

End of the Pipeline: Managed vs market-driven routes to ending fossil fuel production

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About Climate Analytics

Climate Analytics is a global climate science and policy institute. Our mission is to deliver cutting-edge science, analysis and support to accelerate climate action and keep warming below 1.5°C.

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Summary

As global warming approaches 1.5°C and a period of overshoot looms, the world is marching further into a crisis of our own making. Climate impacts continue to escalate around the world, and the risk of triggering catastrophic tipping points grows with every fraction of a degree above 1.5°C.

Fossil fuels are at the heart of climate change, responsible for almost three-quarters of global emissions, so a transition away from fossil fuels (TAFF) must be at the heart of the solution. The question facing the global community is not *whether* we transition away, but *how* to transition quickly enough to keep peak warming as small as possible, bring greenhouse gas emissions to net zero in the second half of the century, and get below 1.5°C by the end of it.

The emissions pathway and technology shifts needed to deliver this scale and pace of change have been analysed extensively. But TAFF will of course have fundamental implications for fossil fuel producers – both states and companies – which will have to adjust to a rapidly shrinking market. Mechanisms for this production transition, and the implications of it, have been less studied.

In 2025, Climate Analytics and PIK released the Highest Possible Ambition scenario, which sees global warming peak at 1.7°C by mid-century and returns it significantly below 1.5°C by 2100. In this scenario, fossil fuel production and use peak immediately:

- coal use falls 72% by 2035 and is phased out around 2050
- gas use falls 51% by 2035 and is gone by 2060
- oil use falls 28% by 2035 and is phased out by 2070.

In this report, we assess two contrasting approaches to the global transition in fossil fuel production: a market-driven world and a coordinated world. In a market-driven transition, cuts in production are determined by competition in which the cheapest producers win out. In a coordinated transition, there is some degree of coordination around the pace at which different producers cut output: those most ready for the transition move first, while those less ready follow soon after. Neither scenario is a prediction of what will nor should happen, but, together, they isolate key dynamics that could shape the transition.

We then explore the implications of these two different transitions for different producers, for the market as a whole and for fossil fuel prices.

Our findings are as follows:

For a just global transition, wealthy countries must lead

We define countries' readiness to transition away from fossil fuel production along two dimensions: how dependent the country is on income from fossil fuels, and its institutional and fiscal capacity to manage a transition. In general, wealthy countries with diversified economies are the most ready and should, therefore, be among the leaders. This group includes Australia, Canada, China, Norway, the United Kingdom and the United States. Oil and gas producers least ready to transition include Algeria, Angola, Iraq and Nigeria, while heavily exposed coal producers include Indonesia and South Africa. These countries couple a high degree of dependency on fossil fuel production with lower income levels, and a rapid transition away from fossil fuels could bring significant economic and social impacts. Any TAFF process must acknowledge these different starting points.

A coordinated transition has significant benefits for the most exposed producers

Under a market-driven transition, some of those least ready to transition are quickly squeezed out by lower-cost production elsewhere. For example, oil and gas production in Equatorial Guinea and Trinidad & Tobago would fall by around three-quarters within a decade. In Angola, Libya and Turkmenistan, the cut is around 40%, while Algeria, Iran and Nigeria would see declines of around 30%. Revenue shocks of this scale would erode already strained spending on health and education, threaten fiscal and political stability, and undermine the just, orderly and equitable transition to which governments committed at COP28. Coordination changes this picture substantially. Over the next decade, it would reduce the scale of production cuts in the least-ready gas producers from over 50% to just over 10%, and in the least-ready oil producers from 50% to 36%. The cuts are still essential, but the cliff edge turns into a manageable gradient. This implies more stringent production cuts from other countries. Australia, Canada, China, Norway, the UK and US would all end coal, oil and gas production by the early 2040s. Other major producers such as Russia, Saudi Arabia and the UAE would end coal production around 2040, gas production in the mid 2040s, and oil production by or just after 2050. Only those producers with the highest dependency and lowest capacity would see fossil fuel production continuing beyond mid-century under this coordinated scenario. For the majority, a phase-out is needed by or before 2050.

Coordination reduces the pain for all producers by moderating the price fall

In both the market-driven and coordinated scenario, oil prices fall well below today's levels, remaining under \$50/barrel from 2035 onwards, so consumers continue to benefit from cheaper and declining fossil fuel imports. However, coordination ameliorates the pain for producers by shifting the marginal producer who is setting prices. Rather than the most competitive producers

maintaining production, the most exposed producers would be able to continue producing for longer. This can reduce the level to which oil prices fall. A similar picture would hold for gas. This would enable countries more dependent on oil and gas revenue to support the transition socially and economically.

Coordination comes with a caution

Particularly with gas, coordination could lead to a very small number of the least ready producers dominating the market towards mid-century, raising concerns over potential political manipulation of supplies. This issue, which diminishes as demand falls, can be addressed and should shape discussions on how coordination is designed.

Coordination does not change the fact that fossil fuel production must shrink and eventually end in all countries

While a coordinated transition would bring benefits to the most exposed producers, it would not change the fundamental logic: production must decline and prices will fall. Without proactive management, this will put a major strain on government revenue and bring substantial shifts in the labour market. Coordination is a complement to, rather than a substitute for, preparing for decline.

Coordination and cooperation should go beyond a narrow focus on who gets to produce what

Even if fully implemented, coordinated production cuts will never be enough to fully shield exposed producers from the impact of TAFF. Conversations around coordination, therefore, need to explore all the options available for cooperation. These can include international support to develop alternative economic sectors and action that increases the fiscal space for the most exposed countries. Access to context-specific, concessional and reliable finance, a renewed commitment to debt relief, targeted foreign direct investment and technical/institutional capacity building are all crucial elements of a coordinated TAFF that should not be neglected.

Full multilateral coordination seems unlikely given today's fractured geopolitics. Clubs of the willing, however, offer a realistic starting point.

On the producer side, the Beyond Oil and Gas Alliance has taken some initial steps. On the demand side, the Powering Past Coal Alliance represents one template for coordination. Consumers and major importers such as China, the EU, India and Japan also have a major role to play in shaping the transition through their choices about where to source their remaining supply. The coalition convened at the TAFF conference at Santa Marta in April 2026 offers grounds for optimism that a core group of countries is ready to begin developing

national phase-out roadmaps. These roadmaps are an obvious place to embed coordination in the phase-out of fossil fuels.

As renewables, batteries, EVs, heat pumps and other electro-technologies continue to scale at pace, the end of the fossil fuel era is growing closer day by day. Two decades ago, only a quarter of demand could be electrified; now, it is over 75%. The recent fossil market turbulence has given an added incentive for the clean energy transition. All of this suggests that fossil fuel demand could peak and fall faster than many producers' plans assume as electro-tech undermines and displaces fossil fuels across the economy.

Meanwhile, impacts of climate change are being felt around the world more painfully than ever, reminding governments, their peoples and businesses why they committed at the 2015 Paris summit to limit global warming to 1.5°C. Delivering this cannot be done without committing to phase out fossil fuels on a commensurate timescale. Fossil fuel demand needs to peak and start falling fast, halving by 2035. Fossil fuel producers most able to transition need to cut production quickly, starting now, with others preparing to follow suit within a few years. Planning a transition is simply prudent politics and, as we show in this report, building international cooperation is one logical component of that plan, reducing the impacts of the transition for all.

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1: Introduction

Due to insufficient global climate action to date, global temperature increase is set to cross 1.5°C by the early 2030s at the latest. The continued rise in temperatures is pouring fuel onto the escalating fire of climate impacts and risks triggering tipping points that could have devastating consequences. In such a world, limiting the magnitude and duration of overshoot and getting back below 1.5°C before 2100 is the only pathway back towards a safe climate.

A transition away from fossil fuels is essential, as fossil fuel extraction and combustion were responsible for around 70% of global greenhouse gas (GHG) emissions in 2023 (Schumer *et al* 2025). Fossil fuel production and use needs to fall around 50% by 2035, 90% by 2050 and 100% by 2070 if we are to bring temperatures back as quickly as possible well below 1.5°C before 2100 (Climate Analytics 2026a).

At COP28, the world agreed to “transition away from fossil fuels” in “a just, orderly and equitable manner” (UNFCCC 2023). Momentum is now building around a transition away from fossil fuels (TAFF). At COP30, the Brazilian presidency announced a global roadmap on transitioning away from fossil fuels would be delivered (UNFCCC 2025). Colombia and the Netherlands announced and delivered the first ever conference on a just TAFF (Climate Analytics 2026b).

Meanwhile, repeated fossil fuel price shocks in recent years continue to highlight the fundamental vulnerabilities of a global economy dependent on fossil fuels and the economic and security benefits of a rapid fossil fuel phase-out (IRENA 2026).

Demand destruction is at the heart of the transition away from fossil fuels. Scaling renewables, accelerating electrification and driving fossil fuels out of the electricity, transport, buildings and industrial sectors is crucial. Without this, demand for fossil fuels will continue and the incentives for continued production will remain. Restricting supply without also cutting fossil fuel demand would also lead to increased prices, which could erode support for the action that is so urgently needed.

However, while climate policy cannot start with supply, it cannot end with demand. Supply-side policy has a critical role in aligning extraction with demand-side policies, which can help maximise the effectiveness of policy portfolios (Asheim *et al* 2019), avoid unnecessary lock-in and stranded assets on the supply side (Green and Denniss 2018), help break dependency on fossil fuel production (Peszko *et al* 2020), and so help manage a transition away from production in an orderly and equitable manner.

TAFF will have fundamental implications for fossil fuel production, which will need to decline rapidly in line with falling demand. However, the exact implications for different fossil fuel producers remain unclear. Producers of coal, oil and gas are diverse,

exemplifying a broad range of transition readiness to undertake TAFF. Some countries have particularly high dependency on fossil fuel production and low economic/regulatory capacity, which means they are more exposed to TAFF, with higher potential for economic disruption from declining fossil fuel production. Highly dependent oil and gas producers include Algeria, Angola, Iraq and Nigeria, while dependent coal producers include Indonesia and South Africa.

Two key possible futures are often at the centre of discussions. TAFF could take place in a world in which future production is determined predominantly by global market forces. This is the market-driven perspective, in which high-cost producers are left stranded while competitive producers capture the remaining market share. Or it could take place in a world in which there is multilateral cooperation between producers and consumers to coordinate the pace at which fossil fuel production is phased out across different countries and fuels, to try and reduce the impact on the most exposed producers. This is the coordination perspective. While a diversity of other futures is also possible, these two options are often the focus of international discussions on TAFF, such as those taking place as part of the continued process initiated at Santa Marta in 2026 (Climate Analytics 2026b).

In this report, we provide a detailed quantification of these two possible futures, exploring what they mean for different producers as the world phases out fossil fuels as quickly as possible. We produce phase-out pathways for fossil fuel production in each country, focusing on near-term reductions (% cuts by 2035), the date of phase-out and the cumulative production by phase-out per country. We then explore the implications of these different futures across a range of key issues, including on the most dependent producers, on market concentration/geopolitical risk and on fossil fuel prices.

Our aim is to highlight the implications of each future and identify key dynamics and principles that actors should be aware of when seeking to advance a just, orderly and equitable transition, rather than advocate for a specific future. **These results should not be seen as production phase-out roadmaps for individual countries, but an exploration of the key dynamics in a world phasing out fossil fuel production as quickly as possible.** They can act as one line of evidence, contributing to the emerging discussions around TAFF roadmaps and the role of international cooperation that has been initiated by the Santa Marta process.

The report is structured as follows: Section 2 explores the global perspective on phasing out fossil fuels, introducing the global pace of TAFF that guides the national-level transitions in this analysis. Section 3 then provides an overview of our methodological approach in modelling TAFF. Section 4 explores the landscape of fossil fuel production in more detail, highlighting the way in which some countries are particularly exposed to TAFF due to their high levels of dependency on fossil fuel production and low levels of fiscal capacity. Section 5 then showcases the different possible worlds for future production, quantifying the market-based and coordinated scenarios. Section 6 explores the implications of these two different futures. Sections 4 to 6 provide results for oil and gas production. Section 7 summarises our results in the case of coal and Section 8 provides discussion of our results and conclusions.

2: Phasing out fossil fuels: a global perspective

The first key element in any analysis on TAFF is its overall ambition. How deeply do we need to reduce fossil fuel production and use, and by when?

The pace of the global TAFF is driven by the need to minimise the magnitude and duration of overshooting 1.5°C and the real-world limits to scaling fossil fuel CCS and/or CDR.

Climate science is clear that, to stop global warming, we need to reach net zero CO₂ emissions globally, and then, to bring temperatures back down, we need to achieve and sustain global net zero greenhouse gas (GHG) emissions (Palazzo Corner *et al* 2023, Tarshish *et al* 2026). The goal of achieving net zero is not merely a scientific goal, but a political goal enshrined in the Paris Agreement's Article 4.1, as well as by numerous countries, subnational governments and corporations (UNFCCC 2015).

How fast we can reach net zero or net zero GHG emissions is a function of how rapidly we achieve TAFF, combined with the scale-up potential for fossil fuel CCS and CDR. Any fossil fuel combustion that remains at net zero needs to either have its emissions captured and stored via CCS, or compensated for via CDR. As we achieve a faster TAFF, our reliance on fossil CCS or CDR is reduced, while a slower TAFF only increases the burden on CCS/CDR to address continued fossil fuel combustion (Climate Analytics 2026a).

This is critical because CCS and CDR availability is likely to be highly constrained. This is due to a wide range of geological, technological, infrastructural and institutional barriers that cap how much CO₂ can realistically be stored (Deprez *et al* 2024, Grant *et al* 2022, Lane *et al* 2021, Zhang *et al* 2024, Gidden *et al* 2025).

In addition, in a world overshooting 1.5°C, CDR should be prioritised for bringing temperatures back below 1.5°C rather than enabling continued fossil fuel consumption. That leaves little to no spare storage capacity to compensate for continued fossil fuel use.

In November 2025, Climate Analytics introduced a new scenario – the Highest Possible Ambition (HPA) scenario – produced in collaboration with the Potsdam Institute for Climate Impact Research (Climate Analytics and PIK 2025). This scenario explored how to limit overshoot of 1.5°C and bring temperatures back to below 1.5°C before 2100. It also limited deployment of fossil fuel CCS to very low levels. Figure 1 shows the fossil fuel phase-out in this scenario, while Table 1 shows the % reductions in fossil fuels relative to 2025.

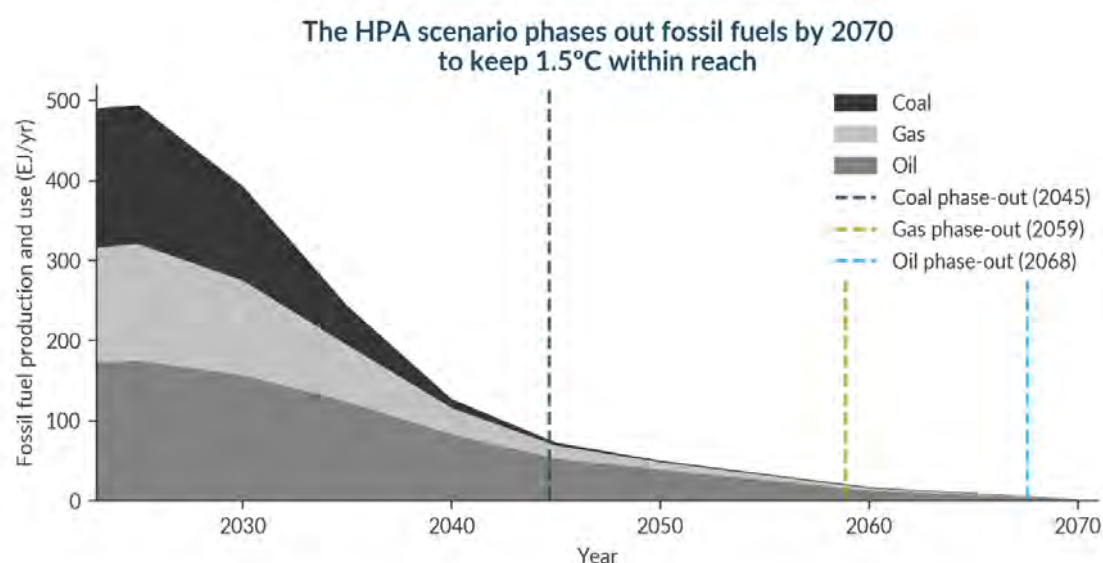


Figure 1: The global transition away from fossil fuels in the HPA. Under the scenario, all coal, gas and oil exit the global economy by 2070, facilitating a complete phase-out of fossil fuel use across all sectors. We define a phase-out as production falling by over 97.5% relative to 2023 levels.

Table 1: Global reductions in fossil fuel production and use in the HPA scenario, relative to 2023

	2030	2035	2050	2070
Coal	-32%	-72%	-99%	-100%
Gas	-18%	-51%	-94%	-100%
Oil	-9%	-28%	-77%	-99%
Total	-20%	-50%	-90%	-100%

This scenario is used as the starting point for our analysis and sets the bounds of how much fossil fuel extraction is possible at the global level in the rest of the report. It attempts to capture the pace of TAFF that aligns with highest possible ambition, to minimise the magnitude and duration of overshoot. While we use this scenario to explore the implications of a market-driven or coordinated phase-out of fossil fuel production, the method we develop could be used with other, less ambitious global TAFF scenarios.

Table 2: Global reductions in fossil fuel production and use in the IEA's NZE scenario, relative to 2024

	2035	2050
Coal	-60%	-92%
Gas	-33%	-77%

Oil	-33%	-77%
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We note that for oil, the HPA scenario has a similar pace of reduction to the IEA's NZE scenario (seen in Table 2). For coal and gas, the pace in the HPA scenario is faster. This is likely to be in part because the IEA has more permissive assumptions around fossil fuel CCS: in the latest version of the NZE, CCS captures around 4 GtCO₂/yr of fossil fuel and industrial process (FFI) emissions in 2050. Though the NZE's reliance on CCS deployment has declined since the first version in 2021, it remains much higher than the HPA's rollout of CCS, where around 1.3 GtCO₂/yr of CO₂ is captured and stored from FFI emissions, of which only 500 Mt CO₂/yr is fossil fuel CO₂. The deployment of fossil fuel CCS in the HPA scenario then falls to zero in the second half of the century as fossil fuels are fully phased out, driven by rapidly growing electrification and limited use of biomass, hydrogen and synthetic fuels.

This highlights how differing assumptions on fossil fuel CCS can have significant impacts on the pace and depth of TAFF required. The IEA have revised their estimates of fossil fuel CCS deployment downwards in successive versions of the NZE scenario. However, their current assumptions would still require a very large scale-up of fossil fuel CCS in the next 25 years. This could be a much more costly transition than relying on direct electrification and renewables (Bacilieri *et al* 2023). In addition, given the feasible potential for geological storage by mid-century could be as low as 5 GtCO₂/yr (Zhang *et al* 2024), this would mean that up to 80% of all geological injection capacity was being dedicated to FFI emissions. This could reduce the storage capacity available for CDR, which would undermine the goal of bringing warming back down below 1.5°C via net-negative CO₂ emissions.

3: Methods

In this section, we provide an overview of how we produce national-level phase-out pathways for fossil fuel production under a market-driven and a coordinated transition.

Overview of our methodological approach

There is a wide range of different perspectives and/or principles by which a transition away from fossil fuel production could be achieved (Sanchez and Linde 2023, Muttitt and Kartha 2020, Civil Society Equity Review 2023, Van De Graaf 2026). These include:

1. **Economic approaches.** Some analysis focuses on a market-driven transition away from fossil fuels (IEA 2021, Welsby *et al* 2021). In such a transition, the scale and location of fossil fuel production is driven by economic competition.

Key beneficiaries of such an approach would be the Gulf states, which have very low production costs for oil and gas. This would leave some highly dependent countries with higher production costs, such as Angola and Nigeria, with a rapid reduction in fossil fuel revenues and, potentially, large-scale stranded assets. This could be seen as undermining the just, orderly and equitable nature of the transition away from fossil fuels.

