

How to invigorate and complete the fossil fuel transition



Authors

Sam Fankhauser, Myles Allen, Johanna Arlinghaus, Kaya Axelsson, Mirte Boot, Aoife Brophy, Ben Caldecott, Emily Cox, Alice Evatt, Siyu Feng, Benjamin Franta, Steven Fries, Cameron Hepburn, Conor Hickey, Stuart Jenkins, Injy Johnstone, Radhika Khosla, Javier Lezaun, Sam Loni, Alexis McGivern, Jessica Omukuti, Stephen M. Smith, Sugandha Srivastav, Joseph Stemmler, Ingrid Sundvor and Thom Wetzer.

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Executive summary

The global transition away from fossil fuels has stalled. While international announcements like the COP28 Global Stocktake signal political intent, actual geopolitical developments reveal a persistent interest in fossil fuels. Current fossil fuel production and consumption trajectories remain fundamentally misaligned with the temperature goals of the Paris Agreement.

Yet the position of fossil fuels is more tenuous than recent trends imply. Several structural factors that have historically underpinned their dominance – most notably their control over energy supply options – are now weakening.

We argue that the fossil fuel transition can be **successfully completed** if policymakers, businesses and financial institutions more systematically deploy solutions that already exist. The problem is not a lack of policy, technological, or financial tools, but their inconsistent application and the limited ambition with which they are implemented.

We identify **eight strategic challenges** that together define the fossil fuel endgame (see Action Points below). These challenges span deep societal views about prosperity, institutional and regulatory distortions that favour fossil fuels, the practical management of decline in fossil fuel demand and supply, and the requirements for a net-zero-aligned residual fossil fuel sector.

We show that for each challenge there are **tested, scalable solutions**. Although inertia and entrenched interests constitute significant barriers, with the right set of interventions, a successful fossil fuel transition is possible, desirable and more likely than is generally assumed.

Action points for a successful fossil fuel transition

1. Demonstrate clean ways of meeting energy needs

- Demonstrate, at scale, that affordable, reliable energy access and economic growth can be achieved without fossil fuels.
- Prioritise renewable energy deployment, electrification and clean energy entrepreneurship, especially in the Global South.
- Integrate energy access, climate and development strategies to counter fossil fuel-led development narratives.

2. Promote models of economic prosperity without fossil fuels

- Build consensus around long-term economic strategies that reduce reliance on fossil fuel revenues and exports.
- Use industrial policy, public investment and institutional reform to expand non-fossil economic sectors.
- Encourage fossil fuel companies, including state-owned enterprises, to pursue fundamental business model transformation.

3. Remove the incumbent advantages of fossil fuels

- Reform fossil fuel subsidies and pricing mechanisms, using gradual approaches and targeted compensation to protect vulnerable households.
- Internalise social and environmental costs through carbon pricing, regulation or extended producer responsibility.
- Align legal, regulatory and investment frameworks so fossil fuels no longer enjoy default “public interest” status.

4. Set clear corporate standards to guide behaviour

- Strengthen net zero standards to include explicit fossil fuel phase-out requirements, timelines and capital allocation rules.
- Embed voluntary standards into regulation or make them legally enforceable.
- Mandate credible transition plans for fossil fuel producers, including asset retirement and full lifecycle emissions management.

5. Reduce fossil fuel demand

- Accelerate electrification of power, transport, buildings and industry using clean electricity.
- Double down on energy efficiency and sufficiency through standards, urban planning and behavioural interventions.
- Deploy coordinated policy packages that combine regulation, pricing and public investment.

6. Reallocate capital and labour at scale

- Integrate climate transition risks into financial regulation, supervision and disclosure frameworks.
- Use transition finance, sustainability-linked instruments and shareholder engagement to drive real-economy change.
- Invest in reskilling, active labour market policies and place-based transition support for affected workers and communities.

7. Manage vanishing economies of scale and scope in fossil fuel systems

- Avoid new long-lived fossil infrastructure and align asset depreciation with climate targets.
- Facilitate orderly downsizing and consolidation of gas networks and refineries.
- Support managed decommissioning and protect consumers from unfair cost burdens during transition.

8. Clean up residual carbon

- Without compromising the transition, scale up geological CO₂ storage as a core component of net-zero-aligned fossil fuel use.
- Apply the polluter-pays principle through mechanisms such as carbon takeback obligations.
- Use public policy to overcome early-stage market failures while preventing carbon removal from becoming a substitute for demand reduction.

1. Introduction

Meeting the temperature goals of the Paris Agreement requires an end to greenhouse gas emissions from fossil fuel production and use. At COP28, the first Global Stocktake was heralded as “the beginning of the end of fossil fuels,” as it called for a transition away from their widespread use and the transformation of global energy systems (UNFCCC, 2023). It was an important milestone, and reaching it has been hard.

