



## **New insights and creative approaches for transitioning away from fossil fuels**

Authors: Ryna Cui, Nate Hultman, Christoph Bertram, Jiehong Lou, Kowan O’Keefe

Center for Global Sustainability, University of Maryland

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Recent events have underscored the urgency of transitioning away from fossil fuels rapidly and globally. Choosing a future of cleaner, cheaper renewable energy, combined with industrial transformations and reductions in non-CO<sub>2</sub> greenhouse gases, shapes national and global economies in ways that are robust and resilient, that support growth and jobs in the economies of the 21st Century, and help the world track more closely to our agreed climate goals. In contrast, dependence on fossil fuels creates severe and significant risks to national security, energy security, national economic growth, manufacturing, domestic jobs, household prices, air quality and human health, and at the same time drives the planet toward increasingly unsafe levels of climate change.

Global consumption and production of fossil fuels rebounded quickly from COVID and have continued to grow since 2021, reaching a new record high every single year through 2025.<sup>1</sup> Countries continue to invest in and develop new fossil capacity and infrastructure<sup>2,3</sup>, such as coal power plants and LNG terminals, despite substantial risks of stranded assets and economic losses. The rapid expansion of clean technology deployments has not yet, by itself, reversed the growing trends of fossil energy. In the absence of enhanced national and global leadership on climate, other priorities in energy security, grid stability, economic growth, competitiveness, and geopolitical tensions have dominated the narratives and slowed the progress in transitioning away from fossil fuels, leading to a significant departure from the Paris-aligned pathways.

Meanwhile, recent years have repeatedly proven the significant risks of fossil dependence to energy security. The ongoing geopolitical conflicts in the Middle East have led to a widespread energy crisis with huge price turmoil in the global crude oil, oil products, and LNG markets. This has triggered a renewed realization within large oil-consuming and importing countries that moving away from fossil fuels is a fundamental strategy for energy security and energy affordability. Although at a smaller scale, the impact of Europe shifting away from Russian gas exports has accelerated the transition to renewables.

The Brazilian Presidency’s call at COP30 for countries to develop roadmaps for transitioning away from fossil fuels comes at a critical time. New insights and creative approaches will be needed to navigate a pathway to success through many near-term geopolitical and economic challenges. There has been a rich literature and a long history of policy discussion on the necessity, pathways, strategies, and outcomes of phasing out fossil fuels to limit long-term warming and deliver other societal benefits. However, the rapidly evolving technological, economic, financial, and political spaces require refreshed thinking to

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<sup>1</sup> International Energy Agency. *World Energy Outlook 2025* (International Energy Agency, 2025).

<sup>2</sup> Global Energy Monitor. <https://globalenergymonitor.org/> (2026)

<sup>3</sup> Fulghum, N. Ember: Electricity Data Explorer. <https://ember-energy.org/data/electricity-data-explorer/> (2026)



reflect the latest trends and emerging contexts. Moreover, lying under the global picture are large regional variations across different fossil fuels.

**Here, we propose an analytical and policy framework with four components to tackle the emerging challenges and opportunities of an accelerated, orderly, and just fossil transition in different country contexts.**

**First, we emphasize the need to differentiate new investments and new builds of fossil fuels from the existing infrastructure and activities.** The transition roadmaps should prioritize avoiding any new capacity or development to the greatest extent possible to allow space for an orderly, just transition of existing fossil capacity. With rapidly declining costs of renewables, batteries, electric vehicles, and other clean technologies, there is no longer an economic case for fossil fuels for most sectors or regions. The low-cost alternative options can be selected based on local conditions, such as renewable resource availability for different technologies and grid infrastructure for central or distributed systems. Moreover, the growth of renewables and clean technologies can already cover the growth of energy demand and can start to displace existing demand filled by fossil fuels. Not only will the newly added fossil capacity be stranded itself, but it further competes with existing fossil infrastructure for the limited and decreasing space displaced by renewables and substantially increases the challenges of achieving an orderly and just transition.<sup>4</sup> Another reason to prioritize the avoidance of new fossil investments is that this risks crowding out needed capital for investing in clean technologies.

**Second, we emphasize the need to differentiate among existing fossil fuel infrastructure along multiple dimensions at the facility level.** The transition roadmaps should develop a deeper, comprehensive understanding of existing fossil capacity by assessing individual facilities from technical, economic, environmental, social, financial, and system perspectives, and identify a set of transition strategies that can be tailored for different types of facilities and local priorities.<sup>5,6,7</sup> For example, earlier retirement can target a small set of fossil plants that are older, dirtier, water-intensive, less efficient, and less profitable, performing below average across all dimensions. Remaining plants, depending on the technical feature, retrofit potential, additional service provided, proximity to other resources, and ownership structure, can deploy different transition strategies such as converting to dispatch service with gradually lowered utilization, co-firing with biomass, or retrofitting with carbon capture and storage.<sup>8,9</sup> Similarly, closure of fossil production capacity should also consider efficiency, profitability, air pollution, water and land impacts, methane emissions, and other factors at the facility level.