2. **Emissions-driven approaches.** In an emissions-driven transition, the fossil fuel production with the lowest emissions intensity would be prioritised. This approach would consider the fugitive emissions from extraction, as well as the emissions intensity of any processing (for example, the difference between pipeline gas and LNG, or between oil sands extraction and conventional oil production). This case is assessed by the IEA in their publication on oil and gas in net zero transitions (IEA 2023). The argument would be that curbing fossil fuel methane emissions is a critical element of 1.5°C pathways and so phasing out the most emissions-intensive fossil fuel extraction first can help maximise the climate benefits of a fossil fuel phase-out. However, in the next 5–10 years, there should be rapid action to curb fugitive emissions worldwide, and therefore an (at least partial) convergence in emissions intensity of fossil extraction regardless (Climate Analytics and PIK 2025). As such, we do not consider these approaches further.
3. **Collaborative and equity-informed approaches.** There is a large range of analyses that focus on how to sequence the phase-out of production in a manner that accounts for equity considerations for the most dependent producers. This approach recognises that, while every country needs to transition away from fossil fuels, countries are starting from very different places. Some countries have high dependency/limited capacity to transition, while others are much less dependent on fossil fuel production and have high capacities to transition away. Allowing more space for the most dependent producers to transition can help reduce the social harms of a rapid phase-out and support a just, orderly and equitable transition (Muttitt and Kartha 2020). Here, coordination focuses on the pace at which fossil fuel production is reduced between countries, and does not consider broader elements (international climate finance, multilateral or bilateral partnerships etc.) that are also a key element of coordination. Much of the focus in the literature is on how to distinguish between different countries' capacity and dependency. Different approaches use different metrics to distinguish between countries (Sanchez and Linde 2023, Anderson and Calverly 2022, Holz *et al* 2024, Lebdioui 2026), and we provide more detail on the approach we use in the following section.
4. **Security-focused approaches.** This approach has received less consideration in the academic literature, although recent publications do begin to consider it (Van De Graaf 2026). Under such an approach, there would be a focus on the reliability and security of fossil fuel supply under a declining market. This could involve steps to avoid undue market concentration in the hands of a small number of producers/geographies, and a focus on the political stability of fossil fuel producers.

In our analysis, we focus on the market-driven and coordination approaches, creating fossil fuel production phase-out pathways at the national level that capture the key dynamics behind both.

We focus on these two perspectives because of their prominence in global discussions around TAFF. The scenarios that we produce are idealised representations of market-driven and coordinated worlds, which can help us understand the role of these specific dynamics within the transition, but do not capture all the real-world dynamics that will ultimately inform TAFF. In the next sections, we describe in more detail how we model these scenarios.

Market-driven scenario

The market-driven scenario depicts a future that is reflective of the way the market works, where more cost-effective resources are prioritised for production. We produce this scenario for oil and gas production, but not for coal.¹

The model used to simulate the scenario is GAPTAP (Global Oil and Gas production, Trade and Pricing Model), a field-level, year-by-year recursive simulation model of global oil and gas production, trade and supply for the period 2025–2050 (Welsby 2022). The model is designed to represent real-world market behaviour under conditions of structural constraints and market segmentation. This results in a focus on cost-competitive oil and gas production.

Key inputs to the model include:

- The global demand for oil and gas, and its regional distribution.
- A detailed assessment of the cost-supply curve in each country at a field level.
- In the case of gas, datasets on existing trade agreements including long-term contracts.

The model brings this all together and provides, per country, a production trajectory for oil and gas that captures how production would evolve if driven by global market competition. For more details, see the Methods annex.

In reality, there are not idealised regional/global free markets for fossil fuels. The existence of cartel behaviour, such as OPEC, which seeks to manipulate price and quantities to benefit a subset of producers, is already well-documented and will continue in the future, albeit arguably to a lesser extent (Golombek *et al* 2018, Gabriel *et al* 2012, Känzig 2021). For example, the strategic incentive of low-cost producers in a declining market could be not to simply produce what is 'optimal', but to flood the market and drive other producers out of the market faster (Mercure *et al* 2021). These

¹ We do not provide a market-driven scenario for coal as we did not have access to a coal market model during this research. However, one could still be produced and is a potential avenue for further work.

strategic incentives are not captured in our market-driven scenario. Further work could consider how the incentives of individual producers, and their ability to manipulate fossil fuel markets, could influence our analysis (E3G 2026). However, the market-driven scenario produced here isolates and captures one key dynamic in fossil fuel transitions, and as such remains a valuable perspective.

Coordinated scenario

While the market-driven scenario sees future production driven by cost competitiveness alone, the coordinated scenario explores how collaboration between producers and consumers can make more space for those countries most exposed to declining fossil fuel production. These are the producers which have high dependency on fossil fuel production and low levels of fiscal/institutional capacity.

Coordination here would be around the pace at which production declines across different producers, with some moving faster and others moving slower. We note that coordination can be driven both by producers *and* consumers. For example, consumers have a choice about who they choose to import from, which can influence the pace of TAFF in different countries, and can coordinate with producers to provide support for their transition.

The coordinated scenario allocates production in two steps: quantifying TAFF exposure, then using this to adjust the rate of production phase-out across countries to make more space for those producers who are most exposed.

Quantifying exposure

When quantifying exposure to TAFF, we focus on two key dimensions: how dependent a country is on fossil fuel production for economic activity, and the capacity of that country to manage a transition away from fossil fuels. We use four key measures of fiscal dependency and two for fiscal/regulatory capacity, building on the analysis conducted by the Civil Society Equity Review in their analysis of dependency (Civil Society Equity Review 2023). These, with their rationale for inclusion, are shown in Table 3 and Table 4.

Table 3: Indicators of dependency on fossil fuel production

Dependency indicator	Rationale for inclusion
Share of export revenue from fossil fuel production (% of total exports)	Fossil fuels can be a key form of exports, which can be essential to gain hard currency (i.e. US dollars). This is in turn critical for paying for imports (many of which are denominated in hard currency) and servicing debt, as much international debt is denominated in US dollars. Losing access to this export revenue could exacerbate debt distress in dependent countries.

Share of government revenue from fossil fuel production (% of total revenue)	Some governments receive a very significant share of revenue from fossil fuel production. This is then critical for funding government spending, including public employees, and health and infrastructure spending . ² Losing this revenue would threaten these critical government functions. We do not consider government revenue from coal, as this revenue is largely collected at the sub-national and regional level.
Share of jobs provided by fossil fuel production and the associated supply chain (% of total workforce)	Fossil fuel production supports jobs across domestic supply chains. These jobs are often concentrated in areas with high levels of dependency. Losing these jobs could create challenges for a just transition in dependent countries, and the larger the share of production-dependent jobs, the greater the economic and social challenges of TAFF would be.
Share of primary energy provided by domestic fossil fuel production (% of total primary energy)	Domestic fossil fuel extraction contributes to meeting domestic energy needs. This is arguably the least relevant of the metrics, as many fossil fuels (particularly oil) are globally traded commodities, and therefore domestic production does not necessarily equate to domestic consumption. However, given increasingly fractured geopolitics, the political relevance of domestic fossil fuel production for energy security needs is growing, and so we consider this metric as a measure of dependency.

Table 4: Indicators of fiscal capacity used in this analysis

Capacity indicator	Rationale for inclusion
GDP per capita	We focus on GDP per capita as a central proxy for capacity. Countries with higher income will typically be more resilient to reduced fiscal benefits from fossil fuel production without jeopardising human welfare in the state.
Institutional capacity	Achieving a just transition will require developing and implementing a broad range of just transition policies (e.g., skills mapping, retraining, industrial transition strategy). Countries with greater institutional capacity and regulatory effectiveness will be more able to deliver a rapid transition

² It is important to acknowledge that the connection between revenue and government-funded public services is fraught in many countries. Corruption in federal governments varies across our producer sample and can siphon away funding from services directed towards the public. While the impact of corruption is not reflected in our methodology, we believe the share of government revenue is still an important indicator to consider.

away from fossil fuels while minimising the social harms of a phase-out.

We take these metrics and, through a process of normalisation and aggregation, assign each producer a final exposure score. The final score is given by the following equation:

$$TAFF_Exposure_c = \frac{DependencyScore_c}{CapacityScore_c}$$

For more details on the data sources, the calculation and for the final scoring of each country, see the Methods annex.

Translating exposure into pathways

We then translate these exposure scores into fossil fuel phase-out scenarios for each country.

We start from the baseline scenario with no coordination included. This is the market-driven scenario that was produced above. For the most exposed producers, their rate of decline in the market is then slowed, accounting for the need for additional time to manage reductions in production. Additional time, however, does not enable investment in new production capacity, as we implement a no new fossil fuels (NNFF) constraint, which we explore more below.

Conversely, for the least exposed producers, their rate of production decline is faster relative to the market-driven case. This is important to ensure that oil and gas production does not exceed that which is compatible with the HPA scenario. The extent to which coordination shifts the pace of fossil fuel phase-out in different countries is controlled by a parameter, alpha. We test various levels of alpha, ranging from 0.1 to 100. In this report, we focus on the central coordination scenario, which is alpha=1.

Constructing the NNFF ceiling. Many analyses have highlighted that, under a range of sufficiently ambitious climate scenarios, there is no need for investment in new long-lead fossil fuel supply projects (IEA 2021, Green *et al* 2024, IEA 2025, Climate Analytics 2026a).³

The benefits of aligning with NNFF are numerous (Green *et al* 2024). Avoiding investment in new fossil fuel infrastructure frees up capital to be directed towards renewables and electrification, which can help maximise the pace of the transition. It also reduces the risk of asset stranding, as investing in new fossil fuel production at the very moment that demand should be falling rapidly creates a high risk of stranded

³ The definition of NNFF used here restricts investment in new fossil fuel supply projects beyond those that are already operating or passed FID and counting as “approved”. It does not restrict continued investment in existing fields, which is required to prevent production declining at the “natural” rate (IEA 2025).

assets. We therefore implement the NNFF constraint in our producer coordination scenario.

Some analysts have highlighted that restricting future fossil fuel production based on current assets could have equity implications (Draeger *et al* 2026). However, our focus is exploring how a more normatively guided transition could improve outcomes for the most dependent producers. Therefore, integrating the NNFF constraint into our analysis can help identify the potential for coordination within a broader normative framework.

We model this using a detailed field-level perspective provided by GAPTAP. Each country's maximum future oil and gas production is capped at what its existing and approved projects could produce. For more details, see the Methods annex. The NNFF constraint is applied in our coordinated scenario, but *not* in the market-driven scenario, which models a world in which market forces alone dictate the scale and location of future production. This means that in the market-driven baseline, there can be some fossil fuel production beyond what is compatible with NNFF, if new fields are competitive against existing legacy fields.

Coal methods summary

We apply this full methodology to create results for oil and gas. For coal, we use a reduced form of this methodology. As such, our baseline for coal is a simple assumption that all countries follow the global average decline rate, and we do not apply an NNFF constraint in the optimisation process for coal. We provide a summary of our results for coal in Section 7.

4: Assessing TAFF readiness

We use the TAFF exposure scores calculated above to identify how ready countries are to lead in a coordinated transition away from fossil fuel production. Countries with low TAFF exposure (lower dependency and higher capacity) are well-placed to lead in a coordinated TAFF, while countries with high exposure are not.

Adopting a framing used elsewhere in the literature (Lebdioui 2026), we group the top 50 producers of each fuel into five waves, ranked by this assessment of TAFF readiness.⁴ Table 5 (p.17) lists each country's assigned wave. Wave 1 captures those states with the lowest exposure, best positioned to manage a fossil fuel production phase-out, as they have lower dependency on fossil fuel production and higher fiscal and institutional capacity. On the other side, Wave 5 encapsulates those countries that

⁴ TAFF readiness and TAFF exposure are conceptual opposites in our analysis. So countries with high TAFF exposure scores have low TAFF readiness, and vice-versa.

are the most exposed and face the biggest barriers impeding a transition away from fossil fuel production. We focus here on oil and gas, with coal shown separately in Section 7.

Figure 2 and Figure 3 display the transition readiness of oil and gas producers. Not all countries are equally ready to transition away from fossil fuel production, with very strong variations in their levels of economic dependency on oil and gas, and their fiscal and institutional capacity to transition away.

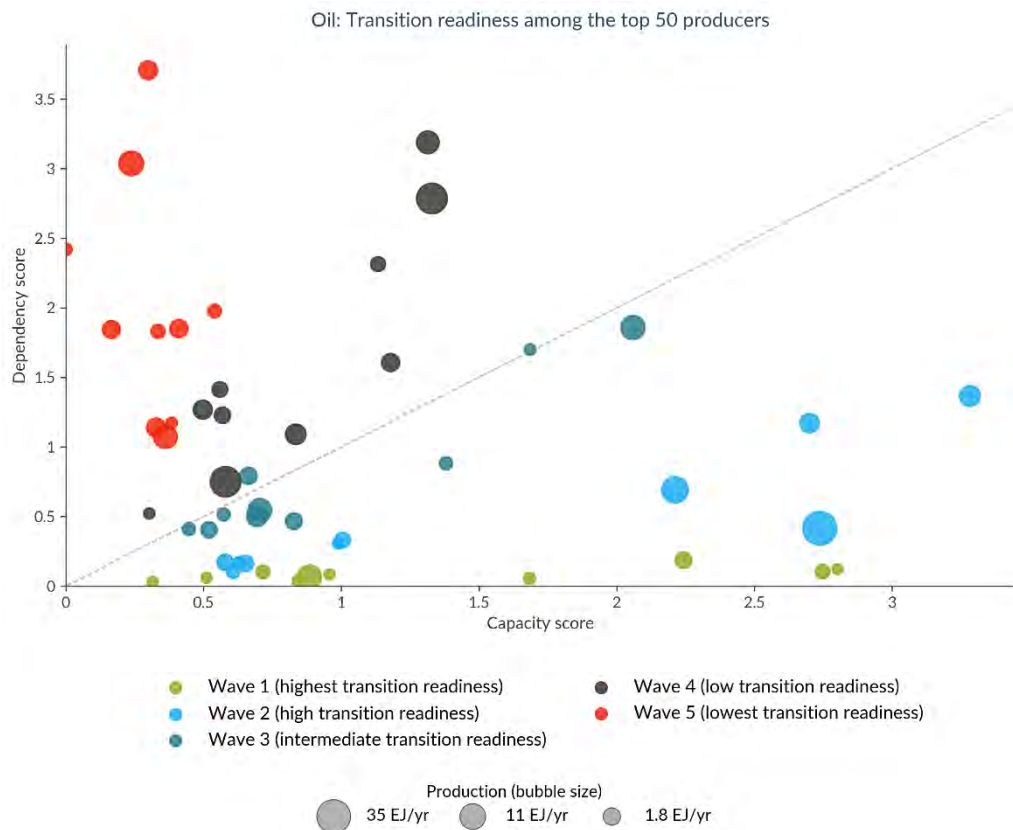


Figure 2: The landscape of TAFF readiness for the top 50 oil producers.

Dots show individual countries, sized by their annual production value. The dashed line marks the boundary where capacity sub-score equals dependency sub-score ($x = y$), defining a soft threshold for the country waves. Countries in Waves 4 and 5 lie above this threshold, while those in Waves 1 and 2 sit below. Countries in Wave 3 are dispersed around (although mainly below) the threshold.

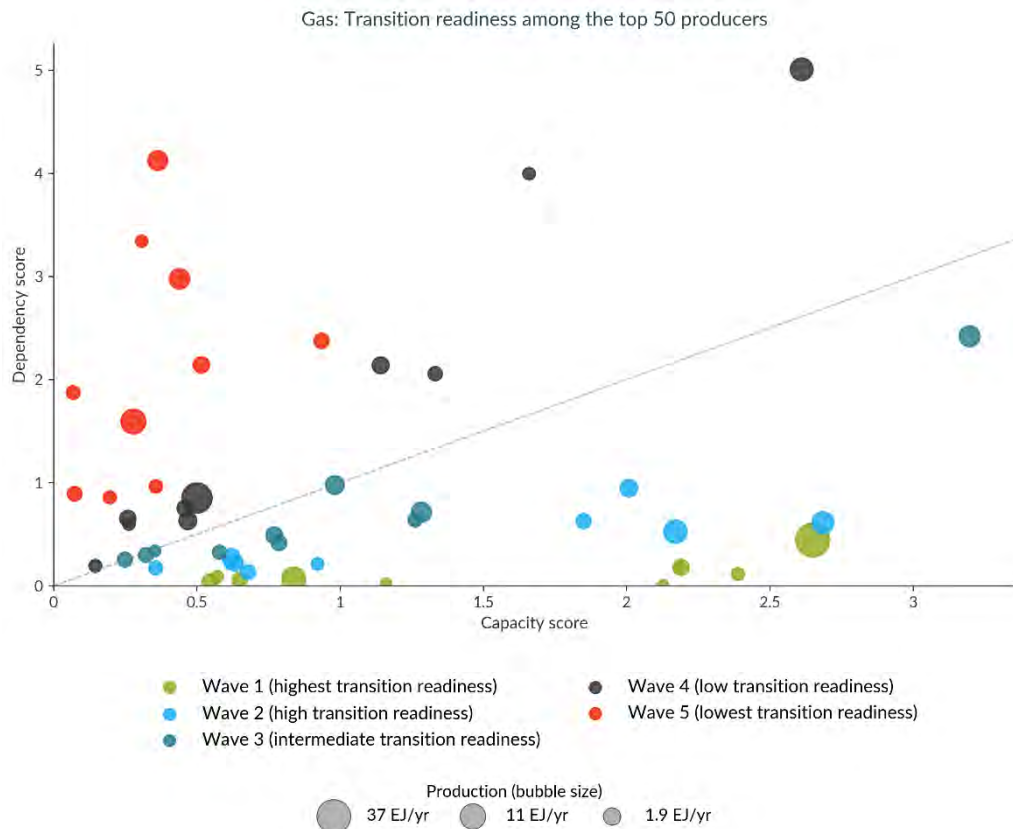


Figure 3: TAFF readiness for the top 50 gas producers.

Dots show individual countries, sized by their annual production value. The dashed line marks the boundary where capacity sub-score equals dependency sub-score ($x = y$), defining a soft threshold for the country waves. Countries in Waves 4 and 5 lie above this threshold, while those in Waves 1 and 2 sit below. Countries in Wave 3 are dispersed (although mainly below) around the threshold.

Waves 1 and 2: the TAFF leaders

There are a number of countries with higher readiness to transition away from fossil fuel production that are broadly grouped into Waves 1 and 2. They include the majority of oil and gas producers in advanced economies, including the **United States** (W2 oil, W1 gas), **Canada** (W2 oil and gas), the **United Kingdom** (W1 oil and gas), **Australia** (W1 oil, W2 gas) and **Norway** (W2 oil).⁵ These countries are wealthy and have high institutional capacity, while oil and gas extraction play a relatively minor or even marginal role in their national economies. For instance, oil and gas extraction provides under 3% of federal government revenue in Canada, despite being the fourth largest producer of oil and fifth largest producer of gas globally. Not far behind, Australia is the seventh largest gas producer, yet receives only 2% of government revenue from gas production (and is only a minor producer of oil). In the United States, the share of overall government revenue is even smaller, at around 1%, while oil and gas make up

⁵ Norway is ranked in Group 3 for gas, because it has a higher dependency score for gas production than oil production. For more details, see the Methods annex.

less than 15% of total exports. These countries are well placed to lead in a transition away from fossil fuels, as will be seen in the following sections.

We note that there are also some countries with relatively lower capacities that also are associated with high transition readiness scores, such as **Indonesia**⁶ (W2 oil and gas), **Peru** (W2 oil), and **Viet Nam** (W1 gas, W2 oil). These are countries where oil and gas production is very marginal to their economies. Peru, for example, scores low across all dependency indicators. The share of export revenue attributed to oil sits at 4%, while the contribution to both jobs and government revenue is below 1%. Although they have lower capacities, their dependency on oil and gas extraction is so small that the disruption of a phase-out of fossil fuel production remains small.

In our analysis, there are, therefore, some lower-income countries that can still move faster than the market would deliver under a coordinated transition. However, we highlight that:

1. None of these lower-income countries in Wave 1 and 2 are in the top 20 oil or gas producers (except Indonesia in the case of gas, where it still only provides around 1% of global gas production). Therefore, their role in 'leading' the transition is actually relatively minor: they can only create limited additional space for the most exposed producers. The key leadership role is in those countries that are major producers *and* have high TAFF readiness, such as China, the United States, Australia and Canada.
2. While some of these Wave 1 and 2 countries have lower income than the richest producers, there are still many poorer, lower-capacity producers, with much higher levels of dependency, where TAFF exposure is even higher.
3. These lower-income Wave 1 and 2 countries might still need support in transitioning away from fossil fuel production, due to their low economic and institutional capacity for action. This highlights that coordination around TAFF must be about not just the distribution of oil and gas production around the world, but also a wider group of issues, including transition finance and debt relief.

Wave 3: countries with intermediate transition readiness

Meanwhile, there are a number of countries with intermediate transition readiness that are associated with Wave 3 in our analysis. Countries in this wave like **Brunei** and the **United Arab Emirates** in the oil sector, and **Malaysia** in the gas sector, have broadly similar capacity and dependency sub-scores. This puts them in the middle of the pack in

⁶ Indonesia has a relatively high readiness to transition away from oil and gas production, due in part to its successful diversification efforts in the face of declining reserves. Oil and gas now provide around 6% of exports, and revenues have more than halved since 2010. Some 7% of government revenue comes from oil and gas, down from around 35% at the start of the decade (Braithwaite and Gerasimchuk 2014). Meanwhile, Indonesia has a low readiness to transition away from coal, sitting in wave 5. For more details on coal, see Section 7: Coal transitions.

terms of transition readiness, needing slightly more time to transition than the leaders in Waves 1 and 2, but still with significantly greater readiness than those countries in Waves 4 and 5. We note that in all three fuels (coal, oil and gas), Wave 3 countries overall accelerate the pace of their transitions away from fossil fuel production, in order to make the most space for Waves 4 and 5 (see Section 5: The different futures for TAFF in fossil fuel production).