The fossil fuel transition is one of the most contentious issues in international climate negotiations. It raises profound questions about the unequal impacts of fossil fuel extraction and use (Muttitt et al, 2020; Healy et al, 2019) and the (un)fairness of proposed transition pathways (Lenferna, 2018; Geels et al, 2017). There is an inherent North-South divide (van Asselt et al, 2023), as well as tension between fossil fuel and non-fossil-fuel-producing countries within the Global South. The debate is occurring in a context of deep polarisation, in which fossil fuels have taken on totemic significance (Lamb et al, 2020). Polarisation stems in part from a deliberate strategy by some stakeholders, who use divisive narratives to delay climate action (Ferns et al, 2019; Franta, 2022).

Since COP28 the transition away from fossil fuels has stalled. There is renewed geopolitical interest in the exploitation of fossil fuels. Production is expanding in the name of energy security and economic growth. Existing and planned fossil fuel infrastructure, and the associated “carbon lock-in”, easily exceed levels consistent with a 1.5°C or even 2°C world (McGlade et al, 2015; Pfeiffer et al, 2018).

Despite these trends, we argue that with the right interventions, a successful fossil fuel transition is possible, desirable and perhaps more likely than generally assumed. Drawing on an extensive body of solutions-oriented research by our multidisciplinary author team, as well as wider evidence, we identify eight strategic challenges which we believe are critical to a faster and fairer fossil fuel transition. They constitute a strategic framework for the fossil fuel endgame.

For each of the challenges we identify and review concrete, scalable solutions. While their deployment must be context-specific, all of them have been tried and tested in practice. The solution space for the fossil fuel transition is much more developed than commonly appreciated.

2. Fossil fuels in global net zero pathways

A good way to understand normatively what the future of fossil fuels needs to be is to look at the decarbonisation pathways reviewed in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

The IPCC’s 1.5°C-compatible pathways make clear that there are no credible scenarios in which fossil fuel use can be sustained at today’s level. Fossil fuel emissions must fall sharply on the way to global net zero CO₂ by the middle of the century. By the very definition of global net zero, at that point any remaining fossil fuel use will require compensating for with permanent carbon storage.

Figure 1 shows the primary energy supply in an average of 1.5°C-compatible scenarios from the Sixth Assessment Report (IPCC, 2021). Net zero is achieved in 2055 (red dot) through a

combination of steep emissions cuts and CO₂ removal, chiefly into biological sinks. Storing carbon in biological sinks, such as forests and soils, plays a critical role in natural source-sink balancing and restoring ecosystems. However, a durable climate stabilisation will require more permanent types of CO₂ storage, primarily in geological sinks (Allen et al, 2022). This state of geological net zero is achieved in 2064 (dark red dot), but fossil fuel use in electricity, heating, cooking and land transport will need to be reduced to near-zero well before that date.

The scenarios assessed by the IPCC are not exhaustive, but they indicate clear trajectories for both fossil fuels and renewable energy (Welsby et al, 2021; Achakulwisut et al, 2023):

- **Coal** use (purple region) decreases by >75% by 2040. At geological net zero, only a small fraction remains, primarily as a feedstock in steel and heavy industry. Approximately 90% of contemporary coal reserves are unexploitable in a 1.5°C-aligned trajectory.
- **Oil** (blue region) declines by >50% by the time of geological net zero and approximately 75% by 2100. Global oil supply peaks between 2020–2030, with around 60% of contemporary reserves projected to remain unexploited.
- **Natural gas** (orange region) shows greater variation, depending on assumptions regarding carbon capture and storage (CCS). Gas use is projected to remain relatively stable, but an increasing fraction is used with CCS. Unabated gas follows a similar decline trajectory to unabated oil. Some 50–60% of contemporary natural gas reserves are unextractable, with a higher fraction for unconventional gas.
- **Renewable energy** (green dotted region) scales up dramatically to simultaneously replace existing fossil fuel use and meet growing energy demand, supplying two-thirds of primary energy by geological net zero.