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<sup>4</sup> M. Edwards, et al. (2022). Quantifying the regional stranded asset risks from new coal plants under 1.5°C. *Environ. Res. Lett.* 17: 024029.

<sup>5</sup> Cui, R. et al. (2021). A plant-by-plant strategy for high-ambition coal power phaseout in China. *Nat. Commun.* 12, 1468.

<sup>6</sup> Cui, R. et al. (2022) *Financing Indonesia's coal phase-out: A just and accelerated retirement pathway to net-zero*. Center for Global Sustainability, University of Maryland, College Park, USA; Institute for Essential Services Reform, Jakarta.

<sup>7</sup> Liu, S., et al. (2024). Diversifying heat sources in China's urban district heating systems will reduce risk of carbon lock-in. *Nat Energy* 9, 1021–1031

<sup>8</sup> Borrero, M. A. et al. (2024). *1.5°C-aligned coal power transition pathways in Indonesia: Additional strategies beyond the Comprehensive Investment and Policy Plan (CIPP)*, University of Maryland, College Park, USA; Institute for Essential Services Reform, Jakarta, Indonesia.

<sup>9</sup> Wang R. et al. (2025). Reducing transition costs towards carbon neutrality of China's coal power plants. *Nat. Commun.*, 16, (1), 241.



**Third, we emphasize the need to identify and implement policy strategies that focus on the demand and supply sides of fossil fuels, respectively.** The transition roadmaps, as relevant to the country context, should include specific strategies for reducing fossil fuel consumption and production. With growing geopolitical tensions and uncertainties, a fossil-dependent energy system or a fossil-dependent economy becomes increasingly vulnerable. On the demand side, a set of alternative energy technologies is already available and competitive across sectors and regions. Near-term priorities include scaling up solar, wind and batteries to reduce gas and coal power generation and scaling up electrification in transport to displace oil, in buildings to displace gas, and in industry to displace gas and coal. On the supply side, targeted strategies to directly reduce production had often been overlooked until more recently, with the expectation that supply declines along with reduced demand. However, the fossil fuel supply sectors and exporting countries face a distinct set of challenges and opportunities, often closely tied to their economies, and require specific strategies for a comprehensive and just transition away from fossil-dependent economies. By illustrating that demand reductions are outside the suppliers' control, a more proactive approach with immediate actions can better prepare for changing external forces.<sup>10</sup> The most critical near-term strategy to limit peak temperature is to rapidly reduce methane emissions in the fossil supply sectors, where a large set of low-cost options are available. While fossil fuel transition can ultimately reduce energy methane emissions, immediate, targeted methane abatement is required to limit temperature overshoot around mid-century.

**Fourth, we emphasize the need to address the political economy around fossil fuels to tackle the social, political, financial, and institutional barriers.** The transition roadmaps should identify the non-technical, non-economic barriers based on a comprehensive assessment of the political economy of fossil transition in each country context. It often includes managing reduced employment and GDP along the entire supply chain, often with concentrated impacts geographically and on specific groups; removing inefficient policies or subsidies that increase the economic advantage of fossil fuels and attract new investment or delay closure; developing innovative financial instruments to support early retirement, reduced utilization, and other transition strategies of existing fossil facilities to minimize stranded assets; balancing stakeholder interests; and improving market and institution efficiency through system reforms.<sup>11,12,13,14</sup> Successful transition roadmaps would require a set of complementary, targeted policies and regulations to address these challenges.<sup>15,16</sup>

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<sup>10</sup> O'Keefe K. T. V. et al. Risks to Canadian oil production from domestic net-zero and external forces. *Nat Comm*, [under review].

<sup>11</sup> Lou, J., et al. (2025). Quantify the Economy-Wide Employment Effect from Coal-Fired Power Plants: Two Different Cases China and the United States. *Applied Energy*, 377 (Part C, 1), 124561

<sup>12</sup> Yuan, J. et al. (2025). The social impacts on China's vulnerable cities in the transition away from coal power. *iScience*. Volume 28, Issue 11, 113643 .

<sup>13</sup> Diluiso, F. et al., (2021). Coal transitions—part 1: a systematic map and review of case study learnings from regional, national, and local coal phase-out experiences. *Environ. Res. Lett.* 16 113003.

<sup>14</sup> M. Zhu, et al. (2023). *Decarbonizing captive coal power plants in Indonesia and implications for Chinese stakeholders: Trends, challenges and opportunities*. University of Maryland, College Park, USA; Institute for Essential Services Reform, Jakarta, Indonesia.

<sup>15</sup> C. Dahl, C. Squire, R. Cui. (May 2023). *Policy Brief: International experience in a just coal workforce transition through fiscal support*. Center for Global Sustainability at the University of Maryland, College Park, USA..

<sup>16</sup> Squire, C. et al. (2023). *How can the federal government support cities in a just and rapid decarbonization of the power sector?* Center for Global Sustainability, University of Maryland, College Park, USA.



