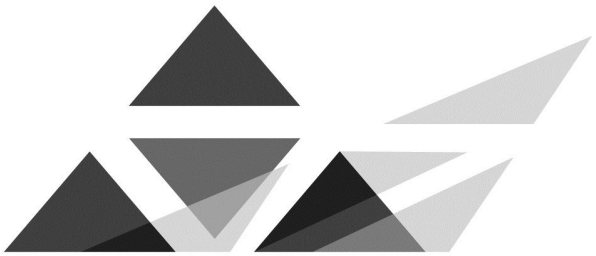


Policy Research on International Services and Manufacturing

Transitioning away from fossil fuels in a just, orderly and equitable manner

A quantitative overview of countries' different national circumstances, fossil fuel dependence and opportunities for flourishing post-fossil economies

Greg Muttitt

Energy and Climate Researcher
Consultant to the University of Cape Town
https://www.gregmuttitt.com/
greg.muttitt@gmail.com

Harald Winkler

School of Economics, University of Cape Town
Policy Research in International Services and Manufacturing (PRISM)
harald.winkler@uct.ac.za

Working Paper Series
Number 2026-2

Acknowledgments

The authors are grateful for valuable review comments from Sivan Kartha, Nicolas Lippolis, Andrew Marquard, Hélène van Rossum and Paola Yanguas Parra. Any remaining errors are the responsibility of the authors. This working paper is part of UCT-IDDRI research on equitable fossil fuel transitions, under a subcontract under a WRI-led consortium on '2050 is now'. This working paper will serve, along with other research, as an input to a wider overall working paper to be published in 2026.

Recommended citation:

Muttitt, G. and Winkler, H. 2026. 'Transitioning away from fossil fuels in a just, orderly and equitable manner: A quantitative overview of countries' different national circumstances, fossil fuel dependence and opportunities for flourishing post-fossil economies.' *PRISM Working Paper 2026-2*. Cape Town: Policy Research on International Services and Manufacturing, University of Cape Town.

Policy Research in International Services and Manufacturing (PRISM) is a research and policy unit located within the School of Economics. PRISM provides a lens to focus research and policy work broadly on issues of globalization, trade and industrialization. It is home to a number of related research activities, projects and programmes concerned with issues of globalization, global value chains, industrialization paths, international trade, foreign investment, the defence industry, policy governance, infrastructure development, the role of knowledge intensive services, innovation, and international competitiveness. Another feature of PRISM's work has been its applied focus, responding to economic policy questions issues in South Africa, the rest of Africa and beyond.

Working Papers can be downloaded in Adobe Acrobat format from

https://commerce.uct.ac.za/prism

School of Economics Building, Middle Campus,
University of Cape Town Private Bag,
Rondebosch 7700, CapeTown,
South Africa
Tel: +27 (0)21 6504470
Website: https://commerce.uct.ac.za/prism

Executive summary

In the Global Stocktake decision of 2023, governments agreed to transition away from fossil fuels in a just, orderly and equitable manner, accelerating action this decade. This paper examines how countries' circumstances shape their readiness to implement equitable fossil fuel transitions. We analyse quantitative patterns of fossil fuel dependence, drawing out policy implications, including the challenges and opportunities in complex transitions.

Energy systems are already changing, with global demand for oil and coal set to peak by 2030 and for gas by 2035, even without further policy efforts. Governments will need to pursue equitable fossil fuel transitions not only to help achieve shared climate goals, but also to make their economies more resilient to these changes.

Transitioning away from fossil fuels offers opportunities to reduce energy costs, create jobs and build more prosperous economies. However, the process of transition will be harder in countries that depend on fossil fuels for energy supplies, employment and/or national wealth generation, and socio-economic impacts must be carefully managed to avoid harmful shocks. Moving at equal speed in all countries would make transitions more disruptive, less just and less orderly in the most dependent countries.

This paper makes six recommendations for equitable fossil fuel transitions:

- **Seek early wins where there are greater opportunities and benefits** from transitioning, such as cheaper energy or improved energy security.
- In parallel, **invest now to overcome entrenched dependence on fossil fuels**, as economic diversification and structural transformation take time.
- **Differentiate timelines between countries**, such that every country moves as fast as it can, understanding more time is needed in countries with greater dependence.
- **Provide and mobilise** finance and capacity-building **support for low- and middle-income countries**, to boost their capabilities to invest in and manage transitions.
- **Build inclusive international coalitions** to provide peer learning and gain momentum, including both early-movers and those that need more time. **Build domestic coalitions** to create political support and engage stakeholders.
- **Avoid building new fossil** fuel-consuming or -producing facilities and infrastructure, and instead focus investments on alternatives that reduce dependence.

Where, what and why?

Fossil fuel production is geographically concentrated. Three countries – China, the US and Russia – produced 49% of the world's fossil fuels in 2023 (in energy terms), and another 11 countries – Saudi Arabia, Canada, Indonesia, India, Australia, Iran, UAE, Iraq, Qatar, Brazil and Norway – take the share up to 80%. Per-capita consumption of fossil fuels varies by income, averaging 157 gigajoules (GJ) in high-income countries, 84 GJ in upper-middle-income countries, 19 GJ in lower-middle-income countries, and just 3 GJ in low-income countries. High-income countries consumed 52% of oil and 62% of gas, but just 17% of coal.

Coal, oil and gas have quite different properties, and so play different functions in energy systems and in economies. Oil is transported much more than the other two fuels: only about 30% of the world's oil is consumed in the same country where it is extracted, compared to 80% of coal and 70% of gas. While coal and gas are commonly used in domestic power generation and industrial development, oil extraction contributes to economies more through fiscal revenues and export earnings.

We characterize three types of transitions:

- **Energy transitions**, from fossil fuels to cleaner energy systems (all countries);
- **Energy-economy transitions**, from fossil-fuelled industry to alternative economic development and employment drivers (some countries, especially coal consumers);
- **Economic transitions**, from dependence on fossil revenues and exports to diversified economies (some countries, especially oil and gas exporters).

Energy transitions

Equitable fossil fuel transitions will create opportunities and benefits:

- Renewable energy generates the cheapest power in countries accounting for over 80% of global power generation. However, in lower-income countries, there is less or no cost advantage due to the high cost of capital. Reducing the cost of capital would massively accelerate and broaden transitions.
- Fossil fuel importers will see energy security benefits from transitions. The cost of net fossil fuel imports exceeds 5% of GDP in 50 countries; it exceeds 10% in 12 of these.
- Energy transitions will reduce health-damaging air pollution. In 42 countries, fossil fuel pollution causes more than 50 deaths per 100,000 (living) population each year.

Transitions will take longer in energy systems that rely heavily on fossil fuel infrastructure, as they have further to go to decarbonize, need to overcome inertias, and face stranded assets.

- Phasing out global coal use faster than oil and gas can put disproportionate burden on emerging economies that rely heavily on coal power. To better balance burdens, faster oil and gas transitions are needed. High-income countries generate more gas power and less coal power on average, compared to middle-income countries.
- Coal plants in most developing countries are younger than in industrialised nations, meaning that initial investment costs have not yet been paid off, and transitions would come at greater cost in terms of stranded assets.
- In most developing countries, new supply is needed to meet growing energy demand, in addition to replacing existing fossil supply. Whereas the electricity access gap is primarily in rural areas that can mostly be electrified using distributed renewable energy, there are also wider problems of energy poverty – including limited, unreliable or costly supply - that require greater centralized supply too.

There are many solutions to integrating variable renewables into power grids; this can proceed fastest and most effectively in countries with strong institutional capabilities and infrastructure. Integration will take longer elsewhere: for example, in the 38 (mostly developing) countries where the average consumer experiences more than one blackout, or more than one hour of blackouts, per month.

Energy-economy transitions

Energy–economy transitions are needed in contexts where fossil consumption shapes not only energy but the overall economy. For example, most coal is used domestically, and has strong forward and backward linkages, extending its economic impact beyond coal mining (upstream) to users of coal (downstream) such as power stations and industry. Examples include China, South Africa and India. Energy-economy transitions shift societies from fossil-dependent industrialisation to alternative drivers of economic development and employment.

Clean energy creates more jobs than fossil fuels, per unit of energy and per unit of investment. Transitions away from fossil fuels will thus be job-creating overall. However, not all new clean jobs will be in the same locations, of the same quality (in terms of job security, salary or unionisation) or requiring the same skills as declining fossil fuel jobs. Policy efforts will be needed to address these gaps, and to manage the process of transition in a just way. Countries differ in the scale of these tasks:

- Fossil fuel jobs (other than informal coal miners) are commonly among the highest-paid, and can play a more important economic and social role than their numbers alone would suggest, as a larger share of total earnings.
- Direct fossil fuel employment is rarely more than 1-2% of the national workforce. However, regionally it is more significant: between 5% and 8% in the coal-producing regions of Colombia, Indonesia and South Africa. The effects of dependence can be intensified where more people rely on each fossil fuel job.
- The number of jobs indirectly dependent on fossil fuel can be significantly larger than those in extraction, refining and or power generation. Others are employed in providing supplies or services to fossil fuel operations, in energy-consuming sectors; in local economies supported by fossil fuel workers' salaries, or in public sector jobs where fiscal revenue from fossil fuels pays their salaries.

Several fossil-dependent economies are failing to create jobs for growing populations, and face risks of becoming uncompetitive, unproductive and stagnating. Often fossil-producing regions have high levels of poverty and inequality, environmental degradation, weak institutions and few other sources of income. The solution is not simply to replace fossil jobs with alternative ones, but to transform economies to rest on a more diversified base. Providing jobs for growing populations can be enabled by a shift away from capital- and energy-intensive, fossil-based economies. Such transformation is no small task, and will take time in the most dependent economies.

Economic transitions

Economic transitions involve shifts from dependency on income from fossil-fuel exports, to more diversified economic structures. The extent to which fossil fuel revenues generate national wealth is the most significant difference in country circumstances for implementing equitable fossil fuel transitions:

- In 22 countries, oil and gas generated more than 20% of fiscal revenue in 2021; in about 10 of these countries, it is more than 50%, and in some as high as 90%. Other major producers are not significantly dependent on fossil revenues: for example, in the US and Canada, fossil fuels provide less than 2% of total fiscal revenues.
- About 20 countries rely on oil and gas for more than half of their exports, some of them at 90% or higher.
- As for coal, only in Mongolia does it constitute a major share of exports, at around 50% of the total (in no other country does it constitute more than 20%).

Countries that are highly dependent on oil and gas revenues face serious economic threats as the world transitions away from fossil fuels, and their export markets decline. Previous periods of low oil prices have caused reductions in delivery of public services and loss of jobs, and sometimes wider macroeconomic crises, including loss of investor confidence, economic contraction, inflation and falling exchange rates. Whereas past episodes have been temporary, the global energy transition must be systemic and long-term.

In an unfortunate irony, the countries that most need to boost economic resilience by transitioning away from oil and gas exports are the countries that will find it hardest to do so: high dependence on fossil revenues both creates vulnerability and creates barriers to reducing it. Too fast a transition of their economies may raise the same issues as the external demand shock: loss of fiscal revenue or of export earnings.

Governments will need to diversify both their economic base and their sources of fiscal revenue, while keeping their populations on board with the vision for the economic future. What is therefore required is a reimagined approach to structural transformation, moving from the focus in traditional economics on increasing productivity, to ensuring that economic transitions achieve multiple objectives of creating employment and reducing emissions. The process of diversifying and structurally transforming an economy faces economic and political barriers, and generally takes decades, meaning it is important to start now.

Capability and readiness

A country's ability to overcome the challenges of dependence will be shaped by its capabilities. Many developing countries have the combined problems of less diversified energy systems and economies, and fewer financial and institutional capabilities to invest in the process. International support will be needed to help close this gap.

In coal transitions, governments have tended to make international political pledges only when coal power is already declining: national efforts and progress come first. For countries where fossil production or consumption are growing, transitions imply a change in the vision of the country's future, which takes time. Countries in decline or whose geological fossil fuel reserves are depleting are more ready to engage in accelerating transitions.

Transitions will be more achievable – and more just, orderly and equitable – through international cooperation than by each country acting on its own. Without international support, countries with limited budgets and pressing developmental priorities may be unable to transition, beyond strengthening their own economic resilience, and in some cases not even that. International coalitions promoting equitable fossil fuel transitions should be able to include those who find it easier to make commitments and support those who face greater challenges. Coalition-building should focus both on achieving early gains where opportunities are greater, while also including countries facing greater challenges and needing more time. By proactively building these broad coalitions, the international community can foster 'broad front politics' that mediate conflicting interests, and provide the necessary finance and capacity-building to help highly dependent nations manage their specific structural transformations.

Similar principles apply to building societal support for transitions at home. Governments can make progress through political coalitions benefiting from opportunities and early wins, while investing for the long term in overcoming dependence, together with key stakeholders.

Table ES1 illustrates some key indicators for selected countries . We show near-term opportunities (green), and investments now in overcoming longer-term dependence (orange). Declining trends in fossil production and use (blue) suggest greater readiness to accelerate transitions, while increasing trends (red) require a change of course.

Having noted the challenges of fossil fuel dependence, there are clear dangers in deepening a country's dependence by adding more fossil fuel capital, which will make transitions harder and more costly. A key element of acting now for the long term is to focus investments on alternatives; indeed, avoiding future commitments to fossil fuels is an obvious first step on the path to reducing dependence.

Table ES1: Indicators of dependence and barriers (orange), transition opportunities (green) and increase/decrease (red/blue) for selected countries

Country	Power generation					Fossil imports share of GDP (2023)	Fossil air pollution deaths /100,000 population (2023)	Share of workforce			Oil and gas of fiscal revenues (2021)	Fossil share of gross exports (2023)	Change 2018-23		
	Coal share (2023)	Fossil share (2023)	Average age of coal plants, years (2024)	Solar PV cost of capital (2024)	Cheapest LCOE source of generation (2024)			Fossil extraction (2023)	Fossil-fuelled manufacturing[a] (2022)	Fossil-funded public sector[b] (2023)			Coal generation	Oil & gas extraction	Gas consumption
Argentina	1%	53%	n/a	17%	wind	0.3%	29	0.3%	10%	4%	20%	3%	n/a	+13%	-11%
Australia	47%	66%	35.5	4%	solar	exp	11	0.5%	8%	0.3%	0.3%	28%	-19%	+34%	+31%
Brazil	2%	9%	n/a	8%	wind	exp	24	no data	4%	1%	5%	14%	-31%	+25%	-17%
Canada	4%	20%	n/a	5%	wind	exp	13	0.3%	4%	0.4%	2%	26%	-53%	+9%	+7%
China	62%	65%	12.6	4%	wind	2.6%	121	0.5%	22%	0.1%	0.5%	1%	+23%	+25%	+39%
France	1%	7%	n/a	3%	solar	2.4%	39	-	6%	-	-	3%	n/a	n/a	-24%
Germany	27%	44%	29.6	2%	solar	2%	55	0.1%	13%	-	-	3%	-44%	n/a	-16%
India	74%	78%	14.3	7%	solar	3.7%	88	0.4%	9%	0.1%	2.4%	14%	+23%	-5%	+11%
Indonesia	69%	84%	9.5	8%	coal	exp	46	0.2%	11%	1%	8%	19%	+62%	-11%	+12%
Italy	5%	55%	n/a	5%	solar	3%	82	-	15%	-	-	3%	-54%	-19%	-15%
Japan	29%	65%	22.8	3%	solar	4.5%	59	-	12%	-	-	1%	-15%	n/a	-20%
Mexico	9%	77%	n/a	9%	solar	0.7%	36	no data	15%	2%	19%	6%	+21%	+3%	+8%
Russia	18%	63%	42.1	11%	gas	exp	66	no data	8%	7%	23%	43%	+19%	-9%	+2%
Saudi Arabia	0%	99%	n/a	6%	no data	exp	6	no data	8%	7%	58%	77%	n/a	-5%	+10%

Country	Power generation					Fossil imports share of GDP (2023)	Fossil air pollution deaths /100,000 population (2023)	Share of workforce			Oil and gas share of fiscal revenues (2021)	Fossil share of gross exports (2021)	Change 2018-23		
	Coal share (2023)	Fossil share (2023)	Average age of coal plants (2024)	Solar PV cost of capital (2024)	Cheapest LCOE power generation (2024)			Fossil extraction (2023)	Fossil-fuelled manufacturing (2023)	Fossil-funded public sector (2021)			Coal generation	Oil & gas extraction	Gas consumption
South Africa	83%	87%	32.8	7%	solar	4.1%	50	0.4%	9%	-	0.2%	9%	-17%	n/a	-27%
South Korea	34%	62%	14.6	5%	coal	6.4%	70	-	11%	-	-	6%	-22%	n/a	-0%
Türkiye	36%	57%	19.0	11%	wind	1.2%	55	-	17%	-	-	4%	+5%	+44%	+1%
UK	2%	37%	n/a	3%	wind	1.4%	49	0.1%	6%	0.01%	0.2%	8%	n/a	-27%	-20%
US	17%	60%	43.2	5%	wind	exp	22	0.2%	7%	0.03%	0.2%	16%	-42%	+24%	+13%
Other countries	BWA 99% XKK 87% MNG 85%	BHR 100% BRN 100% KWT 100% LBY 100% TMN 100% TTO 100% DZA 99%	VNM 8	GHA 16%; PAK 16%; TUN 16%		CPV 34% LBN 22% MRT 16% LBR 15%	BGR 192 SRB 160 BIH 151	NOR 2.1% IRQ 1.4%	TUN 19% IRN 18%	IRQ 33% DZA 16%	LBY 97% IRQ 88% SSD 86% TLS 80% GNQ 80%	KWT 95% AGO 94% NGA 89% AZE 88%			
Sources and details	Figure 4.6	Figure 4.6	Table 4.1	Figure 4.2	Figure 4.1	Figure 4.3	Figure 4.5	Table 5.1	Figure 5.4	Table 5.3	Figure 6.2	Figure 6.3	Figure 7.2a	Figure 7.2b	Figure 7.2c

[a] Manufacturing share of workforce, multiplied by direct and indirect fossil share of manufacturing energy

[b] Public sector share of workforce, multiplied by oil and gas share of fiscal revenue

Policy recommendations

For all governments:

- **Ensure just transitions for workers and communities**: to address disparities in geography and skills, to sustain livelihoods and ensure the quality of new jobs, to build local and regional economies, and to manage the transition process fairly.
- **Stop building new fossil projects**: to focus capital investments instead on alternatives that reduce dependence.