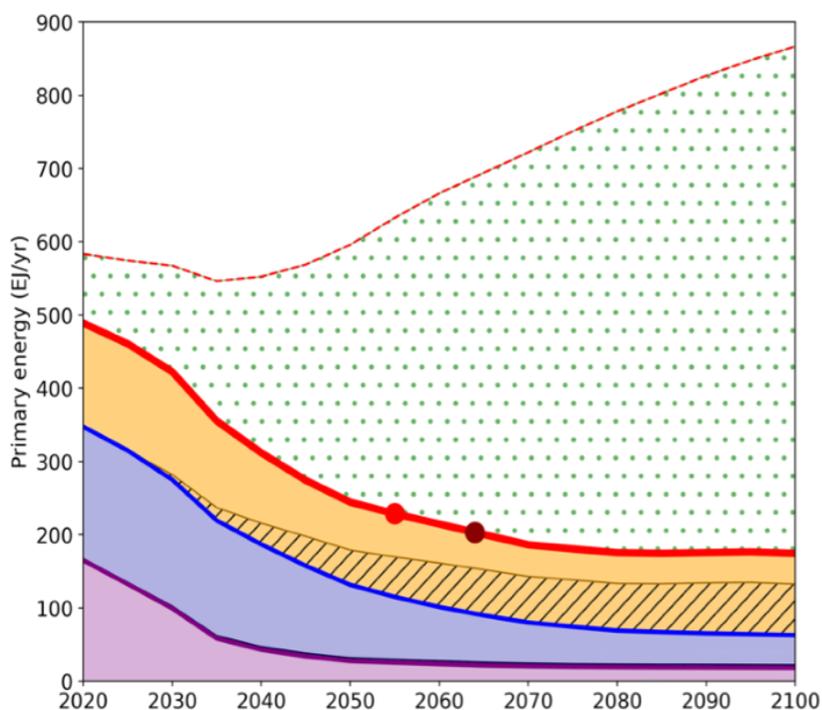


Figure 1 – Primary energy supply between 2020–2100, partitioned between individual sources, in the average across C1 and C2 scenario groups in IPCCAR6. Primary energy supplied from coal is shaded purple, oil is shaded blue, and natural gas is shaded orange (hatched region shows the portion of natural gas primary energy which has CCS attached). The thick red solid line shows the total primary energy delivered by fossil fuels. The green dotted region shows the primary energy supply from sources that the integrated assessment models (IAMs) assume are carbon-free (nuclear and renewables including biomass). The total primary energy supply is shown with a red dashed line. Dates of net zero (2055) and geological net zero

(2064) are shown on the fossil primary energy supply curves with red and dark red dots, respectively.

The crucial point is that all 1.5°C pathways deviate radically from a prolonged history of fossil fuel growth and the trend is barely slowing. The International Energy Agency anticipates continued fossil fuel expansion, with oil demand growing (albeit more slowly), gas demand exceeding a 2.5% annual growth rate, and coal demand stabilising after a possible peak in 2023 (IEA, 2024).

As a result, emissions projections for 2030 surpass 1.5°C and 2°C limits by 110% and 69%, respectively (SEI et al, 2023). If the Paris goals are to be met, more effective transition strategies are urgently needed.

3. A strategic framework for the fossil fuel transition

Figure 1 makes clear that net zero will require a systemic transformation of the fossil fuel industry. Such deep structural change is difficult, but there are precedents from which lessons can be learnt, such as the post-communist transition (Fries, 2021). Systems science can help to identify the economic, institutional, social and regulatory conditions that shape the fossil fuel transition.

These conditions translate into a set of sensitive intervention points (Farmer et al, 2019) – sometimes referred to as leverage points in system theory (Meadows, 1999) – where targeted action can disproportionately influence the success of the transition.

Drawing on these concepts, we identify eight strategic challenges, which can serve as an organising framework for the fossil fuel endgame (Figure 2).

