APS, also emphasize consumer behaviour change as critical to reducing demand.

There is strong consensus around the **rapid scaling of renewables** – especially solar and wind – alongside growing electrification in transport, heating, and industry. EnerGreen, IEA APS, and Shell Horizon envision a future where renewables make up a substantial share of the energy mix, displacing fossil fuels over time. However, many scenarios retain a role for natural gas and other fossil fuels during the transition – particularly where paired with carbon capture, including EnerBlue and IEA STEPS.

Unspoken Risk: Fragile Green Supply Chains

While scenarios assume large-scale clean tech deployment, few fully grapple with the fragility of mineral supply chains, uneven access to finance, or new geopolitical dependencies. These risks could delay or distort transitions.

Insight Activation

- Which supply-side risks (e.g. critical minerals, component availability) are most likely to derail transition timelines in your region?
- Are you testing your plans against trade or technology chokepoints?

Most scenarios assume some level of **government intervention and international** cooperation in driving energy transitions and meeting climate targets. In Shell Horizon, Equinor Bridges, IEA APS, global agreements and policy incentives catalyse change – such as carbon pricing or innovation subsidies.

Diversifying the energy mix is another recurring theme. Scenarios like Shell Horizon, Equinor Bridges, and Rocks and Rivers feature **alternative energy carriers,** such as green hydrogen and synthetic fuels, particularly for hard-to-abate sectors.

Technological breakthroughs are pivotal to all scenarios. Shell Horizon and EnerGreen highlight the importance of early-stage technologies becoming scalable and commercially viable with the right level of government and private sector investment. IEA APS and Equinor Bridges see digitalisation as a tool to drive efficiency and optimise systems.

All scenarios anticipate **shifting power dynamics.** Traditional fossil fuel incumbents face disruption from renewable energy firms, tech startups, and decentralized energy providers. In Shell Horizon, Equinor Bridges, and EnerGreen, clean energy players dominate the future market.

Regional dynamics also shape scenario outcomes. Shell Archipelagos and Rocks emphasize localised, resilient systems, while Shell Horizon and EnerGreen imagine globally integrated energy networks.

Finally, while Outlooks and Explorative scenarios – like EnerBlue, IEA STEPS, and Shell Archipelagos – retain fossil fuels deeper into the transition, Normative scenarios – like Shell Horizon, EnerGreen, and Equinor Bridges – envision a more decisive phase-out. Whether fossil fuels are abated with CCS or replaced altogether depends on policy ambition, technology uptake, and regional preferences.

WHAT KEY DEVELOPMENTS OR ASPECTS ARE UNDER-EXPLORED?

FUTURE SHIFTS IN DEMAND

Most scenarios assume rising demand driven by population growth, economic development, and industrial activity – especially in developing regions. While electrification of transport, buildings, and industry is common in normative scenarios, many scenarios overlook the impact of demand-side measures like energy efficiency, integrated urban planning, and behavioural shifts. For instance, exploring lifestyle changes or circular economy models' impact on demand remains underexplored. Additionally, few scenarios address peak demand and its implications for grid stability.

GEOPOLITICAL INSTABILITY

Some Outlooks and Explorative scenarios, particularly Shell Archipelagos and IEA APS, touch on energy security and resource nationalism, but geopolitical instability – from trade wars to resource nationalization – remains insufficiently explored. The recent disruption of natural gas supply from Russia to Europe exemplifies how geopolitical events can disrupt energy trade. Moreover, geopolitical tensions around critical minerals like lithium and cobalt are not adequately addressed. Rarely factored in are geopolitical tensions arising from land-use conflicts over renewable energy deployment or resource scarcity (e.g., fresh water for hydrogen production).

THE SHIFT FROM ENERGY STOCKS TO FLOWS

The nature of energy trade will be impacted by the shift from fossil fuels to renewable energy and electricity. Historically, global energy distribution channels facilitated the trading of oil measured as stocks and barrels. These channels are likely to be supplanted by regional distribution networks that directly export energy as electricity flows, reshaping the nature of global and regional supply chains and energy infrastructure. Shifting from stocks to flows will redraw the geopolitical landscape as global energy interests become geographically localised. Here, fossil-fuel rich countries would lose their global importance and give way to emerging, regional powerhouses that export energy flows instead.

ENERGY SUPPLY CHAIN VULNERABILITIES

Energy supply chains are critical but underexplored in many scenarios. Dependencies on rare earth materials for renewable technologies (e.g., wind, solar, batteries) pose a strategic vulnerability, particularly given the concentration of these resources in specific regions like China. Few scenarios, like IEA APS, hint at these supply bottlenecks, which could disrupt the pace of energy transitions.

THE MATERIALITY OF RENEWABLES AT SCALE

Scaling up renewable energy requires massive material inputs – yet few scenarios address the material demands of scaling renewables at a global level. Sectors like steel, ammonia, and cement face significant energy needs that are insufficiently quantified. Furthermore, the environmental impacts – such as the mining for critical materials (lithium, cobalt) or large-scale land-use changes for renewables – are often overlooked. In particular, the impact of renewables on biodiversity and local communities is often ignored.

PLANETARY BOUNDARIES

Many normative scenarios prioritize CO2 reductions without considering broader planetary boundaries (e.g., water use, biodiversity loss). The trade-offs between decarbonization and ecosystem impacts, such as land-use change for solar farms or the water footprint of hydrogen production, are underexplored. Water stress in regions already facing shortages is another critical issue not sufficiently modelled. The interconnectedness of energy and water systems is critical but largely overlooked in many scenarios.

FUTURE COLLABORATION DYNAMICS

Most scenarios assume varying degrees of global cooperation, but rarely explore the complexities and frictions involved. For example, permitting delays, challenges integrating energy with sectors like transport or agriculture, lack of social acceptance of large-scale infrastructure projects and policy misalignments are often overlooked. The role of new collaborative models, such as regional energy hubs, public-private partnerships, and citizen-driven energy cooperatives, is insufficiently examined. Additionally, Scenarios often overlook how competition can rapidly accelerate change once a front-runner gains traction.

CLIMATE ADAPTATION AND RESILIENCE

While many scenarios focus on mitigation, the need for climate adaptation strategies is often sidelined. There is an increasing need for strategies that address resilience to climate impacts and disruptions to energy systems.

SOCIOECONOMIC SHIFTS

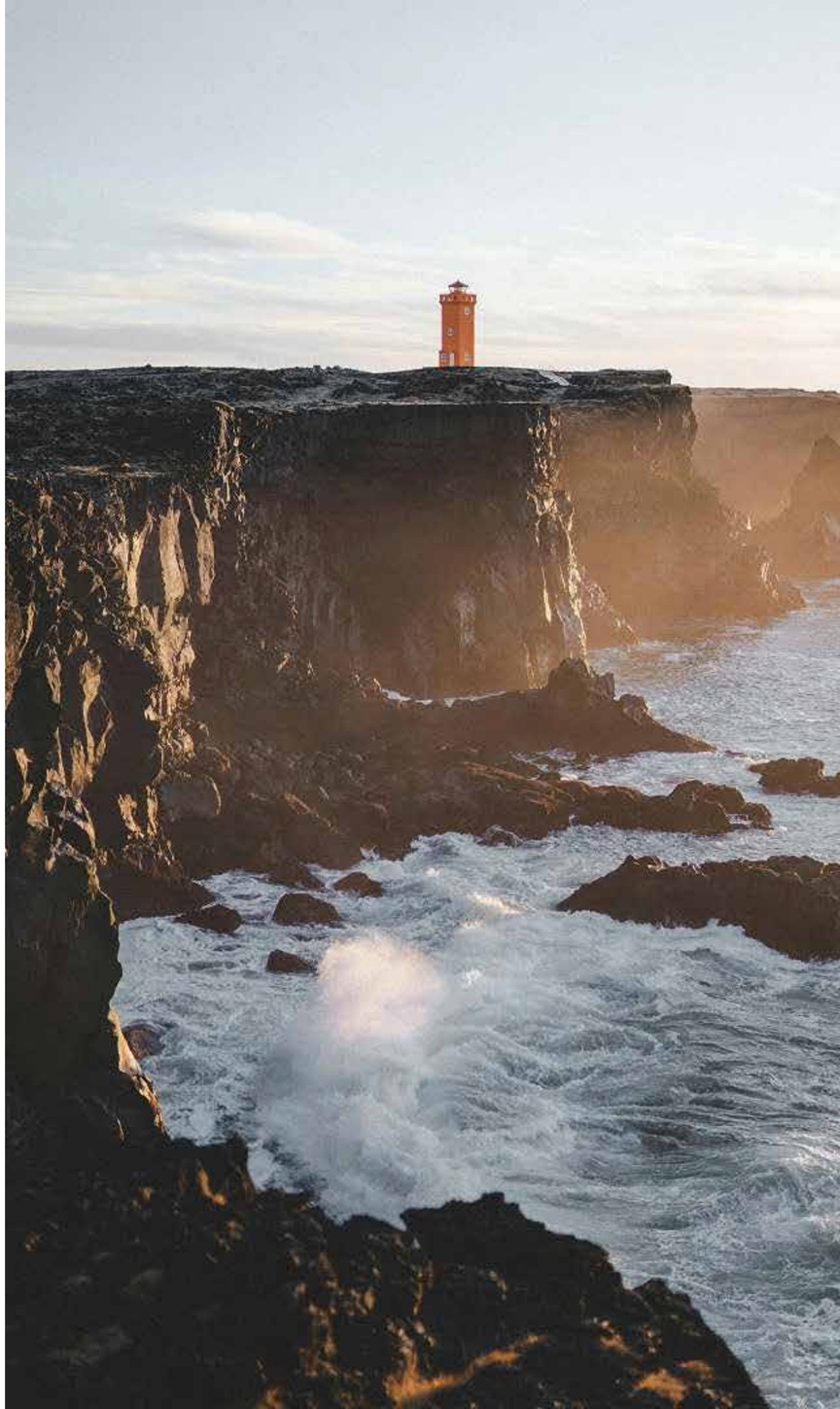
Remote work, AI, and urbanization are underexplored shifts that could significantly alter energy demand patterns. Scenarios like Shell Surge factor in AI-driven growth, but many, like IEA APS, do not fully explore the implications of lifestyle changes, digital transformation, or new work patterns on energy use.

SOCIAL EQUITY IN THE ENERGY TRANSITION

Energy equity is often sidelined in most scenarios. While IEA STEPS and EnerBlue focus on decarbonization pathways, they fail to address unequal access to energy and the impact on low-income and vulnerable populations. With millions still lacking access to modern energy, ensuring that transitions are inclusive and fair is vital, but largely neglected in many models.

Insight Activation

Which of these blind spots is most likely to derail your transition strategy if left unexamined? How are you incorporating non-technical disruptors – like trust, equity, water stress, or geopolitical friction – into your scenario planning and risk assessments?



CHAPTER TWO

KEY NUMBERS

SUMMARY OF KEY TAKE AWAYS

Total energy demand shows significant divergence across scenarios. Despite efficiency gains and electrification, most outlooks and explorative scenarios show continued growth in total energy demand – albeit at a slower pace than in past decades – driven primarily by population growth and economic expansion in emerging markets. In contrast, most normative scenarios envision a sharp decline in demand, enabled by ambitious energy efficiency improvements and systemic electrification.

Sharp growth in **electricity generation** is a consistent feature across all scenarios and outlooks. This is driven by rapid electrification across transport, industry, infrastructure and buildings. Both Rivers and Shell Archipelagos indicate a threefold increase in electricity demand, aligning with the most ambitious normative scenarios.

The future **energy mix** will remain diverse, but the pace of transition away from fossil fuels varies widely. Outlooks diverge on the scale and speed of change, reflecting different assumptions about technological progress, policy ambition, and geopolitical dynamics.