For developed countries and financial institutions:

- **Reduce the cost of capital** for renewable energy development in developing countries: including by derisking investments, increasing international public finance, and removing biases in credit ratings agencies.
- **Adopt clean technologies** as early-movers, helping bring down their costs through learning-by-doing.
- **Provide and mobilise finance and capacity-building** to enable equitable transitions in low- and middle-income countries.

For governments of fossil-fuel-dependent countries:

- **Invest now in long-term transitions**: pursue economic diversification without delay, to stay ahead of changes in global energy markets, and putting in place enablers of long-term sustainable development; .
- **Diversify the economy**: Implement economic diversification including through infrastructure, skills and innovation support; and adopting industrial policies to support and invest in targeted sectors that play to the country's strengths.
- **Assess and manage economic risk**: while initiating transitions, hedge economic risks through economic diversification to build alternative sectors and sources of fiscal revenue.
- **Pursue structural transformation**: evolving from a narrow focus on increasing productivity per worker, to also increase employment, reduce fossil fuel dependence and achieve Sustainable Development Goals.
- **Diversify fiscal revenue sources**: by introducing new sources such as excise, value-added or income taxes, and by strengthening mechanisms for collection of existing revenue streams.

Contents

List of abbreviations **12**

1. Introduction **13**

2. How countries use coal, oil and gas **15**

2.1 The geography of fossil fuels 15
2.2 Properties and economic roles of coal, oil and gas 17
2.3 Uses of coal, oil and gas, and their alternatives 19

3. Types of transitions **21**

3.1 Transition of what? 21
3.2 Where are we in energy transitions? 22
3.3 Just, orderly and equitable 26

4. Transitions in energy systems **29**

4.1 The costs of energy 29
4.2 Energy security and reliability 32
4.3 Energy access and air pollution 34
4.4 Dependence on coal and gas power generation 35
4.5 Implications for equitable energy transitions 38

5. Energy-economy transitions: Jobs and the energy-industrial complex **40**

5.1 Job creation in renewable energy 40
5.2 Fossil fuel jobs 42
5.3 A broader conception of fossil-dependent jobs 45
5.4 Structure of the economy 49
5.5 Implications for equitable energy-economy transitions away from fossil fuels 50

6. Economic transitions and new sources of wealth generation **52**

6.1 The economic imperative and resilience 52
6.2 Economic dependence on oil and gas 54
6.3 Economic transformation 56
6.4 Implications for equitable economic transitions away from fossil fuels 59

7. Capability and readiness for transitions **60**

7.1 Capability for EFFT 60
7.2 Progress precedes the pledge 61
7.3 International cooperation 64
7.4 New fossil fuel projects prolong and deepen dependence 65
7.5 New fossil fuel producers 66
7.6 Implications for equitable transitions 67

8. Conclusion: Overcoming dependencies, grasping opportunities and implementing equitable transitions **69**

References **74**

List of figures

Figure 2.1 (p.15): Fossil fuel production by country, 2023
Figure 2.2 (p.16): Global fossil fuel consumption by country income classification, 2023
Figure 2.3 (p.18): Share of coal, oil and gas consumed domestically versus exported, 2023
Figure 2.4 (p.19): Consumption of coal, oil and gas by end use, 2022
Figure 2.5 (p.20): Alternatives to fossil fuels on the S-curve of technological diffusion

Figure 3.1 (p.23): Global coal, oil and gas consumption (primary energy), major energy forecasters' projections under current policies
Figure 3.2 (p.24): Growth in shares of clean technology: (a) Wind and solar share of power generation; (b) Electric vehicle share of car sales
Figure 3.3 (p.24): Country/region shares of global clean technology manufacturing, 2022
Figure 3.4 (p.25): Coal, oil and gas consumption (primary energy) in IEA scenarios

Figure 4.1 (p.30): Cheapest source of new power generation (LCOE) by country, 2024
Figure 4.2 (p.30): Weighted average cost of capital for solar PV projects in 2024
Figure 4.3 (p.32): Net fossil fuel imports as proportion of GDP, 2023
Figure 4.4 (p.33): Average number or total duration (in hours) of power outages per consumer per month, 2019
Figure 4.5 (p.35): Annual deaths per 100,000 population attributed to fossil-fuel-related PM2.5 and ozone air pollution, 2019
Figure 4.6 (p.35): Source of power generation by income group and G20 countries, 2023

Figure 5.1 (p.40): Employment intensity of renewable energy versus fossil fuels, during construction and operation, various studies
Figure 5.2 (p.41): Median energy salary ranges by sector and country, 2023
Figure 5.3 (p.42): Fossil fuel jobs by region, 2023
Figure 5.4 (p.46): Dependence on fossil fuels for manufacturing jobs, 2022

Figure 6.1 (p.52): Vulnerability of government revenues to reduction in demand during moderate-paced energy transition
Figure 6.2 (p.54): Oil & gas share of government revenue and gross national income, 2021
Figure 6.3 (p.54): Oil & gas share of exports and gross national income, 2021

Figure 7.1 (p.61): % change in coal power generation over 5 years before joining PPCA
Figure 7.2 (p.62): Change from 2018 to 2023 in (a) coal power generation, (b) oil and gas extraction, and (c) gas consumption

A data annex at https://commerce.uct.ac.za/prism/research/prism-working-paper-series provides the data supporting all figures.

List of tables

Table 2.1 (p.17): Properties of the three fossil fuels
Table 4.1 (p.37): Capacity-weighted average age of operating coal plants in the 15 countries with largest generation of coal-fired power, 2024
Table 5.1 (p.43): Fossil fuel extraction workforce, selected countries
Table 5.2 (p.46): 38 countries with more than 10% dependence on fossil fuels for manufacturing jobs
Table 5.3 (p.48): Dependence on oil and gas for public sector employment. Shown for 18 of the 20 largest oil and gas producers
Table 8.1 (p.70): Indicators of dependence and barriers (orange), transition opportunities (green) and increase/decrease (red/blue) for selected countries

List of abbreviations

CBDR-RC	common but differentiated responsibilities and respective capabilities
COP	Conference of the Parties
CRA	credit rating agency
EFFT	equitable fossil fuel transition
EIA	US Energy Information Adminstration
EITI	Extractive Industries Transparency Initiative
G20	Group of 20 nations
GDP	gross domestic product
GEM	Global Energy Monitor
GNI	gross national income
GJ	gigajoules
GST	Global Stocktake
ICE	internal combustion engine
IDDRI	Institut du Développement Durable et des Relations Internationales
IEA	International Energy Agency
IISD	International Institute for Sustainable Development
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LCOE	levelized cost of energy
LMICs	low- and middle-income countries
LPG	liquid petroleum gases
MW	megawatts
MWh	megawatt-hours
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of the Petroleum Exporting Countries
PJ	petajoules
PM2.5	particulate matter less than 2.5 micrometers in diameter
PPCA	Powering Past Coal Alliance
STEPS	Stated Policies Scenario
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change

1. Introduction

Under the Paris Agreement of 2015, there is a Global Stocktake (GST) of progress every five years. The first GST was completed in 2023 at the COP-28 climate summit in Dubai. In it, governments agreed on the need for "deep, rapid and sustained" reductions in greenhouse gas emissions, taking into account different national circumstances, pathways and approaches and calling on countries to contribute to global efforts, including through "Transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050 in keeping with the science" (UNFCCC 2023: para 28(d)).

Such a transition is crucial to limiting climate change, as combustion of fossil fuels accounts for about 90% of global carbon dioxide emissions (Friedlingstein et al 2025) and for 67-76% of all greenhouse gas emissions (IEA 2025d; Ge et al 2024). But while the scientific imperative is clear,[1] one aspect of the GST text on fossil fuels that has been under-explored is how to transition away "in a just, orderly and equitable manner". In this paper, we refer to 'equitable fossil fuel transitions' (EFFTs) as shorthand for the transitions as agreed in the GST decision. Much of the literature implicitly conceives of energy transitions as a substitution of physical elements from coal plants to windfarms, or from oil pipelines to power grids, where the primary challenge is diverting consumers and capital investments from one to the other, with relative costs the key driver (Faridzad et al 2026, Joshi et al 2025). Whilst those changes are part of the picture (Section 2.3), focusing mainly on such techno-economic framing risks downplaying the differences between countries, implying that the task of transition is to make the same technological changes globally.

In reality, countries' circumstances are quite different: their starting points, their opportunities and their challenges differ (Mulugetta et al 2022), including the extent to which they produce and consume fossil fuels (Foster et al 2024). If transitions are poorly designed or conducted, or just left to the market, they could cause economic and social harm to countries and their people, as some countries' economies and energy systems currently *depend* on fossil fuels (Le Billon and Kristoffersen 2019; Muttitt and Kartha 2020; Peszko et al 2020). In his opening speech at COP-30, Brazilian President Lula highlighted this problem when he said, "Despite our difficulties and contradictions, we need maps of the path to reverse deforestation, overcome dependence on fossil fuels, and mobilize the necessary resources for these objectives — all in a fair and planned way" (Brazil 2025).

Even while climate policy is presently experiencing a political backlash in many countries, led by the United States, energy systems continue to transform (Section 3.2), and diplomatic processes continue to advance the transition in 2026. The Brazilian COP-30 Presidency is leading work on a roadmap for transitioning away from fossil fuels. And in April 2026, Colombia and the Netherlands will co-host a conference in April on just transitions away from fossil fuels.

[1] The second half of the GST text on transitioning away from fossil fuels sets out the pace needed to limit warming to 1.5°C above pre-industrial levels, based on the science. In respect of "accelerating action this critical decade", the world is likely to pass the 1.5°C threshold soon without a change of course, and very likely within the next decade (UNEP 2025). As for "net zero by 2050", stabilising temperatures at any level therefore requires global CO2 emissions to reach net zero (IPCC 2013: pp.1108ff); in pathways limiting warming to 1.5°C, this needs to occur in the 2050s (IPCC 2022: Chapter 3).

The aim of this working paper is to unpack the roles fossil fuels play in different countries, and how these roles create both opportunities and challenges for EFFTs. Such understanding will be crucial for designing a transition that is just, orderly and equitable, and thus for moving from the GST's high-level call for EFFTs, towards concrete policies within countries to implement it, and to mechanisms of international cooperation to enable those policies.

While the GST text refers to "fossil fuels" collectively, oil, gas and coal play quite different roles in energy systems and economies, which are outlined in Section 2. In light of these different roles, Section 3 reviews what EFFTs entail for energy systems and economies, where we are today in transition processes, and what would make transitions just, orderly and equitable.

Sections 4 to 6 address various aspects of EFFTs, and how they differ between countries. Section 4 focuses on transitions in energy systems themselves, including shifting power generation from coal and gas to renewable energy, and electrifying end-uses in transport, buildings and industry. Section 5 looks at the transition in how fossil fuels power economies and industry, with a focus on jobs. Section 6 considers fossil fuels' contribution to government revenues and export earnings, primarily in oil- and gas-exporting countries. Each of these sections ends with a summary of key implications for policymakers.

Section 7 turns to cross-cutting factors that make different countries more or less ready, willing and able to transition away from fossil fuels, again ending with a summary of implications. Section 8 concludes by drawing these threads together and proposing a way forward. A data annex at https://commerce.uct.ac.za/prism/research/prism-working-paper-series provides the data supporting all figures.

2. How countries use coal, oil and gas

Designing sound strategies begins with knowing the scale and nature of the problem. A first step in understanding how humanity can transition away from fossil fuels is to ask where fossil fuels are produced and consumed, and for what purpose. That is the subject of this section of the paper, including some important differences between coal, oil and gas.

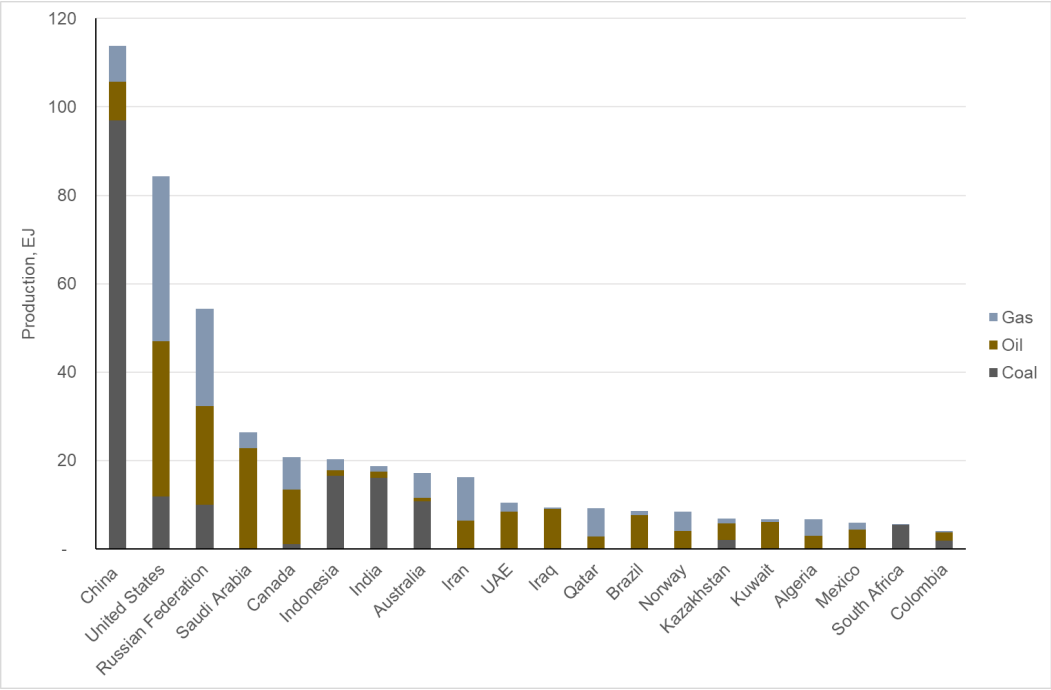
2.1 The geography of fossil fuels

A few countries account for most production of fossil fuels. As illustrated in Figure 2.1, the top three – China, the US and Russia – produced 49% of the world's fossil fuels in 2023, and adding another eleven countries – Saudi Arabia, Canada, Indonesia, India, Australia, Iran, UAE, Iraq, Qatar, Brazil and Norway – takes the share up to 80%. Broken down by fuel, particular countries dominate coal, oil and gas production.