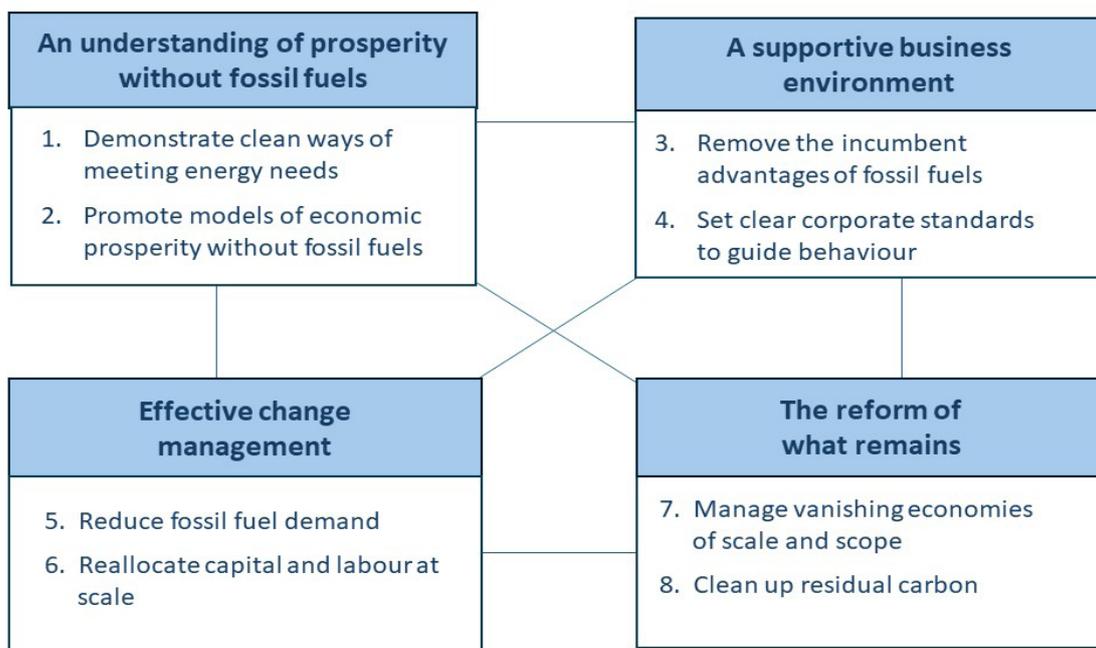


Figure 2 – Eight strategic challenges that the fossil fuel transition must address, based on the notion of sensitive intervention/leverage points. For each challenge, tried and tested solutions exist.

The first set of strategic challenges concerns a shift in understanding of the role of fossil fuels in economic prosperity. Energy consumers need assurances that the fossil fuel transition will not be detrimental to their development and meet their energy needs affordably and sufficiently. Countries, corporates and communities which currently depend on fossil fuel production need alternative pathways to sustainable prosperity. The literature refers to such shifts in underpinning views as deep leverage points (Abson et al, 2017).

The second set of strategic challenges concerns the rules of the system – the institutional and regulatory context in which the transition occurs. The transition is driven by business and household investments, which need a supportive business environment. This means levelling an institutional playing field that remains structurally tilted in favour of fossil fuels and defining clear regulatory standards to guide behaviour.

The third set of strategic challenges concerns the mechanics of systems change – the management of the transition itself. A successful global transition must progress simultaneously on the demand side, with a sharp reduction in fossil fuel use, and on the supply side, with the orderly reallocation of capital and labour away from fossil fuels.

The final set of strategic challenges concerns the design of a new system, that is, the post-transition fossil fuel sector. The fossil fuel industry emerging from the transition must be net-zero-aligned. Economically, this means addressing vanishing economies of scale, for example, in gas networks shared by fewer consumers, and economies of scope in refining, where there will be fewer marketable products. Environmentally, a growing fraction and eventually all remaining CO₂ emissions from fossil fuels must be captured at source or removed from the atmosphere.

4. Revisiting the solutions space

There is no agreement on how these strategic challenges are best addressed. Stakeholders approach the fossil fuel transition with diverging world views, which shape their approach towards issues such as collaboration strategies, policy preferences, burden-sharing and the endpoint of the transition.

Yet for all eight challenges there are tested solutions, which can be adapted and adopted to the fossil fuel transition. The main ones are introduced below. Our aim is not to prescribe a specific transition model, but to demonstrate that the toolkits are in place to successfully tackle the strategic challenges of the fossil fuel transition.

4.1 Demonstrate clean ways of meeting energy needs

Challenge: There is controversy about the importance of fossil fuels in delivering the Sustainable Development Goals, including SDG 7 on universal access to affordable and clean energy. A just transition needs to include not just those directly affected by a movement away from fossil fuels, but also those already marginalised from the energy system, most of whom live in the Global South.

Many development indicators are dependent on the ready availability of affordable energy (McCollum et al, 2018). Commentators poised against a rapid transition argue that fossil fuels are therefore essential for the development prospects of the Global South (Mutezo et al, 2021).

For the fossil fuel transition to advance, an alternative vision to fossil fuel-led development must take hold, which recognises that achieving sustainable development requires abundant energy, but not fossil fuels specifically.

Solutions space: This alternative vision is increasingly implemented in practice, and as such progressively easy to demonstrate. There are multiple examples of successful clean energy transitions, including from Brazil, China and India (Khosla et al, 2020; Bazilian et al, 2012). Solar power is booming in countries like Namibia (Kruger, 2022), Pakistan (Sprung et al, 2025) and Vietnam (Koons, 2025). Clean energy entrepreneurs are introducing business models specifically geared towards boosting electrification, and renewables auctions are attracting ever lower bids (IRENA, 2024). Far from slowing down development, a rapid switch to clean energy will in fact speed up energy access (Fankhauser et al, 2024; Way et al, 2022).

This vision still needs strengthening before it truly takes hold. Different socio-economic contexts will have a bearing on countries' trajectories towards inclusive development (Mulugetta et al, 2022). There is concern about high capital costs slowing down the rollout of renewables (Steffen, 2020). Clean energy and clean energy policies can raise social or environmental issues too (Murphy et al, 2021), and justice is needed in both fossil fuels and clean energy pathways (Newell, 2021). However, energy planners increasingly recognise that renewable energy is a more promising route to economic growth and inclusive development than fossil fuels.

4.2 Promote models of economic prosperity without fossil fuels

Challenge: Many countries depend heavily on hydrocarbon products in terms of export revenues, government income and overall economic activity. Among the 40 most oil- and gas-dependent economies, resource rents stand on average at 14% of GDP and 39% of total government revenue (Jensen, 2024). These countries need an alternative route to prosperity.