Waves 4 and 5: countries with the lowest readiness to transition away from fossil fuel production

There are then a number of countries with lower, or extremely low, readiness to transition away from fossil fuels. These are grouped into Waves 4 and 5 in our analysis. They broadly include countries with higher levels of dependency on fossil fuel production and lower levels of capacity.

Wave 5 includes the set of producers that are least ready to transition away from fossil fuel production. They include **Nigeria** (W5 oil, W4 gas), **Angola** (W5 oil), **Algeria** (W5 gas), **Iraq** (W5 oil, W4 gas) and **Iran** (W4 gas, W5 oil). These countries are marked by very high dependency on fossil fuel production for exports, government revenue, jobs and domestic energy security, and by very low economic and institutional capacities. For example, Nigeria gets over 80% of its export revenue from oil and Angola gets over half its government revenue from oil. Meanwhile in Algeria, gas makes up around half of all export revenue and provides around 2% of all jobs. A rapid transition away from fossil fuel production in these countries is likely to have the largest social and economic harms. Any action to drive a global TAFF needs to account for this reality. We note again that in some of these countries, although oil and gas provide large amounts of government revenue, much of this revenue is diverted by systemic corruption to elites and does not contribute to public finances or broader economic development. Future work would try and better account for this, exploring how much oil and gas revenue translates into benefits for the general population rather than for elites.

Wave 4 also includes some countries with low capacity and high dependency, but to a lesser extent than those in Wave 5. However, Wave 4 also includes several outlying countries, with above-average institutional capacity that is still outpaced by their dependency on fossil fuel production. In the gas sector, **Qatar** and **Brunei** are highly dependent on gas production with high degrees of exposure across the dependency indicators.⁷ However, they are also some of the most capable countries to move away

⁷ Part of Qatar and Brunei's high dependency scores come from the high number of jobs in the gas extraction industry, with an estimated 6%/7% of jobs coming from gas extraction in Qatar and Brunei respectively. We highlight that our estimate of the share of full-time equivalent (FTE) jobs that comes from fossil fuel extraction is driven by IEA World Energy Employment data, which provide estimates of FTE jobs at a high level. We then downscale this to the country-level, assuming that the labour-intensity of oil/gas production within a region is constant (jobs/barrel or jobs/bcm of gas). This should, therefore, be seen as an illustration of jobs dependency, rather

from fossil fuels, having significantly higher GDP-per-capita and governance scores than the average gas producer. This is the same for the rich Middle Eastern oil producers of **Saudi Arabia, Kuwait and Oman**.⁸ These are countries that may benefit from more time to transition away from fossil fuel production, but that should still move notably faster than the most exposed producers in Wave 5, for whom the potential impacts of TAFF are greatest.

Summary of the waves

Table 5: The waves of TAFF producers for oil and gas

	Gas	Oil
Wave 1 – highest transition readiness	Brazil, China, Germany, India, Netherlands, New Zealand, Poland, United Kingdom, United States, Viet Nam	Australia, China, Denmark, Italy, Pakistan, Romania, Thailand, Türkiye, United Kingdom, Uzbekistan
Wave 2 – high transition readiness	Australia, Canada, Colombia, Indonesia, Israel, Mexico, Romania, Thailand, Ukraine, United Arab Emirates	Canada, India, Indonesia, Malaysia, Norway, Peru, Qatar, Trinidad and Tobago, United States, Viet Nam
Wave 3 – intermediate transition readiness	Angola, Argentina, Bangladesh, Kazakhstan, Kuwait, Malaysia, Norway, Pakistan, Peru, Saudi Arabia	Argentina, Bahrain, Brazil, Brunei, Colombia, Egypt, Ghana, Mexico, Turkmenistan, United Arab Emirates
Wave 4 – low transition readiness	Bahrain, Brunei, Egypt, Iraq, Mozambique, Nigeria, Oman, Qatar, Russia, Uzbekistan	Algeria, Azerbaijan, Cameroon, Ecuador, Guyana, Kazakhstan, Kuwait, Oman, Russia, Saudi Arabia

than a bottom-up assessment of the employment contribution of fossil fuel extraction in a country. See the Methods annex for more details.

⁸ We acknowledge that some of these countries are also low-cost producers where production is likely to be more resilient to declining demand regardless. However, the use of the NNFF constraint limits the benefits that these producers would gain from a coordinated scenario. If they would already access large amounts of their existing fossil fuels under market conditions, then the scope to access more is limited. Meanwhile, those producers that are heavily exposed and have higher production costs are likely to struggle to extract their existing reserves under market conditions and so would benefit more from coordination.

Wave 5 – lowest transition readiness	Algeria, Azerbaijan, Bolivia, Equatorial Guinea, Iran, Libya, Myanmar, Trinidad and Tobago, Turkmenistan, Venezuela	Angola, Republic of the Congo, Equatorial Guinea, Gabon, Iran, Iraq, Libya, Nigeria, South Sudan, Venezuela
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Not all producers are equally ready to transition away from fossil fuel production. Some countries have very low levels of dependency on extraction for sustaining government revenues and broader economic activity. In other countries, high dependency and low capacity combine to mean that there is a low readiness to move away from fossil fuels. And yet, a rapid transition away from fossil fuels is essential to minimise the extent and duration of overshoot and get temperatures back down below 1.5°C well before 2100. We should not use the high degree of exposure to TAFF in some countries as a reason to dilute or delay the transition, but instead find a way to deliver a transition away from fossil fuels that is both fair and fast. This requires an understanding of how different possible TAFF futures could impact the most exposed producers. It is to this question that our analysis now turns.

5: The different futures for TAFF in fossil fuel production

This section presents oil and gas production pathways under the market-driven and coordinated scenarios.

Gas

Figure 4 shows the results of our analysis for gas for the five different waves of TAFF exposure. The market-driven scenario is shown in light blue, while the central coordinated scenario is shown in red. It also shows our estimate of what production is possible within the NNFF norm, which is shown in dark blue.⁹

For Waves 1 and 2, which generally have less dependency and greater capacity than the average fossil fuel producer, coordination leads to deeper near-term reductions and

⁹ Our NNFF constraint involves no investment in new oil and gas fields, but does not preclude continued investment in existing fields, and allows fields that have passed FID but not started operation to be developed. For more details on how the NNFF constraint is produced, see the Methods annex.

earlier phase-out dates than would occur under the market-driven scenario. Total gas production falls to zero in these waves by around 2040. Meanwhile for Wave 3, which has similar levels of dependency and capacity, coordination still leads to a faster phase-out with reduced cumulative production, but to a lesser extent than in Waves 1 and 2. Total gas production reaches zero around 2045.

Waves 4 and 5 include countries where dependency on fossil fuels is greater than the average fossil fuel producer, and with generally lower levels of capacity. These countries see a slower rate of phase-out of gas production in the coordinated scenario. In Wave 4, this change in the pace of phase-out is concentrated in the near-term (2025–2040), after which the group collectively follows the market-driven scenario, and in fact slightly accelerates the pace of phase-out. This ensures that the tail of gas production in a declining market is allocated to the most exposed producers in Wave 5. These most exposed producers see gas production increase across the time horizon compared to the market-driven scenario. Cumulative production for this group almost doubles, and the phase-out date of the group is delayed to the late 2060s.

As global gas production and use falls to zero in the 2060s in the HPA scenario, all countries have to phase out gas production by then, regardless of their level of fiscal exposure. In addition, the level of cooperation around phase-out is limited by the NNFF constraint. Under the coordinated scenario, the most dependent producers follow the NNFF ceiling to around 2040, before production declines below this, driven by rapidly falling global demand.

We explore the implications for individual countries further in the following section.

The waves of TAFF for gas phase-out

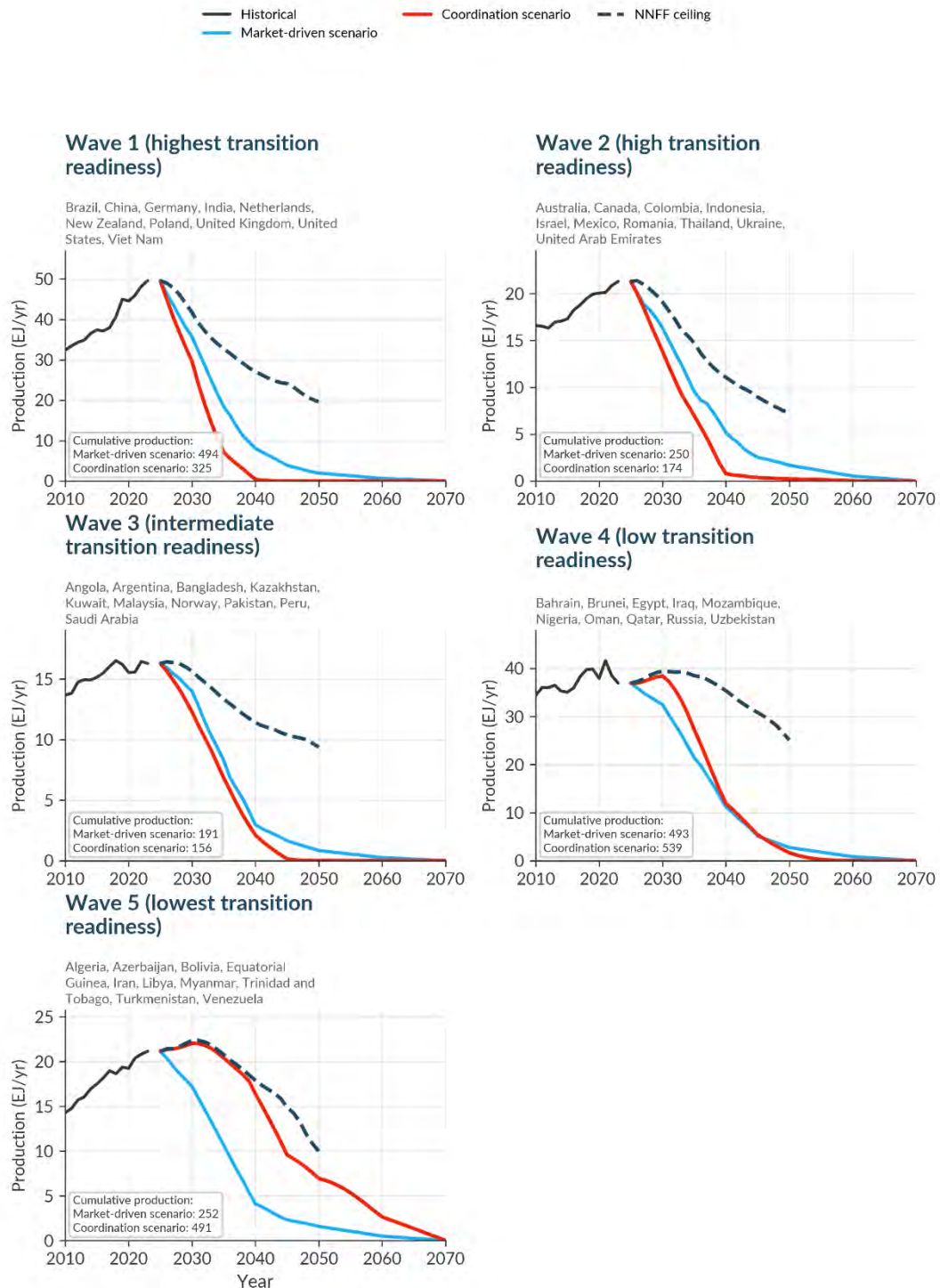


Figure 4: The five waves of transition in gas production

Oil

As Figure 5 shows, there is a similar set of dynamics across the five waves as is seen in the results for gas. Under the coordination scenario, Waves 1 and 2 reduce oil

production faster than they would do in the market-driven scenario, with deeper near-term reductions and faster phase-outs. Both phase out oil production in the early 2040s under the coordinated scenario.¹⁰

For Wave 3, there is a similar pace of phase-out between the two scenarios until around 2040. After this, rather than a gentle decline in production out to 2070, there is an accelerated phase-out by around 2045 in the coordinated scenario. This is to make more space for the oil producers in Wave 5 that are most exposed to a TAFF phase-out.

Finally, Waves 4 and 5 see increased oil production under the coordinated scenario. Wave 4 sees increased production before mid-century, but post-2050 there is an accelerated phase-out of production to make space for the most vulnerable producers in Wave 5. These producers see increased oil production across the time horizon. However, as with gas, this is limited by the NNFF constraint, which ensures that oil production still declines in aggregate, even in these most exposed waves.

¹⁰ We see that in Wave 2, near-term production under the market-driven scenario slightly exceeds what is compatible with NNFF. This is because the market-driven scenario does not enforce the NNFF norm but allows investment in new oil and gas fields if they are competitive under a declining market. In Wave 2, oil producers that open a limited set of new fields are the US, Norway, Canada and India. In the case of Norway, Canada and India, these fields represent ~5% of production in 2035. In the case of the US, 20% of production in 2035 comes from new fields under the market-driven scenario.

The waves of TAFF for oil phase-out

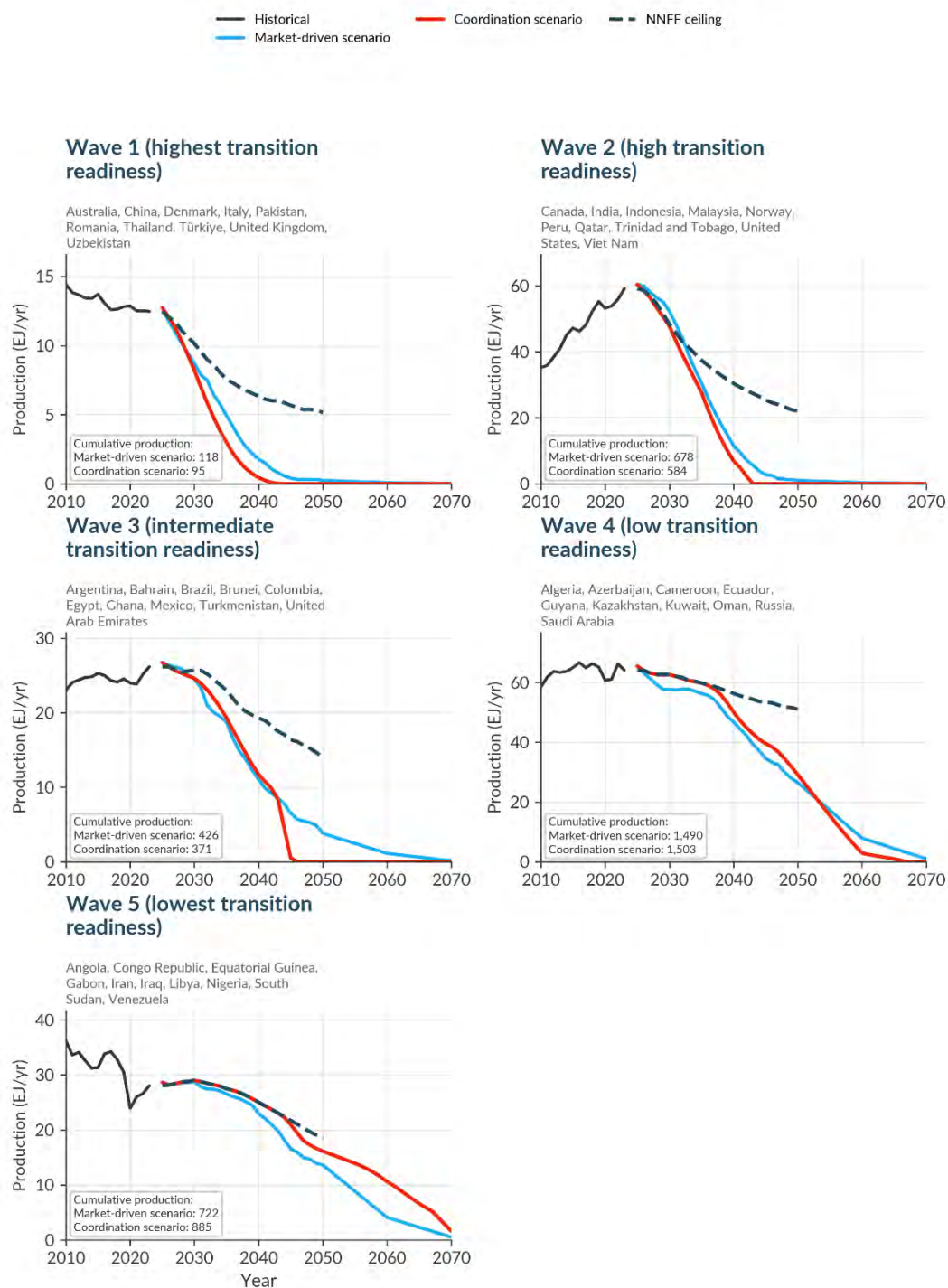


Figure 5: The five waves of TAFF for oil production

6: The implications of these different futures

The implications for producing countries

We focus on three key metrics that define a country's future production. These are:

- The **near-term reductions** – how much a country's production falls over 2025–2035
- The **phase-out date** – the year in which production is reduced by more than 97.5% relative to 2023 levels
- The **total production** – how much fossil fuels are extracted by a given country between 2025 and the phase-out date.

This analysis focuses on exploring the key relative dynamics between a market-driven and a coordinated scenario. The specific results for any individual country should not be taken as a prescriptive recommendation of a TAFF roadmap for that country. Our aim is to quantify and contrast these scenarios, and identify key dynamics of relevance, to help policymakers and decisionmakers considering different possible TAFF futures.

Gas

Figure 6 shows these different statistics for the five different waves in our analysis. In the case of the near-term reductions and the phase-out date, we show both the median for the group and the range (as there can still be considerable variation within any individual wave). The size of the dots represents the scale of production in 2023 from the producer. The horizontal lines show the median production cut by 2035, or the median phase-out year across countries. This is not weighted by production, so two producers of different sizes contribute equally to these medians. They represent the outcome for the median producer, regardless of size.

This reaffirms the findings from previous figures: under coordination, Waves 1–3 see deeper near-term reductions, smaller cumulative production and earlier phase-out years. Meanwhile, Wave 4 sees a slower near-term pace of reduction but accelerated phase-out dates, but overall achieves greater cumulative gas production. Wave 5 sees a slower near-term pace of reduction and a delayed phase-out year, which results in broadly a doubling of cumulative gas production. We now explore the implications for the waves in more detail.

The implications of a market-driven or coordinated transition for the top 50 gas producers

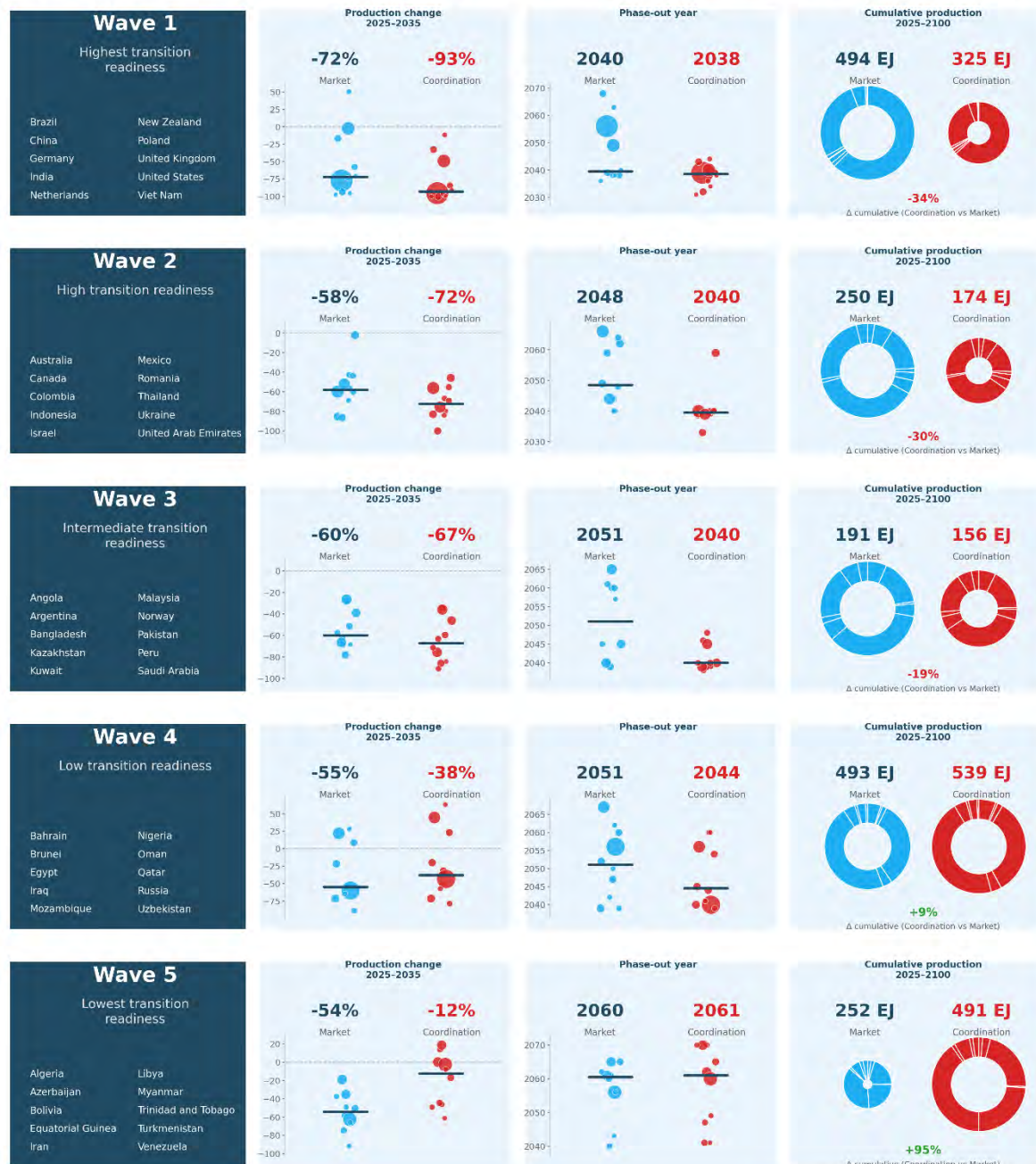


Figure 6: The implication of different TAFF futures for the top 50 gas producers

Size of dots represent scale of gas production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

Figure 7 shows the results for Wave 1, which has the greatest transition readiness. The largest producers in this first wave are the United States and China.