Oil consumption is expected to decline, though gradually. The trajectory reflects a complex balance between electrification, emerging decarbonisation policies, and enduring energy security concerns. Its role as a transitional fuel in certain sectors and regions means its decline will be uneven and contested.

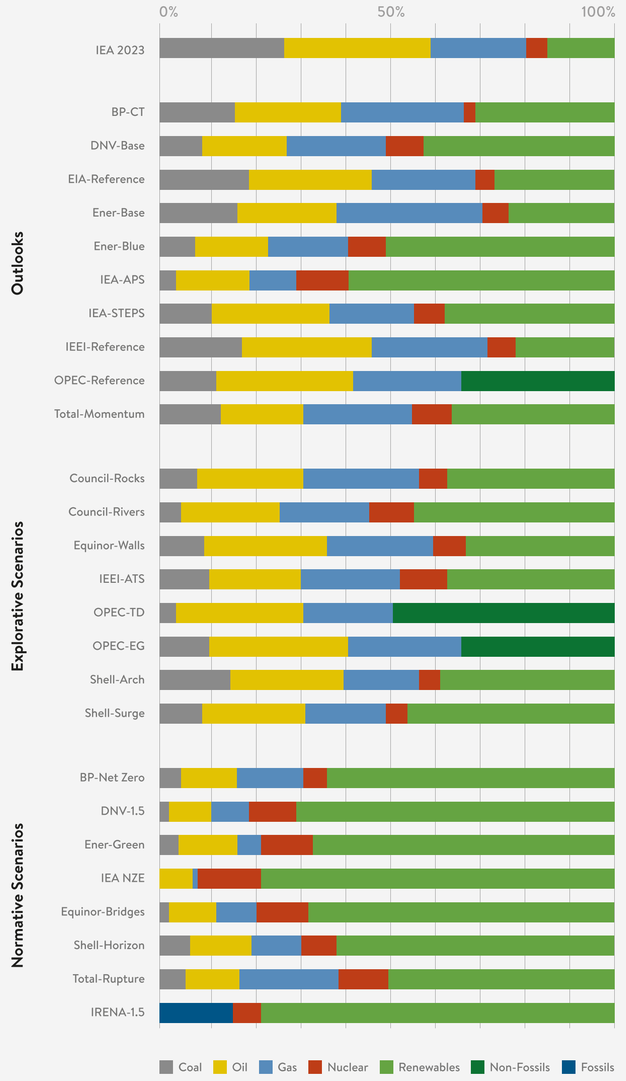
Coal use is set to steeply decline by 2050. Although some emerging markets may temporarily increase coal supply, improvements in technology, falling renewable costs, and policy pressures are expected to drive a strong downward trend in coal consumption.

Natural gas presents a more nuanced and uncertain picture. While most scenarios anticipate a decline over time, gas is not expected to phase out before 2050. Its future hinges on short-term policy decisions, affordability, and the broader tension between international cooperation and national energy security priorities.

Nuclear energy demand is generally expected to increase modestly. Although unlikely to become dominant due to investment barriers and regulatory constraints, nuclear remains an attractive low-carbon option for countries seeking energy security and diversification.

Renewables are set for strong growth. The rate of scale-up will depend on market dynamics and the degree to which national policy choices align with — or diverge from — net zero ambitions. Trade-offs between self-sufficiency, affordability, and emissions reduction will shape the pace of change.

Figure 1 – Primary energy mix by 2050 (in EJ)



DETAILED NUMBERS COMPARISON

1. PRIMARY ENERGY CONSUMPTION

Emerging markets, driven by population growth and economic expansion, are expected to fuel rising primary energy demand. While energy efficiency improvements will help moderate this growth, deeper decoupling from economic activity will be necessary to curb overall consumption.

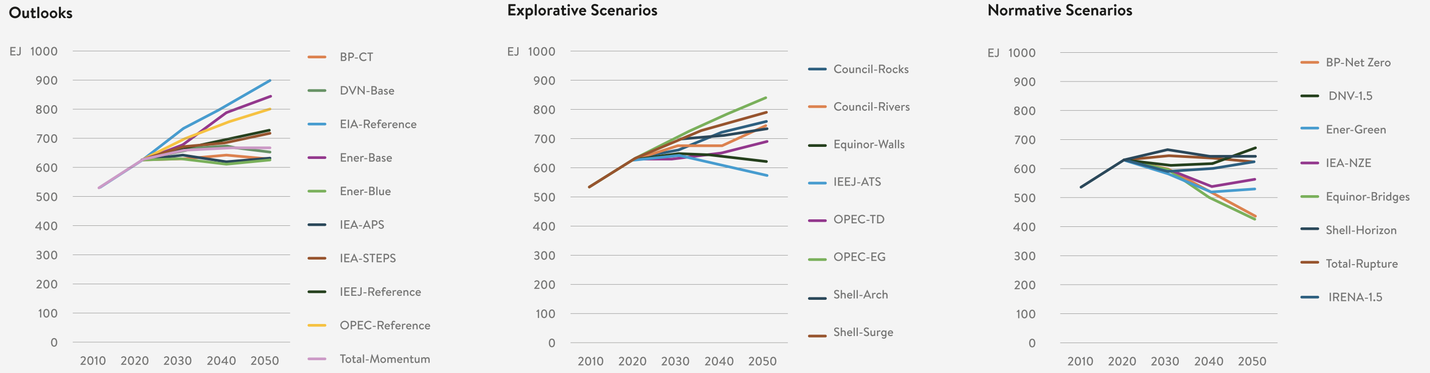
Across most **Outlooks**, primary energy consumption is projected to reach 600-800 EJ per year by 2050, though projections vary widely. EnerBase, EIA Reference and OPEC Reference stand out with growth exceeding 800 EJ, while IEA APS and EnerBlue depict scenarios where consumption plateaus or slightly declines, assuming all governments fully implement their energy and climate commitments. Key difference across these projections stem from varying expectations on population trends, economic shifts, efficiency gains, and electrification rates.

In **Explorative Scenarios,** demand continues to rise at a similar pace, driven by industrial growth, electrification, and population, while efficiency improvements, policy-driven decarbonisation, and renewables contain the increase. Rocks and Rivers, Shell Archipelagos and OPEC Equitable Growth see steady growth, underpinned by economic expansion and ongoing fossil fuel use. In contrast, IEEJ Advanced Technology and Equinor Walls diverge, with structural economic shifts, efficiency improvements, and widespread electrification leading to flattening demand.

Normative Scenarios – such as Equinor Bridges and BP Net Zero – see demand peaking before 2030 and steadily declining through 2050, enabled by aggressive efficiency gains, widespread electrification and a rapid fossil fuel phase-out. Economic shifts toward less energy-intensive sectors decouple energy demand from GDP growth, while carbon pricing, regulatory mandates, and behavioural changes (e.g., reduced material consumption, shared mobility) further limit consumption.

What has changed since 2019? Projections have shifted toward lower growth. Demand across most explorative Scenarios remains broadly unchanged, except for Shell, which exhibit slower growth (down from +900 EJ). Normative scenarios show steeper declines, with some falling to +400 EJ by 2050, reflecting increased climate ambition, rapid renewable update, and growing recognition of system-level accelerators such as digitalisation and modular energy infrastructure.

Figure 2 – Primary energy consumption across scenario sets (in EJ)



2. FINAL ENERGY CONSUMPTION

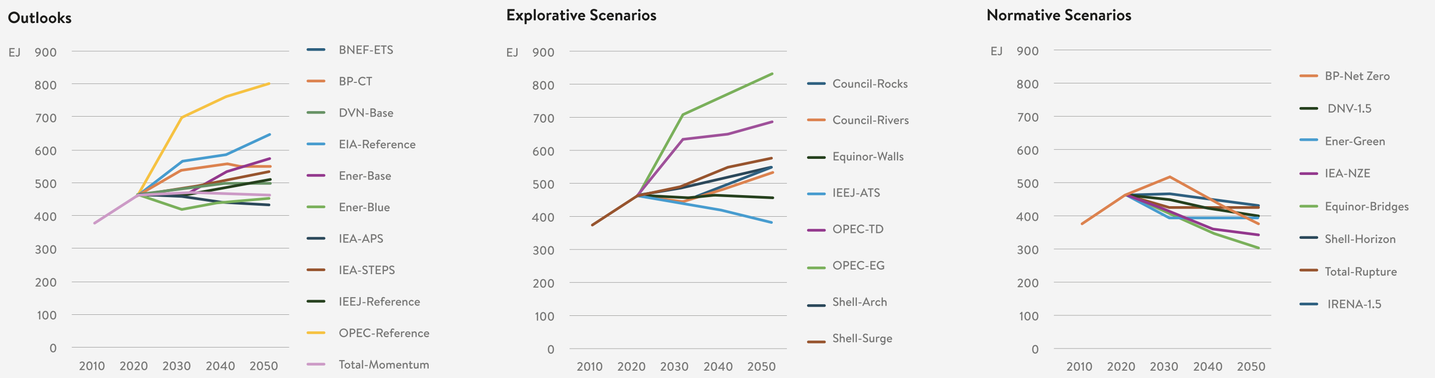
Final energy consumption reflects the energy actually used by households, industry, transport, and other end users – making it a key indicator of how energy transitions play out on the ground. It is shaped by population growth, rising income levels, and the expansion of emerging economies, with the industrial and residential sectors expected to drive the fastest growth unless major policy shifts occur. Electrification and renewables are poised to play an increasingly central role in reshaping this demand.

Outlooks diverge sharply depending on electrification rates, efficiency gains, and policy ambition. Without strong interventions, final energy demand continues rising – as seen in EIA Reference and OPEC Reference – driven by economic and population growth. DNV Base and TotalEnergies Momentum project a stabilisation as electricity displaces inefficient fossil fuel use. IEA APS shows the sharpest break from historical trends, projecting a steep drop to 434 EJ by 2050, enabled by systemic shifts in end-use technologies and policy. Because electrification improves energy conversion efficiency, final energy use can decline even while economies expand.

In **Explorative Scenarios,** two broad futures emerge. One follows a rising trend, where final energy consumption grows steadily, supported by cleaner technologies and economic expansion. Scenarios like Rocks and Rivers and Shell Surge fall into this category – the latter reaching 577 EJ by 2050 – driven by industrial activity and demand growth in emerging markets. In contrast, the IEEJ Advanced Technologies scenario charts a declining path, where fuel switching, vehicle efficiency gains, and widespread electrification reduce demand despite continued growth.

Normative Scenarios aim for a managed decline. Rapid electrification, a shift away from fossil fuels, and structural economic changes drive consumption down to 305 EJ in Equinor Bridges by 2050. Others, such as BP Net Zero, DNV-1.5°C and EnerGreen, show more gradual declines or plateaus, reflecting varying assumptions on behaviour, technology adoption, and policy strength. While trajectories vary, these scenarios converge on the belief that deep reductions in final energy use are both necessary and achievable with the right mix of ambition, innovation, and coordination.

Figure 3 – Final energy consumption across scenario sets (in EJ)



3. ELECTRICITY GENERATION

Strong commitment to electrification is expected across all scenarios, though the pace of change will depend on system inertia and the influence of national priorities.

The **Outlooks** reflect ambitious – but varied – expectations for climate-aligned policies. While electricity generation levels remain modest by 2030 (averaging ~35,000 TWh) all scenario project significant growth by 2050, with upper-range estimates reaching or exceeding 70,000 TWh.