The challenges faced by nation states are mirrored by the strategic choices of fossil fuel companies, many of which are state-owned. Fossil fuel firms have resources and competencies that can be leveraged to support new technologies (Kungl, 2024), but attempts at diversification have so far been disheartening. Even when there is ambition, the existing often wins out at the expense of the new (Nilsen, 2017; Wright et al, 2017).

Solutions space: Economic diversification has long been promoted as an effective strategy to reduce resource dependency (Peszko et al, 2020; Foster et al, 2024). There are powerful arguments for this path, even in the absence of climate change. Fossil fuel-based models of development can generate highly unequal forms of wealth and an overconcentration of investment in a single sector. They can encourage authoritarianism, rent seeking and socio-environmental conflict (Ross, 2015).

The development paths of emerging economies like Malaysia, Mexico and South Korea demonstrate the long-term benefits of diversifying away from primary commodity exports (Gelb, 2012). Crucially, economies with a more complex product mix may also find it easier to switch to new forms of low-carbon prosperity (Andres et al, 2023).

While the benefits of economic diversification are clear, successful examples away from fossil fuels are rare. The experience of the Gulf states tells us that progress is possible when there are a clear economic strategy and strong institutions (Callen et al, 2014). The success of broad-based economic policies in countries like Costa Rica, India and Senegal also yields important lessons (Delechat et al, 2024). Progress often depends on the willingness of elites to “gamble on development” (Dercon, 2022).

Encouraging fossil fuel companies to follow the path of fundamental transition may require a dual approach of identifying new opportunities, while offering clear policy guidance and partnerships to challenge market incumbents (Kivimaa et al, 2016). Positive examples of fundamental transition include several electric utilities and the Danish energy company Orsted. They required strong private- and public-sector leadership and close collaboration between the public and private sector (Dzhengiz et al, 2024; George et al, 2024). These positive examples notwithstanding, creating models of prosperity independent of fossil fuel wealth is one of the hardest challenges of the fossil fuel transition.

4.3 Remove the incumbent advantages of fossil fuels

Challenge: Centuries of economic development moulded around fossil fuels have created institutional structures that benefit incumbent technologies. Across legal systems, laws implicitly favour fossil fuels. Examples include eminent domain to oil pipeline construction but not for transmission to integrate renewables in the US (Coleman et al, 2019); lower due diligence requirements for coal mining in India (Srivastav et al, 2023); burdens of proof assuming fossil fuels are in the public interest (Rafaty et al, 2020); legal provisions that insulate asset owners from transition risks (Wetzer et al, 2024); and international arbitration rules that protect them in investor-state disputes (Tienhaara et al, 2022).

Fossil fuel extractors, operators and users rarely shoulder the external social and environmental costs, which fossil fuels impose at each step of the supply chain, often on vulnerable communities (Ma, 2020; Harfoot et al, 2018; Finkelman et al, 2021). Indeed, many firms do not even bear their own internal costs: in 2023, the fiscal cost of government support to fossil fuels was US\$ 1.1. trillion (OECD, 2024). For a faster transition, the playing field between fossil fuels and their alternatives must become more level.

Solutions space: Breaking incumbent advantages and reforming energy prices is challenging socially as well as politically. While fossil fuel subsidies predominantly benefit high-income groups, they can also contribute to important social welfare objectives (Fattouh et al, 2015). However, experience with successful energy price reform is growing.

A frequent recommendation is to introduce reforms gradually and integrate them into wider economic reform packages. Targeted compensation payments, instead of blanket subsidies, can ease the impact on low-income groups. Extensive stakeholder consultation and transparency about the impact of price changes are key (Inchauste et al, 2017). The same recommendations also apply to carbon pricing, the main policy for making fossil-fuel polluters pay (Klenert et al, 2018).

Policymakers often favour subsidies over pricing schemes. Levelling the playing field through sweeteners is considered easier than removing incumbent advantages outright. Clean energy subsidies and de-risking measures like off-take guarantees are deployed to enhance the

competitiveness of renewables. Emissions trading systems use free allowances to secure the buy-in of industry (Sato et al, 2022). Policymakers will have to decide whether these are acceptable, and affordable, departures from the polluter pays principle. Alternatively, fossil fuel companies could be made to “own” the CO₂ waste disposal problem through extended producer responsibilities (Jenkins et al, 2021).

4.4 Set clear corporate standards to guide behaviour

Challenge: The fossil fuel transition relies heavily on the corporate behaviour of individual firms. While many companies have adopted net zero targets and plans, their implementation is uneven. Most fossil fuel users remain a long way off the necessary benchmarks for transitioning away from fossil fuels. Of the 88% of global emissions covered by a national net zero target, just 7% include a full or partial phase-out commitment relating to exploring, producing or using fossil fuels (Net Zero Tracker, 2024).