Coal production is the most concentrated, with the top six countries accounting for 88% of the world's total. China dominates, with over 50% of global production and consumption. Indonesia and India each produce about 9% and consume respectively 12% and 3% (IEA 2025a).

The US, Saudi Arabia and Russia produce 43% of world oil. The top ten countries produce 74% of the world's oil, five of them in the Middle East. Consumption is more evenly spread: the top ten account for 61%. The US and Russia produce 40% of world gas. The top ten countries produce 73% (Figure 2.1). Since 2008, US oil production has nearly tripled and gas nearly doubled, due to fracking (Energy Institute 2025).

Figure 2.1: Fossil fuel production by country, 2023

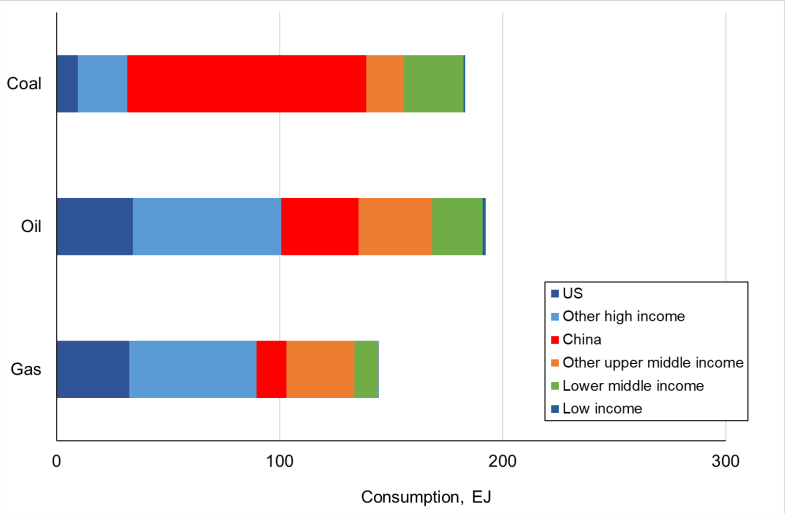


Data source: IEA (2025a)

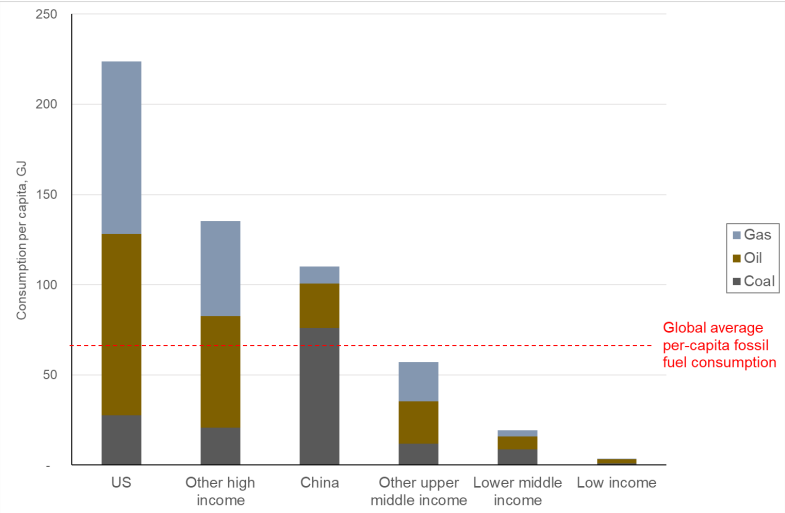
Consumption of the three fossil fuels is less concentrated, but unevenly shared between countries of different income groups. High-income countries account for 62% of gas consumption, 52% of oil and 17% of coal. Consumption by income group is shown Figure 2.2, with the United States and China shown separately to avoid distorting the picture, as they constitute a disproportionate share respectively of the high-income and upper-middle-income categories. Per-capita consumption of fossil fuels in high-income countries is roughly twice as high as in upper-middle-income countries, and eight times as high as in lower-middle-income countries (IEA 2025a).

Figure 2.2: Global fossil fuel consumption by World Bank country income classification, 2023

(a) Total



(b) Per capita



Data sources: IEA (2025a), World Bank (2025a)

2.2 Properties and economic roles of coal, oil and gas

The three fossil fuels – coal, oil and gas – have quite different properties, and so play very different functions in energy systems and in economies:

- Coal is relatively abundant; it is easy to extract in terms of capital and technology requirements. For these reasons, coal is commonly used in the early and intermediate stages of industrializing a country's economy, and as an affordable way to build power plants. On the other hand, coal is expensive to transport because of its bulk, and has a limited range of energy uses.[2] For these reasons, coal is a low-value commodity compared to the other two fossil fuels.
- Oil is very different: it is scarce, and capital- and technology-intensive to extract, creating barriers to new players entering the industry. Its high energy-density makes it uniquely valuable, with few substitutes available in its main uses, notably transport. Oil's chemical composition makes it suited too as a feedstock in manufacturing chemicals. Meanwhile, it is easy to transport: carrying oil across an ocean in a tanker costs only USD 2 to 4 per barrel (Argus 2022) (whereas pipeline transport to inland markets or from inland resources is more expensive). This combination of properties makes oil a highly valuable commodity.
- Gas resembles oil in its scarcity, capital-intensity, high-technology extraction methods,[3] and energy value. But it also resembles coal, in that is more expensive to transport: traditionally this had to be by pipeline, but liquefied natural gas too is costlier to transport than oil, both because of the liquefaction process and the technology required to keep gas liquefied while in ships. The relatively challenging process of transporting gas makes it less valuable as a commodity than oil – but still highly profitable.

Table 2.1: Properties of the three fossil fuels

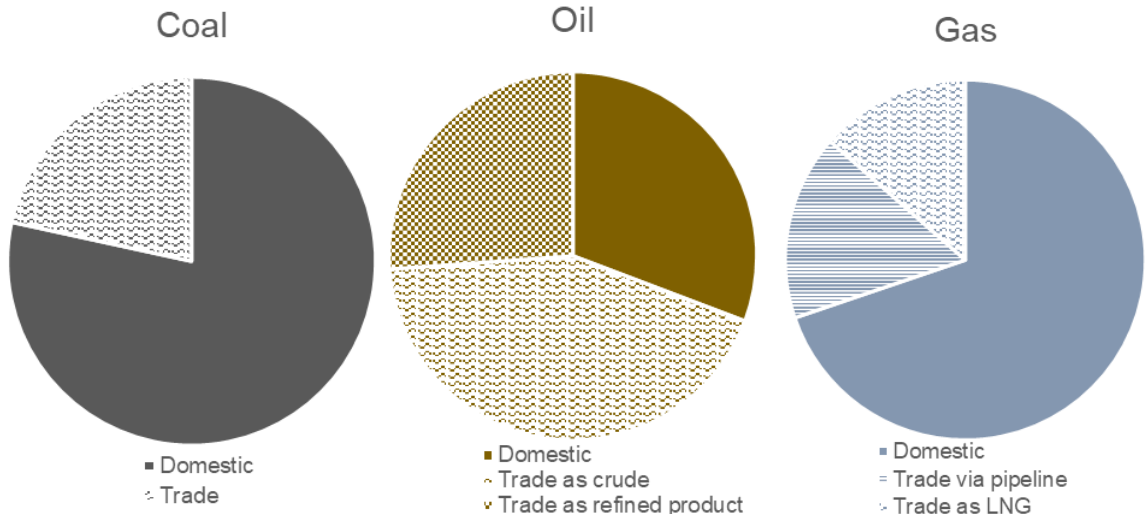
	Coal	Oil	Gas
Deposits	• Abundant, shallow	• Scarce, deep	• Scarce, deep
Extraction	• Medium-tech, moderate capital	• High-tech, capital-intensive	• High-tech, capital-intensive
Transportable?	• Expensive (bulky)	• Cheap by tanker	• Expensive (gaseous)
Uses	• Mainly for power generation	• Transport, feedstock and others	• Power, buildings, industry and others

As a result of these properties, the three fossil fuels differ both in how much they are traded between countries, and in their roles in economies, especially the generation of economic rents. Oil is transported far more than the other two fuels; indeed only about 30% of the world's oil is consumed in the same country where it is extracted. In contrast, most coal and gas (80% and 70% respectively) are consumed domestically (Figure 2.3).

[2] About 70% of coal is used in power generation, with most of the rest in industry, especially in iron and steel production. These latter uses are harder to decarbonise, as alternative technologies are at an earlier stage.

[3] Gas is extracted using mostly the same technologies and equipment as oil, and by the same companies. Many fields contain both oil and gas, so they can be produced together.

Figure 2.3: Share of coal, oil and gas that is consumed domestically versus exported.



Data source: Energy Institute 2024

All three fossil fuels generate economic rents (surplus profits).[4] Capturing these rents through taxation, royalties and profit sharing, or through state-owned companies' participation in extraction, is an important means for governments to generate fiscal revenues. These rents are very large for oil, because of the oligopolistic structure of the market, and because oil has a low price elasticity of demand: the demand for oil does not respond much to changes in price, especially in the short term. This is because there are few alternatives to oil (Nakhle 2009).

The World Bank (2025g, 2025h, 2025i) estimates that oil rents amount to 1.4% of gross world product, gas rents 0.5% and coal rents 0.3%. However, these global totals may underplay the difference between the fossil fuels. Oil rents can be much higher than this global average (which includes high-cost major producers such as Russia, the United States and Canada). Conversely, the true scale of global coal rents may be smaller than the 0.3% estimate, which is calculated based on world prices; in reality, most coal is consumed domestically, where domestic policy and political economy factors in the largest producers lead to lower prices than implied by international commercial factors (Cui and Wei 2017).

Due to its tradability and high rents, oil is extracted primarily for economic reasons: to generate fiscal revenues or export earnings, or to reduce the negative impact of oil imports on balance of payments. In contrast, coal is extracted more for a country's own energy use: its attraction is its relative cheapness and accessibility. Lying between oil and coal in both respects, gas is sometimes extracted for economic/export purposes and sometimes for domestic energy. All three fossil fuels also play a broader economic role beyond energy and revenues, through their direct and indirect contributions to economic activity (as measured by gross domestic product or by employment).

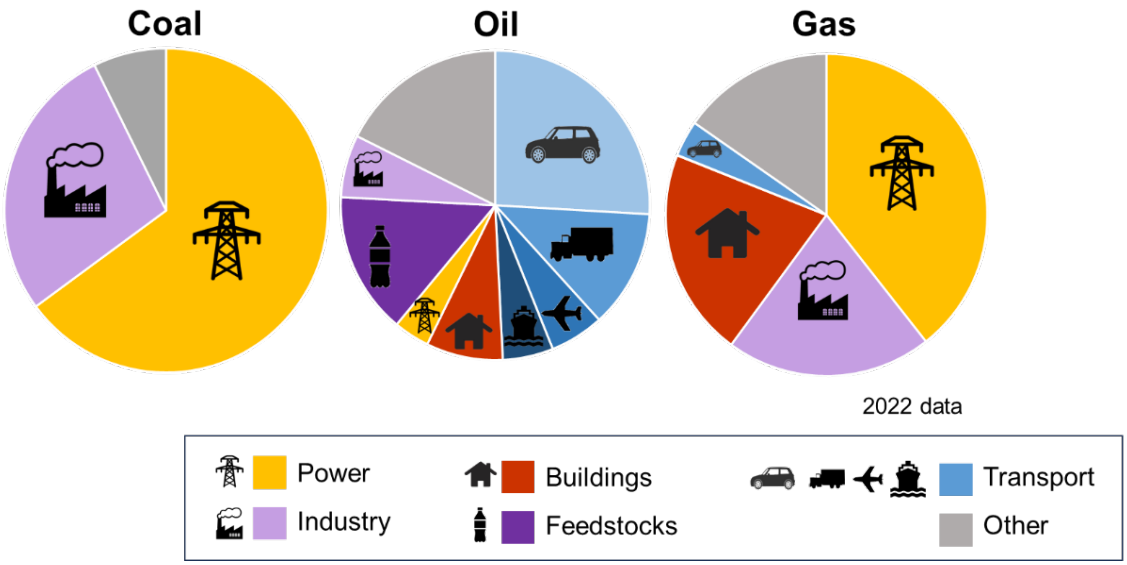
[4] Resource rents arise for two reasons. First, the price at which they are sold is determined by the marginal cost of producing the most expensive unit, so all units with lower production cost than this obtain rents (Ricardian rents). Second, there is a finite amount of geological resource that can be cumulatively produced over time, and resource owners will get the best economic outcomes by saving some to extract later, rather than continuing to expand production in the present moment (Hotelling rents).

2.3 Uses of coal, oil and gas, and their alternatives

In thinking about how to equitably transition away from fossil fuels, a good starting point is to look at how they are presently used. Figure 2.4 shows the uses of the three fossil fuels globally.

Power generation accounts for a majority of coal use and is also the largest use of gas. The largest use of oil is in transport, mainly road transport. All three fossil fuels are used in the industry sector, either for process heat or for feedstock. A third use of gas is in buildings: heating and cooking in homes, and heating in offices.

Figure 2.4: Consumption of coal, oil and gas by end use, 2022



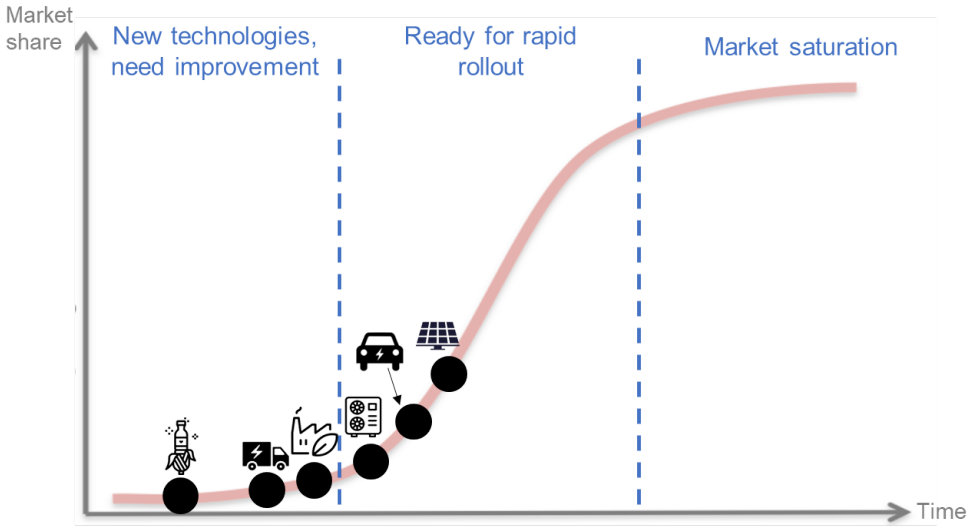
Source: Muttitt (2025), using data from IEA (2023)

There are however differences between countries in how the fossil fuels are used. For example, in India the largest use of gas is in petrochemical feedstocks (mainly for fertilizer production), accounting for 37% of the country's gas consumption; the second-largest is industrial heat with 25% (India Ministry of Statistics and Program Implementation 2025; IEA 2025a). In Japan by contrast, 69% of gas is used in power generation, and 19% in residential and commercial buildings (IEA 2025a).