Wave 1: TAFF transition leaders

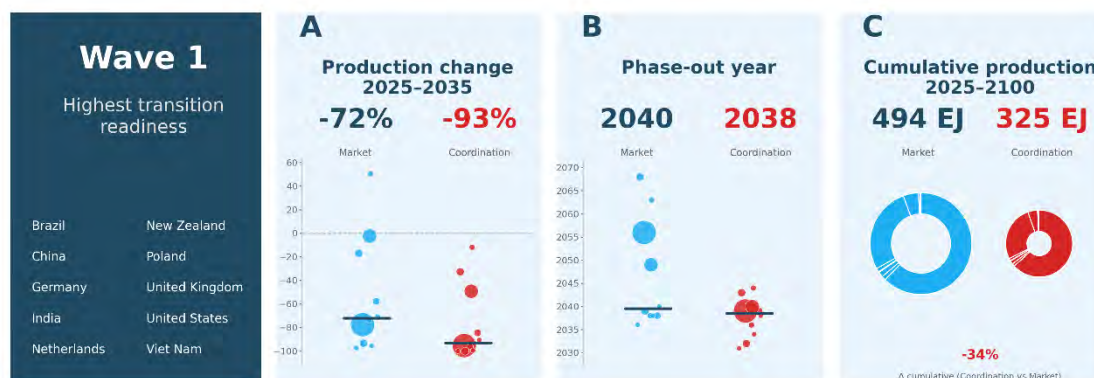


Figure 7: The implications of TAFF for the gas producers in Wave 1

Size of dots represent scale of gas production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

When looking at the near-term reductions, Wave 1 would already see a rapid decline in gas production of around 70% on average in the market-driven scenario (Figure 7A). Under coordination, however, all countries accelerate the gas phase-out over the next 10 years, with a median reduction of 93% (Figure 7A).

Under the market-driven scenario, this group would, on average, phase out production by 2040, but with some producers continuing to extract until after 2050. Under coordination, the average phase-out date is brought back to 2038. **All Wave 1 countries achieve a full phase-out of gas production before 2045, and all but two (India and Viet Nam) achieve a full phase-out by 2040** (Figure 7B), ending gas production within the next 15 years.

Faster near-term reductions and earlier phase-out dates lead to lower cumulative production. In the coordinated scenario, this wave produces around a third less gas than in the market-driven scenario (Figure 7C).

Figure 8 shows the results for Wave 2. The largest producers in this wave are Canada and Australia.

Wave 2: Countries with high transition readiness

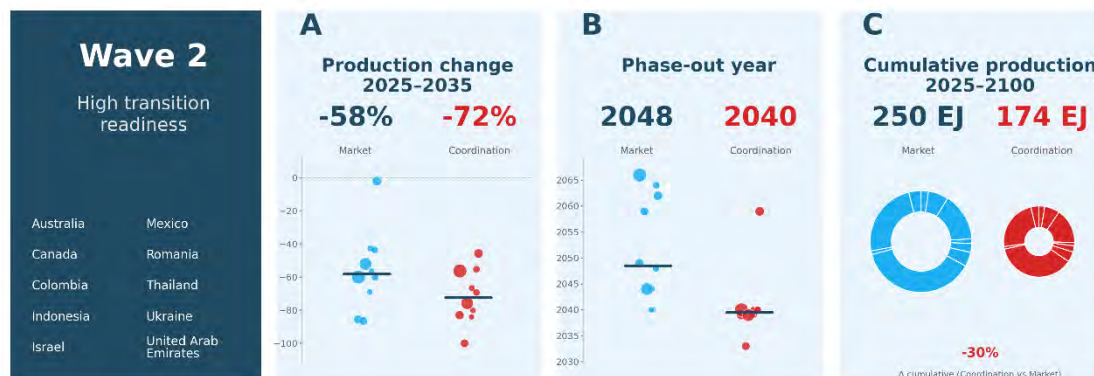


Figure 8: The implications of TAFF for the gas producers in Wave 2

Size of dots represent scale of gas production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the market-driven scenario, Wave 2 would see gas production fall by around 60% on average (Figure 8A), again with some strong variations. Under coordination, this would increase to 71%.

When looking at phase-out year, this group would on average phase-out production by 2048 under the market-driven scenario. Under coordination, the average phase-out date is brought back to 2040, and all Wave 2 countries except Indonesia achieve a full phase-out of gas production before 2045 (Figure 8B).

Faster near-term reductions and earlier phase-out dates lead to lower cumulative production: Wave 2 produces around 30% less gas in the coordinated scenario than it does in the market-driven scenario (Figure 8C). This is a smaller change than in Wave 1, but still substantial, as these countries with high transition readiness make space for those countries that are least ready to transition away from gas production.

Figure 9 shows the results for Wave 3. The largest producers in this wave are Norway, Saudi Arabia and Malaysia.

Wave 3: Countries with medium transition readiness

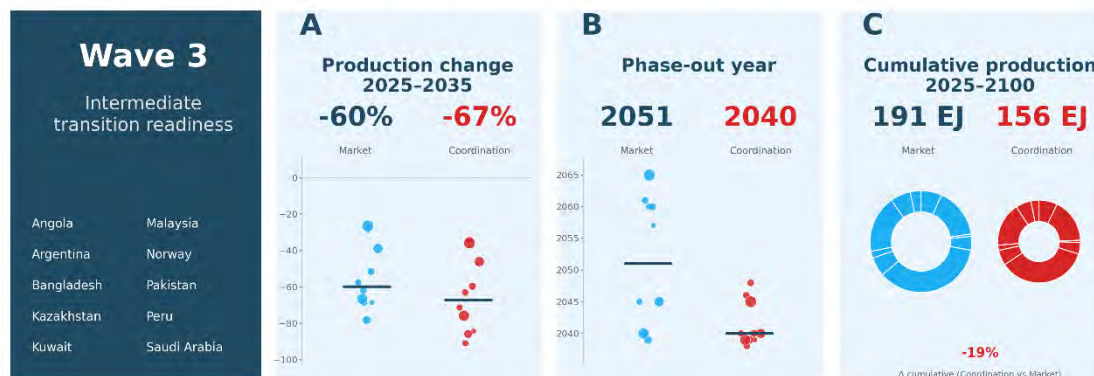


Figure 9: The implications of TAFF for the gas producers in Wave 3

Size of dots represent scale of gas production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the market-driven scenario, Wave 3 would see gas production fall by around 60% on average (Figure 9A), again with some strong variations. Under coordination, this would be increased to 68%. This shows that even countries with intermediate transition readiness would need to accelerate their transition away from fossil fuels to create space for the most exposed producers under a coordinated approach. It is not only the richest and readiest countries who have to lead.

When looking at phase-out dates, under the market-driven scenario, this group would have a median phase-out date of 2051. Under coordination, the median phase-out date is brought back to 2040, and all Wave 3 countries achieve a full phase-out of gas production before 2050 (Figure 9B). As a result, this wave produces around 20% less gas than it does in the market-driven scenario (Figure 9C).

Wave 3 includes some countries with seemingly low readiness to move away from fossil fuels, such as Pakistan. And yet all countries in this group accelerate the pace of phase-out, achieve a full phase-out earlier and cut total gas production by around a fifth. This highlights the extreme levels of dependency and exposure seen in some countries in Waves 4 and 5, which requires strong action even from mid-range countries to create space for them.

Figure 10 shows the results for wave 4. The largest producers in this wave are Russia and Qatar.

Wave 4: Countries with low transition readiness

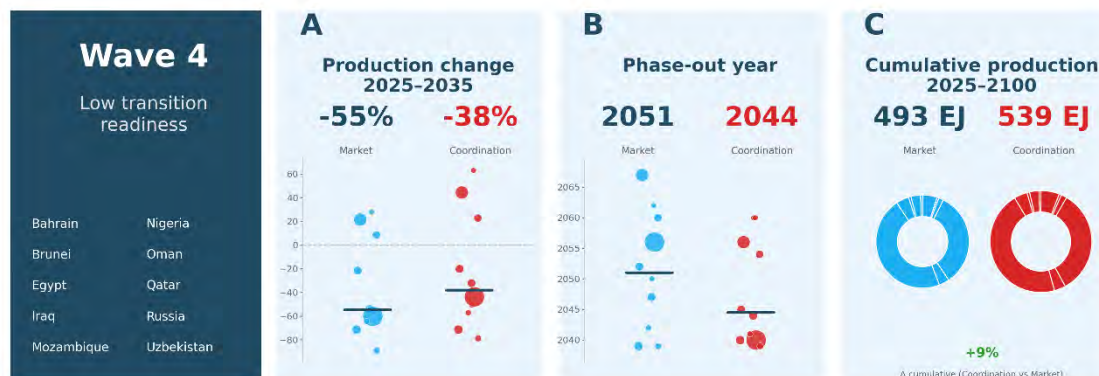


Figure 10: The implications of TAFF for the gas producers in Wave 4

Size of dots represent scale of gas production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the market-driven scenario, Wave 4 would see gas production fall by around 55% on average (Figure 10A), but with very strong variations within the group.¹¹ Under coordination, on average gas production would fall 38%, slowing the pace of phase-out.

When looking at phase-out years, under coordination, even Wave 4 broadly accelerates the date of phase-out to make space for those producers with the lowest transition readiness in Wave 5. The median phase-out date moves from 2051 to 2044 (Figure 10B).

In Wave 4, this faster phase-out under coordination only eliminates a small tail that is slowly diminishing to zero. The long-term production lost by this accelerated phase-out is small, while the increased near-term production from a slower pace of production cuts to 2035 is larger. As a result, cumulative production in this wave grows by around 10% (Figure 10C). This could give increased space to these countries to diversify their economies and achieve prosperity post-fossil fuels.

Figure 11 shows the result for Wave 5, which includes the producers with the lowest readiness to transition away from fossil gas production. This includes Iran, Algeria and Turkmenistan as the largest producers.

¹¹ We note that in Wave 4 there are a set of three countries that actually increase gas production in the near-term under the market-driven scenario. These are Qatar (growing around 20%), Mozambique (+30%) and Nigeria (+10%). In the case of Mozambique and Qatar, this is due to new gas fields coming online, while in the case of Nigeria this comes largely from existing fields and represents only a partial recovery to 2020 levels of production (gas production fell ~20% over 2020-2023 in Nigeria). In the case of Qatar, these new fields are already approved and therefore within our assessment of what is compatible with no new fossil fuels. In Mozambique, ~35% of production in 2035 comes from new gas fields beyond NNFF in the market-driven scenario.

Wave 5: Gas producers with the lowest transition readiness

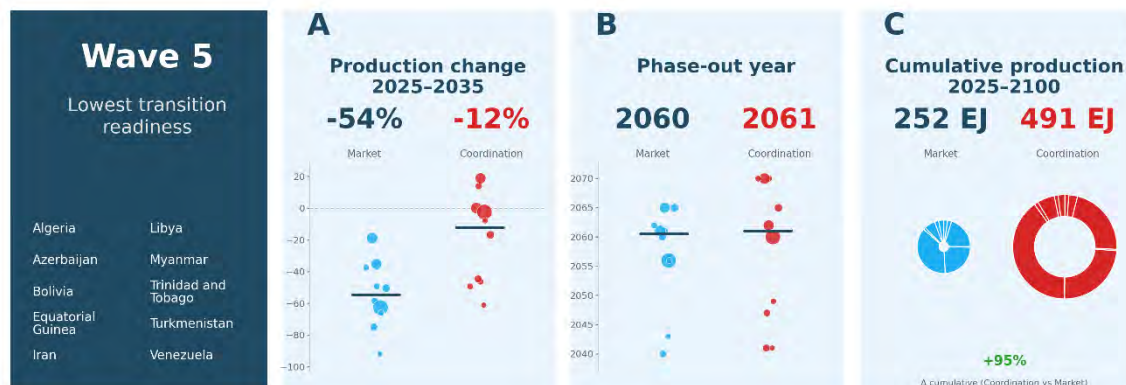


Figure 11: The implications of TAFF for the gas producers in Wave 5

Size of dots represent scale of gas production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

Under the market-driven scenario, Wave 5 would reduce production by over 50% by 2035 (Figure 11A). However, some countries within this group would reduce production even faster, including Equatorial Guinea (90%), Trinidad and Tobago (75%) and Iran (63%). In these countries, gas production provides up to one half of all government revenue. The financial and macro-economic consequences of such a rapid reduction in fossil fuel revenues would be very substantial for all countries in this wave. This would have implications for the provision of critical public services such as health and education, as well as debt servicing.

Coordination enables a slower pace of phase-out in Wave 5, with the pace of phase-out reduced on average by around 40% over the next 10 years. However, almost all countries still reduce production by 2035, with production falling on average 11% (Figure 11A). Only two countries – Turkmenistan and Venezuela – can actively increase production in the next decade.¹² In a world phasing out gas production in line with 1.5°C, reducing production should be the norm, not the exception, even in the most exposed producers. **However, this highlights that coordination alone will not be sufficient to achieve a just and equitable transition as it cannot eliminate the macro-economic and financial challenges that the most exposed producers will face in all Paris-aligned mitigation scenarios.** Therefore, other measures will be an essential part of the toolkit for international coordination.

Meanwhile, we see that coordination does not necessarily lead to a later date of phase-out (Figure 8B). Some countries (Trinidad and Tobago, Libya, Turkmenistan and Equatorial Guinea) can reach their cumulative coordination-adjusted targets without delaying their phase-out year. For these countries, coordination delivers a slower pace

¹² In other countries, the NNFF constraint prevents expanding production. If new gas fields beyond that which is compatible with existing and approved assets were allowed, this could change and would require an even faster phase-out of gas production from earlier waves.

of decline towards the same (or even earlier) end-date. Meanwhile in other countries (Iran, Algeria, Venezuela, Myanmar and Bolivia), achieving an increase in total gas production requires not only a slower rate of production cuts, but a longer period of production. Their phase-out dates are delayed, but still fall within the global gas phase-out in the HPA scenario. There are three countries (Bolivia, Algeria and Myanmar) where the phase-out date is pushed to the late 2060s and which make up the tail of gas production in these final years, seen in Figure 4 previously.

Overall, coordination enables a slower pace of gas production phase-out for Wave 5 countries and an increased cumulative production. Cumulative production grows around 90% across the wave with coordination.

Oil

Figure 12 shows the same statistics for the five different waves in our oil analysis. This reaffirms the findings from Figure 5: that under coordination, Waves 1 and 2 see deeper near-term reductions, smaller cumulative production and earlier phase-out years. Meanwhile, Wave 3 broadly sees the same production out to 2035 across both the market-driven and coordinated scenarios, but an earlier phase-out date under coordination. Wave 4 sees a slower near-term pace of reduction but accelerated phase-out dates, but still achieves slightly greater cumulative gas production. Wave 5 sees a slower near-term pace of reduction and a delayed phase-out year, which leads to cumulative oil production growing by around a third. We now explore the implications for the waves in more detail.

The implications of a market-driven or coordinated transition for the top 50 oil producers

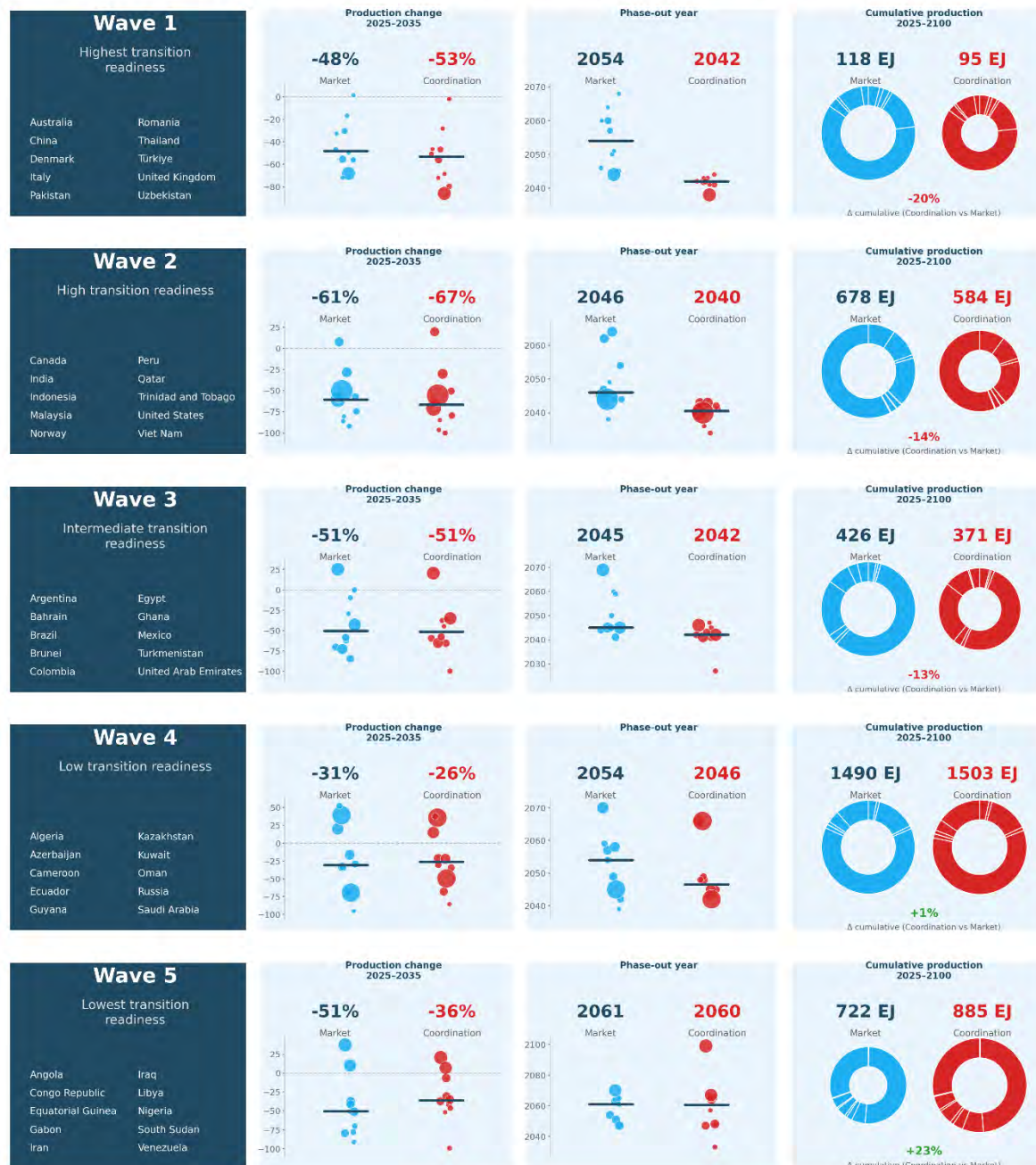


Figure 12: The implication of different TAFF futures for the top 50 oil producers

Size of dots represent scale of oil production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

Figure 13 shows the results for Wave 1. For oil, this wave includes China but no other producers within the top 20. These are mainly small producers where oil production is a negligible part of their economies.