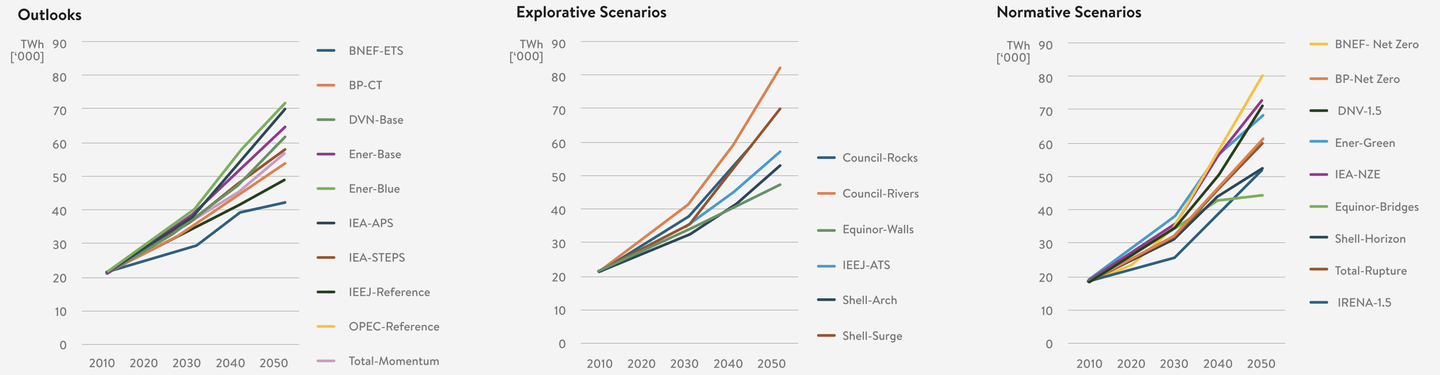
Explorative Scenarios depict steady expansion in electricity generation, driven by economic growth, digitalisation, and gradual renewables integration. However, the pace varies by region and national self-interest. For example, Equinor Walls sees moderate growth, while the Rivers scenario projects a more rapid shift, exceeding 80,000 TWh. Shell Surge, with its AI-enabled productivity boom, forecasts one of the steepest increases in electricity generation among explorative pathways – highlighting rising demand from electrified transport, automation, and data centres.

The **Normative Scenarios** reflect the scale of transformation required to meet net-zero goals. Electricity generation rises sharply in these scenarios, driven by widespread electrification of end-use sectors and clean power expansion. Irena-1.5°C, IEA NZE and DNV-1.5°C project growth exceeding 80,000 TWh by 2050, while TotalEnergies Rupture and BP-Net Zero presents a more measured but still ambitious rise to +67,000 TWh.

The consistent upward trajectory across normative pathways underscores alignment on the urgency of power system transformation – even if the means vary.

What has changed since 2019? Projections for electricity generation are now significantly more ambitious across all scenario types. In Explorative Scenarios, peaks that were once typical of only high-policy or normative pathways now appear in models like Rivers and Shell Surge. Compared to 2019, 2024 Outlooks reflect broader and faster electrification, with Normative Scenarios consistently exceeding earlier projections, driven by updated assumptions on technology, investment, and system-level change.

Figure 4 – Electricity generation across scenario sets (in TWh)



4. ENERGY SOURCES

A. Oil consumption

Oil consumption is projected to decline gradually toward 2050, shaped by geopolitics, energy security concerns, and policy responses.

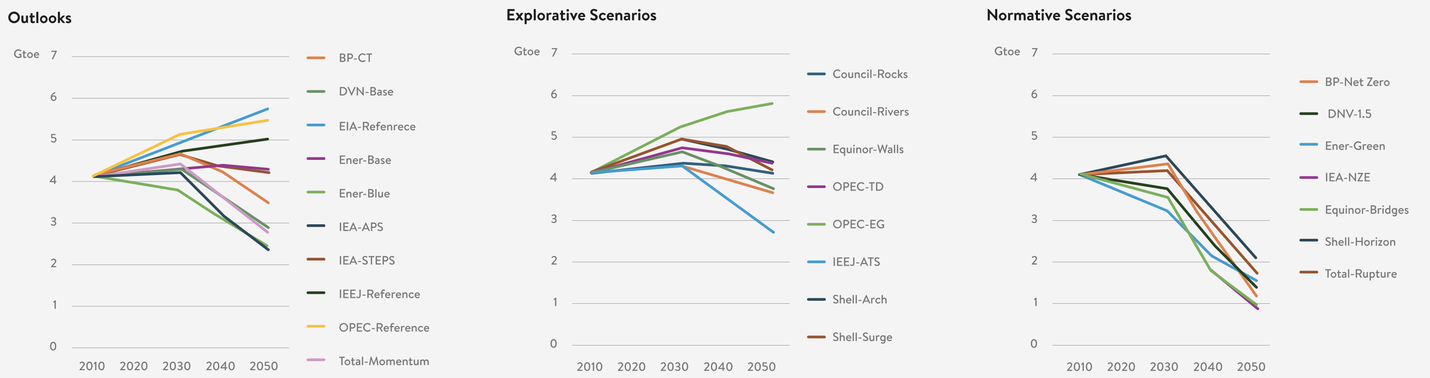
Near-term demand remains uncertain, and **Outlooks** diverge based on the strength and timing of climate policy. OPEC, IEEJ and EIA Reference project continued growth to 2050, while more optimistic cases like IEA APS and Ener Blue project significant reductions post-2030, with oil use lower by 2050.

Explorative Scenarios generally show modest declines in oil consumption after 2030, with oil remaining important for transport, industry, and petrochemicals. In Shell's scenarios, consumption peaks at 4.9 Gtoe in 2030. The Council's Rocks and Rivers scenarios see continuous declines, falling to 3.6 Gtoe in Rivers and 4.1 Gtoe in Rocks by 2050 – reflecting differing pace and scales of transitions and additions across regions. IEEJ Advanced Technology stands out with a sharper long-term decline.

Normative Scenarios depict rapid and deep reductions. IEA NZE and Equinor Bridges show a near-phaseout by 2050 – representing a drop of nearly 75% – while Shell Horizon sees a reduction of almost 50% over the same period.

What has changed since 2019? Scenarios have shifted toward expecting continued growth through 2030, with most now anticipating a slowdown, stagnation or eventual decline of oil use by 2050. In 2024, the majority of Explorative Scenarios grow to around 4.7 Gtoe by 2030 before declining. Outlooks now reflect more consistent policy-driven reductions, and Normative Scenarios converge around 1-2 Gtoe by 2050 – declining later than trajectories projected in 2019.

Figure 5 – Oil consumption across scenario sets (in Gtoe)



4. ENERGY SOURCES

B. Coal Supply

Coal consumption is projected to decline significantly toward 2050, with emerging markets like India and China maintaining near-term demand but ultimately reducing reliance due to cheaper alternatives, improved technologies, and mounting policy pressure. While some regions may see short-term increases, the long-term trend across scenarios is downward.

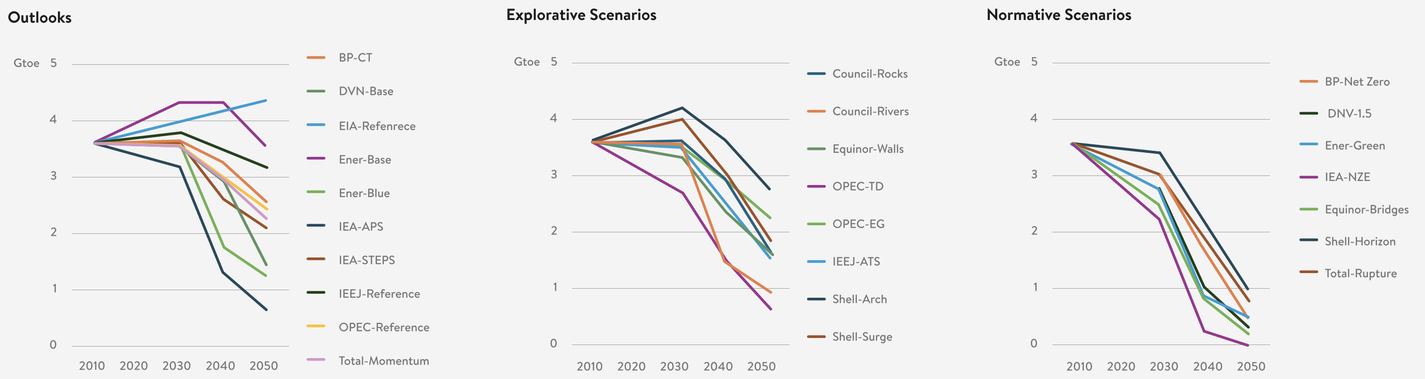
In the **Outlook** scenarios, technological advances and policy interventions drive consistent declines. IEA APS projects a +80% drop in coal use by 2050, as renewables and gas displace coal in power generation. Even in less ambitious pathways, coal loses share as emissions targets tighten.

Explorative Scenarios similarly expect coal to decline, though at varied speeds. Rivers projects a sharp fall to 1 Gtoe by 2050, while Rocks sees a slower trajectory as coal remains important in regions with slower transitions. Despite divergence, most explorative models anticipate coal's diminished role post-2025, especially in power.

Normative scenarios reflect the most dramatic shifts, with accelerated renewable deployment, early coal plant retirements, and stringent carbon policies driving near-phaseouts. IEA NZE and Equinor Bridges illustrate the steepest declines, approaching minimal coal use by mid-century.

What has changed since 2019? In the 2019 comparison, nearly half of the Outlooks and explorative scenarios still projected rising coal use. By 2024, all but one (EnerBase, which peaks only mid-2030s) show immediate declines. This shift reflects stronger net-zero commitments, reduced coal financing, and rapidly falling costs of renewable electricity.

Figure 6 – Coal supply across scenario sets (in Gtoe)



4. ENERGY SOURCES

C. Natural Gas consumption

Natural gas consumption is not expected to phase out by 2050, but most scenarios anticipate a decline, particularly after 2030. Gas continues to serve as a transition fuel, especially in power and industry, but its long-term role is increasingly questioned due to climate targets, policy uncertainty, and growing tensions between international cooperation and national self-interest.

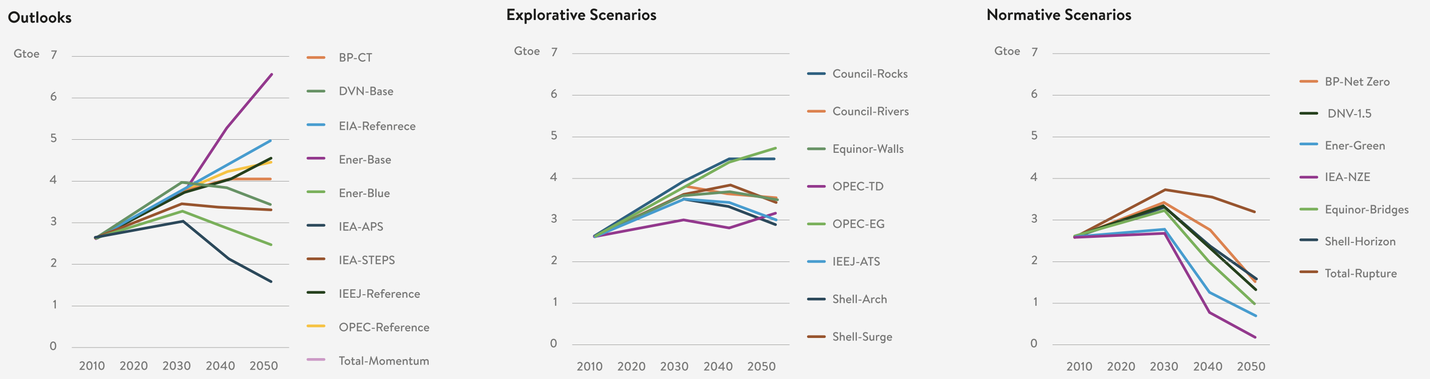
Outlook scenarios show the widest variation. In some, current policies support rising near-term demand, while others like IEA APS and EnerBlue show steep declines – down to around 2 Gtoe by 2050. Despite short-term divergence, most Outlooks begin to converge toward lower gas use by mid-century.