The alternatives to fossil fuels are at differing stages of technological development. It so happens that the most advanced clean technologies compete with fossil fuels in their largest uses: wind and solar for power generation, and electrification for cars. These are therefore the demand segments in which EFFTs can advance most rapidly in the short and medium term.
The diffusion of new technologies follows an S-shaped curve. During an early, formative phase, the designs and manufacturing methods are being honed; take-up by early adopters follows an exponential path as popularity spreads. Once the technologies are affordable, they enter a middle phase of rapid rollout, where their market share grows near-linearly. A final, slowing phase occurs as the technologies approach market saturation. This same pattern has consistently been seen in historical innovations, both in energy technologies and beyond, from refrigerators to mobile phones (Marchetti and Nakicenovic 1979; Grubb et al 2020; Speelman and Numata 2022).

Wind and solar power, and electric cars are both in the rapid rollout phase (Figure 2.5, adapted from Victor, Geels and Sharpe 2019). Heat pumps are at the beginning of this phase. Non-fossil industrial heat (especially high-temperature heat for heavy industry), electric trucks and bioplastics are all still in the formative phase, requiring further improvements before they can spread in the mass market.

Figure 2.5: Alternatives to fossil fuels on the S-curve of technological diffusion



Source: Muttitt (2025), adapted from Victor, Geels and Sharpe (2019)

The costs of wind and solar power and of electric cars have fallen dramatically over the last decade – respectively by 58%, 77% and 84% from 2014 to 2024 (Bond et al 2025) – and continue to fall as innovation leads to more efficient manufacturing. New wind and solar plants now generate power more cheaply than coal and gas in most of the world (Section 4.1). In many places, they are cheaper even when combined with battery storage, thus providing dispatchable power cost-competitively (Lazard 2025).

Electric cars are widely cheaper than internal combustion engine (ICE) cars, when assessed on a total cost of ownership basis, including lifetime fuel and maintenance as well as purchase price (Carello 2024). In China, electric models now also have lower purchase prices than their ICE equivalents, in most car types, a threshold that is expected to be met in the coming years in other countries too (IEA 2025b).

For home heating, heat pumps are increasingly cost-competitive with fossil-fuelled boilers, because of their greater efficiency. The European Heat Pump Association (2024) estimates that heat pumps are competitive wherever the price of electricity is less than twice the price of gas. Heat pumps and other forms of electrical heat are becoming competitive with fossil fuels for low-temperature forms of industrial heat in light industry.

Electrical technologies for higher-temperature applications, especially in heavy industry, are more nascent, though extensive efforts are under way to develop solutions (Muttitt et al 2021). Continuing innovation – including both research and development, and learning by doing – is bringing down the costs of all of the alternative technologies, such that even those that are not yet cost-competitive fossil fuels are expected to be within the next 10 or 20 years.

3. Types of transitions

Having reviewed in Section 2 where and how fossil fuels are extracted and consumed, this section turns to the process of transition. What are we transitioning from and to, how much are transitions already happening, and what would make transitions just, orderly and equitable? We characterize three types of transitions : energy transitions, energy-economy transitions and economic transitions. These three types of transitions reflect a shift in the role fossil fuels play: moving from fossil fuels as a primary source of energy (fuelling power and heat), through their role in employment and in fuelling industry, to fossil fuels as a critical source of national income (generating fiscal revenues and export earnings). One can differentiate across these types of transitions, while also recognizing some connections and similarities. The way in which each transition is implemented will, additionally, be different by fuel and country characteristics. We unpack each type of transition in turn.

3.1 Transition of what?

For all countries, EFFTs entail an energy transition, away from fossil fuels and to a system where people's energy needs are met using clean sources. This transition is understood primarily[5] to involve three elements (WeMake Consultores 2023):

- replacing fossil generation of electricity with clean sources of power,
- replacing direct end-use of fossil fuels in transport, buildings and industry with electricity, and
- reducing energy use through efficiencies, technology and behavioural change.

In the Global Stocktake, in addition to EFFTs, governments agreed to triple global renewable energy capacity and double the rate of global energy efficiency improvements by 2030 (UNFCCC 2023: para 28(a)). Country circumstances affecting their ability to undergo transitions in the energy system are examined in Section 4.

Energy supplies play a vital role in economies, as a creator of direct and indirect jobs, and provider of fuel to other industries. Historically, fossil fuels have been a key driver of industrialisation, and the reason countries' income is correlated with their historic emissions. Indeed, this correlation has underlain many of the equity debates in the international climate regime.[6] There is thus also a need for transitions in the drivers of economic development, which is not necessarily as simple as a substitution with clean energy sources. In South Africa, for example, analysis has focused extensively on just energy transition and replacing coal as a source of energy, and while cost improvements in renewable energy bring the possibility of a clean-energy-powered industrial economy a little closer, there is also thinking about how a

[5] There are some exceptions to this schema, such as heavy industry and aviation, where non-electric energy carriers are needed, including hydrogen and bio-energy. In general, these alternatives are less technologically advanced than electrification.

[6] While not explicitly naming fossil fuels, the UNFCCC Convention notes that Global South countries will need to emit more as they develop their economies and lift people out of poverty (UNFCCC 1992: Preamble). The need for fossil fuels as a driver of economic development has diminished since that time, with the significant advances and cost reductions in clean energy sources; at the same time, atmospheric space for further emissions has dramatically diminished. Nonetheless, the past use of fossil fuels in economic and industrial development leaves a need to transform many economies.

change in the composition of the economy might yield broader and deeper mitigation (Altieri et al, 2016). Countries' circumstances in relation to the transition away from fossil fuels' role in powering economies is explored in Section 5.

In the case of fossil fuel exporters (especially of oil), fossil fuels are not just about energy but also money, as they generate fiscal revenues for governments and of export earnings for the macroeconomy. They too need to undergo an economic transition, to a thriving economy that does not rely on fossil fuels. A fundamental question in implementing EFFTs is about changing the relationship between fossil fuel and the economy (IDDRI 2025). This involves both transforming the sectors making up the economy, and replacing fossil fuels as providers of fiscal revenues (Foster et al 2024; Muttitt 2025; van Rossum et al 2025). The economic alternatives to fossil fuels will be specific to countries' circumstances. Only in very few (if any) cases might the full role of fossil fuels in the economy be replaced by clean energy. Often it will not be a case of one-for-one replacement at all, but a transformation of the whole structure of the economy, into one that is more broad-based and less reliant on a single, high-value sector. These transitions are explored for different country circumstances in Section 6.

We can thus characterize three types of transition:

- **Energy transitions**, from fossil fuels to cleaner energy systems;
- **Energy-economy transitions**, from fossil-dependent industry to alternative drivers of economic development and employment;
- **Economic transitions**, from dependence on fossil revenues and exports to diversified economies.

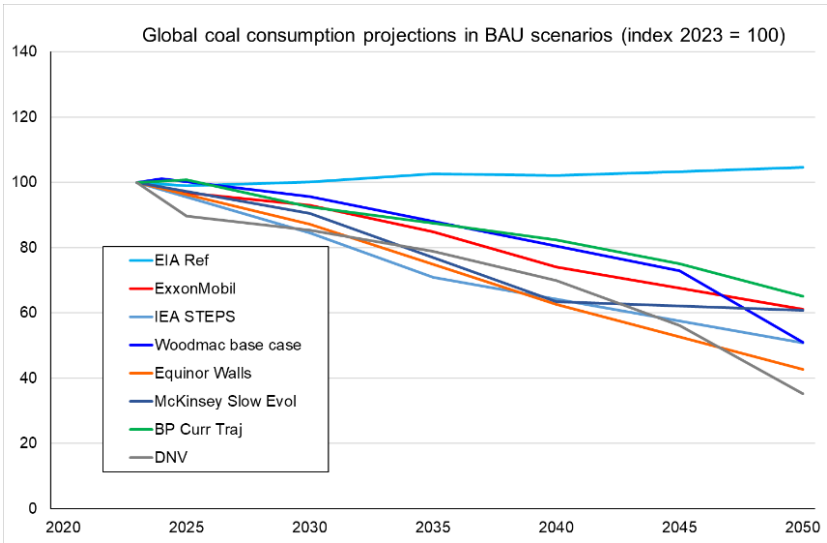
All countries consume fossil fuels, and so need to undergo energy transitions. Some countries rely on fossil fuels – either imported or domestically produced – for employment and industry, and so face energy-economy transitions. Some countries are fossil fuel exporters, for whom economic transitions will be important. Note that in this paper, we assess employment in the section on energy-economy transitions (although some employment issues arise from energy transitions or from economic transitions).

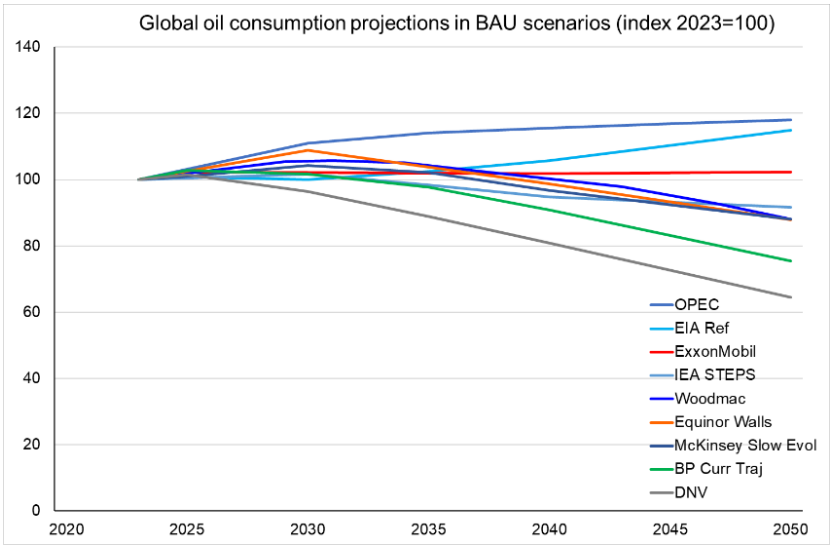
3.2 Where are we in energy transitions?

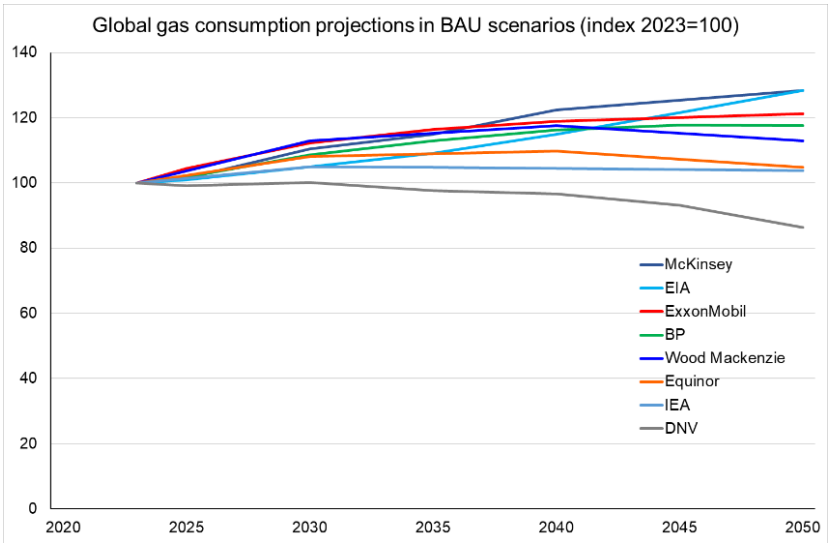
All of the world's major energy forecasters except OPEC and the US Energy Information Administration project a peak in global coal and oil demand before 2030, even if governments adopt no new policies (Figure 3.1). Projections on gas are more varied, with forecasters variously projecting peak in the 2020s, 2030s or 2040s. A key reason for these projections of peak demand is the technological changes already taking place in power generation and in cars, the largest respective demand segments.

Following the rapid fall in costs over the last decade (Section 2.3), expansion of wind and solar power is eating into demand for coal and gas in power generation. Having been the largest driver of global emissions growth in the last two decades, coal power generation in China appears now to have peaked, due to rapid growth of wind and solar (Myllyvirta 2025). Worldwide, wind and solar now generate about 15% of power (Figure 3.2a). Among major economies, the EU has the largest share, at 28% in 2024, but in absolute terms China is by far the largest, with 40% of total global wind and solar generation (Energy Institute 2025).

Figure 3.1: Global coal, oil and gas consumption (primary energy), major energy forecasters' projections under existing policies





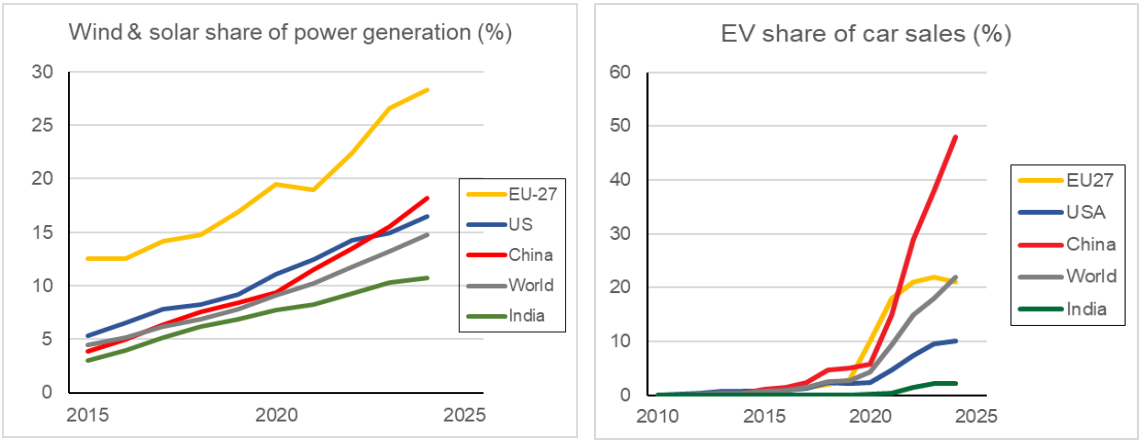


Source: Muttitt (2025), using data from various outlooks

Over 20% of global car sales are now electric (Figure 3.2b), a share that is climbing fast. A key driver is China, the world's largest car market, where more electric cars are now sold every month than petrol and diesel cars. These car sales trends are transforming the global car fleet over time, as existing petrol and diesel cars are replaced by electric ones (a new car stays on the road for about fifteen years on average).

With these trends, the global energy transition is already under way. Even if governments adopt no further policies to meet their climate goals, fossil fuel exporters face economic dangers as their export markets decline.

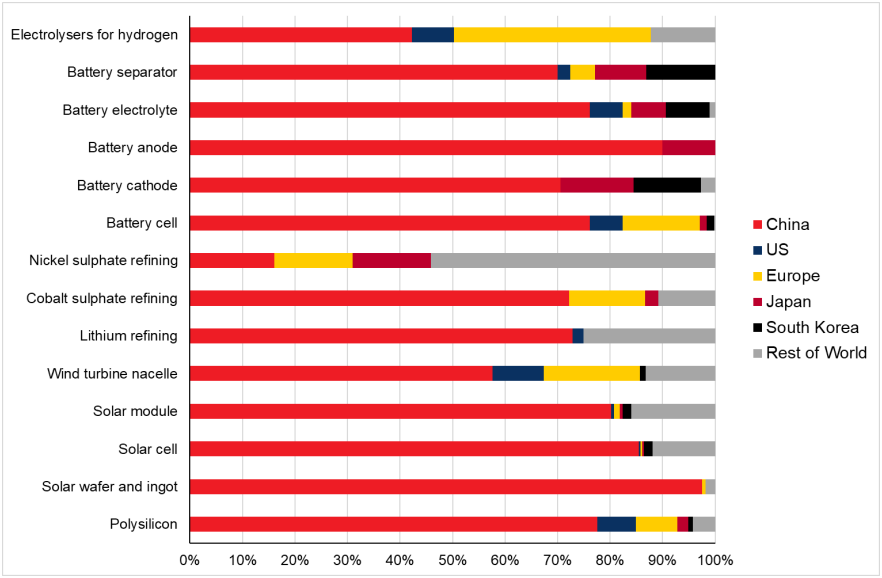
Figure 3.2: Growth in shares of clean technology: (a) Wind and solar share of power generation; (b) Electric vehicle share of car sales



Data sources: Energy Institute (2025); IEA (2025c)

When it comes to manufacturing of clean technology, China is again dominant, with more than 70% of global production of most clean technologies (Figure 3.3).