Wave 1: TAFF transition leaders

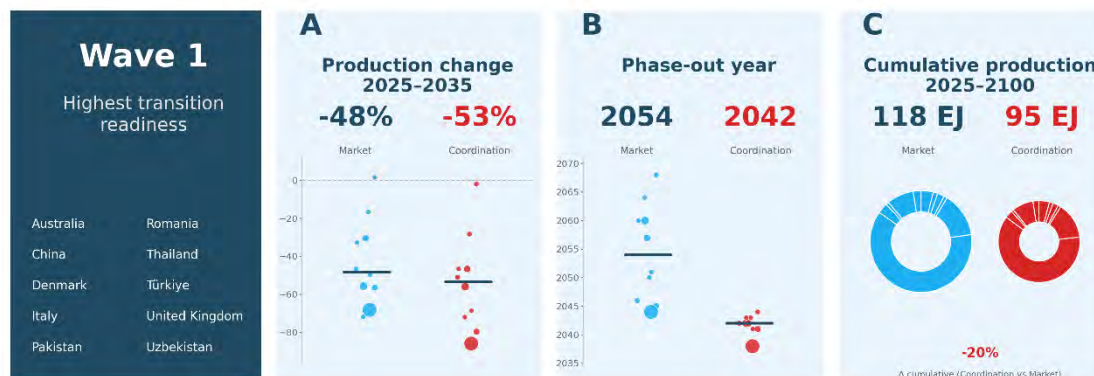


Figure 13: The implications of TAFF for the oil producers in Wave 1

Size of dots represent scale of oil production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

When looking at the near-term reductions, Wave 1 would see oil production fall 48% by 2035 under market conditions (Figure 13A). Under coordination, all Wave 1 countries accelerate the phase-out of oil production, with an average cut of 53% by 2035. China would increase oil production cuts from around 70% by 2035 to over 85% under coordination (Figure 13A). The geopolitical plausibility of such an outcome is discussed further later, but without China taking part in coordination, the extent to which phase-out trajectories could be modulated across countries would be significantly diminished.

Under the market-driven scenario, this group would on average phase out production by the mid-2050s. Under coordination, the average phase-out date is brought back to 2042 and all Wave 1 countries achieve a full phase-out of oil production before 2045 (Figure 13B). On average across this wave, the phase-out year is brought forwards by 12 years under coordination.

Faster near-term reductions and earlier phase-out dates lead to lower cumulative production, and this wave produces around 20% less oil in the coordinated scenario than it does in the market-driven scenario (Figure 13C).

Figure 14 showcases the results for Wave 2. The largest producers in this wave are the United States, Canada and Norway.

Wave 2: Countries with high transition readiness

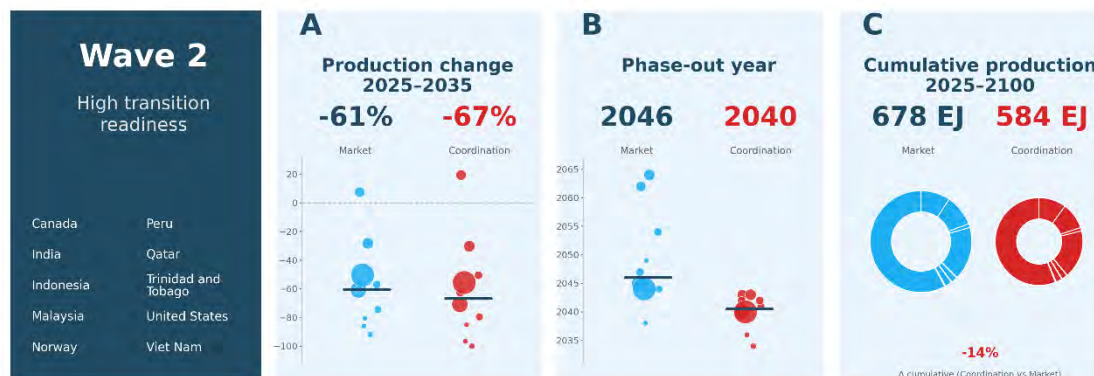


Figure 14: The implications of TAFF for the oil producers in Wave 2

Size of dots represent scale of oil production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the market-driven scenario, Wave 2 would see oil production fall by around 60% on average (Figure 14A), again with some strong variations. Under coordination, this would increase to 67%. Wave 2 would on average phase out production by 2046 under market conditions. Under coordination, this is accelerated to 2041, and all Wave 2 countries achieve a full phase-out of oil production before 2045 (Figure 14B). For Wave 2, the average phase-out year is brought forwards by six years under coordination. Faster near-term reductions and earlier phase-out dates lead to lower cumulative production, and Wave 2 produces around 15% less oil in the coordinated scenario than in the market-driven scenario (Figure 14C).

Figure 15 showcases the results for Wave 3. The largest oil producers in this wave are the UAE, Brazil and Mexico.

Wave 3: Countries with medium transition readiness

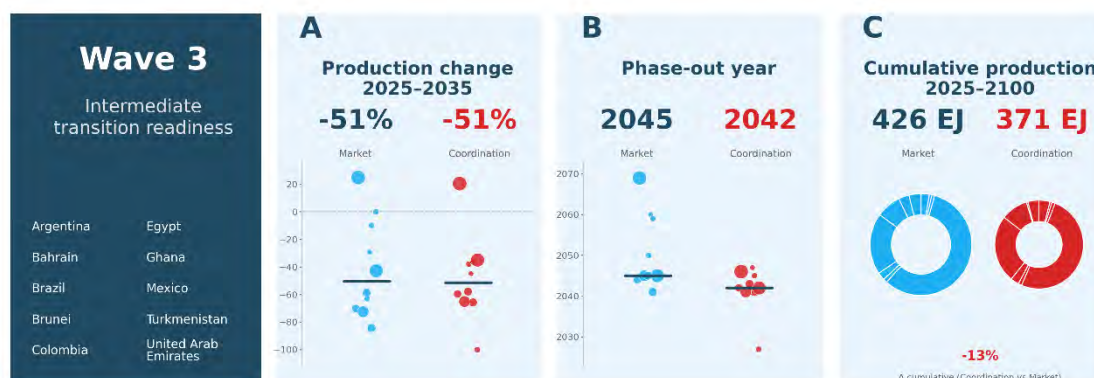


Figure 15: The implications of TAFF for the oil producers in Wave 3

Size of dots represent scale of oil production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the market-driven scenario, Wave 3 would see oil production fall by around 51% (Figure 15A). This doesn't noticeably change out to 2035 under coordination: these

countries with medium transition readiness neither accelerate nor slow down their pace of production phase-out.

This is because, under an NNFF constraint, there is a limit to the oil that countries in Waves 4 and 5 can produce by 2035, and they are already producing at this limit in the coordinated scenario. A consideration of transition readiness alone would lead to Wave 3 countries phasing down oil production faster, to make even more space for the most exposed countries in Waves 4 and 5. However, as we model a world that is aligned with NNFF, this provides an additional limit on the extent of redistribution possible, particularly out to 2035, where global oil demand is still relatively robust (having fallen only around 30%). If global oil demand fell faster by 2035, then additional cuts to production would need to be made. These would fall on Waves 1-3, which could lead to further cuts to production in these countries.

Post-2035, as oil demand falls further, then the scope for flexibility around oil production grows. Under the market-driven scenario, this wave would on average phase-out production by 2045, with a large tail of production coming from cost-competitive fields in the UAE. Under coordination, phase-out is accelerated to 2042, and all Wave 3 countries achieve a full phase-out of oil production before 2050 at the latest (Figure 15B). Although near-term production remains broadly the same for this wave, the accelerated phase-out date leads to a cumulative reduction in oil production from Wave 3 of around 13% under coordination (Figure 15C).

Figure 16 shows the results for Wave 4. The largest producers in this wave are Saudi Arabia, Russia and Iran.

Wave 4: Countries with low transition readiness

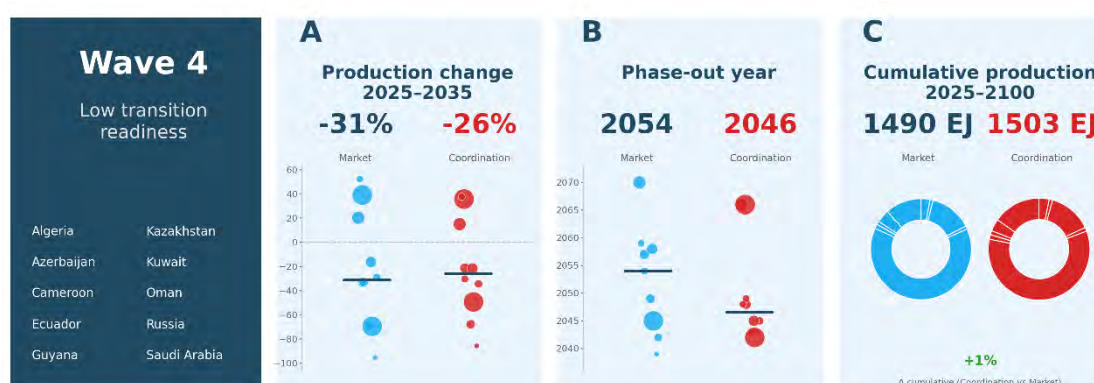


Figure 16: The implications of TAFF for the oil producers in Wave 4

Size of dots represent scale of oil production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the market-driven scenario, Wave 4 would see oil production fall by around 31% on average (Figure 16A). Three countries (Saudi Arabia, Kuwait and Guyana) would see production growing, driven by the competitive nature of their oil fields and the new

fields that have already been approved coming online. Under coordination, oil production would fall on average by 26%, slowing the pace of phase-out.¹³

Under coordination, even Wave 4 broadly accelerates the date of phase-out, to make space for those producers with the lowest transition readiness in Wave 5 (Figure 16B).¹⁴

For Wave 4 producers, accelerating the phase-out date involves keeping the pace of cuts steady as production approaches zero, rather than slowing the rate of cuts across a small tail of production. This means that the fall in production from an earlier phase-out date is relatively limited, as the counterfactual is a small tail. As a result, even though Wave 4 accelerates phase-out dates under coordination, the slower pace of near-term cuts means that cumulative production grows slightly, by ~2% as a whole (Figure 16C).

Figure 17 shows the result for Wave 5, which includes the producers with the lowest readiness to transition away from oil production. Iraq is the largest producer within this group, but it also includes a range of medium scale but highly exposed producers such as Nigeria, Angola and Libya.

Wave 5: Oil producers with the lowest transition readiness

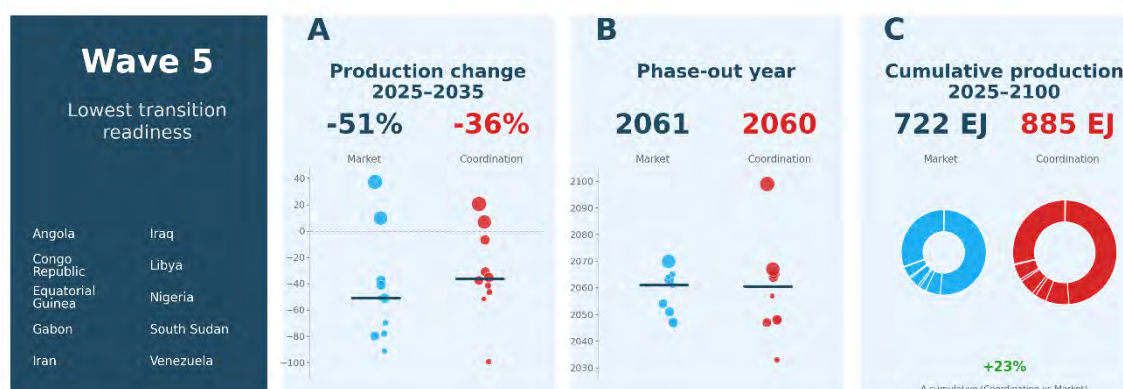


Figure 17: The implications of TAFF for the oil producers in Wave 5

Size of dots represent scale of oil production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

Under the market-driven scenario, this group would on average reduce production by over 50% by 2035 (Figure 17A). There is a bloc of countries that would reduce even faster, with Gabon, Venezuela, Congo and South Sudan all seeing production fall 70-90% over the next decade. Algeria, Libya, Angola and Equatorial Guinea all reduce oil

¹³ It also reduces the growth in oil production from Saudi Arabia, Kuwait and Guyana. Overall, coordination slows the rate of growth in competitive Wave 4 producers and also slows the rate of decline for Wave 4 producers. The net impact is to slow the rate of phase-out for Wave 4 producers.

¹⁴ Saudi Arabia does not phase out oil production in the market-driven scenario, because it does not meet our strict phase-out threshold of a 97.5% reduction. In the market scenario, Saudi Arabia reduces production by 96.5% by 2070, which, though slightly below our strict phase-out threshold, could be seen as an effective phase-out given that it remains a considerable reduction in production.

production by 40-50%. Meanwhile, Iraq is still able to ramp up extraction, with oil production growing over the decade as existing but pre-peak fields ramp up production.

The eight countries that see declines in oil production currently obtain over 50% of their government revenue and over 70% of export revenue from oil. The financial and macro-economic consequences of such a rapid reduction in oil revenues would be very substantial for all countries in this group and would have implications for the provision of critical public services such as health and education, as well as debt servicing.

Coordination enables a slower pace of phase-out in Wave 5, with the pace of reductions falling to a 36% cut by 2035. However, almost all countries still reduce production by 2035, with only Iraq still increasing it (Figure 17A).¹⁵ In a world phasing out oil production in line with 1.5°C, production cuts should be the norm, not the exception, even in the most exposed producers. **As with gas, this highlights that coordination alone will not be sufficient to achieve a just and equitable transition, as it cannot eliminate the macro-economic and financial challenges that the most exposed producers will face in all Paris-aligned mitigation scenarios.** Therefore, other measures will be an essential part of the toolkit for international coordination.

Meanwhile, we see that coordination does not noticeably change the date of phase-out (Figure 17B). This is because these dates are broadly driven by the global transition away from oil in the HPA scenario. As oil demand falls to near-zero by 2070 in the HPA, almost all countries still need to phase-out pre-2070, regardless of coordination. The only exception is Iraq, which has a small level of oil production post-2070 in this analysis. This is entirely due to the small tail of oil extraction in the HPA scenario, which, if it was eliminated, would also require Iraq to phase-out entirely by 2070.¹⁶

Overall, coordination enables a slower pace of oil production phase-out for Wave 5 countries and increased cumulative production. Cumulative production grows around 30% across the wave with coordination.

The implications for global market concentration

Coordination can ensure that producers least able to absorb fiscal and social costs of rapidly declining fossil fuel production have greater space to transition. But this could have implications for security of supply and market concentration that must be assessed.

¹⁵ For Iraq, the scale of oil production growth is actually reduced in the coordinated scenario, as some of the developments in the market-based scenario require new fields to come online beyond what is compatible with NNFF.

¹⁶ Iraq is absent from the market-driven scenario phase-out graph because it does not meet our strict phase-out threshold of a 97.5% reduction. In the market scenario, Iraq reduces production by 3% in 2050 and 96% in 2100. As with Saudi Arabia, this could be seen as an effective phase-out in the market-driven scenario, which becomes a total phase-out in the coordinated scenario.

The Herfindahl-Hirschman Index (HHI) is used to evaluate the market concentration of a particular industry. It captures how close a market is to a monopoly and subsequently how much power producers have to manipulate prices. Values range from close to 0, indicating a market with many relatively small producers, to 10,000, a pure monopoly where a single country accounts for 100% of global exports. The index is nonlinear, and values reaching 1800 and above already indicate a highly concentrated market where a handful of producers dominate. We use this index to compare the concentration of the oil and gas markets in the market-driven and coordinated scenarios.

Our results show that in the coordinated scenario, gas production becomes more concentrated relative to the market baseline as the number of producing states declines approaching 2050 (Figure 18). In the coordination scenario, the number of producers in the market declines and the remaining producers control greater shares of total production, resulting in greater concentration than in the market-driven scenario. The HHI doubles as the top four producers come to dominate 93% of global production, compared to 71% in the market-driven scenario, and the gas market becomes “highly concentrated” (HHI>1800) by 2050.

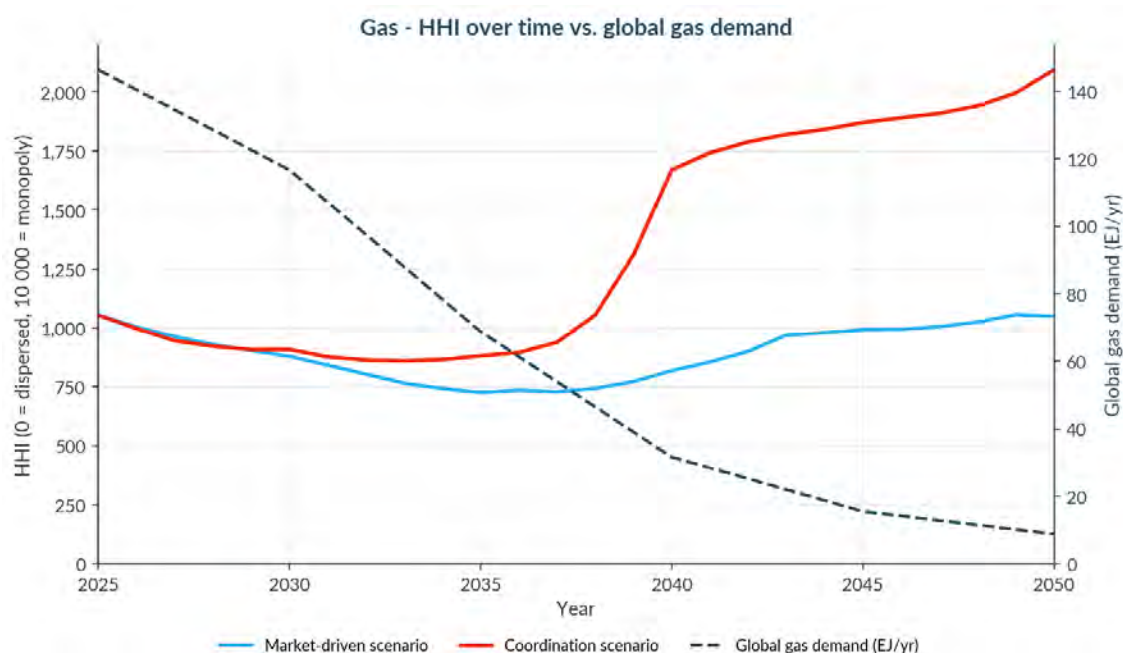


Figure 18: The HHI score of the gas sector over time, comparing the market-driven and coordinated scenarios. Global demand, shown as the dashed line, declines by 94% over 2023-2050.

In the case of oil, coordination also increases the extent of market concentration, but the difference between the market-driven and coordination scenario is much smaller (Figure 19). In the market-driven scenario, the HHI more than triples by 2050 and market-concentration becomes severe as an increasing share of the declining market is captured by low-cost producers in the Middle East. The coordinated scenario only shows small increases to market concentration compared to the market-driven scenario. This highlights that the challenge around market concentration for oil is not a matter of whether there is coordination or not between producers, but about broader strategic decisions in the oil market as global demand declines.

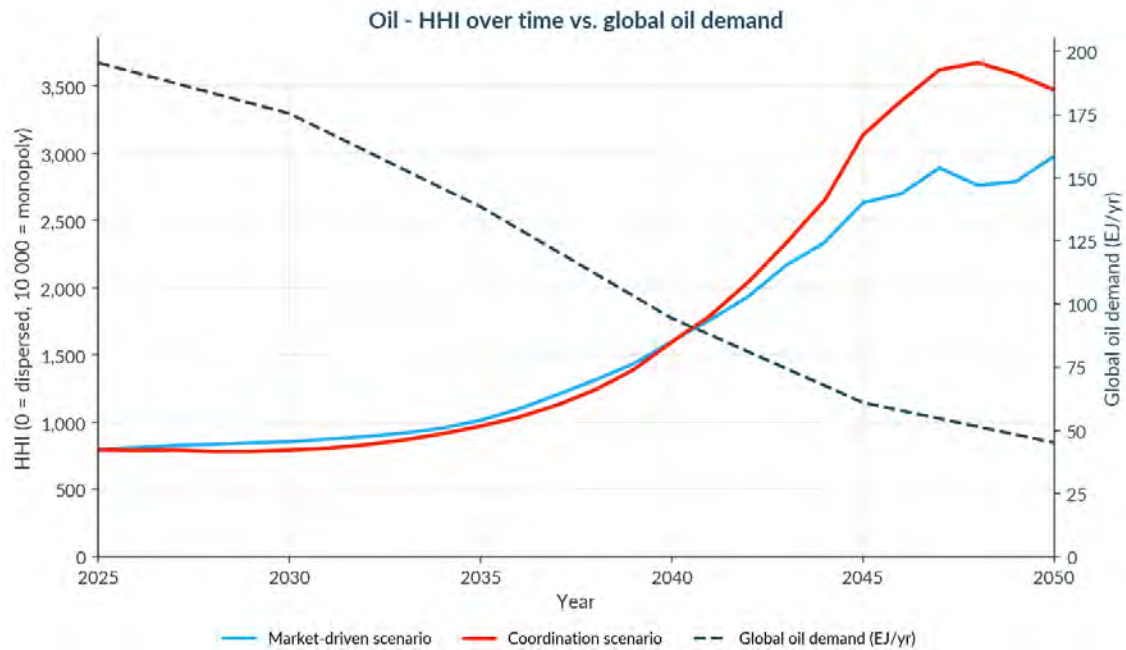


Figure 19: The HHI score of the oil sector overtime, comparing the market-driven and coordinated scenarios. Global demand, shown as the dashed line, declines by 77% over 2023-2050.