Corporate standards and voluntary guidance help to formalise common visions of the future and can lead firms through the fossil fuel transition. Companies validated by the Science Based Targets Initiative are cutting Scope 1 and 2 emissions faster than their peers by 12% year-on-year on average (SBTi, 2023).

However, standards must be strengthened. One-third of net zero standards and guidance do not explicitly recommend that companies phase fossil fuels out of operations or investment portfolios, and only two provide specific targets and timelines for doing so (Becker et al, 2024). Existing standards also contain limited guidance for professional service firms on their operational emissions, missing an important accountability lever for the law firms, advertising agencies and consulting firms that advise the users and producers of fossil fuels.

On the producer side, frameworks like the International Energy Agency's emissions guidance and the Transition Plan Taskforce's sectoral guidance exist, but they are insufficiently adopted. Recent rollbacks of energy companies' net zero pledges underscore the limits of voluntary ambition.

Solutions space: Net zero standards are updated constantly and important new standards are under development, such as those by the International Organization for Standardization (ISO). They should be improved by including stronger requirements on how fossil fuel users and enablers engage with the industry.

However, to scale, voluntary standards need to be embedded into policy or non-compliance must be challengeable in courts (Benjamin et al, 2022). This is slowly starting to happen. Best practices codified in climate standards are increasingly consolidated into regulation (Hale et al, 2024). Data from the Climate Policy Monitor shows 27 of the 30 jurisdictions mapped adopted at least one climate-related standard or guidance document into a policy tool.¹ This practice was most advanced in regulations related to climate-related disclosure, where 87% of jurisdictions referenced a standard and 47% mandated their use.

Mandates are equally critical on the producer side. A science-based net-zero-aligned standard for fossil fuel producers would require a complete transformation of business models via operational decarbonisation, investment in permanent storage (ultimately reaching 100% of the CO₂ produced and sold in the form of fossil fuels), and managed asset retirement for unextractable

¹ <https://climatepolicymonitor.ox.ac.uk>.

reserves. These are difficult ambitions to achieve and maintain in a competitive globalised market. Net zero for the fossil fuel industry will therefore require regulatory mandates.

4.5 Reduce fossil fuel demand

Challenge: As long as fossil fuel demand remains high, incentives to continue using existing supply structures will persist. The transition away from fossil fuels therefore necessitates significant demand reduction. Fossil fuel demand can be cut in two ways: by lowering overall energy consumption and by limiting the share of fossil fuels in that consumption.

Both aspects are critical. Continued demand reduction entails investing in the synergies between renewable energy, energy efficiency and electrification. The switch from fossil fuels to renewables is advancing, but energy efficiency progress is lagging the COP28 pledge to double the global average annual rate of energy efficiency improvements by 2030 (IEA, 2024).

Solutions space: Energy efficiency and renewable energy are perhaps the most studied aspects of climate policy. The available policy interventions are well understood and associated challenges well-rehearsed. While the solution space is contested, it is rich, and elements of good practice are emerging.

Energy efficiency, and more broadly energy sufficiency, is about reducing the amount of energy needed to meet given economic development or social welfare objectives (Fawcett et al, 2019). It requires systemic changes in energy-use infrastructure, end-use technology, and through socio-cultural factors. Examples include the use of urban planning (e.g., 15-minutes cities) and modal shifts in transportation, improved appliance standards and selected lifestyle changes (Cabeza et al, 2022). Most countries with falling carbon emissions, including France, Ireland and the UK, have seen a reduction in energy use, contributing about a third to their drop in emissions (Le Quéré et al, 2019). This potential is far from being exhausted (Barrett et al, 2022; Millward-Hopkins et al, 2020), and there are multiple co-benefits, including lower costs and improved energy security.

Reducing the share of fossil fuels in total energy use is in large part about electrification. Power generation can become virtually fossil-fuel-free by switching to clean alternatives, such as solar and wind. Clean electricity, with appropriate storage, can then be used efficiently to reduce fossil fuel use in sectors such as surface transport (through electric vehicles), buildings (heat pumps) and parts of industry (green hydrogen, which is electro-intensive to produce). The move away from fossil fuels is gathering momentum in electric power and electric surface transport, where critical tipping points have been reached. Renewables are now the least-cost energy option in most contexts (Way et al, 2022; Nijssse et al, 2023).

Even so, without policy intervention the fall in fossil fuel use is unlikely to be fast enough. The evidence tells us that synergistic policy combinations, which address different barriers simultaneously, are most successful in reducing fossil fuel demand (Stechemesser et al, 2024; van den Bergh et al, 2021). The UK's experience in phasing out coal-fired power is a case in point. The government deployed two carbon price signals, pollution control regulation, clean energy subsidies and, at least initially, access to a dedicated green investment bank (Green et al, 2021), aided by a steady fall in electricity demand (Climate Change Committee, 2025).