Figure 3.3: Country/region shares of global clean technology manufacturing, 2022

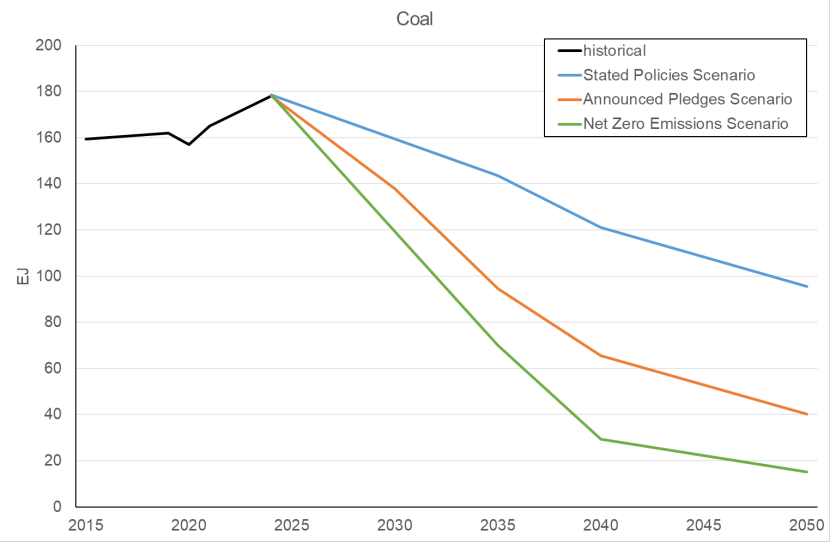


Graphic adapted from, and using data from,: BloombergNEF (2023b)

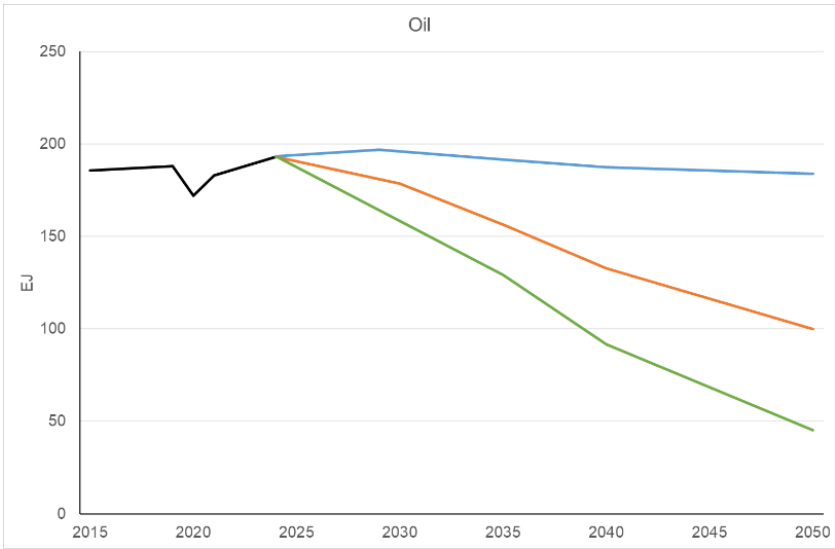
This growth of clean technology, and the prospect of peaking fossil fuel demand, is happening even if governments adopt no new policies to mitigate emissions or advance transitions, beyond those already in place. However, it is not sufficient to achieve the Paris temperature goal. Figure 3.4 shows projections of coal, oil and gas demand in three scenarios published by the IEA assuming different sets of government policies influence future demand for fossil fuels; this illustrates what levels of consumption and production would be consistent with climate goals:

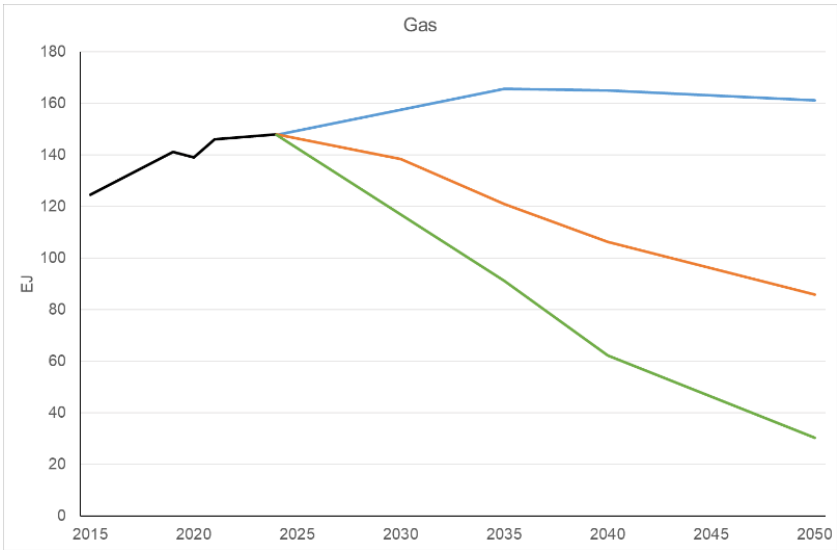
- The IEA's Stated Policies Scenario – based on today's policy settings – sets the world on course for 2.5°C of warming. In this scenario, coal consumption and production decreases steadily from today, while oil and gas peak respectively in 2030 and 2035, followed by slow decline. Note that this already reflects the political backlash against climate policies in 2025, including the reversal of climate measures including the Inflation Reduction Act in the United States.
- The Announced Pledges Scenario, where governments achieve their mid-century net-zero pledges, leading to 1.7°C of warming . In this scenario, consumption and production of coal, oil and gas decrease faster, falling respectively by 77%, 48% and 42% from today's levels by 2050.
- The Net Zero Emissions Scenario, where governments achieve the Paris goal of limiting warming to 1.5°C, and achieve the energy-related Sustainable Development Goals. [7] In this scenario, consumption and production of coal, oil and gas decrease faster still, falling respectively by 92%, 77% and 80% by 2050.

Figure 3.4: Coal, oil and gas consumption (primary energy) in IEA scenarios



[7] The IEA did not include Announced Pledges in its *World Energy Outlook 2025*, because not enough countries had yet published their updated Nationally Determined Contributions; therefore in Figure 3.4 this scenario is taken from *World Energy Outlook 2024*, whereas the other two scenarios are the most recent versions. Note also that *World Energy Outlook 2025* resuscitated the obsolete Current Policies Scenario – previously discontinued since 2019 – due to political pressure from the United States. Only the usual three core IEA scenarios are included here, as Current Policies is not considered very instructive.





Data sources: IEA (2024d, 2025e)

3.3 Just, orderly and equitable

In the GST, governments agreed to transition away from fossil fuels in a just, orderly and equitable manner (UNFCCC 2023, paragraph 28d). Clearly, this phrase implies, among other things, that developed countries must act first and fastest in transitioning away from fossil fuels, as in other areas of climate mitigation. In this paper, we follow an approach of nuanced differentiation, consistent with the Paris Agreement (Rajamani 2016), which affirms the principle of common but differentiated responsibilities and respective capabilities, but applies it “in light of different national circumstances” (UNFCCC 2015: Art.2.2). In implementing EFFTs, there are differences between developed and developing countries, and also within each of these country groups. A simple binary of “developed” and “developing” country groupings does not explain sufficiently, and so we also examine factors that differ across national contexts and are salient to fossil fuel transitions, such as cost of capital, age of existing infrastructure, levels of income and other capabilities. Different national circumstances also evolve over time, making differentiation a dynamic concept.

A **just transition** is defined by the International Labour Organisation (2023: para 11) as promoting "environmentally sustainable economies in a way that is inclusive, by creating decent work opportunities, reducing inequality and by leaving no one behind". The Paris Agreement (UNFCCC 2015: Preamble) takes into account "the imperatives of a just transition of the workforce and the creation of decent work and quality jobs". It thus ensures that benefits from the transition are broadly shared among people in a society, and that any losses are not carried by specific groups or individuals, in particular workers and communities whose jobs and livelihoods depend on fossil fuels. An extensive literature has explored and unpacked what this means and how to achieve it, both for workers and in the context of broader conceptions of justice (Pai et al 2020; Wang and Lo 2021).

An **orderly transition** can mean a transition that is planned and managed across the whole energy system and economy, and that occurs smoothly, with minimum social and economic disruption. There is a tension between careful planning and urgent action; opponents of EFFTs argue for delay to avoid disorderliness or social inequity (Lamb et al 2020). In reality though, such delay would make transitions *more* disorderly, as they would have to occur much faster to achieve the same outcome. An orderly transition aims to promote desirable disruptions (transformation) while minimising harmful disruptions (socio-economic loss). This includes avoiding geopolitical and financial volatility, such as price shocks, or political disputes disrupting or reversing EFFTs (Lins et al 2024). Elements of orderly transition thus include tackling fossil fuel supply and demand in parallel to minimize price spikes, ensuring that policy signals are clear so that investment is directed in the right way, and building a public and political consensus about the way forward. The international dimension of orderly transitions is international cooperation rather than rivalry and obstruction (Walker and Pastukhova 2024). One way to minimise both stranded assets and political difficulties is to avoid investments in new fossil fuel projects that may become stranded, and instead focus investments on clean energy solutions (IEA 2021a; Green et al 2024).

An **equitable transition** is one in which efforts are fairly shared between countries.[8] The principle of common but differentiated responsibilities and respective capabilities (CBDR-RC) (UNFCCC 1992: Art.3.1) means that whilst all countries need to contribute to tackling climate change, the greatest efforts should be made by countries most responsible for causing climate change and those that possess the greatest capabilities to act, including financial, technical and institutional resources. The Paris Agreement includes CBDR-RC, qualifying it with the phrase "in the light of different national circumstances" (UNFCCC, 2015, Art 2.2, 4.3 and 4.19). Equity also means that, developed countries should provide support to enable efforts by developing countries, through finance, technological transfer and capacity building. Like just transitions, climate equity has been extensively explored in the literature, ranging from its moral basis to its practical application (IPCC 2014: Chap.4).

Whilst the three forms of transition see different elements emphasised in the literature, as outlined above, they are overlapping, not least because the words "just" and "equitable" have

[8] "Just" and "equitable" represent overlapping dimensions of fairness. In this paper, we consider "just" to express a societal imperative (justice for people), which applies within countries. We treat "equitable' as expressing a global imperative, applied across countries and their different national circumstances, both in the sharing of climate mitigation efforts and in the context of international rules governing trade and investment.

similar meanings, leading some of the literature to include just transitions as a dimension of equity (IPCC 2022: Sec.4.5). Meanwhile, a transition is unlikely to be orderly if it is unfair, to the extent of generating political resistance. The GST outcome notes that just transitions can support more robust and equitable mitigation outcomes (UNFCCC 2023: Para.10).

The literature exploring just transitions specifically away from fossil fuels has primarily focused on coal, both internationally (Caldecott et al 2017; Diluiso et al 2022; Yanguas Parra et al 2025), and in key producing and consuming countries (He et al 2020; Nishikanta Mangang et al 2024; Burton et al 2022; Edwards et al 2022). Key messages from this literature include the importance of deliberate policy to guide transitions, and the need for diversification of coal-dependent local economies. The IEA (2024a) creates a Coal Transition Exposure Index that ranks the largest coal-consuming and -producing countries' energy and economic dependence on coal, level of economic development, and degree of lock-in of coal capacity. On this index, Indonesia, Mongolia, China, Viet Nam and India are the most coal-dependent countries. Yanguas-Parra's (2024) Coal Transitions Vulnerability Index builds on this, adding indicators to account for the likely speed of the transition, and national and regional resilience, finding Colombia, South Africa and Indonesia the most vulnerable countries to the transition.

A newer but growing literature begins to explore an equitable transition away from oil and gas, from extraction of all fossil fuels, or from fossil fuels more broadly (Mogess and Winkler 2025). Early contributions to this literature consider the interaction between economic efficiency and equity principles (Lenferna 2018; Le Billion and Kristoffersen 2019; Muttitt & Kartha 2020; Rempel and Gupta 2021). Subsequent contributions seek to propose timelines or orderings for transition, based on CBDR-RC principles (Sengupta 2024), on indicators of fossil fuel dependence (Calverley & Anderson 2022; Civil Society Equity Review 2023), or on a composite of indicators of fossil fuel relevance, competitiveness, energy security, emissions and institutions (Lins et al 2024, 2025).

Coming out of these literatures then, is a notion of dependence on fossil fuels – a problem named by President Lula is his opening address to the COP-30 Leaders' Summit in November 2025. Dependence on fossil fuels creates barriers to EFFTs. The resulting inertia has been characterized as "carbon lock-in" (Unruh 2000, 2002), a problem that has economic, political and social elements, due to the respective (interlinked) roles of infrastructure, institutions and behaviours (Seto et al 2016). Clearly, such inertias will make EFFTs harder in some countries than others.[9] Central to all this is the importance of countries' circumstances in determining how, and how fast, they can undergo EFFTs. Indeed, the GST decision specifies that the various elements of energy transitions – including EFFTs – are to be pursued by countries taking into account their different national circumstances (UNFCCC 2023: para.28).

This paper looks more closely at what various indicators tell us about countries' ability and readiness for EFFTs. It builds on other work to understand developing countries' transition circumstances (Mulugetta et al 2022; Foster et al 2024, Heras & Gupta 2024), extending to all countries, across a wider range of indicators, and with a particular emphasis on fossil fuel dependence.

[9] The notion of fossil fuel dependence is somewhat related to that of capabilities, in that a country that is less dependent will be more capable of implementing an EFFT.

4. Transitions in energy systems

Of all the dimensions of transitions away from fossil fuels, it is the energy system itself that has received the most attention, both in the literature and in policy-making. The energy system refers to the interlinked set of infrastructure, institutions and individuals that extract, transform, transport and consume energy. People need energy to meet basic needs, to facilitate a better life, and for societies to flourish. This section examines how transitions in the energy system create opportunities and face challenges in different countries.

4.1 The costs of energy

Decarbonising the energy system involves three main elements, as noted in Section 3.1: switching power generation from fossil to renewable sources, electrifying end-uses, and increasing the efficiency with which energy services are delivered. Over the long run, the transition will make most energy services less costly, as electricity is more efficient than fossil fuels in most applications[10] (Walter et al 2024).

New technologies get cheaper over time through learning-by-doing and economies of scale: the more a new technology is deployed, the more its manufacturers find efficient and effective ways to produce it, bringing costs down. And as they scale up from a prototype to large production, the cost of each unit falls. There is a well-established literature on learning curves, and data on the rate by which a technology reduces in unit cost for each doubling of global installed capacity (IEA and OECD 2000; IPCC 2022: Chap.16). This is also a reason wealthier countries are expected to take the lead in deploying new clean technologies, to help bring the cost down for others. In contrast, fossil fuel technologies are mature, so see slower cost reductions, which are in any case offset by the increasing cost of extracting ever more difficult and remote resources as the prime resources get depleted (Way et al 2022). Thus the long-run trend is towards falling costs for clean alternatives, while fossil fuel costs remain unchanged or increase. A key opportunity of EFFTs then, is to achieve cheaper energy for households and for economies.

Following dramatic cost reductions over the last ten to fifteen years, wind and solar are now the cheapest forms of generation in countries accounting for more than 80% of global power consumption (Figure 4.1). This assessment compares the levelized cost of energy (LCOE), a measure that combines capital and operating costs, across different sources of generation.[11] However, there is an absence of data for many low- and middle-income countries (LMICs), especially in Africa, shown in white in Figure 4.1. And it is generally in these countries that renewable power is most expensive. The reason is that these countries face a higher cost of capital, which affects renewables most because their costs are mostly front-loaded, whereas fossil generation economics are shaped more by operating costs over their lifetime due to fuel purchases.

[10] An exception to this is in high-temperature industrial heat, where fossil energy is used more directly.

[11] While LCOE combines all of the direct costs of generation, it does not include indirect costs such as grid expansion costs in the case of wind and solar (see Section 4.2), or air pollution in the case of fossil fuels (Section 4.3). Figure 4.1 also does not adjust for the supply variability of wind and solar, but in many cases the LCOE of wind and solar combined with storage is lower than that of fossil fuels, and significantly cheaper than of flexible fossil generation such as gas peaker plants (Section 2.3).