As well as looking at the overall level of market concentration, it is important to consider in which countries fossil fuel production is being concentrated. We assess this by quantifying the production-weighted average governance risk for gas and oil supply over time. For each year, every country's share of global output is weighted by its World Governance Indicators (WGI) score and averaged. The line reflects how risky a unit of global fossil fuel production is. The market-driven scenario is shown in red, while the coordinated scenario is shown in blue.

In gas production (Figure 20), the risk gap between the coordinated and market-driven scenario gradually widens. This occurs as producers most ready to phase out fossil fuel production (Waves 1 and 2) decline faster in the coordinated scenario, while producers with the lowest readiness (Waves 4 and 5) – often higher-risk countries – benefit from reallocated production capacity.

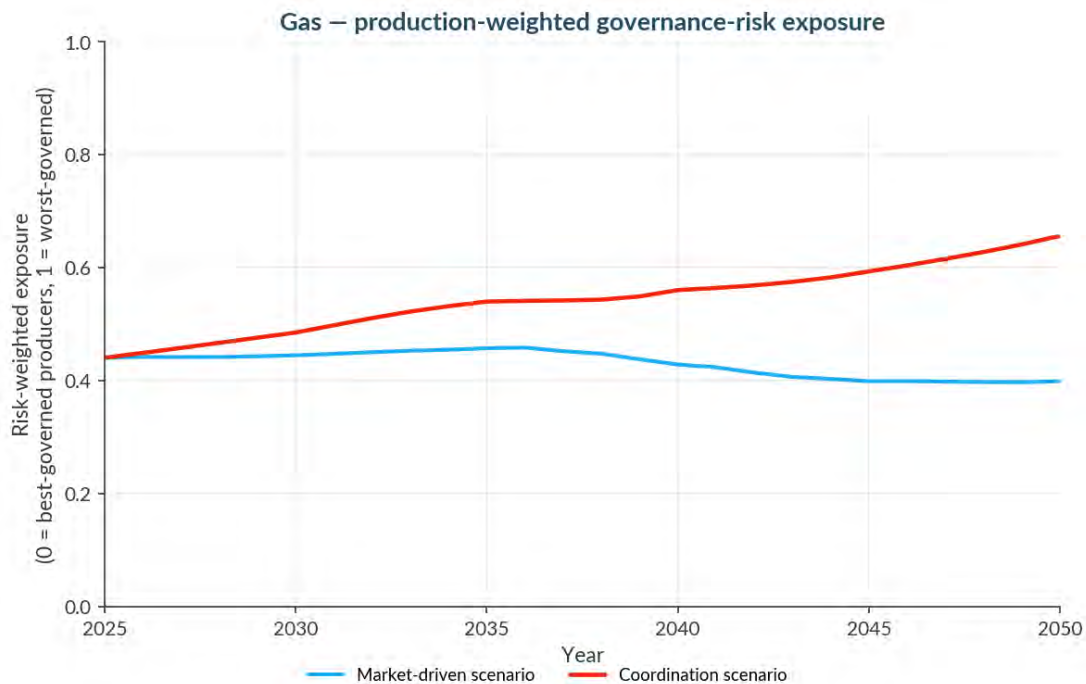


Figure 20: Risk curve for a unit of global gas production, comparing the market-driven and coordinated scenarios.

In the oil sector (Figure 21), risk exposure holds relatively constant out to 2050 under the market-driven scenario.¹⁷ Traditional producers such as Saudi Arabia continue to dominate production throughout this period as global demand continues to decline. Coordination does increase slightly the share of production coming from countries with low governance scores, but only minorly. As with our analysis of market concentration, this suggests the impact of coordination is greater in gas markets than oil markets.

¹⁷ The oil market is dominated by a few large incumbents – Saudi Arabia, Iraq, Iran and Kuwait – in both scenarios. For oil, the largest changes to production under the coordination scenario happen in smaller but highly dependent oil producers such as Angola and Nigeria. This has a smaller impact on the global weighted average risk than in the case of gas.

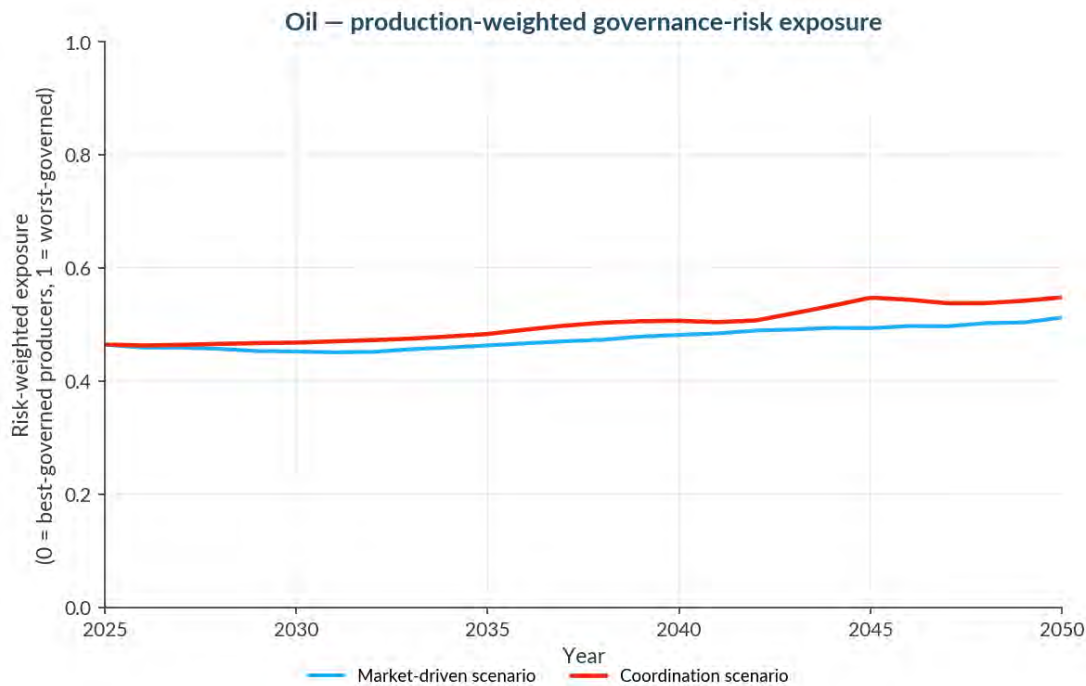


Figure 21: Risk curve for a unit of global oil production, comparing the market-driven and coordinated scenarios.

This analysis shows that coordination can lead to a market that is both more concentrated, and potentially more exposed to the risk of disruption, particularly in the case of gas.

Recent years have underlined the dangers of concentration in the global fossil fuel economy. A more concentrated fossil fuel market can give greater market power to remaining producers, potentially creating conditions where supply lines could be weaponised by exporting countries against import partners, as in the case of Russia (Khoma and Nikolaieva 2025). As production becomes geographically concentrated, fossil fuel supply chains are also exposed to bottleneck risks, as shown by the US-Israel war with Iran and the associated fallout in global energy markets. Further constraining the number of fossil fuel exporting states and concentrating supply could exacerbate existing bottlenecks and create new supply chain vulnerabilities.

This phenomenon of growing market concentration is occurring at the same time as total demand for oil and gas shrinks rapidly. In 2050, total gas demand is down by more than 90% and oil demand is down by almost 80% globally in the HPA scenario. This means that the supply-side shocks to fossil fuel markets would be much lower than in today's world, where fossil fuel dependency is embedded into almost every sector of the economy. This does not mean that supply-side risks should be ignored, given that certain slower-to-decarbonise sectors such as petrochemicals and aviation might still be dependent on global fossil fuel markets. However, it does reduce the importance of market concentration as the role of fossil fuels in the global economy declines.

Therefore, concerns around market concentration should not be used to oppose coordination. Efforts to advance coordination around TAFF need to still be cognisant of

risks that exist and engage in broader security considerations to avoid undesirable outcomes. For example, coordination could modulate remaining fossil fuel production at the margin to avoid a small number of states gaining undue influence. Ultimately, the most effective way to mitigate risk is to accelerate the transition away from fossil fuels across the global economy.

The implications for fossil fuel prices

A just and equitable transition away from fossil fuels must consider the position of the world's fossil fuel producers, some of which are significantly exposed to TAFF due to their high dependency on fossil fuel production and limited capacity to achieve prosperity post-fossil fuels.

However, equity and justice must also consider the perspective of fossil fuel importers. 75% of the world's population is in fossil fuel importing countries, and 25% spend over 5% of GDP on fossil fuel imports (Ember 2025). This includes a number of low-income countries including Guatemala, Namibia and Cambodia.

It could be argued that a strength of a market-driven TAFF is that by allowing competition between producers, the price of oil and gas is driven down, ensuring the greatest benefits for the most vulnerable fossil fuel importers. Meanwhile, the coordinated scenario might, by enabling oil to be extracted that is not cost-competitive, lead to higher oil and gas prices, hitting importers.

This fails to capture the fact there is no pure market-driven option in the real world, in which cartel behaviour and manipulation of markets avoids fair and free competition across producers. Nevertheless, an assessment of the difference in global oil prices between the coordinated and market-driven scenarios is an instructive comparison.

We do so by running the coordinated scenario through the GAPTAP model, constraining production in each country rather than leaving it to be governed by market dynamics alone. This allows us to identify at each point in time what the marginal producing field is and, therefore, what the price in a cost-competitive market would be. We do this exploration for oil only, as the assumption of a single global market is more justified for oil than it is for gas.

Table 6 shows the results of this analysis. It highlights that under a rapid TAFF that aligns with the need to limit the magnitude and duration of overshoot, fossil fuel prices will fall substantially. In our analysis, oil prices fall by 40-50% in the next decade as oil demand falls around a third, and by 50-80% by 2050.

Table 6: Impact of coordination on global oil prices

	Price in 2025	Price in 2035	Price in 2050
Market-driven	\$70/bbl	\$32/bbl	\$15/bbl
Coordination	\$70/bbl	\$42/bbl	\$35/bbl

The market-driven scenario does show lower prices, with prices in the coordination scenario 30% higher in 2035 and more than double in 2050. However, this is within the context of demand destruction at scale pushing oil prices down to historic lows. Under the IEA STEPS scenario, in which there is no real action to accelerate the transition away from fossil fuels, global warming would reach 2.5°C by 2100 and continue to rise thereafter. The IEA estimates that oil prices in such a scenario would be around \$70/bbl in 2050.¹⁸ Therefore, in both scenarios, current fossil fuel importers are still reaping a double dividend to their import bill, by reducing the amount of oil that needs to be imported (via demand destruction) and paying less for it (as a smaller market clears at a lower price). While coordination dilutes the benefits to fossil fuel importers somewhat, any concern it could raise significant equity concerns for importing countries (in terms of elevated fossil fuel prices) is probably overblown.

7: Coal transitions

Assessing TAFF readiness

Figure 22 shows how different countries are prepared for the transition away from coal production.

As mentioned in Section 3, we use a reduced methodology for coal. Unlike oil and gas, we do not have a model to provide a market-driven perspective for coal. Instead, our baseline for coal assumes that all producers follow the global average decline rate, and no NNFF constraint is applied in the optimisation process. The results from the coal analysis, while still informative, are methodologically separate from those for oil and gas.

Coal production is even more heavily concentrated than oil and gas, with the top five producers – China, Indonesia, India, the United States and Australia – responsible for

¹⁸ This does not account for the significant climate impacts that would be experienced as global temperatures rise towards 2.5°C in 2100 and beyond. These would have fundamental impacts on the global economy that make the assumption of stable oil prices in the STEPS scenario questionable at best.

more than 80% of production. China alone produces around half of the world's coal. Wave 1 for coal represents a series of marginal producers that collectively represent less than 0.3% of global production to date, where coal production has been rapidly collapsing towards zero anyway. Therefore, Wave 1's role in coordination is very limited, with the larger opportunity for coordination between Waves 2 to 5, which include larger producers.

Of these producers, **Mongolia** (W5) has the highest dependency on coal by a wide margin, over four times greater than the next highest producers, **South Africa** (W5) and **Australia** (W3).

South Africa's dependency is driven largely by coal's role in the domestic energy mix. Coal supplies 70% of the country's primary energy, while jobs share (~1%) and export revenue (7%) also contribute.

In the case of Australia, dependency is due to a high share of export revenue (coal accounts for around 18%). However, Australia also has very high capacity and, as a result, its overall exposure score is low, ranking 23rd across all producers for transition readiness. It sits in Wave 3 in our analysis.

Mongolia is the most dependent country in the world for total exports and jobs, as well as getting almost 70% of its primary energy from coal. We estimate that coal mining also provides over 3% of total employment in Mongolia, with coal providing over 60% of export revenue. Mongolia also has much lower capacity than Australia to transition away from coal, with a GDP per capita more than 10x smaller. This puts Mongolia as the country with the lowest level of transition readiness in our analysis.

Table 7: The waves of TAFF producers for coal

	Country Wave Assignment - Coal
Wave 1 – highest transition readiness	Bangladesh, Brazil, Hungary, Japan, Malaysia, Mexico, New Zealand, Nigeria, United Kingdom
Wave 2 – high transition readiness	Canada, Germany, Greece, Pakistan, Romania, Slovenia, Thailand, Türkiye, United States, Uzbekistan
Wave 3 – intermediate transition readiness	Australia, Botswana, Bulgaria, Czechia, North Macedonia, Philippines, Poland, Tanzania, Viet Nam, Zambia
Wave 4 – low transition readiness	Bosnia and Herzegovina, China, India, Iran, Kazakhstan, Montenegro, Myanmar, Russia, Serbia, Ukraine
Wave 5 – lowest transition readiness	Colombia, Indonesia, Kyrgyzstan, Laos, Mongolia, Mozambique, North Korea, South Africa, Tajikistan, Zimbabwe

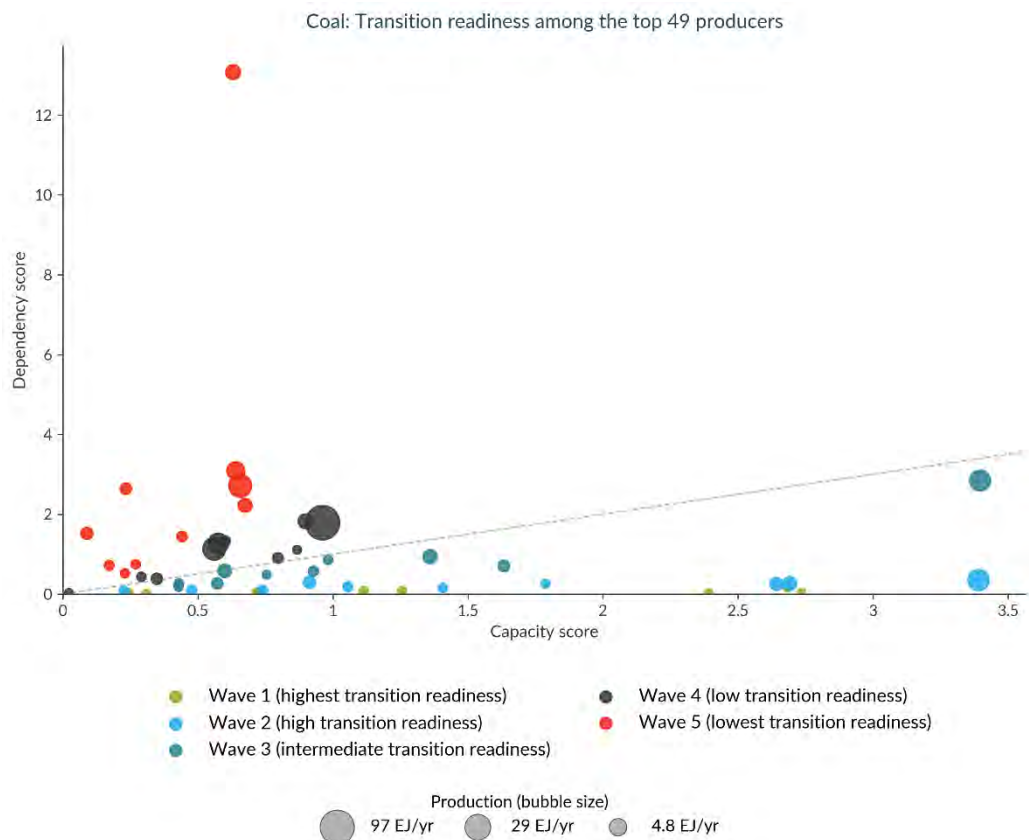


Figure 22: Transition readiness for the top 50 coal producers.

Dots show individual countries, sized by their annual production value. The dashed line marks the boundary where capacity sub-score equals dependency sub-score ($x = y$), defining a soft threshold for the country waves. Countries in Waves 4 and 5 lie above this threshold, while those in Waves 1 and 2 sit below. Countries in Wave 3 also generally sit beneath the threshold.

The implications for coal producing countries

Figure 23 shows the five waves of TAFF readiness for coal, aligned with HPA in our simplified analysis. In all cases, there are substantial reductions in coal production as wind and solar displace coal from the power system at pace, and electrification and other zero-carbon technologies displace coal use in industry. In general, Waves 1 to 3 (including Australia and the United States) accelerate the pace of their phase-out under coordination, while Wave 4 remains broadly unchanged in aggregate. The faster phase-out of coal production from Waves 1 to 3 makes space for Wave 5 (including Indonesia, Mongolia and South Africa) to have a slower, but still rapid, transition away from coal, giving them space to diversify their economies and achieve prosperity post-fossil fuels.

The waves of TAFF for coal phase-out

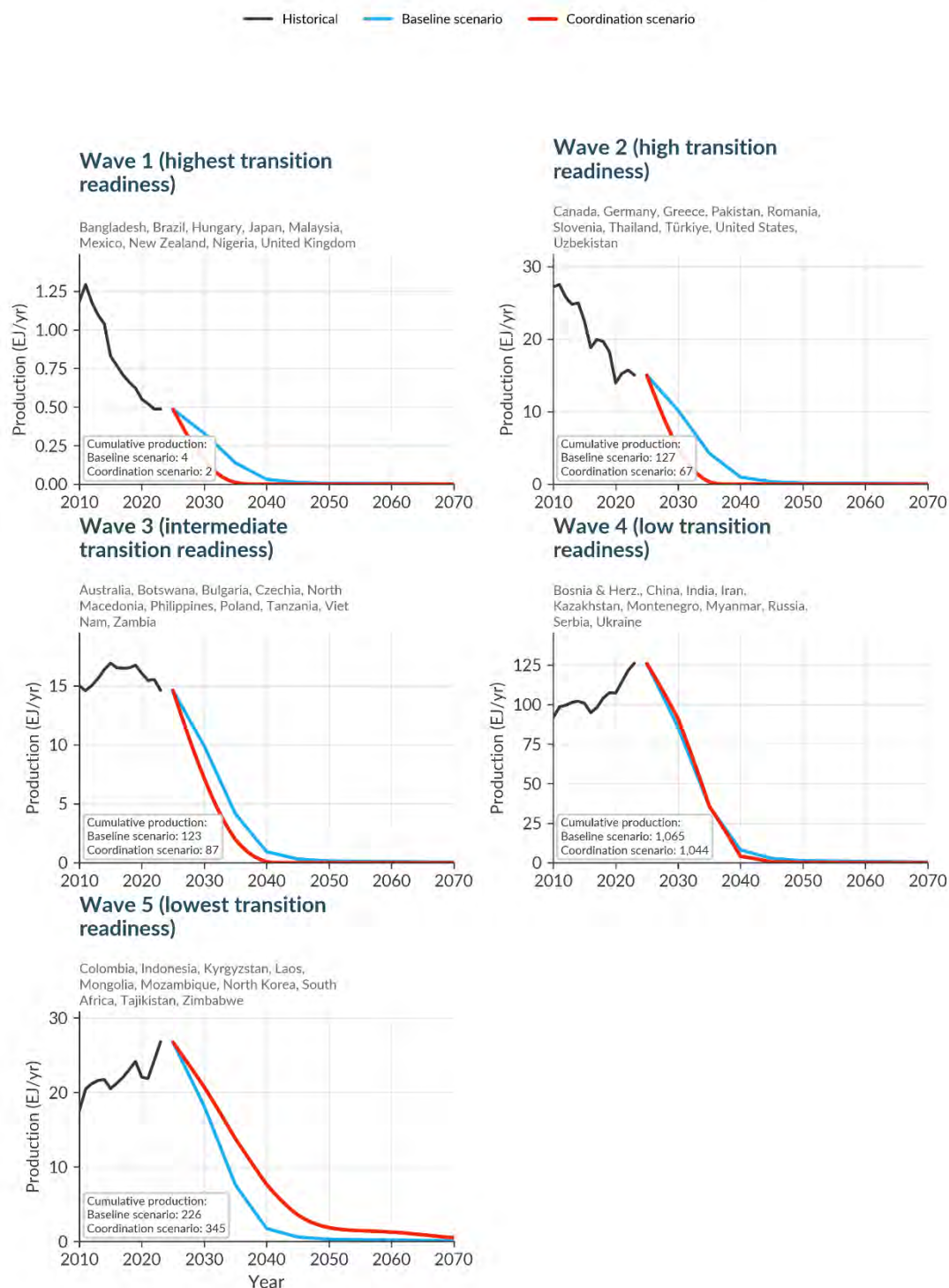


Figure 23: The five waves of TAFF for coal production

Meanwhile, Figure 24 displays the near-term reductions, phase-out date and total production statistics for coal producers across the five waves. As we were unable to produce a market-driven scenario for coal, the counterfactual to the coordinated scenario is a “global average” scenario, in which all countries reduce coal production at

the same average rate. We term this the baseline scenario. While it does not capture market dynamics, it does show an alternative future in which the different levels of transition readiness are accounted for. As such, it remains a valuable counterfactual to compare with the coordinated scenario.