Gas might play an important role amidst declining oil consumption trends. In **Explorative Scenarios** trajectories differ depending on the level of international cooperation. Rivers and IEEJ Advanced Technology project moderate declines under assumptions of increased global cooperation and the use of gas as a bridge fuel. In contrast, Rocks and OPEC Equitable Growth assume greater national self-interest might slow down the transition away from gas, with Rocks peaking in 2040 and then plateauing through 2050.

The Normative Scenarios aligned with net-zero pathways present consistent and steep declines after 2030. IEA NZE, EnerGreen, and Equinor Bridges all fall below 1 Gtoe by 2050. Even Shell Horizon, with a slower start, eventually converges with the more ambitious pathways, though gas is not entirely phased out.

What has changed since 2019? In 2019, most outlooks and explorative scenarios projected continued gas growth. By 2024, nearly all scenarios peak earlier and decline faster. Most explorative pathways now stabilize or fall after 2030, while most Normative Scenarios show steep reductions after 2030 – underscoring a shift in expectations driven by stronger climate policy and electrification momentum.

Figure 7 – Natural Gas consumption across scenario sets (in Gtoe)



4. ENERGY SOURCES

D. Nuclear supply

Nuclear energy is generally expected to grow through 2050, supported by its low-carbon profile and ability to enhance energy security. While unlikely to become the dominant source due to regulatory, economic, and social barriers, it is increasingly seen as a stable complement to variable renewables.

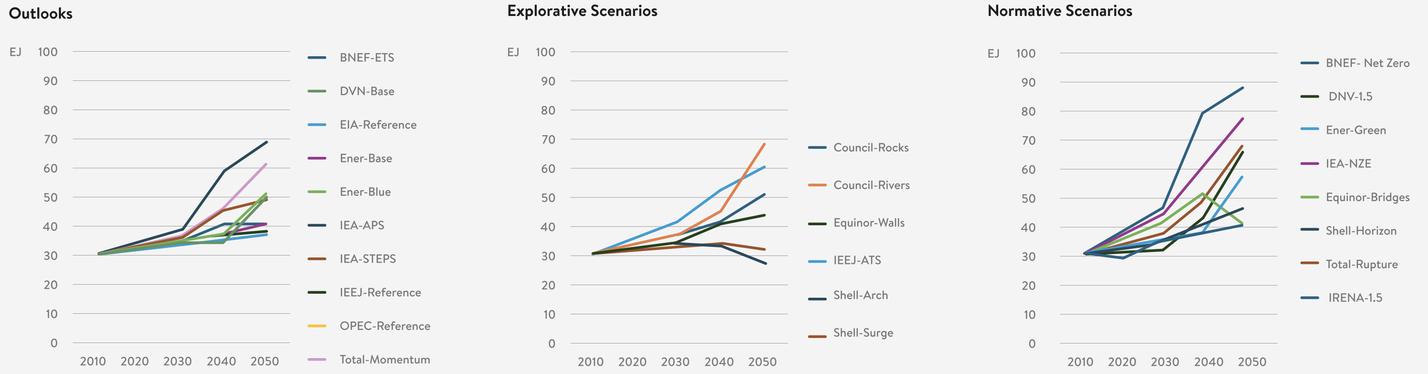
Outlook scenarios reflect an optimistic but measured view of nuclear. IEA STEPS projects a 50% increase by 2040, while TotalEnergies Momentum and IEA APS reach over 60 EJ by 2050. These pathways balance expected policy support with practical deployment constraints.

Explorative scenarios generally project modest and steady nuclear expansion. Most scenarios assume persistent regulatory and political hurdles that limit accelerated growth, keeping the share of nuclear around 10% of the mix. However, IEEJ Advanced Technology and Rivers stand out by highlighting modular nuclear as a potential enabler of faster deployment, driven by increased electricity demand from AI and digital infrastructure. By contrast, Shell Archipelagos anticipates a gradual decline after 2040.

Normative scenarios envision more aggressive nuclear growth, viewing it as essential to achieving net-zero targets. BNEF NZS leads with projected supply reaching 88 EJ by 2050. These scenarios assume successful scaling of nuclear capacity, including the deployment of Small Modular Reactors (SMRs), which are increasingly discussed as solutions to the siting and cost barriers of traditional nuclear.

What has changed since 2019? Nuclear projections in 2024 have shifted upward across most scenario types. In 2019 outlooks, growth was more conservative, often linear. Today, Explorative Scenarios like Rivers expect nuclear to exceed 60 EJ by 2050, while some Normative pathways trend toward 90 EJ – reflecting growing recognition of the important role of nuclear in clean energy transitions and future energy system resilience.

Figure 8 – Nuclear supply across scenario sets (in EJ)



4. ENERGY SOURCES

E. Solar and wind

Solar and wind see strong growth across all scenario types. The pace of expansion is shaped by market dynamics, national policy choices, and tensions between energy sovereignty and global net-zero targets.

Outlook scenarios reflect broad consensus on continued growth in solar and wind. IEA STEPS projects slower increases, while IEA APS and EnerBlue show stronger trajectories, with significant renewables share by 2040. By mid-century renewables play a significant role in the energy mix displacing oil and coal.

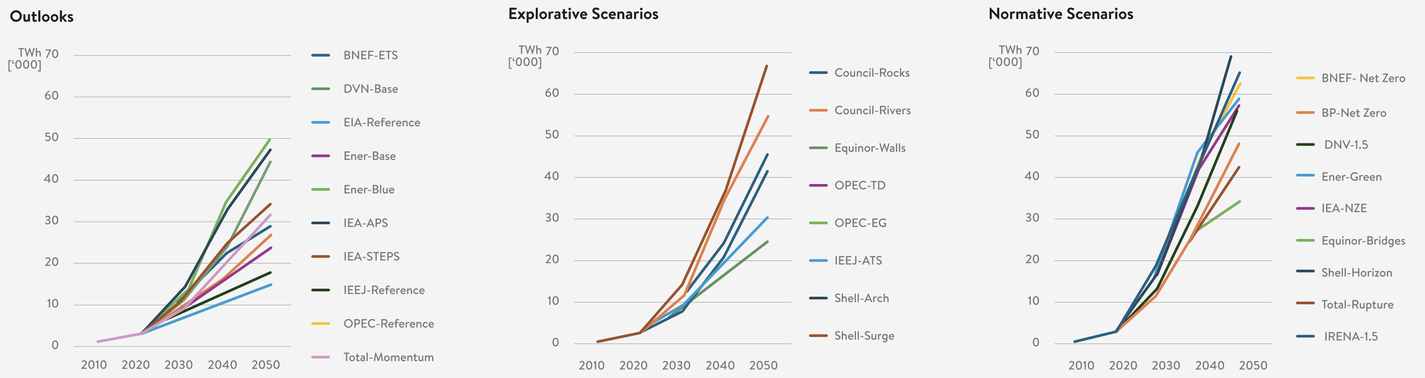
In **explorative Scenarios**, show robust but varied acceleration, particularly after 2030. Growth is strongest in Shell Surge and Rivers, where market-enabled national action boosts renewables, while Rocks and Shell Archipelagos project more moderate uptake. Shell Surge stands out for projecting a sharp rise driven by digitalisation and AI-driven demand, including hyperscale data centres.

Normative Scenarios present the steepest growth curves. IRENA 1.5°C, BNEF NZS and others envision renewables becoming the backbone of net-zero systems. Solar and wind are projected to deliver nearly 60% of electricity globally by 2050, with strong growth starting before 2030.

What has changed since 2019? Solar and wind expansion has accelerated across all scenarios. Explorative models like Rivers now exceed 55,000 TWh by 2050, with some Normative scenarios surpassing 60,000 TWh. Compared to 2019, there is broader confidence and earlier take-off in all pathways.

However, this rapid scale-up of solar and wind hinges on access to critical minerals. Many scenarios underplay the fragility of supply chains for materials like lithium, nickel, and rare earths – key inputs for batteries, wind turbines, and solar panels. Concentrated control over processing (especially in China) and geopolitical risks introduce major uncertainties in renewables deployment. BP Net Zero, for instance, expects copper demand to double and nickel to triple by 2050.

Figure 9 – Solar and wind across scenario sets



5. ENERGY-RELATED CO_2 EMISSIONS

A. CO_2 emission levels

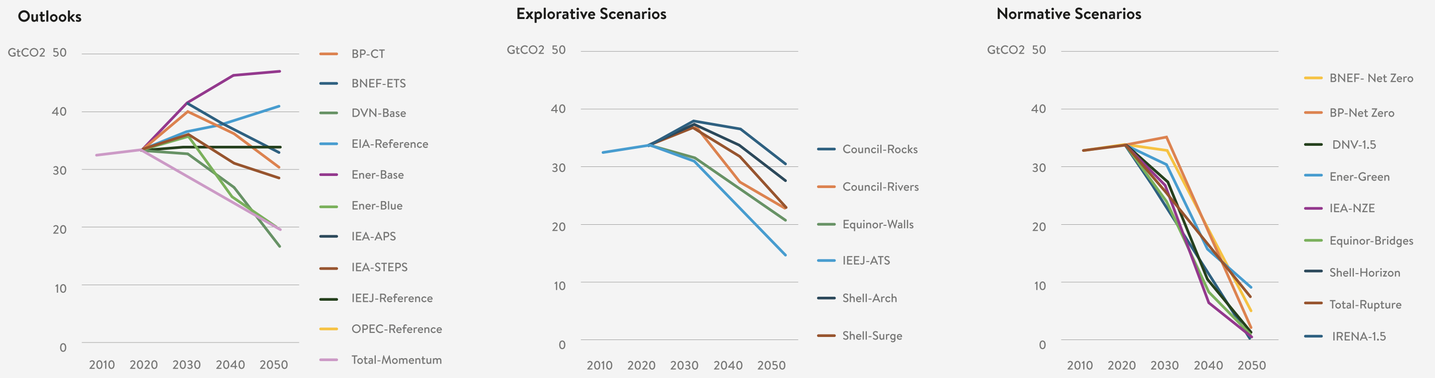
CO_2 emissions from fuel combustion are projected to decline across all scenario types, but the pace and depth of this decline vary dramatically, shaped by the strength of policy action, system inertia, and the balance between global cooperation and national self-interest. Net-zero targets are now prominent across many scenarios, yet actual trajectories diverge widely -highlighting that pledges alone are not guarantees of delivery.

Outlooks scenarios show a spectrum of future emissions trends. IEA APS forecasts the steepest decline among policy-based projections, falling from nearly 36 $GtCO_2$ today to around 12 $GtCO_2$ by 2050. DNV-Base and EnerBlue also show substantial reductions. However, other scenarios – such as EIA Reference and EnerBase – project continued emissions growth, with EnerBase reaching nearly 50 $GtCO_2$ by 2050. This range highlights the critical importance of timely and credible policy action to move from emissions pledges to real-world reductions.

Explorative scenarios reflect the complexity and inertia of current systems. Some project emissions peaking before 2030, followed by gradual – but insufficient – declines to meet net-zero goals. Rocks projects emissions falling to 30 $GtCO_2$ by 2050, while Shell Archipelagos sees a similarly slow decline. In contrast, Rivers – though still not aligned with net-zero – shows a steeper drop to around 23 $GtCO_2$ by mid-century. IEEJ Advanced Technology is an outlier, reaching 15 $GtCO_2$, assuming strong cooperation, efficiency gains, and fuel switching, despite modest assumptions on policy coordination.

The **Normative scenarios** – designed to illustrate what's needed to meet climate goals – show the most dramatic emission reductions. IEA NZE, BNEF NZS, and IRENA 1.5°C all approach net-zero or even net-negative CO_2 emissions by 2050. These pathways assume a near-total transformation of the energy system, including rapid electrification, phase-out of unabated fossil fuels, large-scale renewables deployment, carbon pricing, and carbon removal technologies. DNV-1.5°C is somewhat more conservative but still aligns with a strong downward trajectory, converging to near-zero by 2050.