Figure 4.1: Cheapest source of new power generation (LCOE) by country

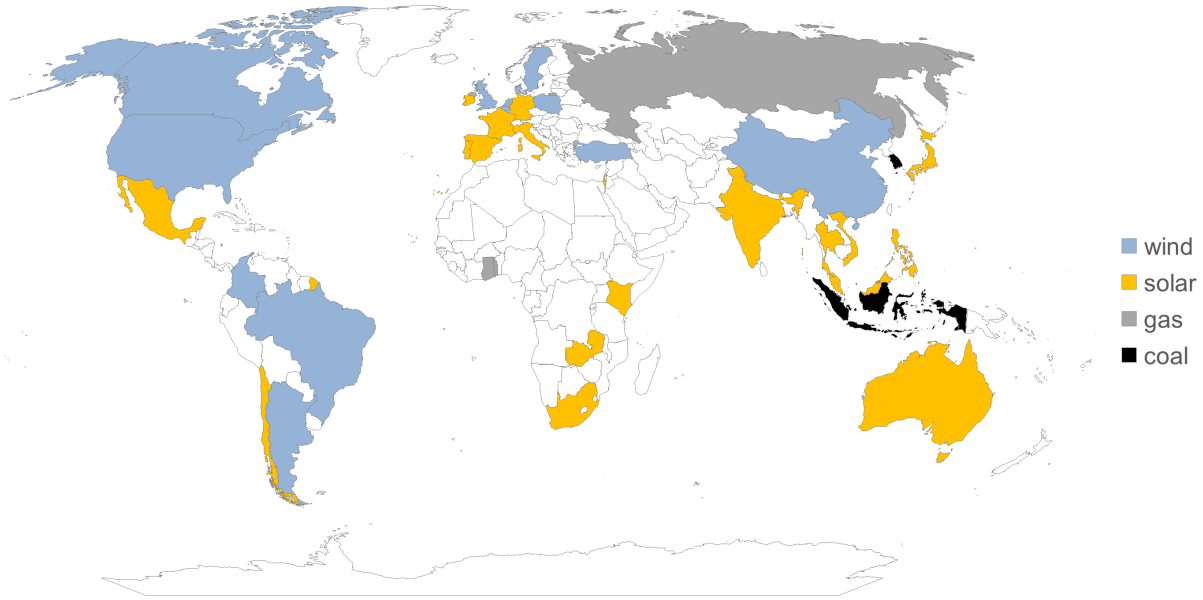
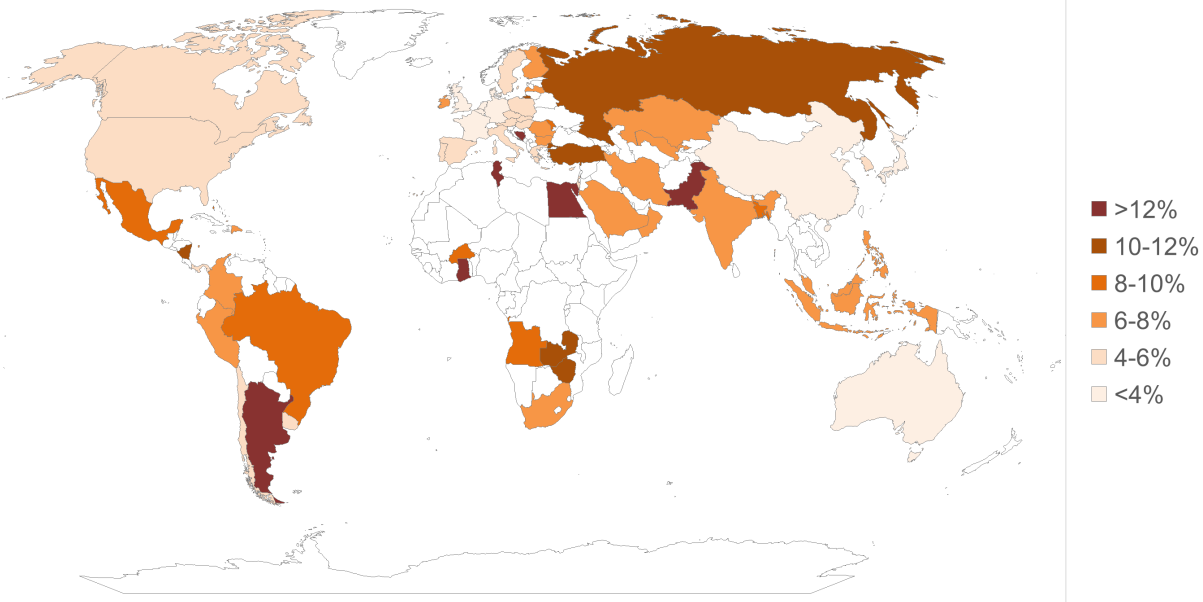


Figure adapted from, and using data from, BloombergNEF (2023a)

Differences in cost of capital are a good example of how nuanced differentiation applies in EFFTs. Compared to 3-5% in high-income and upper-middle-income countries, the weighted average cost of capital is commonly between 6-12% elsewhere (Figure 4.2). Even where renewables have lower LCOE, a capital-poor nation may find it easier to build cheaper coal plants and defer the fuel cost. The cost of capital is thus a major barrier to deployment of renewable energy in many LMICs.

Figure 4.2: Weighted average cost of capital for solar PV projects in 2024



Data source: IRENA (2025)

The capital issue arises similarly for electrified end-uses, which tend to be more capital-intensive whilst having lower operating costs due to improved efficiency. For example, electric

cars are significantly cheaper to run than ICE cars, in terms of both fuel and maintenance, but often with higher purchase price (Carello 2024). Electrification will also require additional infrastructure, such as vehicle charging points and greater distribution capacity to homes (Kearney 2025). Countries where the cost of capital is high will be disadvantaged in their ability to build this (IEA 2021b). In addition, high capital cost will weaken the cost advantages of electric technologies. Whilst the transition is under way, countries will suffer the inefficiencies and costs of having both old and new infrastructures (Grubert and Hastings-Simon 2022). And for energy efficiency, the capital issue is even clearer: greater efficiency saves on energy costs, but requires up-front investments. Thus all three elements of energy system transitions face barriers in countries where capital is scarce or expensive.

In the case of Africa, the Africa Expert Panel's (2025: sec.3.3) report to the G20 Presidency in 2025 stresses that high costs of capital remain a major obstacle to investments in cleaner energy and equitable transitions. While domestic context matters, the Panel identifies as a key international barrier the influence of credit rating agencies (CRAs), whose methodologies often rely on narrow indicators such as GDP per capita and fail to reflect economic diversity or growth potential. These ratings amplify risk perceptions and lead to procyclical downgrades, raising borrowing costs for African countries. The Panel calls for reforms to improve CRA accountability and transparency, including full disclosure of rating data, methodological changes, and global quality standards. It also urges the G20 Finance Track to convene regular dialogue between CRAs, regulators, and African nations.

Almost all developing countries have limited fiscal space, some are highly indebted and large parts of government budgets go to repaying interest, not even the principal. The Africa Expert Panel (2025) called sovereign debt crisis a shared responsibility, and proposed addressing it by a new G20 refinancing initiative, a Borrowers' Club to strengthen debtor coordination, a transparent multilateral debt-resolution mechanism with automatic standstills and fair burden-sharing, and improved debt transparency and sustainability analysis.

Aside from the capital issues, developing countries may have an advantage, however. China is increasingly exporting large quantities of low-cost clean technology to developing and emerging economies, while Europe and North America are erecting trade barriers against imports from China (Yang et al 2025). For example, Pakistan increased its imports of Chinese solar panels tenfold from 2020 to 2024, as the price of panels fell by more than half. Up to 33 GW of panels have been installed on individual homes and businesses (Santos et al 2025),[12] protecting users from rising electricity costs and unreliable supply, and keeping some businesses afloat that would otherwise have been driven to bankruptcy. However, a barrier to just transition in this case has been the existing contracts with foreign operators of fossil fuel plants, which require the operators to be paid regardless of whether the power is needed. To reach those that cannot afford to buy their own panels, government will need to renegotiate or cancel these contracts, and subsidise provision of panels to poorer households (Pirani 2025). Conversely, vehicle electrification will be slower in countries where large shares of vehicle sales are second-hand imports. While over 20% of global new car sales are electric (Section 3.2), this is a new phenomenon, so only 4.5% of the global fleet is electric so far, as of 2024 (IEA 2025c). It will be some years before these new vehicles come to be sold on.

[12] This is compared to the 46 GW total capacity of Pakistan's power stations (Renewables First 2025)

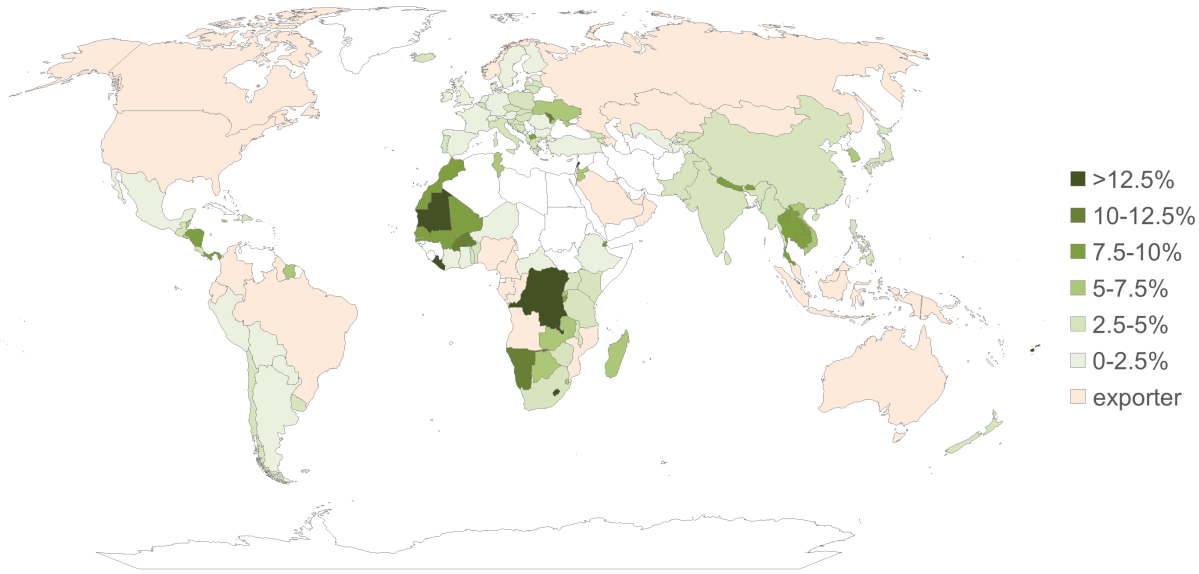
Furthermore, the transition to renewable energy may give a physical advantage to countries in the Tropics, compared to those at higher latitudes (Goodall 2016). Batteries have seen the fastest cost reductions of the energy storage technologies, and are most suited to storage over periods of a few hours. Thus in tropical regions, where solar irradiation is more consistent through the year, a combination of solar plus batteries can deliver year-round electricity by storing during the sunniest period at the middle of the day, and discharging during high-demand periods in the evening. In contrast, temperate regions experience greater seasonal variability, and need storage solutions that can provide for periods of weeks without wind or sun, which are more expensive and less technologically advanced.

4.2 Energy security and reliability

Energy transitions can also offer energy security advantages to fossil fuel importers, as renewable resources – wind, sun and water – are located within their own borders. Whereas the concept of the energy trilemma historically captured the tension between the policy priorities of affordability, security and environmental sustainability, the reduced costs and energy security advantages of renewable-powered electrification offer the opportunity for all three goals to be achieved simultaneously (Kueter 2024).

Costly fossil fuel imports have a strong negative impact on balance of payments, especially in LMICs (UNEP2023: Chap.6). Furthermore, fossil fuel prices are highly volatile, and sudden price spikes can disrupt import-dependent economies. Reducing exposure to these costly imports is thus a policy priority for most importers. The cost of fossil fuel imports exceeds 5% of GDP in 50 countries; it exceeds 10% in 12 of these, with the highest levels in Cabo Verde (34%), Lebanon (22%), Mauritania (16%) and Liberia (15%) (Figure 4.3).

Figure 4.3: Net fossil fuel imports as proportion of GDP, 2023 *(except Iran, Nepal and Rwanda 2022; Russia 2021)*



Data sources: World Bank (2025b, c, d, e, f)

Whereas fossil-fuelled facilities rely on fuel supplies throughout their life, renewable energy projects avoid this reliance, once they have been installed. The concentration of clean technology manufacturing in China (Figure 3.3) has raised energy security and geopolitical

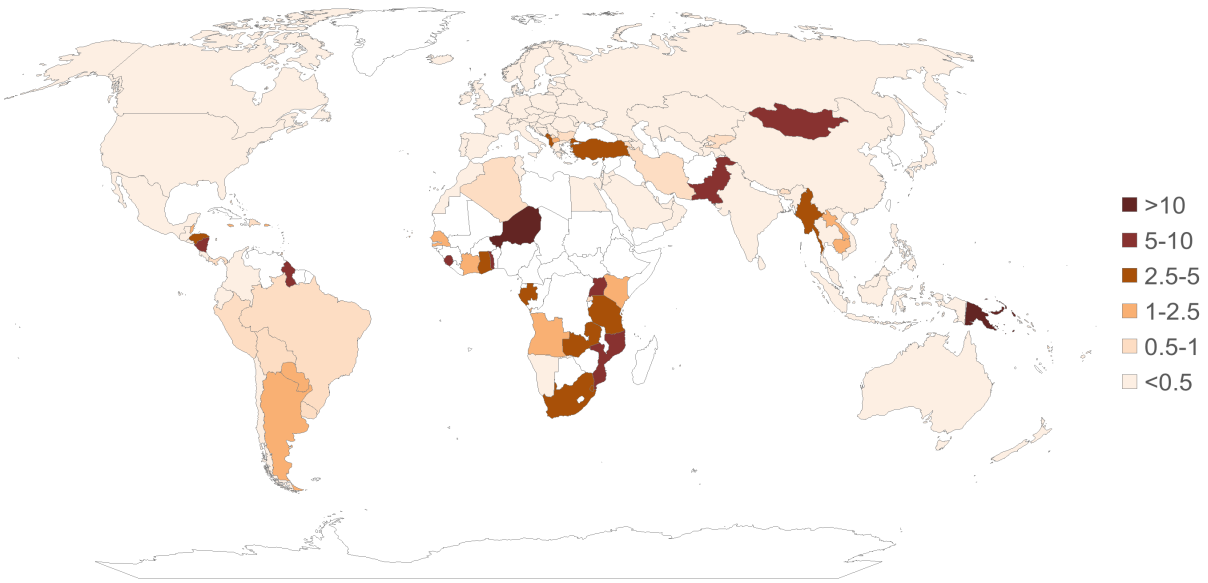
concerns for European and North American countries, in part because it challenges their own dominant role in supplying fossil capital equipment, technology and (in the case of North America) fuel. Many other countries already rely on imported foreign fossil fuel equipment and technologies (Bond et al 2025).

There are now well-developed and affordable mechanisms for incorporating variable renewables into power systems as their share of generation increases (IEA 2024c). At lower levels of penetration, renewables can be enabled by low-cost, institutional measures such as improved data and forecasting, or reformed market structure. At moderate penetrations, measures such as demand response, smart grids and flexible supply response, all at moderate cost. It is only at higher levels of penetration that major investments are needed in grid infrastructure such as expanded transmission, and interconnectors.

Wind and solar now exceed 40% of generation in several European countries, including Denmark, Germany, Greece, Ireland and the Netherlands. Progress is not limited to the Global North: wind and solar constitute 41% in Uruguay, 33% in Chile, 26% in Namibia, and 25% in Lebanon, for example (IEA 2025a). In the case of Uruguay, the government adopted policies in the 2010s to enable and accelerate wind power growth, in order to reduce electricity costs (Bertram 2020).