4.6 Reallocate capital and labour at scale

Challenge: As the fossil fuel value chain downscales, large capital pools and a substantial workforce will need to be reallocated. Rigidities in labour and capital markets could substantially increase the economic and human costs of the transition.

The redeployment of fossil fuel workers is particularly challenging. The issue is not primarily job numbers; energy-related jobs are expected to grow overall (IRENA, 2020). However, those new jobs may be in different locations and require different skills. Studies suggest that green jobs demand higher levels of formal education and work experience (Bowen et al, 2018). For a faster and fairer transition, structural rigidities must be addressed.

Solutions space: Easing the workforce transition requires both labour market and social policy interventions. Labour mobility and flexible labour markets will allow skilled workers to move into adjacent jobs. However, without additional support, the fossil fuel transition could be difficult for workers who lack the newly-required capabilities, creating pressure in vulnerable communities (Rodríguez-Pose et al, 2024).

There are only a few examples of relatively successful community transitions, such as the Ruhr valley in Germany. The Ruhr valley example highlights the need for close collaboration between government, industry, labour unions and local communities, as well as active labour policies like reskilling programmes, vocational training and job search assistance (Gambhir et al, 2018).

The redeployment of capital is comparatively less challenging. Transition risks (Semieniuk et al, 2021) are already understood and priced by some financial institutions. The process is still at an early stage, but can be scaled up with well-designed and properly implemented financial regulation. This will increase the cost of capital for fossil fuel companies (Zhou et al, 2025), help to reduce the risk of stranded assets and protect the stability of the financial system.

Implementation requires the integration of climate-related risks into micro-prudential and macro-prudential frameworks, financial conduct rules and monetary policy (Campiglio et al, 2018). A good example is the Bank of England's supervisory expectations for banks and insurers in relation to climate, which have been replicated across much of the G20. Transparency and measurability are key enablers, supported by enhanced climate-related financial disclosures, asset-level data, and spatial finance tools (Caldecott et al, 2022).

Some finance providers will respond to changing risk profiles through divestment. While this may restrict access to capital, there is also a risk that assets are merely transferred, rather than transitioned, and perhaps to less committed owners (Armour et al, 2022). To avoid such "paper decarbonisation", financial products and services must incentivise change through shareholder engagement and transition finance. Instruments such as sustainability-linked bonds and loans that tie favourable financial terms to measurable sustainability outcomes can drive change. Legal provisions can protect transition progress after an ownership change (Armour et al, 2023).

Governments will have to decide whether to absorb part of the losses from stranded fossil-fuel assets by, for instance, subsidising closures, taking on remediation liabilities or funding worker- and community-support programmes. Germany's lignite phase-out deal (Popp, 2023) shows how the burden can be cascaded so investors take the first hit and public money secures wider social benefits. Operators wrote down plant values by roughly half, but federal compensation was released for lost earnings and is used for worker redeployment, mine-land clean-up and

regional diversification. South Africa's Just Energy Transition Investment Plan applies a similar logic (Presidential Climate Commission, 2025).

4.7 Manage vanishing economies of scale and scope

Challenge: The ubiquitous use of fossil fuels has given rise to significant economies of scale and scope. Large production volumes have created relatively low average refining and distribution costs. Faced with declining demand, these benefits will reduce and require a re-evaluation of the industry's business models.

The natural gas sector exemplifies the diminishing economies of scale facing fossil fuels. As gas demand falls, the fixed network costs will need to be allocated over smaller volumes, creating a feedback loop that further dampens demand (Hickey et al, 2019).

The refining industry will experience significant shifts in economies of scope. Refineries have increased their profitability by adopting complex processes that deliver a range of higher-value products, including jet fuel and petrochemical feedstocks (IEA, 2018). With the increasing electrification of surface transport, the product mix of refineries will become reliant on a few higher-value products, which themselves could eventually be substituted by plant-based and synthetic alternatives (Vidal et al, 2024).

Solutions space: Structural change in the fossil fuel sector should be market-led. The industry has a long history of adapting to market and technology trends, for example the UK's rapid move out of town gas (Pearson et al, 2017).

Natural gas network operators can respond by focusing on the business-to-business sector of power generation and certain industrial applications, alongside CCS, leveraging existing sunk infrastructure while decommissioning much of the distribution network. Gas transportation systems with smaller-scale LNG units closer to end-users offer a more flexible delivery model that obviates long-lived pipeline infrastructure investments (Budiyanto et al, 2020).

The refining sector will have to reconfigure existing facilities for narrower product mixes or bio-based products (Fitzgibbon et al, 2023). The most efficient refineries with the lowest emissions may survive the longest in their current form, but the need for complex fossil-based refineries will fade. Simpler refineries may be better candidates for retrofits and can serve market niches such as jet fuel, alongside purpose-built biorefineries.