Figure 10 – CO_2 emission levels across scenario sets



What has changed since 2019? The trajectory and tone of emissions scenarios have shifted markedly. In 2019, most Outlooks projected continued emissions growth, while most Explorative scenarios foresaw flat or slowly declining trends, with net-zero still framed as aspirational. Today, many Outlooks show clearer downward trajectories, and Explorative scenarios now see emissions peaking before or by 2030 – with some, like Rivers, projecting deeper cuts than before. Normative scenarios have consolidated around net-zero by 2050 as a central benchmark, with steeper decline rates and growing emphasis on systemic change and energy system redesign. The remaining gap is not in ambition – but in action and implementation.

Even among scenarios with declining emissions, few fully account for non-CO_2 emissions (e.g., methane) or scale-up of carbon removals (e.g., DAC, BECCS), which could be critical in achieving net-zero. The effectiveness of emissions reduction will ultimately depend not only on energy system transformation, but on the full lifecycle of decarbonisation policies and technologies.

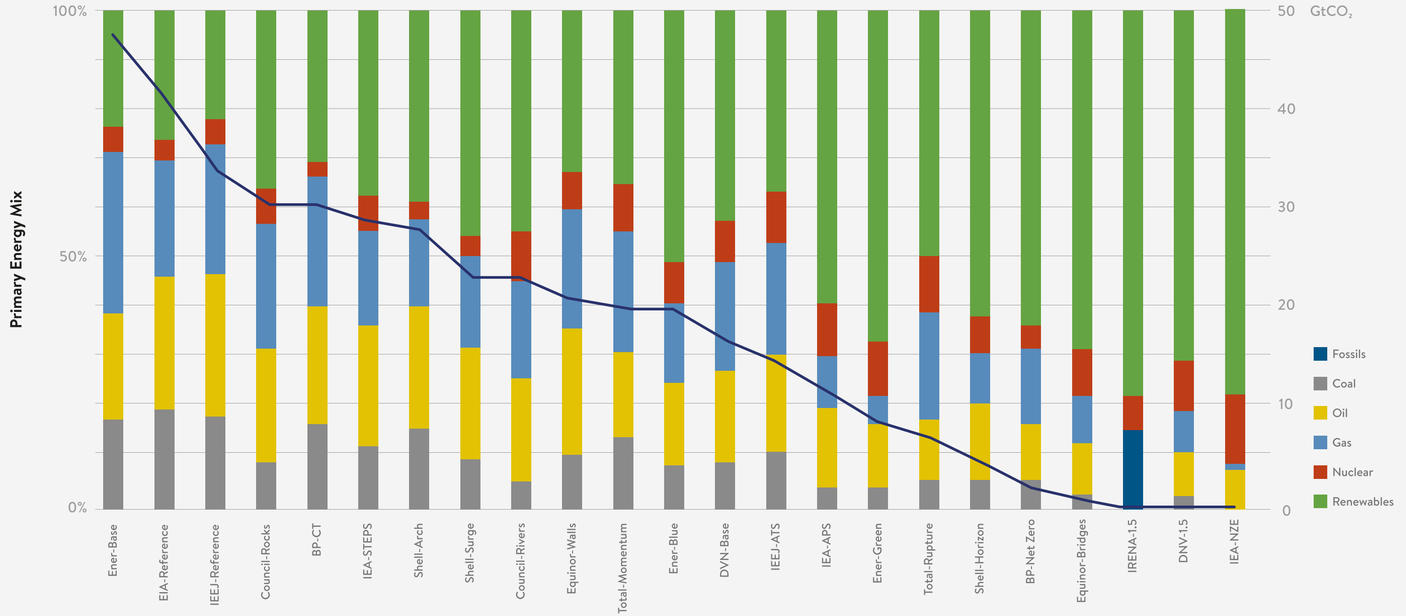
Missing the Resilience Conversation

Most scenarios focus on mitigation – but what happens if the world misses net-zero targets? How will systems and societies adapt?

Insight Activation:

- Is your strategy future-proofed for disruptive climate impacts, not just decarbonisation?

Figure 11 – Depicting CO2 emissions from fuel combustion across scenarios by 2050



5. ENERGY-RELATED CO_2 EMISSIONS

B. Net-zero prospects and global temperatures

Outlook scenarios reflect the wide range of uncertainty in current policy pathways. For example, IEA STEPS projects a global temperature rise of 2.4°C by 2100, assuming today's policies are maintained, while IEA APS shows that enhanced ambition could limit warming to 1.7°C. Other scenarios, like BNEF ETS, suggest a 2.6°C trajectory, underlining the persistent gap between commitments and outcomes.

Explorative Scenarios follow moderate transition paths that fall short of the 1.5°C target. Shell Archipelagos, for instance, sees warming of 2.2°C, reflecting a world where national priorities delay stronger global coordination. These scenarios acknowledge progress, but the scale and speed of change are insufficient to achieve deep decarbonisation.

In contrast, **Normative Scenarios** are explicitly designed to chart viable pathways for reaching net-zero by 2050, and keeping temperature rise well below 2°C, ideally close to 1.5°C. Scenarios such as IEA NZE, BP Net Zero, Equinor Bridges, IRENA 1.5°C, Shell Horizon, and DNV-1.5°C all assume global net-zero is achieved by mid-century. These pathways are not forecasts but normative benchmarks – they show what's possible if ambition, coordination, and innovation align.

Three key levers emerge across all Normative Scenarios:

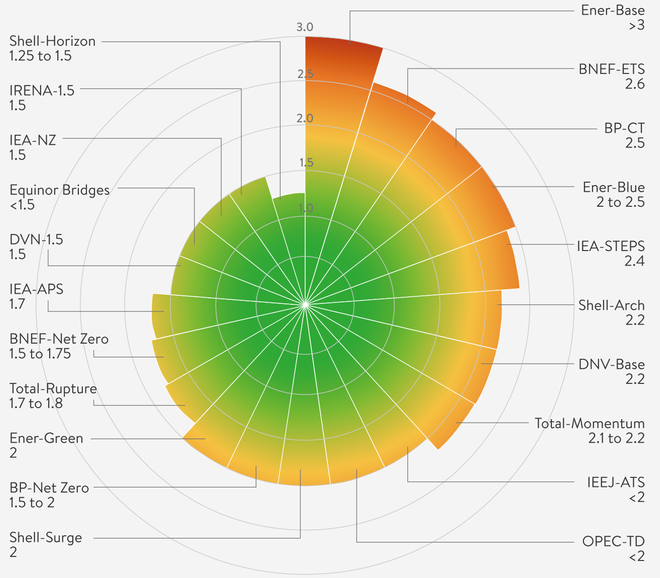
1. **Deep electrification of end-use sectors** – Widespread electrification in transport, buildings, and low-heat industry sectors – powered by renewables – is critical to displacing fossil fuels and boosting energy efficiency.

2. **Massive scaling of renewables and clean power infrastructure** – Rapid deployment of wind, solar, hydro, nuclear, and supporting grid infrastructure is the backbone of every net-zero pathway, with renewables supplying over 60–80% of electricity by 2050.

3. **Deployment of enabling policies and carbon pricing** – Strong regulatory frameworks, global carbon pricing, fossil fuel phase-out mandates, and financial support mechanisms are essential to steer investment and behaviour change at the pace required.

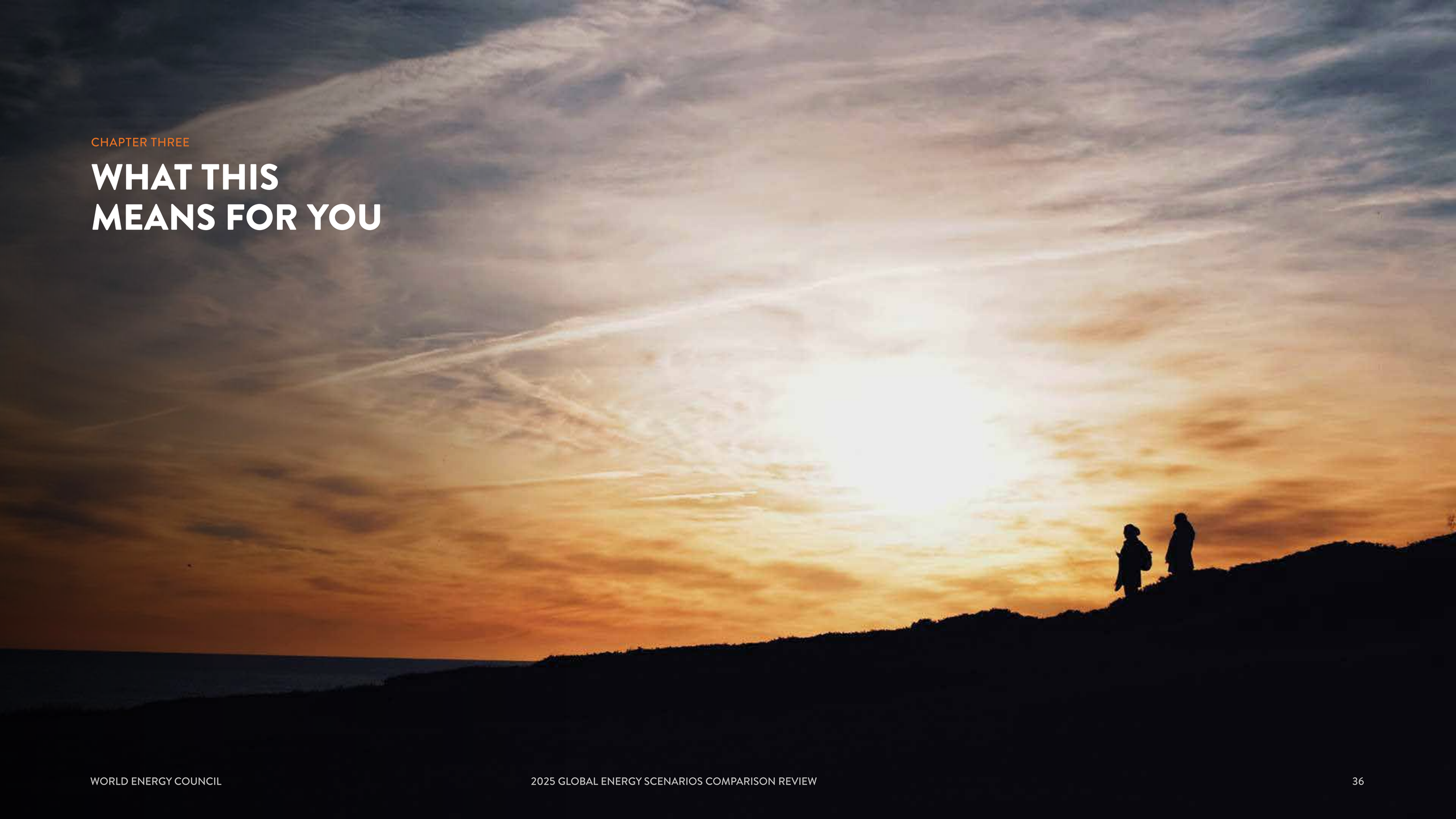
Projected temperature outcomes highlight that even under optimistic scenarios, **mitigation must go hand in hand with resilience and adaptation.** The risk of overshooting the 1.5°C target remains real. Countries, cities, and communities must prepare for impacts and develop adaptive strategies in parallel – ensuring that societal wellbeing and planetary stability can be safeguarded even if net-zero is delayed or derailed.

Figure 12 – Degrees of warming per scenario by 2100 (in degrees Celsius)



CHAPTER THREE

WHAT THIS MEANS FOR YOU



ROLE BASED ACTIVATION BRIEF

Use the global to think local. Use the plausible to imagine the possible. Use the scenarios to lead with clarity under uncertainty.