While the four components of the analytical and policy framework apply in general to all fossil fuels and across regions, there are also specific considerations for different fuels in different national contexts.

- Among all three fossil fuels, **coal** can be phased down most quickly and easily.<sup>17</sup> It is the most carbon-intensive and also the most polluting in terms of air quality, leading to strong synergies between coal transition and public health benefits.<sup>18,19</sup> Consumption of coal is heavily concentrated in electricity generation, where low-cost alternatives are widely available. While wind resources are also highly concentrated in specific geographies, solar and battery offers good conditions in all locations within 45° latitude<sup>20</sup> and thus can provide local job opportunities in coal communities<sup>21</sup>. New investments in coal infrastructure have mostly stopped worldwide, except for China and India, while many OECD countries have closed a large amount of coal capacity over the past decade.<sup>22</sup> Moreover, production of coal is also concentrated in a few countries, where trade is primarily through regionally segmented markets with lower infrastructure lock-in.
- By contrast, **oil** trade is highly globalized, with concentrated and powerful suppliers, where geopolitical uncertainties can easily lead to considerable price fluctuation with widespread impact, and energy security concerns provide strong incentives for importing countries to transition away. Meanwhile, oil consumption is heavily concentrated in transportation, where for a large part, cost-competitive alternatives are already available, especially for road transport. Oil revenue tends to contribute to a significant portion of the economy for major producing countries and regions, where proactive strategies for diversification and just transition are crucial on the supply side. For oil importers, avoiding the trade balance liability and exposure to price risks is a large factor for the shift towards lower cost and more predictable alternatives, like electric vehicles for transport, and solar and battery for backup electricity generation. The emergence of low-cost technology options in these fields has led to a boom particularly in low-income countries<sup>23</sup>, which the current oil price spike is bound to accelerate further.
- In comparison, the role and transition pathways for **natural gas** are the most uncertain among the three. Being the least carbon-intensive and least polluting, natural gas has been in part characterized as a “bridge fuel” between coal and renewables, following many OECD countries’ pathways. However, new trends show that such a “bridge” is completely unnecessary, as countries are leapfrogging to renewables directly without locking in to new gas or other fossil infrastructure. Meanwhile, gas consumption is more spread across buildings, electricity, and

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<sup>17</sup> Diluiso, F. et al., (2021). Coal transitions—part 1: a systematic map and review of case study learnings from regional, national, and local coal phase-out experiences. *Environ. Res. Lett.* 16 113003.

<sup>18</sup> J. Sampedro, et al. (2021). Health co-benefits from air pollutant reduction through coal-fired power plant cancellations. *Energy and Climate Change* Volume 2: 100023.

<sup>19</sup> M. Cropper, et al. (2021). The Health Impacts of Coal-Fired Power Plants in India and the Co-benefits of GHG Reductions. *PNAS* 118 (5) e2017936118.

<sup>20</sup> Victoria, M. et al. (2021). Solar photovoltaics is ready to power a sustainable future. *Joule* 5, (5), 1041-1056.

<sup>21</sup> Malik, A. & Bertram, C. (2022). Solar energy as an early just transition opportunity for coal-bearing states in India. *Environ. Res. Lett.* 17, 034011.

<sup>22</sup> Cui, R. et al. *State of Global Coal Power 2023*. (2023). Center for Global Sustainability, University of Maryland, College Park, USA.

<sup>23</sup> Graham, E. Ember: China Cleantech Exports Data Explorer. <https://ember-energy.org/data/china-cleantech-exports-data-explorer/> (2026)



industry sectors, and a more diverse set of strategies is needed.<sup>24</sup><sup>25</sup> Natural gas trade used to be mostly infrastructure-constrained and fragmented through pipelines; however, with increasing liquified natural gas (LNG), gas trade is gradually globalizing and exposed to geopolitical uncertainties.

Achieving an accelerated, orderly, and just fossil fuel transition is fundamental for delivering national and global climate goals. As countries develop the transition roadmaps, it should reflect the latest trends of technologies, markets, and their potentials, and emerging contexts in terms of energy security, affordability, and economic sustainability. The roadmaps should also consider the four key components and link to the broader national long-term strategy. The world has been wrestling with the issue of how to achieve a transition away from fossil fuels for decades. The roadblocks and obstacles are well-known and substantial. Nevertheless, informing our national, subnational, and global strategies with creativity and new insight can help navigate these challenges to reach a cleaner, healthier, and more economically vibrant global future.

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<sup>24</sup> R. Cui, et al. (2022). *Strategies to Transition away from Russian Gas and Deliver Climate Goals in Germany*. Center for Global Sustainability, University of Maryland, College Park, Maryland. 19 pp.

<sup>25</sup> Nicolletti, M. et al. (2023). The Cost of Fossil Gas: Policy Recommendations for a Clean Energy Transition and a Swift Gas Phase-out in Cities. *Journal of City Climate Policy and Economy*, 2(1): 77-94.