In this baseline scenario, all producers reduce coal production by 72% in 2035 and effectively phase out coal production in 2044 (this is the point at which coal production is reduced more than 97.5% relative to 2023 levels). In reality, a very small tail of coal production continues post-2044, but this is the date at which coal production reaches near-zero levels in all countries.

Coal sees similar dynamics play out across the different coordinated scenarios as observed in the oil and gas sectors. Under coordination, Waves 1, 2 and 3 see deeper near-term reductions, smaller cumulative production and earlier phase-out years. This requires faster action from Australia and the United States as the largest coal producers in these waves. All three waves see coal production on average phased out before 2040 in the coordinated scenario. Even those countries which we describe as having “intermediate” transition readiness would accelerate the pace of production cuts under a coordinated scenario.

Wave 4 is a bridging category, which includes some countries that accelerate coal phase-out under coordination, and others that see a slower rate of decline in coal production. The wave is dominated by China, India and Russia. China sees a minor acceleration of coal phase-out, with cumulative production down 3% under coordination. Meanwhile, India and Russia produce cumulatively 1% and 6% more under coordination. All countries in Wave 5 see a slower near-term pace of reduction and a delayed phase-out, which leads cumulative coal production to grow by over 50% between the baseline and coordinated scenarios.

The implications of a baseline or coordinated transition for the top 50 coal producers

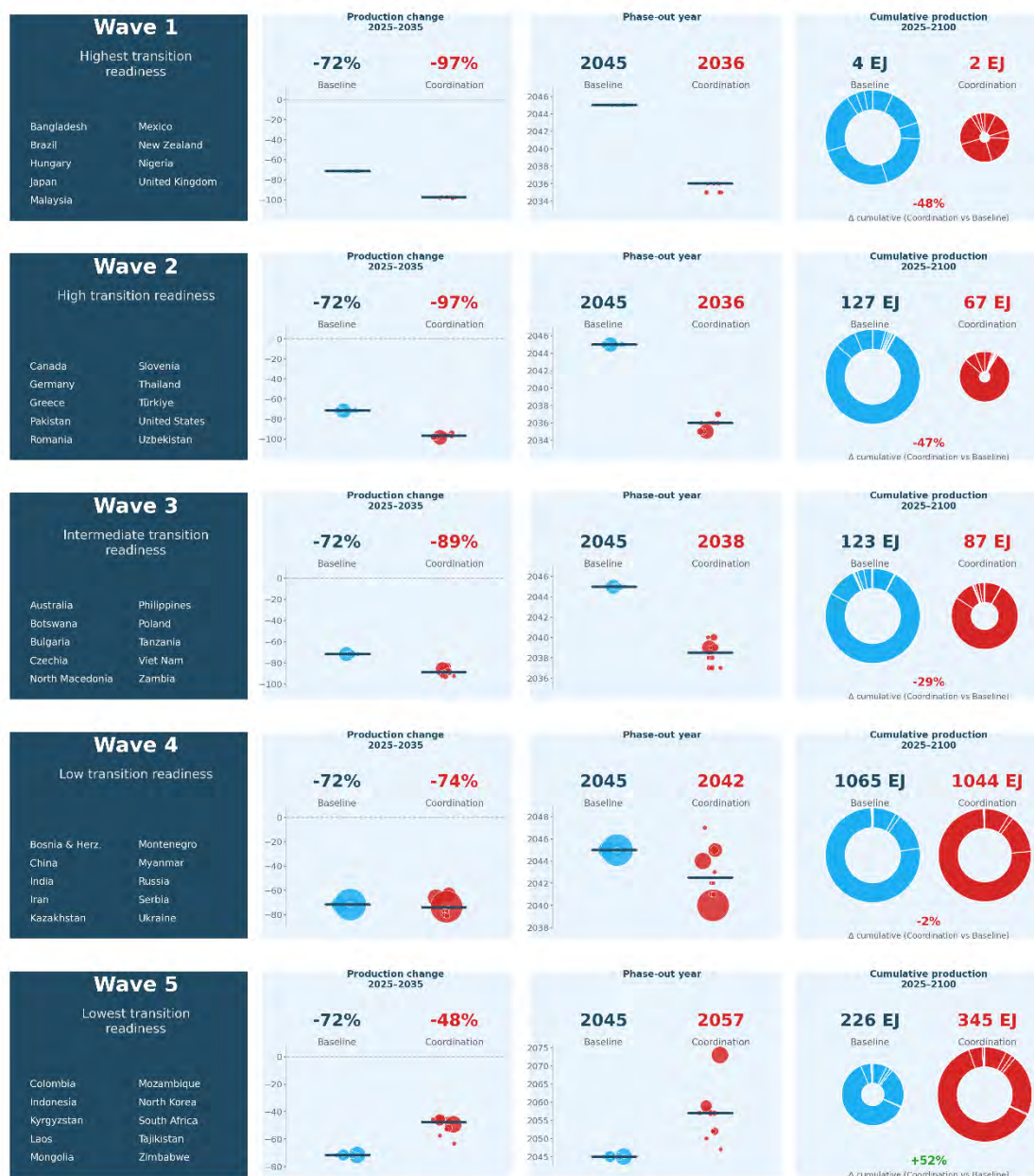


Figure 24: The implication of different TAFF futures for the top 50 coal producers

Size of dots represent scale of coal production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

Figure 25 shows the results for Wave 1 in the coal sector. This wave is made up of small producers where coal production is a negligible part of their economies. Together, they represent less than 0.3% of global coal production, and aggregate coal production has fallen more than 50% since 2010. It includes countries such as the UK, Japan and New Zealand.

Wave 1: TAFF transition leaders



Figure 25: The implications of TAFF for the coal producers in Wave 1

Size of dots represent scale of coal production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the coordination scenario, coal production phase-out accelerates for all Wave 1 countries, averaging a reduction of 97% by 2035. The average phase-out date also accelerates to 2036 for these producers.

Faster near-term reductions and earlier phase-out dates lead to lower cumulative production. In the coordination scenario, this wave produces around 50% less coal than it does in the baseline scenario (Figure 25C). However, as these countries are all marginal coal producers, the impact on other producers is small.

Figure 26 shows the results for Wave 2. The largest producer in this wave is the United States, accounting for 77% of all cumulative coal production. Canada and Germany are a distant second and third.

Wave 2: Countries with high transition readiness

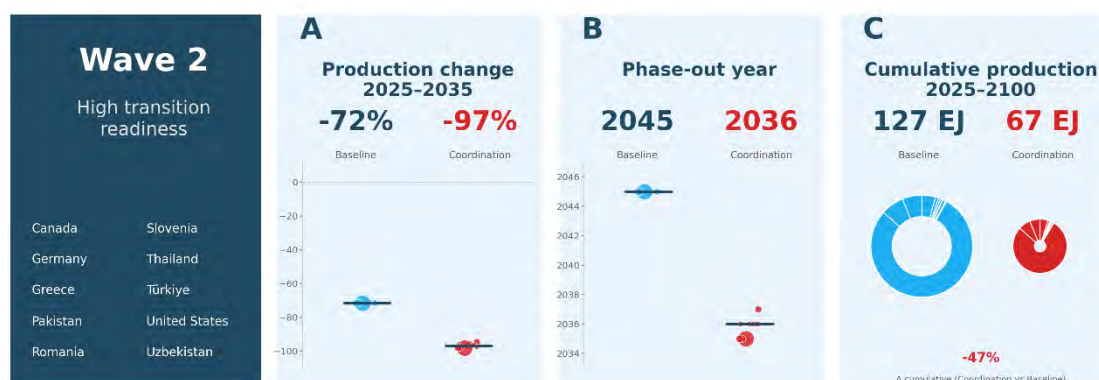


Figure 26: The implications of TAFF for the coal producers in wave 2

Size of dots represent scale of coal production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the baseline scenario, Wave 2 sees coal production fall by around 72% on average (Figure 26A). In coordination, this jumps to 97%. The United States, Canada and Germany experience the steepest declines in production, phasing out by 2035. Other

Wave 2 members phase out coal production by 2037 at the latest. On average, coordination accelerates the phase-out of coal production by nine years from the baseline year of 2045.

Cumulative production in this wave is 47% lower in the coordinated scenario compared to the baseline (Figure 26C). This is driven principally by the United States, where total lifetime coal production is cut in half. The United States, therefore, emerges as the principal source of flexibility in a coordinated transition away from coal, responsible for around 40% of the overall flexibility in coal phase-out transitions across all countries. Without the United States participating in such a cooperative approach, the scope to alter the pace of coal phase-out in other countries would be significantly diminished.

Figure 27 showcases the results for Wave 3. As was the case with the Wave 2, Wave 3's largest producer, Australia, is an outlier that accounts for 75% of all cumulative coal production. Poland and Viet Nam follow in second and third place, at 10% and 8% respectively.

Wave 3: Countries with medium transition readiness



Figure 27: The implications of TAFF for the coal producers in wave 3

Size of dots represent scale of coal production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

Under coordination, the near-term reductions in coal production jump from 72% to 89%. Czechia, the Philippines and Zambia experience the steepest declines in production, phasing out by 2037. Other Wave 3 members phase out coal production sometime between 2038 and 2040, with Viet Nam having the slowest rate of decline and, alongside Botswana, the latest phase-out date among producers. On average, coordination accelerates the phase-out of coal production by seven years from the baseline of 2045.

As with Waves 1 and 2, faster near-term reductions and earlier phase-out dates lead to lower cumulative production. Compared to the baseline, the coordinated scenario leads to an average cumulative decline of 29% (Figure 27C). Cumulative decline is much slower in Wave 3 than in Waves 1 or 2. The decline in Wave 3 is dominated by Australia, where total lifetime coal production falls by around 29% relative to the baseline.

Several of the world's major coal producers are in Wave 4, shown in Figure 28, including China, India and Russia. China, the single largest producer in the coal sector, dominates this wave, with 77% of all cumulative coal production, dwarfing India (13%) and Russia (8%). Kazakhstan is a distant fourth (1.6%) and the remaining six members (Ukraine, Serbia, Bosnia, Iran, Montenegro and Myanmar) together account for barely half a percent between them.

Wave 4: Countries with low transition readiness

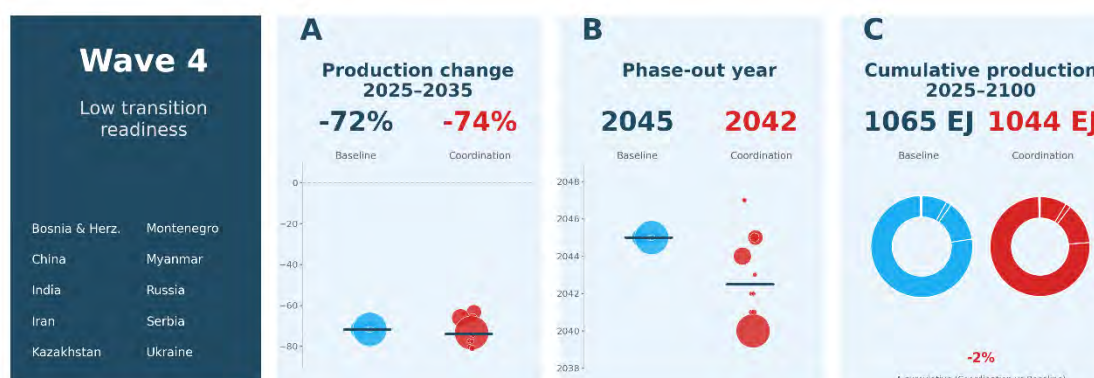


Figure 28: The implications of TAFF for the coal producers in wave 4

Size of dots represent scale of coal production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

In the baseline, production falls uniformly by 72% by 2035 and every country phases out coal production in 2045. But coordination doesn't uniformly deepen that decline here the way it did in Waves 1, 2 and 3. Instead, it splits the wave in two. China, Ukraine, Serbia, Iran, Montenegro and Myanmar see steeper cuts and earlier phase-outs under coordination, led by China phasing out coal production by 2040. India, Russia and Kazakhstan see the opposite result: coordination reduces their near-term decline (India falls only 66% by 2035 versus 72% at baseline) and leaves their phase-out timing unchanged from the baseline.

Wave 4's average cumulative production barely moves between scenarios. It comes down by just 2% under coordination, a fraction of the 29–47% cumulative declines seen in Waves 1, 2 and 3 (Figure 28C). However, China reducing its cumulative production 3% under coordination does create more space for the most exposed producers in Wave 5.

Wave 5, in Figure 29, covers the countries with the lowest transition readiness to move away from coal production. This includes notable coal producers such as Indonesia, South Africa, Mongolia and Colombia.

Wave 5: Coal producers with the lowest transition readiness



Figure 29: The implications of TAFF for the coal producers in wave 5

Size of dots represent scale of coal production in 2023. Unweighted medians are shown in black and give the outcome for the median producer, independent of scale.

If coal production follows the global average, then many of these countries would face a significant erosion of export revenue and major labour transitions in a short period of time. Mongolia and Mozambique, for example, source around 60% and 25% respectively of their export revenue from coal. If coal production falls by around three-quarters in 2035, this could significantly erode their trade balance, with implications for access to hard currency and debt payments. Under coordination, the pace of phase-out would be reduced somewhat. Coal production falls by around half in 2035, compared to the global average cut of 72%.

Coordination would also delay the date of phase-out in these most exposed countries. In Indonesia, coordination pushes phase-out to 2073, nearly three decades later than baseline (although there are still strong cuts, with Indonesian coal production declining around 95% by 2050). The rest of Wave 5 countries phase out somewhere between 2047 (Tajikistan) and 2059 (South Africa). On average, coordination delays phase-out around a decade for these producers.

Wave 5's total production is 52% higher under coordination than at baseline, driven overwhelmingly by Indonesia, where cumulative production rises from 140 EJ to 215 EJ (Figure 29C).

These producers are among the most dependent and lowest-capacity countries in the sector, so coordination creates more space for them. However, as with oil and gas, it cannot overcome the fundamental need to transition away from coal production and use. As such, while coordination could ease the transition in these countries, there remains an urgent need in all coal producers to prepare for a world of rapidly declining coal demand, and a need to consider wider means of cooperation beyond the relative pace of coal phase-out in different producers.

8: Discussions and conclusions

Our analysis has quantified two different possible roads to phasing out fossil fuel production: a market-driven world and one in which there is some degree of multilateral coordination around the pace at which different countries reduce production. We acknowledge that these are not the only TAFF futures that are possible, but they remain two central perspectives that feature prominently in discussions around TAFF. We also acknowledge that, in reality, TAFF transitions will be a much more complex and multifaceted event, with a wide range of actors, incentives, goals and power dynamics competing in a complex system. The transitions we have modelled should be seen as isolating and illustrating key dynamics, and not as predictions of how TAFF is likely to transpire, or as normative benchmarks for any individual country.

Key findings

Our key findings include:

The TAFF process must account for transition readiness

Producer readiness to deal with the fiscal and wider economic implications of declining fossil fuel production varies hugely across countries. There are some countries that are relatively well-placed to manage a declining fossil fuel production industry, with low levels of dependency on production and often high levels of financial and institutional capacity. This includes many large, advanced economies such as the United States, Canada, Australia, Norway and the United Kingdom. There are other countries that are in the middle of the pack when it comes to transition readiness, including some Middle Eastern producers that have high dependency on fossil fuel production but also relatively high capacities. Meanwhile, other producers display very low readiness for the impending transition, with high dependencies and low capacities that must be accounted for. Some of the most exposed producers are Turkmenistan, Algeria, Libya and Iran for gas; Iraq, Angola and Nigeria for oil; and Mongolia, Mozambique and South Africa for coal. Equally, it is not simply the case that all low-income producers have low TAFF readiness: there is a wide degree of heterogeneity within these countries. Any TAFF process that does not acknowledge this varied landscape will fail to deliver a just, orderly and equitable transition, as committed to at COP28.

A market-driven transition would be to the detriment of some of the most exposed producers.

Under our modelling of a transition driven predominantly by market forces, a group of countries with some of the lowest transition readiness scores still reduce fossil fuel production rapidly, as their relatively high-cost production base is undermined by low-cost resources from other countries.

In gas, some of the most exposed producers include Trinidad and Tobago, Libya, Equatorial Guinea and Iran, although even more competitive producers such as Algeria and Turkmenistan still face notable declines. In the case of oil, the most exposed producers include South Sudan, Gabon and Congo, although Nigeria, Angola and Libya also emerge as producers that would face notable declines in the next decade.

On average, oil or gas production falls over 50% in each of these countries in the next decade under a market-driven transition. This would pose supreme challenges for their fiscal and macro-economic stability and would likely lead to large-scale negative social consequences, as declining fossil fuel revenues erode already-strained public spending on key provisions such as health and education. This would severely undermine the just transition. It would also lead to wider regional and global impacts that would cascade beyond these individual countries as rapidly declining revenues would contribute to fiscal and political instability.

Coordination can smooth the road for the most exposed producers

We have modelled a scenario in which there is multilateral coordination between producers and consumers on the pace of production phase-out, with producers with the greatest transition readiness moving first and those with the least transition readiness following later. The coordinated scenario does reduce the fiscal and macro-economic challenges facing the most exposed producers and could, if realised, buy them valuable breathing space on the way to a fossil fuel-free future.

In gas, coordination can change the cuts needed by the least ready producers in 2035 from over 50% to just over 10%. For oil, it changes the cuts from 50% to 36%. Meanwhile, total gas production from Wave 5 almost doubles under a coordinated scenario, while total oil production grows by around a quarter.

Coordination implies more stringent production cuts from other countries. Australia, Canada, Norway and the United States end coal, oil and gas production in the early 2040s. Other major producers such as Russia, Saudi Arabia and the UAE would end coal production around 2040, gas production in the mid 2040s, and oil production by or just after 2050.. Only those producers with the highest dependency and lowest capacity see fossil fuel production continuing beyond mid-century under a coordinated scenario. For the majority, a phase-out is needed by or before 2050.

At the same time, coordination modulates the extent to which fossil fuel prices decline by changing the marginal producer. In our exploratory analysis for oil, we see that oil prices in the coordinated scenario are 30% higher than those the market would deliver by 2035, and more than double in 2050. While prices still decline strongly from today's levels, this modulation in the pace of price decline would increase the revenues that exposed producers can extract from each barrel of oil or cubic foot of gas.

A slower pace of transition away from fossil fuel production and a slower decline in fossil fuel prices are both elements that could be critical in mitigating the disruptive social and economic impacts of TAFF for the most exposed producers.

However, the impact of coordination is limited by the fundamental logic of TAFF

The coordinated scenario is not a panacea for fossil fuel dependent countries. It may be able to smooth the pathway, but it cannot change the destination. It still sees production decline notably by 2035 in all waves, with only a very few countries able to sustain flat or growing production over the next decade. And all countries still have to reduce production significantly by 2050 and phase it out entirely by around 2050 for coal, 2060 for gas and 2070 for oil. In addition, oil and gas prices will still decline notably as demand for these commodities falls, regardless of whether there is coordination or not. Coordination can modulate the phase-out dynamics that deep mitigation scenarios require, but it cannot eliminate them.

This means that coordination can be seen, at best, as a partial solution to the challenge of exposed and dependent fossil fuel producers. If pursued, it must be accompanied by a broad range of other cooperative and supportive measures.

Coordination can have broader impacts on market concentration and prices, but these are limited by a rapid transition away from fossil fuels

TAFF decisionmakers will consider not only equity, but also the perspectives of security of supply and cost-effectiveness (Van De Graaf 2026).

We find that for gas, coordination could notably exacerbate market concentration into a smaller number of more autocratic fossil fuel producers, which could raise security of supply concerns. This highlights a potential negative side-effect of coordination that should be considered in discussions. Meanwhile for oil, the impact of coordination on market concentration is much lower, as a market-driven transition already results in large-scale concentration of supply in low-cost Middle Eastern producers.