ROLE	KEY IMPLICATIONS FROM THE SCENARIO INSIGHTS	PRIORITY ACTIONS
Policy Makers	Fragmentation is rising; public trust and legitimacy will be key transition enablers. Demand is changing faster than models suggest.	Stress-test national plans for public acceptance and delivery capacity. Enable adaptive regulation.
Business Leaders / CEOs	New transition pathways are opening – but so are geopolitical and supply chain risks. AI and data infrastructure are shifting energy economics.	Reassess clean tech strategies and location risks. Explore partnerships for resilience and innovation.
Analysts & Strategists	Most scenarios underplay demand-side shifts and new system stress points. Non-linear transitions are possible.	Use scenarios to challenge base-case assumptions. Create custom stress scenarios for demand and resilience.
Regional & Community Leader	Global narratives are diverging – regional realities matter. Inclusion, fairness, and legitimacy will determine local success.	Convene diverse stakeholders. Use scenarios to engage on place-based pathways and energy literacy.

EXPLORING TRANSITIONS IN YOUR OWN CONTEXT

This guide supports leaders and practitioners in using the scenarios to make sense of uncertainty in their own context. Use it to explore what's possible, challenge what you think you know, and surface viable transition pathways for your sector, region, or organisation.

NOT JUST SCENARIOS – A TOOL TO RETHINK

Use this section to stress-test what you think you know. These exercises are built to help:

- Navigate tensions between ambition and delivery
- Map "what's missing" in national or sector strategies
- Identify your ecosystem's disruptors and enablers

The following reflection questions are meant to support deeper thinking – whether you're using Rocks and Rivers or other scenarios – as a way to identify emerging risks, spot opportunities, and clarify your preferred way forward.

SETUP

Pick an element from the scenarios that you want to explore and apply to your own context

This might be an aspect from the Rocks and Rivers narratives or one of the specific variables such as Natural Gas supply and its related graphs.

Explore this element to make sure you understand what it is about.

ACTIVITY 1 | EXPLORING TRANSITIONS

Given the topic or element, you have chosen, ask yourself what a transition to a preferable future might look like for your country, organisation or community. Try to describe this briefly.

Reflecting on the scenarios,

- What risks would you face during this transition?
- What opportunities might you make use of to make this transition?
- What gaps do you need to fill to have a successful transition, for instance in knowledge, capabilities, resources and so on?

ACTIVITY 2 | EXPLORING ECOSYSTEMS

What would a viable ecosystem look like to enable you to transition the topic in your context to a preferred future?

- What governance, policies or financing would be needed?
- What skills, resources, technologies or other advances would be needed?
- What supporting infrastructure, systems, services or solutions would be needed?
- What values and societal norms might need to change?

ACTIVITY 3 | EXPLORING TRANSITION ACTORS

Who are the actors in your current ecosystem? Identify the following roles they might play:

- Who are the maintainers of the current system? How might they redirect their resources to transition effectively? What would be a key message to them?
- Who are the entrepreneurs and innovators who could provide practical solutions for a transition? What might be a key message for them to support in pragmatic ways?
- Who are the visionaries that could impart hope and provide social energy to sustain the transition journey? How can they be approached to collaborate and support a transition?

CHAPTER FOUR

SCENARIOS OVERVIEW

OUTLOOKS

BNEF ECONOMIC TRANSITION SCENARIO (ETS)

Partial progress with emissions reaching 2.6°C

Core Narrative: A moderately ambitious scenario where energy transitions advance, but fragmentation, investment gaps, and infrastructure delays prevent alignment with 1.5°C goals.

Energy Governance: Governments strengthen efforts but lack full global alignment. National transitions progress unevenly based on domestic priorities and capacities.

Energy Efficiency and Electrification: Efficiency improves substantially. Electrification of transport and parts of industry advances steadily, with EV adoption surging, but full sectoral transformation is incomplete.

Innovation: Renewables and EVs expand rapidly. However, clean technology innovation and deployment – especially for heavy industry and emerging markets – face financial and policy barriers.

Energy Mix: Oil demand declines gradually; gas demand grows modestly to support power and industrial needs. Renewables rise but gaps remain in heavy transport and industrial sectors.

Regional Demand & Disparities: Emerging economies transition slower due to investment and infrastructure constraints. Developed regions decarbonise faster but uneven global outcomes persist.

Climate Outcome: Global emissions plateau before falling modestly, with global warming reaching 2.6°C by 2100.

BP CURRENT TRAJECTORY

Fragmented progress under existing policies and moderate ambition

Core Narrative: Continuation of current trends, where rising energy demand, infrastructure gaps, and uneven ambition slow global decarbonisation.

Energy Governance: Regional policies dominate; no unified global push. Markets and national priorities drive transition paths in a fragmented energy landscape.

Energy Efficiency and Electrification: Energy demand grows steadily. Electrification advances steadily across transport and industry, with progress constrained by limited investment and regulatory inertia. CCS and hydrogen adoption remain sluggish due to high costs.

Innovation: Solar and wind expand but face grid and storage bottlenecks. Green hydrogen adoption accelerates after 2035, primarily in heavy industry and transport. Industrial CCUS gains traction, but economy-wide deployment lags.

Energy Mix: Coal declines rapidly in developed economies but persists in Asia. Oil demand peaks mid-2030s but remains strong in aviation and petrochemicals. Gas acts as a transition fuel into the 2040s before gradually declining.

Regional Demand & Disparities: India and Southeast Asia drive the largest energy demand increases. Africa's energy access improves, but fossil fuels remain critical. OECD countries stabilise demand with renewables filling most new growth.

Climate Outcome: Emissions plateau or decline slowly but remain incompatible with a 1.5°C pathway. Temperature rises to 2.5°C.

DNV BASE SCENARIO

Current trends with slow but steady transition progress

Core Narrative: A realistic baseline scenario assuming moderate improvements, growing electrification, and fragmented global progress, but insufficient to meet the 1.5°C target.

Energy Governance: Governments encourage but do not fully enforce rapid transition pathways. Regional fragmentation persists.

Energy Efficiency and Electrification: Efficiency improves and electrification grows significantly, especially in transport and industry. However, gaps in developing regions persist due to financing constraints.

Innovation: Clean tech investment rises, especially in CCUS and hydrogen, but innovation diffusion is uneven and hampered by lack of international cooperation.

Energy Mix: Fossil fuels remain dominant through 2050, with slow decline. Oil peaks around 2030; gas grows modestly before peaking later. Renewables grow but not fast enough to fully displace fossil use.

Regional Demand & Disparities: Developing economies face slower transitions due to capital and technology access barriers. Developed economies decarbonise faster.

Climate Outcome: The world overshoots the Paris targets, heading toward 2.2°C of warming.

EIA REFERENCE SCENARIO

Current policy trajectory with persistent fossil fuel dominance

Core Narrative: The Reference Scenario reflects a continuation of existing energy and environmental policies without additional climate ambition. Without new measures, energy systems evolve slowly and emissions continue to rise.

Energy Governance: Governments maintain present policies, focusing on national energy needs rather than global climate targets. No major new interventions are introduced to accelerate decarbonisation.

Energy Efficiency and Electrification: Efficiency improves modestly across transport and industry. Electrification expands gradually, but not at the scale or speed required for meaningful emissions reductions. Energy intensity declines, but rising energy demand offsets most gains.

Innovation: Clean energy technology advances incrementally, driven primarily by market forces. Without stronger policy signals, adoption of renewables, CCS, and advanced fuels remains slow and limited in scale.

Energy Mix: Fossil fuels remain dominant through 2050. Coal consumption growth slows, but oil and natural gas demand continue rising, especially in non-OECD regions where energy access and economic growth drive consumption.

Regional Demand & Disparities: Substantial energy demand growth occurs in developing economies, notably in Asia and Africa, due to urbanisation and industrialisation. Developed economies experience slower growth or plateauing energy demand as efficiency gains and demographic trends take hold.

Climate Outcome: Global energy-related CO_2 emissions rise steadily. The world remains on a trajectory significantly above 2.5–3°C warming, with a wide gap between current reality and net-zero pathways.

ENERDATA ENERBASE

Business-as-usual trajectory with limited climate ambition

Core Narrative: A continuation of current policies and historical trends. No major new climate measures are introduced, and existing commitments fall short of long-term targets.

Energy Governance: Global coordination is weak. National priorities prevail, with fossil fuel-exporting countries retaining significant influence. Climate pledges are not backed by effective implementation.

Energy Efficiency and Electrification: Efficiency improves modestly, with slow electrification across sectors. Electrification of transport and heating is constrained by policy and investment gaps. Fossil fuels dominate end-uses, particularly in developing economies. Smart systems are limited to higher-income regions.

Innovation: Clean energy innovation progresses incrementally, driven by markets rather than public investment. Breakthroughs are uneven, and diffusion is slow.

Energy Mix: Fossil fuels remain the backbone of the global energy system. Renewables grow but do not significantly alter the energy mix by 2050.

Regional Demand & Disparities: Developing regions, especially in Asia and Africa, experience sharp increases in energy demand, widening the gap with more mature economies. Energy access improves but emissions rise steeply.

Climate Outcome: Emissions continue to rise. The world remains on a trajectory exceeding 3°C of warming, far off track from Paris targets.

ENERDATA ENERBLUE

Policy-led decarbonisation aligned with NDCs and moderate ambition

Core Narrative: A middle-ground scenario where announced national climate pledges (NDCs) are met, but without a coordinated push toward full net-zero alignment. Transition efforts are significant but uneven.

Energy Governance: Governments implement stronger policies than in business-as-usual, but ambition varies. Some nations move faster on decarbonisation, while others prioritise energy security or economic growth.

Energy Efficiency and Electrification: Steady but uneven electrification, led by industrialised regions. Significant improvements in power sector efficiency, with growing electrification in transport and buildings. Energy intensity declines moderately, but fossil fuels remain in use in harder-to-abate sectors and in developing regions due to cost and access issues.

Innovation: Technological deployment accelerates, especially for renewables and storage. Innovation is policy-supported but not transformative across all sectors or regions.

Energy Mix: Coal declines sharply. Oil and gas fall more gradually, with natural gas playing a key transitional role – particularly in regions facing affordability or reliability concerns. Renewables supply between 50% and 80% of electricity by 2050.

Regional Demand & Disparities: Asia-Pacific becomes the largest energy consumer, exceeding half of global primary energy use by 2050. Africa's share of demand rises and surpasses Europe's. Developed economies experience flat or declining demand due to energy efficiency and structural shifts.

Climate Outcome: Global emissions peak around 2030 and begin to decline, but not fast enough to stay within a 1.5°C pathway. The scenario is more aligned with a 2–2.5°C outcome, reflecting real-world ambition gaps.

IEA APS

Policies aligned with national climate pledges

Core Narrative: This scenario assumes that all announced national climate pledges are met in full and on time. It reflects increased government ambition but still reveals a gap between pledges and 1.5°C outcomes.

Energy Governance: Governments commit to net-zero targets and introduce supportive policy frameworks. However, pace and depth of implementation vary across countries and sectors.

Energy Efficiency and Electrification: Significant improvements in efficiency and widespread electrification in transport and industry. Clean electricity becomes central to the energy system, but scaling challenges – especially in infrastructure – persist.

Innovation: APS anticipates broader deployment of CCUS, hydrogen, and clean technologies, supported by growing public and private investment. However, uptake is constrained by regional disparities in capacity and finance.

Energy Mix: Fossil fuel use declines steadily. Oil peaks in the early 2030s, but decline is gradual, reflecting ongoing reliance on fossil fuels in certain sectors and regions. Natural gas continues to grow modestly before peaking later, particularly in regions that face energy security concerns. Coal demand drops fastest.

Regional Demand & Disparities: Demand continues to rise in developing countries, especially in Asia and Africa, due to industrialisation and urbanisation. Financing constraints slow clean energy deployment, despite increased international collaboration.

Climate Outcome: APS closes part of the ambition gap but is not fully aligned with 1.5°C. The world remains on a trajectory closer to 1.7°C, requiring stronger follow-through to hit climate targets.