However, some countries will face a barrier where their grid infrastructure is already stressed. Power systems that rely on renewables such as wind and solar generally require more transmission capacity to take power from wherever it is being generated to where it is needed, and more informational and management capacity to respond to changes in supply and demand.

Figure 4.4: Average number or total duration (in hours) of power outages per consumer per month, 2019[13] *(figure shows whichever is larger)*



Data source: World Bank (2021 a, b)

[13] More recent data are not available

One indicator of weaker grids is that they can be a key cause of blackouts and brownouts, even under the current, fossil-dominated systems. There is thus a need for investments in both physical infrastructure and institutional capacities, without which countries' ability to increase the renewable share in their power systems will be limited. Ayaburi et al (2020) propose a definition of "reasonably reliable" power as not exceeding one outage per month or one hour's total outage per month on average. Figure 4.4 shows countries in bands based on multiples of this definition, as an indicator of where greater efforts will be needed to integrate renewables.

4.3 Energy access and air pollution

Lack of access to modern energy services is perhaps the greatest moral issue facing energy policy. 666 million people worldwide lack access to electricity, 565 million of them in Africa. 2.1 billion people lack access to clean, modern cooking fuels, and suffer respiratory health problems due to indoor air pollution caused by cooking with solid biomass or paraffin (IEA et al 2025). Sustainable Development Goal SDG 7 aims to close these gaps by 2030, ensuring access to affordable, reliable, sustainable and modern energy for all.

Wind and solar power are the best means to deliver electricity access to most of the people who presently lack it, as 84% of the people lacking electricity live in rural areas (IEA et al 2025), where the optimal means to provide access are through distributed renewable energy, including in home-scale systems or using community-scale micro- or mini-grids. Over time, these local solutions can be integrated in expanding national grids. Whilst delivering electricity access to households that who presently lack connections is thus potentially consistent with EFFT, there are many others who have grid connections but suffer inadequate, unreliable, expensive or unsafe electricity, including in urban areas (Bhatia and Angelou 2015; Kersey et al 2025). Meeting the needs of these connected but energy-poor households will require increased generation and improved infrastructure, which may make EFFTs more challenging. Furthermore, over the long term, national and regional grids are preferred, as they provide economies of scale that lead to cheaper unit costs for energy (Khennas & Sokona, 2020).

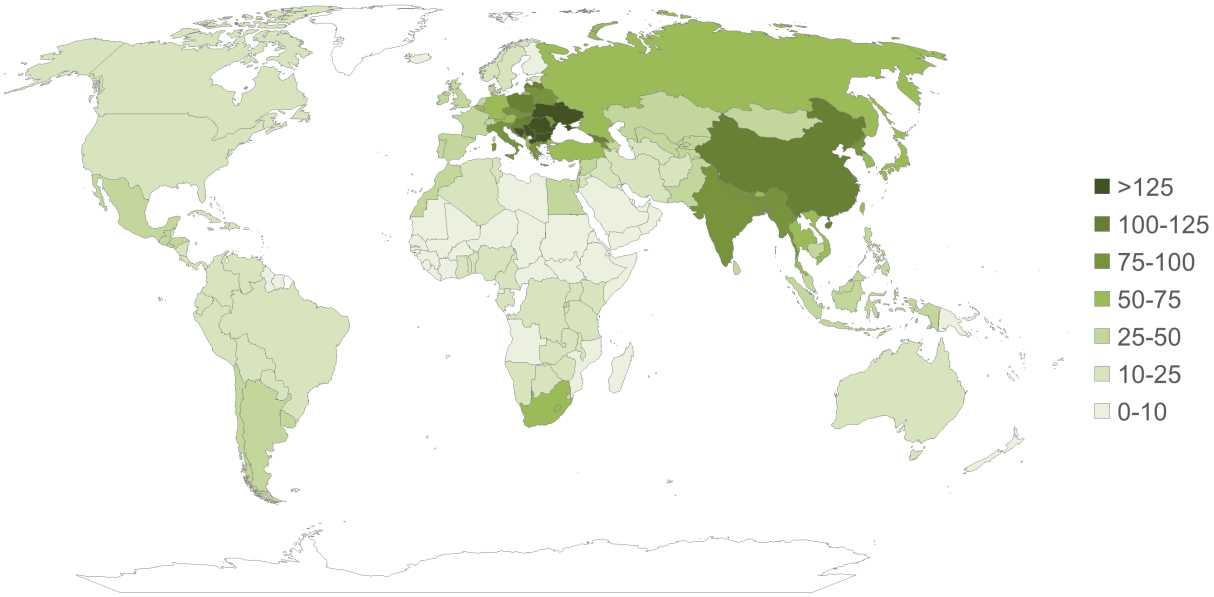
Conversely, the flexibility of wind and solar power compared to centralized fossil generation offers other advantages beyond delivering electricity access. Because wind and solar projects are generally smaller than fossil plants, they can be added in a modular and phased way, targeting specific needs for additional power, such as local economic development or increased household provision (Arndt et al., 2019).

Most switches to clean cooking are currently achieved through use of liquid petroleum gas (LPG). About 60% of LPG is produced by separation of natural (fossil) gas, and 40% from oil refining (World Liquid Gas Association 2025). Around half of global LPG consumption is met by imports, a share that rises to two thirds in lower-middle-income countries, and three quarters in low-income countries (IEA 2025a). Increased use of LPG does not require significant infrastructure, as it is distributed in canisters by truck. As with electricity, the potential challenge for EFFTs is not so much in the near-term provision of access to clean cooking for those who presently lack it, but over longer-term solutions. In this regard, the choice is over whether to provide secure access to clean cooking using piped gas or electricity.

Electricity is becoming increasingly attractive through technological improvements, such as rice cookers and induction stoves, and has the advantage of relying on a single set of infrastructure (the grid) rather than two sets (grid and pipelines) (Muttitt et al 2021). Still, different governments are pursuing different approaches to improving domestic access to cooking.

While traditional biomass cooking is a primary cause of indoor air pollution, fossil fuels are a culprit in outdoor air pollution, which also has severe impacts on respiratory health. Transitioning away from fossil fuels thus offers an opportunity to reduce air pollution and improve health. In 42 countries, fossil fuel pollution causes more than 50 deaths per 100,000 (living) population each year, with the worst impacts in Eastern Europe, followed by some parts of Asia (Figure 4.5).

Figure 4.5: Annual deaths per 100,000 population attributed to fossil-fuel-related PM2.5 and ozone air pollution, 2019 *(this shows total deaths attributed to PM2.5 and ozone, minus the modelled expectation in the absence of fossil fuels)*



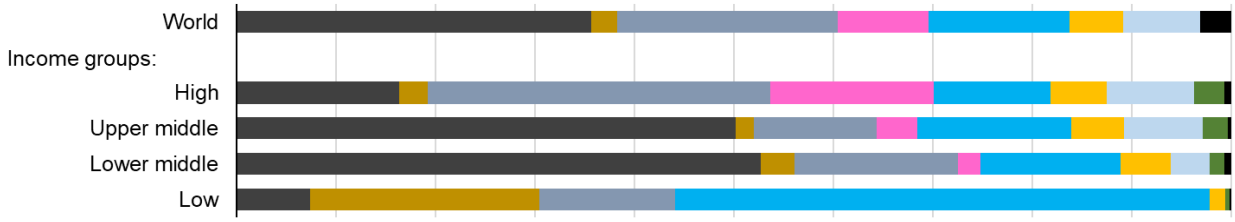
Data source: Lelieveld et al 2023

4.4 Dependence on coal and gas power generation

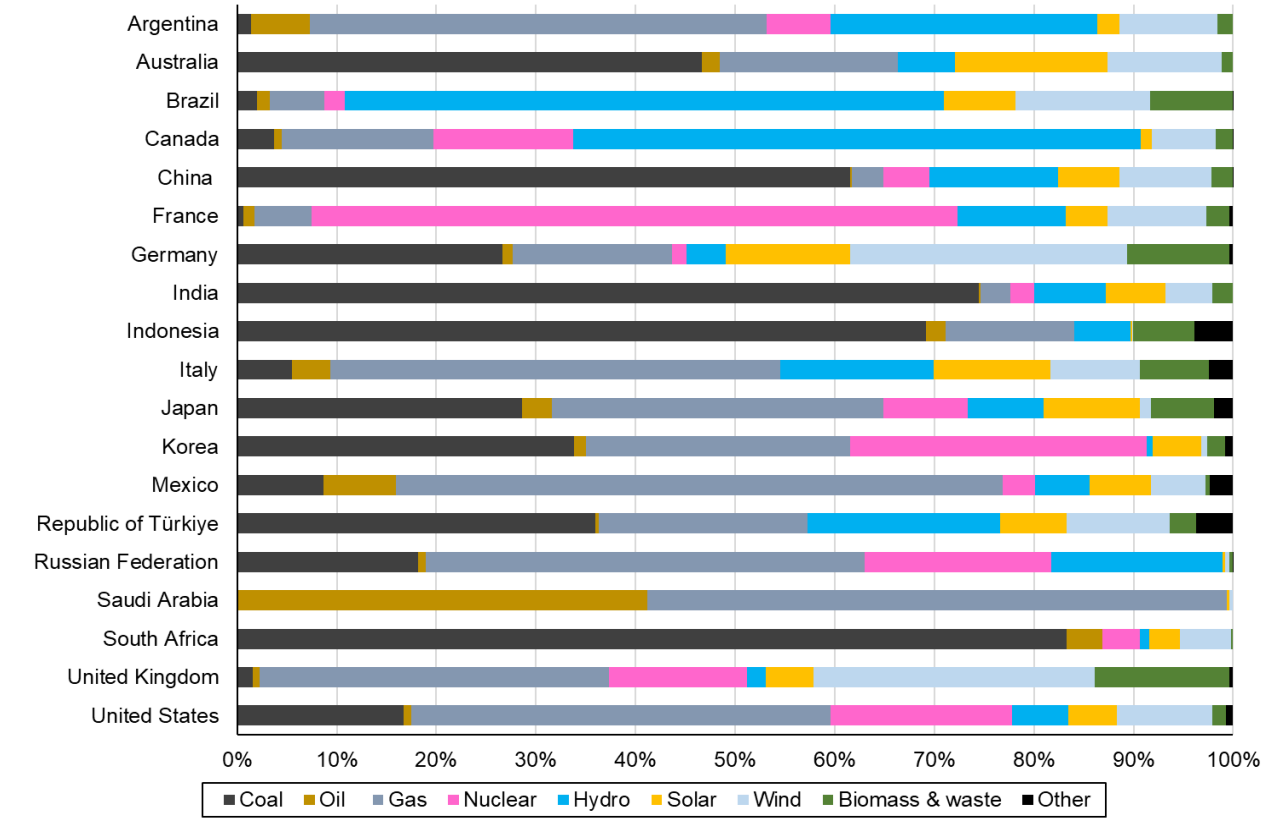
Power systems that are more fossil-dependent have a further way to go to replace fossil generation than countries in which fossil fuels comprise a smaller share. On average, fossil fuels provide 54% of generation in high-income countries, with the remainder fairly evenly split between nuclear, hydropower and other renewables. The fossil fuel share rises to 64% in upper-middle-income countries and 73% in lower-middle-income countries, with smaller amounts of nuclear generation. In low-income countries, hydropower provides the largest share of generation, followed by fossil fuels with 44% (Figure 4.6a). At the same time, there is significant variation within these income groups, as illustrated for G20 countries in Figure 4.6b (and including a wider range of countries than G20 would show even greater variation).

Figure 4.6: Source of power generation (2023)

(a) by World Bank income category



(b) for G20 countries



Data source: IEA (2025a)

While there is a common finding in integrated assessment models (and echoed by many Global North governments) that coal should be phased out faster than oil and gas because of its higher emissions intensity, this emphasis can lead to unfair sharing of mitigation efforts, as 80% of global coal power generation occurs in LMICs, compared to 34% global gas power generation (IEA 2025a). In the median 1.5°C pathway from the IPCC's Sixth Assessment Report, coal power drops globally by 87% by 2030, compared to 14% reduction in gas power, and 10% reduction in overall oil use (Byers et al 2022). Whilst this may make sense when the world is considered as a single geographical unit, it would imply that some coal-dependent developing countries would have to replace virtually their entire power fleet within a decade. In 2023, coal provided 99% of generation in Botswana, 87% in Kosovo, 85% in Mongolia, 83% in South Africa and 74% in India (IEA 2025a).

While all countries should avoid building additional coal plants, which will make the challenges even greater (Section 7.4), just, orderly and equitable transitions will almost certainly require

longer than a decade in such countries. This implies that in the real world, oil and gas transitions may need to occur faster globally – and especially in countries with more diversified power mixes – than in models, to compensate for slower coal transitions (Muttitt et al 2023). As Figure 4.6a shows, high income countries rely significantly less on coal generation and significantly more on gas generation, compared to middle-income countries. Therefore, equitable transitions entail a different balance of phaseout among the three fossil fuels, compared to scenarios reviewed by the IPCC.

Larger power systems – with more power plants – change more slowly than smaller systems due to the inertias associated with numbers and diversity of power plants, regions and socio-political interests (Vinichenko et al 2021). Another complication is that hydropower, which is disproportionately used in poorer countries (Figure 4.6), is often facing challenges due to climate change-induced droughts. This creates further strain on new-build renewable power plants to substitute weakening hydro generation, as well as deliver on growing demand, before they can start to substitute existing fossil generation.

The cost comparisons in Sections 2.3 and 4.1 relate to new-build power plants. Existing plants can deliver power more cheaply than new ones, as their capital costs are already sunk, and generation then incurs only operating costs. Early retirement of plants creates barriers of political economy too, as the companies and institutions that built them will lose money on their investments, though there have been some experiments with financializing the cost advantage of renewables or of concessional loans to create incentives for early coal retirement (Wilke 2024). Most fossil power plants in LMICs are younger, and so their phaseout in the new future would come at greater cost to those investments, many of which have not yet broken even and paid off their capital costs. In industrialised countries, older plants may already be approaching retirement.

Table 4.1: Capacity-weighted average age of operating coal plants in the 15 countries with largest generation of coal-fired power, 2024

	Coal generation (TWh)	Average plant age (years)
China	5,827	12.6
India	1,517	14.3
US	712	43.2
Japan	300	22.8
Indonesia	228	9.5
Russia	215	42.1
South Africa	202	32.8
South Korea	188	14.6
Viet Nam	152	7.9
Australia	127	35.5
Türkiye	122	19.0
Taiwan	113	21.9

	Coal generation (TWh)	Average plant age (years)
Germany	106	29.6
Malaysia	98	8.1
Poland	95	36.0
Kazakhstan	64	42.2

Data source: Global Energy Monitor (2025a)

The lock-in effect of infrastructure often applies beyond the power sector too. For example, the economic case for electrification of home energy uses such as cooking and heating will be weaker where gas distribution pipelines already exist.

Decreasing fossil generation from present levels will also be more challenging in countries where electricity consumption is growing, as new power investment is needed just to meet growing needs; any replacement would have to be on top of this. Conversely, growing systems have an opportunity to focus their growth on clean energy generation, so can more readily reduce fossil fuels' share of the total. Electrification of end uses will further increase electricity demand, intensifying the challenges outlined earlier in this section, especially in countries with weaker grids, more expensive generation or higher capital costs. From 2013 to 2023, power generation grew by 41% on average in LMICs, compared to only 3% in high-income countries (IEA 2025a).

One part of the solution, then, is to stop adding to the problem with additional fossil-fuelled infrastructure, and instead focusing new investments wherever possible on clean energy (Section 7.4).

4.5 Implications for equitable energy transitions

Drawing together the foregoing findings of this section, we now outline some key implications for policymakers. Progress on EFFTs can be made by capitalising on opportunities and benefits:

- **Lower energy costs**: Renewable electricity generation is cheaper than fossil fuels in countries accounting for 80% of global power generation, especially in high-income countries and some upper-middle-income countries. Wind and solar PV in particular have seen massive decreases in unit costs.
- **Improved energy security**: Once installed, renewable energy removes reliance on imported energy supplies. The cost of fossil fuel imports exceeds 5% of GDP in 50 countries; it exceeds 10% in 12 of these. The highest fossil import dependence among G20 members is South Korea, equal to 6% of GDP.
- **Reducing air pollution**: The transition away from fossil fuels will reduce and eventually remove a key source of air pollution, which has a severe impact on respiratory health. In 42 countries, fossil fuel pollution causes more than 50 deaths per 100,000 (living) population each year, with the worst impacts in Eastern Europe, followed by some parts of Asia.