Governments can accelerate this industry-led transition and mitigate its distributional impacts (e.g. on heating costs), by removing incentives for grid expansion (e.g. through bans on new gas boilers), introducing compensation mechanisms for network disconnections and decommissioning, and shortening depreciation periods for network assets to align with climate targets. Policy combinations that raise fuel standards, ban new petrol and diesel car sales, and reduce demand for petrochemical products (e.g. plastics), as seen in California, could hasten industry consolidation.

4.8 Clean up residual carbon

Challenge: Any continued fossil fuel use beyond net zero will require the capture and permanent storage of associated CO₂ either at the point of fossil fuel combustion (thus preventing emissions to the atmosphere) or from the ambient atmosphere (generating removals to counterbalance emissions). The fossil fuel transition must therefore be accompanied by a large-scale expansion of permanent, most likely geological, CO₂ storage (Achakulwisut et al, 2023).

Building a CO₂ storage industry at the required scale and speed is expensive. It requires infrastructure and skills, including knowledge of storage potential and the ability to access it. The fossil fuel industry is well placed to provide this and should be mandated or incentivised to do so.

Solutions space: The carbon removal market will not scale without government intervention. The polluter pays principle suggests that the costs of CO₂ storage should be borne by fossil fuel producers and consumers. However, there are multiple market failures and externalities that call for state intervention, for example related to innovation, shared infrastructure, and environmental, health and safety regulation. Governments also have to decide to what extent they should support cost reductions in the short term (e.g., until carbon prices match removal costs).

Policymakers are starting to explore different regulatory options, typically building on existing policy designs (Arlinghaus et al, 2025). The US under the Biden administration offered tax rebates under Section 45Q of the Internal Revenue Code. Sweden has held its first reverse auction for bio-CCS. The UK plans to support carbon dioxide removal through contracts-for-difference and integration into its emissions trading system. Extended producer responsibilities, such as a “carbon takeback obligation” (Jenkins et al, 2021), would mandate fossil fuel producers to sequester some, and ultimately all, the carbon contained in their product. An early move towards this was made in the EU Net Zero Industry Act.

The scale-up of carbon storage is undeniably challenging, but with well-structured policies, the fossil fuel industry may fall in line. Geological CO₂ storage not only addresses its own carbon footprint, but offers diversification into an activity that will increasingly be needed. However, even with strong policy support, the scale and speed at which carbon storage can be deployed remain too limited to offset continued, unrestricted fossil fuel production and use (Stuart-Smith et al, 2023).

5. Conclusions

In 2025 fossil fuel-related CO₂ emissions reached a record high (Friedlingstein et al 2025). Global mean temperatures over the past three years (2023–2025) have averaged more than 1.5°C above the pre-industrial level for the first time (ECMWF, 2026). The two records underline the critical urgency of transitioning away from fossil fuels.

Yet the position of fossil fuels may be more tenuous than the two statistics suggest. Some of the structural factors that underpin the dominance of fossil fuels are weakening, not least their control over energy supply options. A concerted effort to tackle a small number of strategic challenges can advance the fossil fuel transition decisively. For all of them, we identify concrete interventions, which are ready to be deployed and scaled.

With the right set of interventions, it is possible to see how the fossil fuel transition can be concluded successfully. Critical to any effective strategy is a structural reduction in the demand for fossil fuels. In power generation and surface transport the shift away from fossil fuels is well on its way, and a determined push will make it all but irreversible. The economics will continue to shift in favour of clean energy, not just due to its relentless fall in costs, but also because fossil fuels will lose their economies of scale and scope. Guided by clear corporate standards, ideally mandatory or enforceable in the courts, the demand for fossil fuels could fall rapidly.

If incentivised by pertinent regulation, capital providers will respond swiftly to this new reality, and the redirection and repricing of capital will further accelerate the transition. The redeployment of workers is harder and will require flexible labour markets, as well as targeted support for vulnerable communities. Carbon storage requirements can advance the transition by internalising climate costs and opening up new business opportunities. They are also essential for the environmental integrity of remaining fossil fuel use.

There are factors that may slow down these dynamics, not least the heavy reliance on fossil fuel revenues by many countries and a playing field that remains structurally tilted in favour of fossil fuels. Even small progress in these areas will make a difference.

The future of fossil fuels remains controversial and is caught up in intensifying geopolitical competition. Alternative models of prosperity are emerging and must be promoted more forcefully. A shared global vision, around which different viewpoints can coalesce, is urgently needed.

In pursuing the fossil fuel transition the concern must be with socio-economic outcomes and the welfare of affected people. Played well, the fossil fuel transition can maintain economic prosperity, while addressing inter- and intragenerational equity concerns. The fate of individual companies is a commercial issue: forward-looking firms will thrive and laggards will perish, as is the wont of dynamic markets.

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