IEA STEPS

Cautious progress under current policy frameworks

Core Narrative: A scenario rooted in existing and officially adopted policies, reflecting a conservative outlook where announced pledges are not assumed to be fulfilled unless backed by clear implementation plans. This scenario highlights the importance of making energy transitions affordable and inclusive, particularly in regions where access to modern energy is still limited

Energy Governance: Policy is driven by current national priorities, with limited forward momentum. Governments act within domestic political constraints, resulting in slower, fragmented global progress.

Energy Efficiency and Electrification: Efficiency and electrification advance steadily but insufficiently. EVs and heat pumps gain ground, especially in the US, China, and Europe, yet adoption levels fall short of climate targets. Clean technologies remain financially out of reach for many in developing economies.

Innovation: Incremental innovation continues in mature markets. Breakthroughs are limited and concentrated in wealthier economies. Infrastructure gaps and cost barriers slow diffusion.

Energy Mix: Coal, oil, and gas demand peaks before 2030, but fossil fuels still make up +70% of energy use by that year. Renewables expand in power generation but cannot fully offset fossil reliance.

Regional Demand & Disparities: Energy demand grows sharply in emerging and developing economies, especially in Asia. Access gaps persist: many people still lack clean cooking and electricity access, slowing social progress.

Climate Outcome: Global emissions plateau and begin to decline slightly, but STEPS remains on a trajectory to 2.4°C, far from 1.5°C alignment.

IEEJ REFERENCE SCENARIO

Policy inertia, energy security focus, and persistent fossil dominance

Core Narrative: A continuation of today's energy systems and policy frameworks. No major new interventions are assumed, and energy transitions unfold slowly and unevenly.

Energy Governance: Governments maintain current policies without raising ambition. Energy security and national interests drive decisions more than climate objectives.

Energy Efficiency and Electrification: Gradual, uneven progress. Some electrification in transport and industry, mostly in high-income regions. Efficiency improvements occur through incremental technology upgrades rather than coordinated policy action. Electrification in developing economies is limited by affordability and infrastructure.

Innovation: Clean energy technologies progress incrementally, mostly driven by markets. Investments remain modest and unevenly distributed. Energy Mix: Fossil fuels retain a central role through 2050. Coal peaks mid-2020s, but oil and gas demand continue rising, especially in Asia and Africa.

Regional Demand & Disparities: Developed economies see demand stabilise, while emerging markets – particularly in Asia – see steep increases driven by industrialisation and urban growth. Access to affordable clean technologies remains a challenge for many.

Climate Outcome: Global CO_2 emissions stay relatively flat. Warming exceeds 2.5–3°C, with a wide gap between pledges and actual outcomes.

OPEC REFERENCE SCENARIO

Continuation of current trends keeps fossil fuels dominant and emissions high

Core Narrative: Continuation of current trends without major policy or technology shifts. Assumes existing policies and energy systems persist through 2050.

Energy Governance: Moderate intervention; focus on energy security and market-driven stability. No major acceleration of climate policies.

Energy Efficiency and Electrification: Incremental efficiency gains; electrification continues but remains secondary to traditional fuels in many regions.

Innovation: Technological change is evolutionary. No major disruptive breakthroughs; existing energy systems remain dominant.

Energy Mix: Fossil fuels remain dominant. Oil, gas, and coal usage declines slowly, with modest growth in renewables and nuclear. By 2050, non-fossil fuels make up about 34% of primary energy.

Regional Demand and Disparities: Developing regions drive steady demand growth, particularly in Asia and Africa. Developed economies see slower energy demand growth or mild decline.

Climate Outcome: Not aligned with Paris Agreement goals; global emissions remain high. Energy transitions proceed too slowly to limit warming below 2°C.

TOTAL ENERGIES MOMENTUM

Current policy inertia and uneven transition progress

Core Narrative: A continuation of current policies where electrification expands but infrastructure and geopolitical barriers slow the pace of decarbonisation, leading to a warming trajectory above 2°C.

Energy Governance: Efforts are regionally driven. While decarbonisation policies strengthen in some economies, global coordination remains limited.

Energy Efficiency and Electrification: Electrification of end-use demand grows steadily, primarily driven by renewables and energy efficiency. However, grid bottlenecks and capital constraints slow widespread adoption, particularly in the Global South.

Innovation: Innovation and investment in clean technologies are uneven across regions. Access to green finance and technology remains a major barrier for emerging economies.

Energy Mix: Fossil fuels remain dominant through 2050, with slow decline in shares. Oil demand peaks but declines only gradually. Natural gas continues to grow modestly, especially in non-OECD regions.

Regional Demand & Disparities: China progresses rapidly toward decarbonisation. Developing regions face slower transitions due to high costs and limited access to clean technologies.

Climate Outcome: Warming is limited to between 2.1°C and 2.2°C by 2100 – insufficient to meet Paris Agreement goals.

EXPLORATIVE SCENARIOS

OPEC EQUITABLE GROWTH

Prioritisation of economic growth in developing regions leads to delayed climate targets

Core Narrative: Prioritisation of strong economic growth in the Global South, allowing differentiated, flexible approaches to emissions reduction. Supports development over strict uniform climate action.

Energy Governance: Policies focus on energy access, poverty eradication, and national development needs. Global emissions goals are secondary to regional growth imperatives.

Energy Efficiency and Electrification: Efficiency and renewables improve but are uneven across regions. Fossil fuels (oil and gas) remain heavily used to support industrialization and urbanization.

Innovation: Renewables expand alongside traditional energy sources. Innovation spreads unevenly; no massive global tech convergence.

Energy Mix: Oil and gas demand increases significantly. Renewables grow strongly but fossil fuels still play a major role. Non-fossil fuel share reaches ~34%.

Regional Demand and Disparities: Africa, India, and other developing regions experience rapid energy demand growth. Developed economies grow slowly and decarbonize faster.

Climate Outcome: Higher global emissions than the Reference or Technology-Driven scenarios. Oil demand grows to 127 mb/d by 2050, about 7 mb/d higher than the Reference Case.

IEEJ ADVANCED TECHNOLOGY

Pledges in action, tech-driven decarbonisation, and system redesign

Core Narrative: Built on the full implementation of national net-zero pledges, this scenario envisions strong government-led transitions powered by technological breakthroughs and strategic investment.

Energy Governance: Governments set the pace, aligning policies with long-term carbon neutrality goals. National targets are assumed to be fully implemented, though operational challenges remain.

Energy Efficiency and Electrification: Ambitious government policies accelerate electrification across all sectors. Transport and industry shift rapidly to electric systems. Major improvements in efficiency, with widespread smart grid deployment and behavioural change driven by incentives. Clean fuels, hydrogen, and digital optimisation reduce emissions intensity in harder-to-abate sectors.

Innovation: Rapid innovation is driven by policy and investment in hydrogen, CCUS, advanced nuclear, and energy storage. A new industrial ecosystem begins to emerge.

Energy Mix: Coal declines sharply. Oil and gas peak before 2030 and steadily decline. Electricity becomes the dominant final energy carrier by 2050.

Regional Demand & Disparities: Global energy demand stabilises mid-century due to efficiency gains. Advanced economies lead the transition, but emerging economies benefit from accelerated tech diffusion and infrastructure development.

Climate Outcome: Emissions fall significantly, aligned with a well below 2°C trajectory. Net-zero becomes plausible mid-century if action follows through on current pledges.

EQUINOR WALLS

National focus, slow coordination, and incremental transition

Core Narrative: Governments focus on domestic energy security and affordability in response to geopolitical instability. Climate ambition is subordinated to national resilience, leading to fragmented, slower energy transitions.

Energy Governance: Energy policy is driven by national self-interest. International cooperation weakens, with each country charting its own course. Energy security trumps coordinated climate action.

Energy Efficiency and Electrification: Efficiency improvements occur, but progress is uneven and region-specific. Electrification expands, especially in power and transport, but at a slower pace than required for climate goals. Hydrogen adoption is limited – under 2% of the global energy mix by 2050 – and mostly focused on industry and shipping.

Innovation: Technology development continues but lacks urgency. Incremental improvements are made, particularly in Europe and Asia, but global breakthroughs in renewables, hydrogen, or negative emissions technologies lag.

Energy Mix: Fossil fuels remain dominant through 2050, with slow decline in shares. Oil peaks around 2030, gas around 2040, yet fossil energy still supplies +60% of global primary energy in 2050. Renewable energy grows, but not fast enough to shift the global system away from hydrocarbons.

Regional Demand & Disparities: Demand rises in emerging economies, while developed countries stabilise or decline. Fragmented global approaches worsen regional disparities in clean energy access, climate resilience, and emissions reductions.

Climate Outcome: The world overshoots the 1.5°C and even 2°C thresholds. Emissions decline, but not fast enough to align with the Paris Agreement, resulting in heightened climate risks.

OPEC TECHNOLOGY DRIVEN

Accelerated technology deployment enables emissions cuts while sustaining fossil fuel use

Core Narrative: Accelerated global action on energy efficiency, carbon removal technologies (CCUS, DAC), and renewable deployment, while maintaining oil and gas with lower emissions. A technology-centred path to meet the Paris goals below 2°C.

Energy Governance: Proactive investment in clean tech, efficiency, and carbon management, enabling emissions reductions without severe economic impacts on energy-exporting countries.

Energy Efficiency and Electrification: Rapid efficiency improvements across all sectors. Electrification accelerates, with renewables and nuclear energy supporting decarbonization of power and industry.

Innovation: Widespread deployment of CCUS, hydrogen, and advanced renewables. Extensive adoption of a Circular Carbon Economy (CCE) framework.

Energy Mix: Coal demand almost eliminated by 2050. Renewables and nuclear grow substantially, reaching over 48% of primary energy. Oil and gas continue but with heavy mitigation through carbon capture.

Regional Demand and Disparities: Non-OECD energy demand moderates but remains substantial; technology spreads slowly to developing regions.

Climate Outcome: Aligned with Paris goals. Primary energy demand is about 52 mboe/d lower than the Reference Case by 2050. Oil demand declines to ~96 mb/d by 2050.

SHELL ARCHIPELAGOS

Fragmented world, regionally driven transitions, and energy sovereignty

Core Narrative: A world of geopolitical fragmentation where national governments and state-owned entities dominate. Energy independence takes priority over global cooperation, limiting multinational influence.

Energy Governance: Power is dispersed. Global coordination weakens, with regions reinforcing local sovereignty and erecting policy and technology barriers.

Energy Efficiency and Electrification: Highly uneven progress. Some regions electrify quickly, others continue relying on gas and oil. Fragmented policies and investment hinder efficiency improvements. Regionalisation limits knowledge-sharing and slows diffusion of best practices.

Innovation: Innovation is security-driven and uneven. Lack of global cooperation leads to siloed solutions, rising inefficiencies, and slower diffusion of low-carbon technologies.

Energy Mix: Natural gas remains prominent in regions where renewables scale slowly. Despite local gains, global emissions remain too high.

Regional Demand & Disparities: Strong regional differences emerge. Wealthier regions decarbonise faster, while others rely on local fossil resources, reinforcing inequality.

Climate Outcome: Progress is patchy. Global temperature rise stabilises around 2.2°C, falling short of climate goals.

SHELL SURGE

AI-driven growth, accelerated tech uptake, and energy demand rebound

Core Narrative: A wave of AI-driven productivity sparks a global economic boom. Energy demand rebounds sharply, but clean technologies scale rapidly alongside growth.

Energy Governance: Governments and markets align to enable faster innovation cycles. AI enhances planning and accelerates infrastructure deployment, especially in modular energy systems.

Energy Efficiency and Electrification: AI and smart systems drive rapid gains in efficiency across buildings, transport, and industry. Electrification expands fast, especially in autonomous mobility and industrial processes. High demand offsets some efficiency gains, particularly in emerging markets, but emissions intensity declines.