However, in both cases, the importance of security of supply and market concentration will decline as demand for oil and gas falls. This means that security considerations might be a reason to modulate the extent and form of coordination, but should not be a reason to abandon it altogether. For example, it may be desirable to prevent all gas production in 2050 coming from one or two remaining producers. But this does not mean that coordination around the pace and scale of fossil fuel production cuts on the road to 2050 is either impossible or undesirable. We should not use these concerns to argue against coordination, but rather to guide the aims and modalities of it. Further analysis would be needed to explore a pathway away from fossil fuels that accounts for these security considerations in greater detail.

We also estimate the impact of coordination on oil prices. We find that coordination could boost oil prices by around a third in 2035 compared to the market-driven scenario. However, in both cases, oil prices would be below \$50/barrel by 2035 onwards, which would already represent a considerable reduction from today's levels, where oil trades at nearer \$100/barrel. This again suggests that concerns over price rises should not be a reason to move away from exploring coordinated approaches to TAFF. Indeed, a slightly slower reduction in fossil fuel prices could represent a scenario

that still delivers benefits to consumers (who are paying less for fossil fuels, and importing less as they decarbonise), but which reduces the fiscal cliff-edge producers face.

The way forward

As the climate crisis continues to escalate across the world, a rapid transition away from fossil fuels remains the world's best hope of avoiding the very worst impacts of climate change. Fossil fuels are at the heart of global warming, and stopping their extraction, use and combustion is essential.

However, as this analysis shows, cutting fossil fuels in line with the needs of the climate crisis brings its own set of impacts, particularly on those countries that are heavily dependent on fossil fuel production for government revenue, exports and broader economic performance.

In such a world, many have focused on the idea of a managed transition, in which declines in fossil fuel extraction are coordinated across producers to minimise the impact on the most vulnerable.

We have quantified this world and shown that it does significantly mitigate the challenge that is otherwise facing those producers with the lowest transition readiness. However, it does not eliminate the challenge. This suggests two key ways forward for the global community.

First, attempts to develop coordinated approaches are to be welcomed

Given today's fractured geopolitics, achieving multilateral coordination is hugely challenging. It seems highly unlikely that a global consensus on cooperation will emerge. However, as this analysis has shown, the potential benefits of coordination are still large, and therefore we should not abandon attempts to realise its benefits, even if only partially.

The road towards greater coordination could start with clubs of the willing, in which smaller groups of countries come together to try and make decisions around fossil fuel production and use that align with the coordinated TAFF scenario outlined here. On the producer side, initiatives such as the Beyond Oil and Gas Alliance (BOGA) are already promising first steps towards this world. This could involve those countries with the greatest transition readiness recognising that they need to take the lead in phasing out fossil fuel production. Importantly, it would also involve a recognition from those producers with lower transition readiness that, even within a coordinated approach, they need to plan and prepare for the end of fossil fuel production.

The likelihood of producers coordinating on the pace of TAFF in isolation is perhaps low. This highlights the critical role for consumers in also helping to guide coordination. Major importers have significant leverage on the pace of fossil fuel production via the

fossil fuel supply chains they choose to rely on while decarbonising. For example, the EU27 needs to decide how it engages with the considerations of security of supply, equity, justice and cost as it seeks to reduce oil and gas demand and associated imports. The EU's gas imports come from a range of producers with very different levels of transition readiness, ranging from Algeria to the United States. Decisions that the EU makes about future supply will influence the transition away from fossil gas production in each of these countries. The role for 'consumer clubs', that try to advance a just transition when deciding which producers they source their remaining fossil fuels from, and how they collaborate with them, is a critical idea to explore further.

Groups of the willing may be the only way to advance coordinated approaches to TAFF in the current geopolitical climate. However, such clubs can provide a critical incubation space for multilateral cooperation on TAFF. If fossil fuel demand peaks and begins to decline in line with the goals of the Paris Agreement, this could also bring other countries to the table to build a coordinated approach to managing decline. The group of the willing coordinated at Santa Marta represents an obvious forum under which to continue this work. While full coordination may represent an unlikely but desirable gold standard, this should not stop countries working to advance coordination where possible on the pace and scale of transitioning away from fossil fuel production.

Second, do not neglect the other critical aspects of coordination beyond scheduling production declines

Coordination on how fast production declines in different countries makes a difference to the most exposed producers. But it does not eliminate their dilemma: how to transform economies that are highly dependent on fossil fuel production, and have very limited fiscal space, to achieve urgently needed development goals while still achieving TAFF.

Therefore, other elements of urgently needed coordination, such as upscaled climate finance, global debt relief and support to achieve macro-economic diversification, will remain essential. They also may face fewer challenges to their successful uptake than the multilateral coordination of production decline across a diverse range of producers. For example, debt relief and restructuring can be a minilateral discussion between a debtor and its creditors, rather than requiring broader buy-in by all producers. As such, our recommendation to policymakers seeking to advance a just, orderly and equitable transition away from fossil fuels is to explore the broadest possible toolkit for coordination. This includes debt restructuring, transition finance and bilateral trade partnerships, alongside conversations around the pace of fossil fuel production decline.

Methods annex

This annex provides more detail on the methods we use in the report to produce our two scenarios.

The GAPTAP model

Summary of the model

We use the GAPTAP model, initially developed for gas and extended to produce market-driven scenarios for oil (Welsby 2022, Zhang 2026). GAPTAP has several features that enable it to provide market-orientated oil and gas scenarios. These include:

- Field-level based representation of reserve/resource levels and costs
- Interdependency between oil and gas production to inform levels of associated gas in the gas module¹⁹
- For gas, representing different market dynamics including long-term contracts, direct domestic consumption and the spot market, for determining regional prices
- For gas, supply infrastructure capacity and new investment options (pipelines, LNG) that determine trade between producers and consumers
- Gas production assets make operational decisions based on a short-run marginal cost basis once capital investment is sunk into the project, meaning assets can produce if gas prices fall below the long run marginal cost (LRMC) of a given asset, but remain above the short-run marginal cost (SRMC). The oil module of GAPTAP does not yet have this functionality, making both investment and operational decisions on a LRMC basis.

The model is a highly detailed supply side model of the oil and gas sectors, with production and trade responding to an exogenous demand projection. For a given period (e.g. 2025-2050), the model first resolves demand in year one, determining the stack of field level production (existing and new) determined by economic ranking, but shaped by a range of other system factors (e.g. infrastructure capacity, trade costs, fiscal regimes). The model then resolves to meet demand in year two by building on investment and operating decisions in year one, and so on.

For this study, country level demands were provided from the HPA scenario for oil and gas. These demands were converted from units of joules to volumetric measurements (barrels of oil and bcm of gas), as used in GAPTAP.²⁰ The oil simulation was run first to

¹⁹ Associated gas is gas which is produced alongside the extraction of crude oil

²⁰ The conversion factor between volumetric (barrels/bcm) and energy (EJ) varies depending on the energy content of the fuel (e.g. NGLs have lower volumetric energy density than crude oil). In

determine oil production trajectories by country for this scenario, along with associated gas level. The gas simulation was then undertaken to determine the gas production needed (in addition to the associated gas) to meet country demand.

GAPTAP was run for a time horizon of 2025-2050. This does not fully cover the timelines of phase-out in the HPA, in which gas demand falls 94% in 2050 and oil demand falls 77%. To extrapolate the market-driven scenario forwards, we assume the geographical production mix in 2050 (in terms of shares of global production) is continued forwards.

Quantifying TAFF exposure

The key steps in the methodology are as follows:

1. **Normalisation.** Different metrics can have different scales. For example, while the share of jobs in fossil fuel production ranges from 0 to ~10%, the share of government revenue from fossil fuel production can reach almost 90%. Without normalisation, this could lead to some metrics having larger weight than others, not due to an explicit design choice in the methodology, but due to differences in the distribution of data. We normalise metrics to consider them on an equivalent basis. We use a *min-mean normalisation method*, where data is rescaled by the difference between the minimum and mean value in the datasets. This is shown in Equation 1:

$$Variable_{norm,c} = \frac{Variable_{raw,c} - \min(Variable)}{mean(Variable) - \min(Variable)}$$

We explored alternative normalisation steps, including a *min-max* and a *z-score* normalisation process, but these methods performed more poorly in dealing with outliers in the datasets, which often display a strong right-handed skew (a few countries with very extreme levels of dependency). We also explored using a global-weighted mean as our standard for normalisation, rather than an unweighted mean. However, as our focus is on how a country compares to the typical country in our sample, rather than the global average, we retain the use of unweighted means in this normalisation step.

2. **Aggregation.** To produce individual fiscal dependency and capacity scores, we compute the arithmetic mean of these normalised indicators.
3. **Combination.** To produce a final overall capacity-dependency score, we divide a country's fiscal dependency by its fiscal capacity. This is shown in Equation 2 below. This means that the higher a country's fiscal dependency on fossil fuel

this work, we use standard conversion factors of 1.95 EJ/barrel of oil, and 0.03471 EJ/bcm of gas.

production, the higher it scores in our system. The higher its fiscal capacity to transition away from fossil fuels, the lower it scores in our system.

$$TAF\!F_Exposure_c = \frac{DependencyScore_c}{CapacityScore_c}$$

We explored an alternative multiplicative approach, which is shown below in Equation 3:

$$TAF\!F_Exposure_c = Dependency_c * (Capacity_{max} - Capacity_c)$$

In this system, the country with the highest capacity would get a score of zero, regardless of how dependent it is on fossil fuel production.

Data sources and assumptions used

Table 8 and Table 9 outline the data sources and assumptions we used for quantifying the capacity and dependency indicators. Where country-level data is missing from the main data source, we use country-specific sources to infill.

Table 8: Data sources used in calculating dependency on fossil fuel production

Indicator	Dependency Indicators	
	Source(s)	Detail
Export revenue	United Nations Comtrade database	Fuel specific export values are divided by total export revenue in a country.
Government revenue	International Monetary Fund and International Energy Agency	Overall hydrocarbon revenue share by country retrieved from IMF Article IV reports. This number is then itemised into oil and gas revenue using each country's oil and gas production ratio from IEA production data. Missing country data is sourced from government sources.
Primary energy	International Energy Agency	Considered IEA production, primary energy and energy import/export data to estimate how much of a country's primary energy comes from domestically produced coal/oil/gas.

Jobs	International Energy Agency and World Bank World Development Indicators	IEA jobs data is downscaled from the regional level to the country level using IEA production shares within each IMF World Economic Outlook region. This downscaling from the regional level assumes a uniform labour intensity across countries, where in reality producers with more developed fossil fuel industries may have a lower ratio of workers to unit of production.
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Table 9: Data sources used in calculating fiscal and regulatory capacity to manage TAFF

Indicator	Capacity Indicators	
	Source(s)	Detail
Governance	World Bank Worldwide Governance Indicators	The World Bank's Worldwide Governance Indicators have six dimensions: Voice & Accountability (V&A), Political Stability, Government Effectiveness, Institutional Quality, Rule of Law, Control of Corruption. We elect to leave out V&A because we want to avoid rewarding countries with additional fossil fuel production that have a reputation for domestic repression. A similar argument could hold for other indicators such as control of corruption. However, a sensitivity analysis excluding each of the other five dimensions was done, and their inclusion/exclusion did not make a significant difference to the ranking and distribution of countries. These dimensions remained in our aggregate, where we average across them to produce a score for each country.

GDP-per-
capita

World Bank World
Development Indicators

GDP divided by population.

TAFF exposure scores

The tables below show the final outcomes of our analysis of TAFF exposure, where we identify leaders (those with low TAFF exposure who are well placed to lead the transition away from fossil fuel production) and followers (those with higher TAFF exposure who may need more support in managing the transition away from fossil fuel production).

Table 10: Country-level transition readiness scores for gas producers, aggregated from capacity (incorporating indicators for GDP-per-capita and governance) and dependency (incorporating indicators for export revenue, government revenue, primary energy and employment) sub-scores based on indicators for export.

Country	Transition readiness scores: gas producers		
	Dependency score	Capacity score	Final score
Myanmar	1.87	0.07	27.44
Venezuela	0.89	0.07	12.14
Turkmenistan	4.12	0.36	11.33
Equatorial Guinea	3.34	0.31	10.87
Algeria	2.98	0.44	6.77
Iran	1.59	0.28	5.72
Libya	0.86	0.2	4.37
Azerbaijan	2.14	0.52	4.15
Bolivia	0.96	0.36	2.7
Trinidad and Tobago	2.37	0.94	2.54
Nigeria	0.65	0.26	2.52
Brunei	4	1.66	2.41
Mozambique	0.6	0.26	2.27
Qatar	5.01	2.61	1.92
Oman	2.14	1.14	1.87
Russian Federation	0.85	0.5	1.7
Uzbekistan	0.75	0.46	1.63
Bahrain	2.06	1.33	1.54
Egypt	0.63	0.47	1.35
Iraq	0.19	0.15	1.32
Pakistan	0.25	0.25	1.02
Malaysia	0.98	0.98	1
Angola	0.34	0.35	0.95
Bangladesh	0.3	0.32	0.93
Norway	2.42	3.2	0.76
Argentina	0.49	0.77	0.63
Peru	0.32	0.58	0.56
Saudi Arabia	0.71	1.28	0.56
Kazakhstan	0.42	0.79	0.53
Kuwait	0.64	1.26	0.51
Ukraine	0.17	0.36	0.49
United Arab Emirates	0.95	2.01	0.47
Indonesia	0.27	0.62	0.44
Colombia	0.22	0.62	0.36
Mexico	0.22	0.63	0.35
Israel	0.63	1.85	0.34

Canada	0.53	2.17	0.24
Romania	0.21	0.92	0.23
Australia	0.61	2.69	0.23
Thailand	0.13	0.68	0.19
United States	0.44	2.65	0.17
Viet Nam	0.09	0.57	0.15
Brazil	0.06	0.65	0.09
New Zealand	0.18	2.18	0.08
United Kingdom	0.18	2.19	0.08
China	0.07	0.84	0.08
India	0.04	0.55	0.07
Netherlands	0.11	2.39	0.05
Poland	0.02	1.16	0.02
Germany	0	2.13	0

Table 11: Country-level transition readiness scores for oil producers, aggregated from capacity (incorporating indicators for GDP-per-capita and governance) and dependency (incorporating indicators for export revenue, government revenue, primary energy and employment) sub-scores based on indicators for export.

Country	Dependency scores: oil producers		
	Dependency score	Capacity score	Final score
South Sudan	2.42	0	N/A
Iraq	3.04	0.24	12.79
Libya	3.71	0.3	12.41
Venezuela	1.84	0.17	11.15
Congo	1.83	0.33	5.47
Angola	1.85	0.41	4.51
Gabon	1.98	0.54	3.66
Nigeria	1.14	0.33	3.48
Equatorial Guinea	1.17	0.38	3.06
Iran	1.07	0.36	2.97
Algeria	1.27	0.5	2.55
Ecuador	1.41	0.56	2.53

²¹ South Sudan's capacity sub-score is listed at zero, reflecting its extremely low GDP-per-capita and governance rating, which is the lowest among oil producers for both indicators. The final score for producers is calculated by dividing dependency by capacity, producing a mathematically extreme and non-comparable value because of the zero capacity score. South Sudan's final score is instead reported as NA rather than a distorting outlier.

Kuwait	3.19	1.31	2.43
Azerbaijan	1.23	0.57	2.16
Saudi Arabia	2.78	1.33	2.1
Guyana	2.31	1.13	2.04
Cameroon	0.52	0.3	1.72
Oman	1.61	1.18	1.36
Kazakhstan	1.09	0.83	1.31
Russia	0.75	0.58	1.29
Colombia	0.79	0.66	1.19
Brunei	1.7	1.69	1.01
Turkmenistan	0.41	0.45	0.92
United Arab Emirates	1.86	2.06	0.9
Ghana	0.51	0.57	0.9
Egypt	0.4	0.52	0.78
Brazil	0.54	0.7	0.77
Mexico	0.5	0.69	0.72
Bahrain	0.88	1.38	0.64
Argentina	0.47	0.83	0.56
Qatar	1.17	2.7	0.43
Norway	1.37	3.28	0.42
Malaysia	0.33	1.01	0.33
Canada	0.69	2.21	0.31
Trinidad and Tobago	0.3	0.99	0.31
India	0.17	0.58	0.29
Peru	0.17	0.63	0.27
Indonesia	0.16	0.65	0.25
Viet Nam	0.1	0.61	0.17
United States	0.41	2.74	0.15
Thailand	0.1	0.72	0.14
Uzbekistan	0.06	0.51	0.12
Pakistan	0.03	0.31	0.1
Romania	0.08	0.96	0.09
United Kingdom	0.19	2.24	0.08
China	0.06	0.88	0.07
Türkiye	0.04	0.84	0.05
Denmark	0.12	2.8	0.04
Australia	0.11	2.75	0.04
Italy	0.05	1.68	0.03

Table 12: Country-level transition readiness scores for coal producers, aggregated from capacity (incorporating indicators for GDP-per-capita and governance) and dependency (incorporating indicators for export revenue, government revenue, primary energy and employment) sub-scores based on indicators for export.

Country	Dependency scores: coal producers		
	Dependency score	Capacity score	Final score
Mongolia	13.08	0.63	20.76
Mozambique	2.64	0.23	11.32
South Africa	3.09	0.64	4.83
Zimbabwe	0.72	0.17	4.19
Indonesia	2.71	0.66	4.13
Colombia	2.22	0.67	3.29
Lao	1.44	0.44	3.27
Kyrgyzstan	0.74	0.27	2.76
Tajikistan	0.52	0.23	2.26
Bosnia and Herzegovina	1.33	0.6	2.21
Russia	1.27	0.57	2.2
Kazakhstan	1.82	0.9	2.03
India	1.13	0.56	2.02
China	1.79	0.96	1.86
Iran	0.43	0.29	1.49
Myanmar	0.03	0.02	1.28
Montenegro	1.11	0.87	1.28
Serbia	0.9	0.8	1.13
Ukraine	0.38	0.35	1.1
Viet Nam	0.58	0.6	0.97
Botswana	0.85	0.98	0.87
Australia	2.84	3.4	0.84
Poland	0.93	1.36	0.69
North Macedonia	0.48	0.75	0.64
Tanzania	0.27	0.43	0.63
Bulgaria	0.57	0.93	0.61
Philippines	0.27	0.57	0.47
Czechia	0.7	1.63	0.43
Zambia	0.18	0.43	0.42
Türkiye	0.3	0.91	0.32
Pakistan	0.06	0.23	0.28

Uzbekistan	0.1	0.48	0.21
Romania	0.18	1.06	0.17
Slovenia	0.26	1.79	0.14
Thailand	0.09	0.74	0.12
Greece	0.15	1.41	0.11
United States	0.35	3.39	0.1
Canada	0.27	2.69	0.1
Germany	0.25	2.64	0.1
Nigeria	0.02	0.24	0.09
New Zealand	0.17	2.68	0.07
Hungary	0.07	1.26	0.06
Malaysia	0.06	1.11	0.06
Mexico	0.03	0.72	0.04
Brazil	0.02	0.73	0.03
Bangladesh	0.01	0.31	0.02
United Kingdom	0.03	2.74	0.01
Japan	0.02	2.39	0.01

Optimisation model

Here we provide a brief summary of the optimisation model that we developed for the coordinated scenario.

As discussed in the main report, the main stages in this analysis are:

- **Coordination-adjusted cumulative targets:** Here we calculate the share of cumulative future production that each country would achieve under the market-driven baseline as the starting point. We then redistribute production based on each country's exposure score: higher-scoring, more dependent, less capable countries are allocated a larger share, lower-scoring countries a smaller one. These new coordination-adjusted cumulative targets feed into the optimisation as a weighted objective rather than a fixed requirement. A coordination parameter alpha can be used to set the level of coordination in the scenario. We explored ranges from 0–100. We identified that over 90% of the variance in results occurs in the 0–10 range. As such, we used parameters of 0.5, 1 and 10 to represent moderate, strong and maximum coordination. Our results focus on alpha=1.
- **Annual pathway optimisation:** A constrained optimisation converts each country's coordination-adjusted cumulative production target into a smooth, year-by-year production trajectory. The multi-objective optimisation aims to minimise the curvature of the outputs (to ensure the decline curves are as

smooth as possible), while achieving the coordination-adjusted targets produced in the first step.

- **Modelling NNFF.** In the coordinated scenario, we constrain production to be compatible with NNFF. To create the NNFF constraint used in the analysis, we feed oil and gas demand from the IEA STEPS scenario into the GAPTAP model. We extract the future production that comes from existing and already approved oil and gas fields and use this as the estimate of what production is feasible via existing fields. This shows what level of production could be achieved by existing fields under the prices seen in the IEA STEPS scenario. We apply this as a hard constraint in our coordination, which ensures that the coordinated scenario aligns with NNFF. This constraint could be removed in the optimisation to explore how oil and gas production would differ in a world that is not aligned with NNFF.

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