Innovation: AI drives breakthroughs in materials, storage, and grid optimisation. Rapid commercialisation of clean technology is enabled by global competition and demand.

Energy Mix: Energy demand is high, but renewables, advanced nuclear, and hydrogen grow fast. Fossil fuel use plateaus earlier, aided by smart carbon management.

Regional Demand & Disparities: All regions see demand growth, but access to AI-driven solutions varies. Developed regions scale faster; developing economies benefit more gradually.

Climate Outcome: The system decarbonises faster than expected, but emissions remain above net-zero trajectories. Temperature rise stabilises closer to 2°C, not below.

NORMATIVE SCENARIOS

BNEF NET ZERO SCENARIO (NZS)

Full-sector electrification and policy-driven net-zero achievement

Core Narrative: An ambitious, coordinated transition where electrification, robust policy frameworks, and socioeconomic strategies enable global net-zero by 2050.

Energy Governance: Strong, globally aligned government action drives decarbonisation through carbon pricing, subsidies, and clean tech mandates, ensuring rapid systemic change.

Energy Efficiency and Electrification: EVs dominate road transport by early 2030s. Electrification expands deeply into buildings, heavy industry, and heating. Alternative fuels decarbonise shipping and aviation.
Innovation: Breakthroughs in clean technologies are scaled rapidly. Policy incentives ensure widespread adoption of renewables, storage, hydrogen, and biofuels.

Energy Mix: Oil and gas use decline sharply. Renewables and clean fuels become the primary energy sources across all sectors.

Regional Demand & Disparities: Clean energy access is expanded globally. Energy transition policies integrate social equity, worker reskilling, and community support to deliver a just transition.

Climate Outcome: Net-zero emissions are achieved globally by 2050 to 1.75°C relative to pre-industrial levels.

BP NET ZERO

Coordinated, ambitious transition to net-zero emissions by 2050

Core Narrative: A vision-driven scenario where strong policy action, innovation, and international collaboration deliver deep emissions cuts and systemic change by 2050.

Energy Governance: Shared global commitment drives ambitious policies, climate finance, and technology transfer, particularly supporting emerging economies.

Energy Efficiency and Electrification: Efficiency gains sharply reduce overall energy demand. Electrification surpasses 50% of final energy consumption by 2050, with widespread clean power deployment and energy storage.

Innovation: Green hydrogen becomes a core pillar of decarbonisation across shipping, aviation, and heavy industry. CCUS expands at industrial scale, mitigating residual emissions in sectors like cement and steel.

Energy Mix: Coal use is almost eliminated by 2050. Oil demand collapses, replaced by EVs and sustainable fuels. Gas declines sharply and is replaced by renewables and hydrogen.

Regional Demand & Disparities: Developing regions leapfrog to clean energy systems via technology transfer and financing. Global energy equity improves, avoiding carbon lock-in.

Climate Outcome: Emissions fall to net zero globally by 2050, aligning with the 1.5°C limit.

DNV 1.5°C SCENARIO

Transformative, front-loaded transition aligned with 1.5°C

Core Narrative: A normative scenario requiring rapid emissions cuts, technology breakthroughs, circular economy scaling, and deep decarbonisation of industry, transport, and energy sectors by 2050.

Energy Governance: Robust global policy coordination, aggressive incentives for green industries, and universal deployment of clean technologies.

Energy Efficiency and Electrification: Widespread electrification across sectors, massive deployment of heat pumps, green hydrogen, and synthetic fuels for heavy transport and industry. Circular economy solutions mitigate material constraints.

Innovation: Breakthrough innovation in hydrogen, CCUS, renewables, and industrial decarbonisation. Green finance instruments accelerate private sector investment.

Energy Mix: Fossil fuel use drops sharply. Oil use is restricted mainly to petrochemicals and aviation. Unabated gas plants are phased out by 2040. Renewables dominate the energy system.

Regional Demand & Disparities: Transitions are more balanced through international financing and technology transfer, with strong job creation globally.

Climate Outcome: Emissions fall steeply, keeping warming within 1.5°C, with net-zero achieved globally by 2050.

ENERDATA ENERGREEN

Policy-driven pathway aligned with Paris goals and deep system transformation

Core Narrative: A strongly normative scenario where coordinated government action drives a rapid, global shift to low-carbon systems. The pathway is designed to limit warming to well below 2°C.

Energy Governance: Strong national and international policy coordination steers the transition. Governments set ambitious targets and implement regulatory frameworks that accelerate renewables and efficiency.

Energy Efficiency and Electrification: Rapid electrification across transport, heating, and industry. EVs dominate new sales, and public policies support infrastructure rollout and modal shifts. Efficiency gains are high, enabled by strong policy mandates. Digital tools and behavioural changes help drive down demand per capita. Electrification is more equitably distributed than in other scenarios, though infrastructure gaps remain in some emerging regions.

Innovation: Technology innovation is enabled by public investment and policy mandates. Renewable and digital technologies thrive; fossil incumbents retreat.

Energy Mix: Natural gas plays a limited transitional role early on but declines steeply by 2050. Renewables dominate, supported by hydrogen, efficiency, and grid flexibility.

Regional Demand & Disparities: Energy demand grows fastest in emerging economies but is managed through efficiency and electrification. The transition is more evenly distributed than in other scenarios, though some regions lag due to capacity constraints.

Climate Outcome: Designed to achieve deep decarbonisation, the scenario aligns with keeping global warming well below 2°C by 2100.

EQUINOR BRIDGES

Globally coordinated transition toward a 1.5°C-aligned future

Core Narrative: A collaborative, net-zero-oriented world. Countries work together to decarbonise, prioritising shared climate goals, with financial and technological support flowing to the Global South.

Energy Governance: Multilateralism strengthens. International institutions help align national targets, climate finance supports just transitions, and global frameworks drive down emissions equitably.

Energy Efficiency and Electrification: Electrification surges, reaching over 50% of final energy use by 2050. Hydrogen plays a significant role, especially in industry, heavy transport, and shipping, reaching nearly 10% of total energy use. Road transport is almost entirely decarbonised, and hydrogen-based fuels power large parts of aviation and marine sectors. Strong policy and innovation accelerate efficiency gains across all sectors.

Innovation: Clean tech innovation flourishes, with breakthroughs in hydrogen, renewables, CCS, and energy storage. Technology transfer and global knowledge-sharing fast-track decarbonisation across all regions.

Energy Mix: Fossil fuel use falls to 22% of the global mix by 2050. Most remaining use is abated or offset. Coal is rapidly phased out, oil demand collapses, and gas is used in sectors with CCS or negative emissions integration.

Regional Demand & Disparities: Demand is met more equitably. Developed countries lead the transition and fund efforts in developing economies, supporting leapfrogging to clean technologies and closing gaps in access and resilience.

Climate Outcome: Bridges is consistent with a 1.5°C pathway. Emissions fall sharply, and carbon neutrality is achieved mid-century through a mix of mitigation, efficiency, and removals.

IEA NET-ZERO EMISSIONS (NZE)

Cooperative, transformative pathway to net zero

Core Narrative: A highly ambitious, 1.5°C-aligned scenario that assumes transformative change, deep international collaboration, and immediate action across all sectors and regions.

Energy Governance: Governments coordinate and implement robust policies for deep decarbonisation. Net-zero targets are backed by enforcement mechanisms, subsidies, and global cooperation.

Energy Efficiency and Electrification: Electrification accounts for over 50% of final energy consumption by 2050, requiring massive investment in renewables, grids, and storage. Efficiency gains are accelerated through policy, technology, and behavioural change.

Innovation: Breakthrough innovation is critical. NZE relies on rapid scaling of hydrogen, advanced nuclear, CCUS, and next-gen storage. Annual clean energy investment must triple to reach $4 trillion by 2030.

Energy Mix: Fossil fuel use drops sharply. What remains is abated or offset through carbon removals. Renewable energy dominates, and coal is eliminated.

Regional Demand & Disparities: The transition is globally inclusive but requires substantial financial and technology transfers. Developing economies face higher demand growth and must overcome structural challenges with international support.

Climate Outcome: The NZE scenario is consistent with limiting warming to 1.5°C. It delivers net-zero emissions globally by 2050 through a systemic transformation of the energy landscape.

IRENA 1.5°C SCENARIO

Global acceleration toward renewable dominance and net-negative emissions

Core Narrative: A transformative, 1.5°C-aligned future built on renewable energy leadership, global workforce reskilling, and expanded international energy cooperation.

Energy Governance: Strong international collaboration ensures rapid renewable deployment, green hydrogen scaling, and equitable transition financing across regions.

Energy Efficiency and Electrification: Electricity becomes the backbone of final energy use, with renewables providing nearly all generation. Electrification reaches deep into transport, industry, and buildings. Smart grids and regional energy market integration support flexibility and reliability.

Innovation: Rapid expansion of green hydrogen, BECCS (bioenergy with carbon capture and storage), and direct air capture (DAC) technologies deliver emissions reductions and carbon removals at scale.

Energy Mix: Solar PV and wind provide over 75% of electricity by 2050. Fossil fuels are nearly phased out, with remaining emissions offset by negative emission technologies.

Regional Demand & Disparities: Asia leads cost reductions; Africa leapfrogs to renewables with international support; Latin America becomes a major green hydrogen hub. Cross-border infrastructure boosts energy access and resilience.

Climate Outcome: Global warming is limited to 1.5°C, with net-zero achieved mid-century and substantial negative emissions beyond 2050.

SHELL HORIZON

Coordinated action, strong governance, and a net-zero push

Core Narrative: A government-led world where policies and global coordination drive the transition. Carbon pricing, fossil phaseouts, and clean tech mandates reshape the energy system.

Energy Governance: Governments take the lead. Global institutions align around Paris targets, with high coordination across regions and sectors.

Energy Efficiency and Electrification: Strong policy mandates drive widespread electrification of mobility, heating, and industrial processes. Fossil fuel use in mobility declines rapidly post-2030 as infrastructure and regulation support the shift. Efficiency measures are integrated across sectors, supported by digital infrastructure and global cooperation. Energy intensity drops sharply in both developed and emerging economies.

Innovation: Public funding drives early-stage technologies, while private actors follow regulatory signals. New players in clean tech rise as fossil incumbents fade.

Energy Mix: Natural gas plays a transitional role but is phased out. By 2050, electricity dominates, powered by renewables, storage, and hydrogen.

Regional Demand & Disparities: Developed economies peak in energy demand and decarbonise first. Emerging economies follow through financial and technological support, with rising demand met through electrification and efficiency. Equity and inclusion are key principles of global cooperation.

Climate Outcome: Rapid emissions cuts and global policy alignment keep warming well below 2°C, approaching the 1.5°C target by 2075, and then around 1.2-1.3 °C by 2100.

TOTAL ENERGIES RUPTURE

Global acceleration towards deep decarbonisation and equity

Core Narrative: A transformative scenario where global decarbonisation levers are deployed across all regions, enabling emerging economies to grow sustainably while sharply cutting emissions.

Energy Governance: Stronger international cooperation, with developed nations providing financing, technology transfers, and capacity-building to support just energy transitions globally.

Energy Efficiency and Electrification: Rapid global electrification of transport and industry. Massive adoption of EVs, sustainable aviation fuels, e-fuels, biofuels, and biogas accelerates the decarbonisation of hard-to-abate sectors.

Innovation: Circular economy initiatives – especially plastics recycling – expand worldwide. Hydrogen, bioenergy, and CCUS scale up to complement renewables and efficiency gains.

Energy Mix: Fossil fuel use declines sharply. Renewables, hydrogen, and sustainable fuels dominate the primary energy mix by mid-century.

Regional Demand & Disparities: Global South transitions faster with international support, achieving growth alongside decarbonisation. Equity improves substantially.

Climate Outcome: The world aligns with the well below 2°C target, with emissions peaking before 2030 and falling sharply thereafter.

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