Countries also differ in how much they depend on fossil energy:

- **Diversified power mixes**: Some countries have a low reliance on fossil power due to significant generation from nuclear (e.g. France) or hydro (e.g. Canada, Brazil). Measures to manage high shares of variable renewables are increasingly being proven. Wind and solar exceed 25% of generation in 2023 in sixteen countries, including Denmark (67%), Uruguay (41%), Germany (40%), the United Kingdom (33%), Chile (31%), Namibia (26%), and Lebanon (25%).
- **Fossil-dependent power systems**: Coal plays the largest role in middle-income countries' power mixes, with more than half of the total on average. Coal dependence is highest in Botswana (99% of generation), Kosovo (87%) and Mongolia (85%), and within the G20 in South Africa (83%), India (74%) and Indonesia (69%).
- **Coal versus gas**: Equitable transitions require faster reduction of gas power generation than appears in integrated assessment models, to allow for more realistic rates of reducing coal power. Countries with fossil-dependent power systems can avoid adding more fossil power plants to the mix, which would deepen dependence.
- **Growing energy demand**: From 2013 to 2023, power generation grew by 41% on average in LMICs, compared to only 3% in high-income countries. Where generation is growing, the relative share of renewables can be increased by prioritising renewables for new plants, but it will take longer to replace existing fossil fuel stock, especially where fossil plants are younger and may not yet have recouped their investment costs. In richer countries, the challenge is to use less energy in absolute terms and convert existing capital stock to cleaner energy.

Policy interventions can help enable equitable transitions in energy systems:

- **Reduce the cost of capital** for renewable energy development in developing countries: including by derisking investments, increasing international public finance, and removing biases in credit ratings agencies.
- **Adopt clean technologies** as early-movers, helping bring down their costs through learning-by-doing.

5. Energy-economy transitions: Jobs and the energy-industrial complex

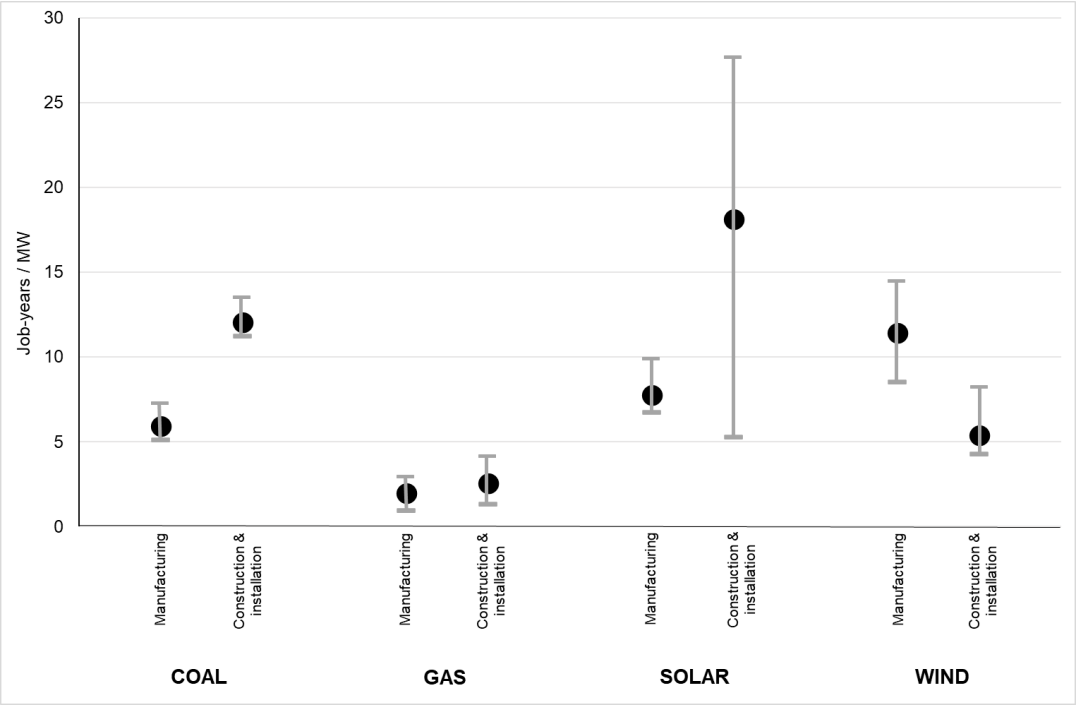
Fossil fuels play a central role in many economies. People are employed in fossil fuel extraction, refining or power generation, and these activities also support supply chains and provide energy to a range of industries. This section assesses how transitions will affect the structure of economies, through the lens of employment, to explore how economic opportunities and transition challenges vary between countries.

5.1 Job creation in renewable energy

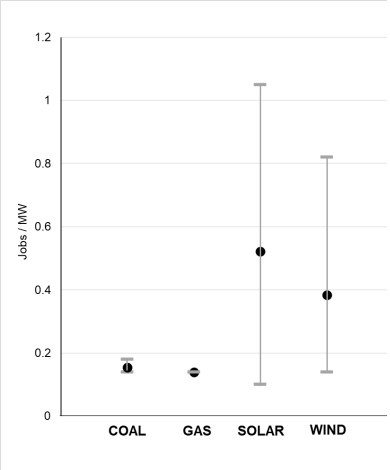
There is a consensus among researchers that clean energy creates more jobs than fossil fuels, a key economic opportunity from EFFTs. Averaged across countries and studies, wind and solar generation create 2-3 times as many jobs as gas and coal generation per dollar invested, according to Hanna et al's (2024) systematic review (Figure 5.1). While renewable energy jobs are often thought of as being temporary during construction, the review finds that wind and solar create more than 2.5 times as many operation and maintenance jobs as gas and coal, again averaged across countries and studies. Since renewable systems require higher capacity to allow for variability, job creation per megawatt-hour generated will be even greater compared to gas and coal. Improving the energy efficiency of buildings is even more job-creating.

Figure 5.1: Employment intensity of renewable energy versus fossil fuels, during construction and operation. *Error bars show range of estimates in different studies; black circles show averages across those studies. Graphs (a) and (b) are based on six studies; graph (c) is based on 18 studies.*

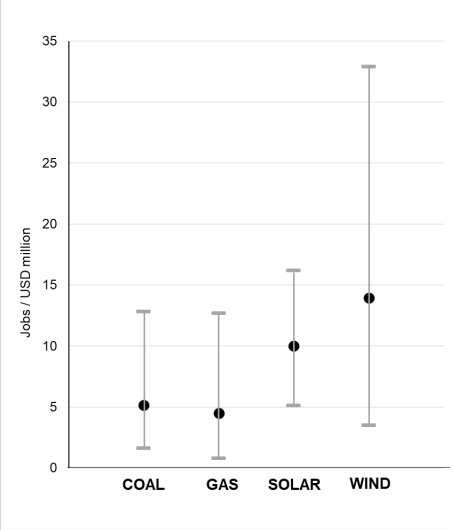
(a) Manufacturing/construction & installation roles: job-years per MW of installed capacity;



(b) Operation & maintenance jobs created per MW of installed capacity



(c) Jobs created per million USD invested



Data source: Hanna et al (2024)

Even in the absence of a global energy transition, fossil fuels' contribution to employment is declining. Fossil fuel extraction has long had low levels of employment intensity in developed economies, and emerging economies are headed the same way due to mechanisation (coal) and automation (oil and gas, which are already highly mechanised). Mechanisation reduced South Africa's coal mining workforce from its 1981 peak of nearly 140,000 to below 50,000 twenty years later (Burton et al 2019), while production increased by 70% (Energy Institute 2025). More recently, 2.6 million coal mining jobs (around half of the total) have been lost in China since 2000 (IEA 2024a), even as production has more than tripled (Energy Institute 2025). In other words, mechanisation has cost more jobs than the energy transition will.

In most studies, the net effect of transitioning away from fossil fuels – taking into account the full effect on the economy – is job-creating (Hanna et al 2024; IEA 2024b). Median salaries remain lower in wind and solar than in oil and gas or nuclear, as shown by the IEA in Figure 5.2, though higher than coal. Efforts are needed to boost the quality of renewable energy jobs, including by increasing the rate of unionisation in a sector dominated by private companies.

Figure 5.2: Median energy salary ranges by sector and country, 2023

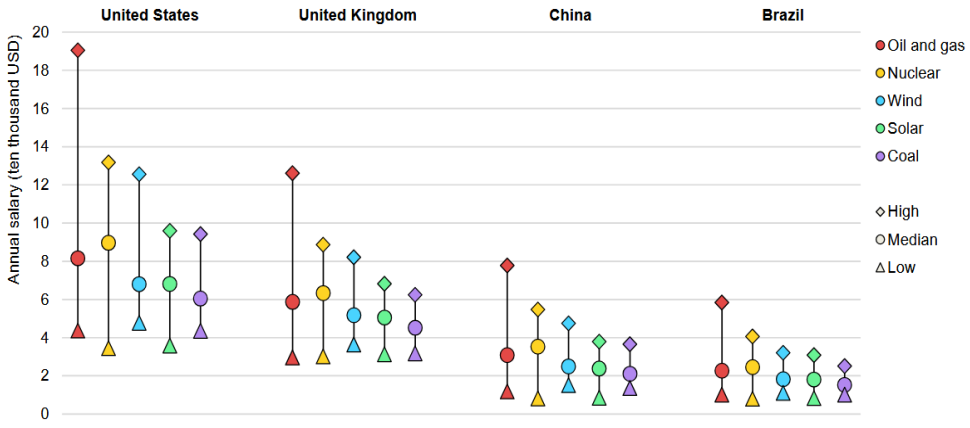


Figure reproduced from IEA (2024b)

The net increase in job numbers needs to be qualified according to how well the skills and location of the new jobs match those of declining fossil fuel jobs. According to the IEA (2024b), only around half of the fossil jobs lost between 2023 and 2030 in the Net Zero Emissions scenario involve skills that can be readily transferred to new clean energy jobs with retraining – including about two thirds of jobs in car manufacturing and oil and gas extraction, and about half of power plant jobs, but only a small portion of coal mining jobs. A study on skills for South Africa confirms the gross job creation potential from transitions, but finds that the bulk of job creation in renewable power generation is within the high-skilled labour group (Hartley et al 2019). In countries with relatively low skills base in the labour force, efforts will be needed to both to upskill the workforce, and to create employment opportunities for the lower-skilled in other sectors beyond renewable power generation.

Meanwhile, new clean energy jobs may be located in different locations from lost fossil fuel jobs, especially in large countries. For example, India's jobs in coal mining and coal power plants are concentrated in eastern states such as Jharkhand, West Bengal and Chhattisgarh, whereas potential new jobs in wind and solar are concentrated in western and southern states, such as Maharashtra and Tamil Nadu (Ordonez et al 2023).

5.2 Fossil fuel jobs

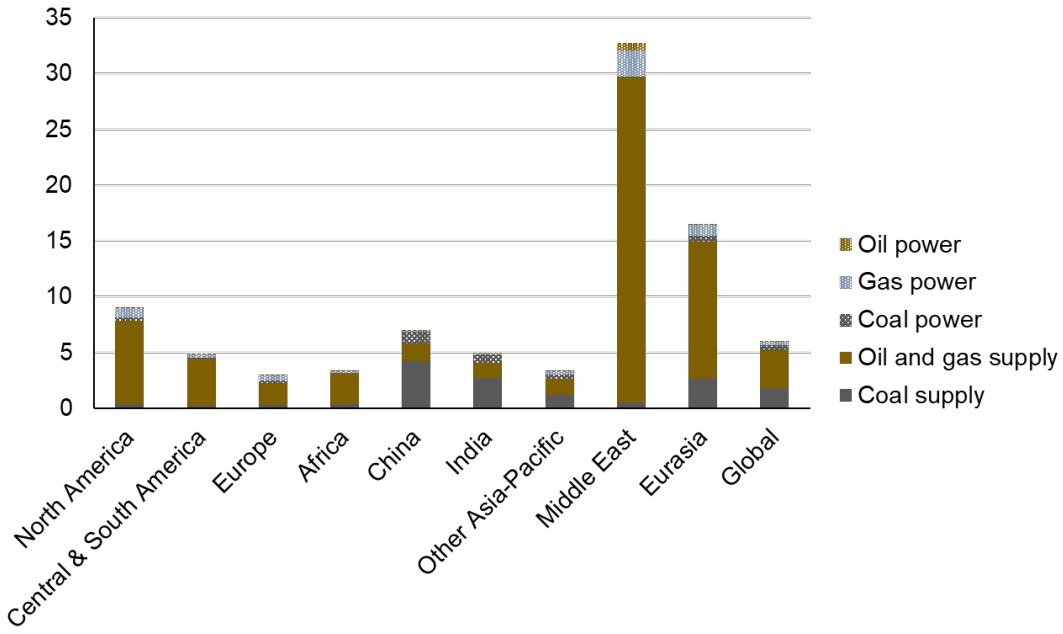
Whilst the post-fossil fuel economy is likely to involve greater employment, the process of transition from here to there will require policy efforts and incur costs, and will be disruptive for the workers and communities affected. As such, countries face differing challenges in conducting a transition, according to their level of dependence on fossil fuels.

One measure of economic dependence on fossil fuels is the proportion of the workforce employed. There are limited country-level data available. The International Energy Agency (2024b) estimates energy employment by region, where China and India are the only single countries treated as regions. The largest absolute numbers of fossil fuel workers are in China, with nearly 10 million coal, oil, gas and power workers, but the greatest share of the workforce is in the Middle East, with about 3% (Figure 5.3).

For some individual countries, data can be obtained (Table 5.1), usually from government statistics or Extractive Industries Transparency Initiative (EITI) reports. However, these do not generally have common definitions (for example, whether they include service company jobs), and in the case of EITI reports are often based on incomplete surveys of companies, and so are only indicative. For many countries, data are not available at all, including for major oil and gas producers Saudi Arabia, Russia, Iran and UAE.

Outside the Middle East, fossil fuel employment is relatively small, rarely higher than 1-2% of the total national workforce. However, regionally it is more significant: between 5% and 8% in Cesar in Colombia, East Kalimantan in Indonesia and Mpumalanga in South Africa (IEA 2024a). In Colombia, coal mining accounts for just 2% of GDP nationwide, but 40% of GDP in Cesar (Furnaro and Yanguas Parra 2022).

Figure 5.3: Fossil fuel jobs by region, per 1,000 workforce, 2023



Data sources: IEA (2024b); World Bank (2025g)

Table 5.1: Fossil fuel extraction workforce, selected countries

	Number of extraction workers		Year	Total labour force	Fossil extraction share of workforce	Source of extraction worker number
	Coal	Oil & gas				
Angola	-	28,900	2023	15,430,000	0.2%	EITI (2025a)
Argentina	-	65,000	2023	22,069,900	0.3%	EITI (2024a)
Australia oil & gas	50,600	22,000	2022/23; 2023/24	14,594,300	0.5%	AEP (2024); MCA (2025)
Canada	10,900	54,600	2025	22,867,600	0.3%	Statistics Canada (2025)
Chad	-	580	2023	6,221,500	0.01%	EITI (2025b)
China	2,800,000	1,400,000	2024	773,879,700	0.5%	IEA (2024b)
Congo-Brazzaville	-	930	2023	2,485,700	0.04%	EITI (2025c)
Gabon	-	4,200	2022	789,400	0.5%	EITI (2024b)
Germany	10,600	-	2025	43,775,200	0.02%	GEM (2025b)
Ghana	-	4,100	2022	13,346,800	0.03%	EITI (2024c)
India	1,500,000	800,000	2024	607,691,500	0.4%	IEA (2024b)

	Number of extraction workers		Year	Total labour force	Fossil extraction share of workforce	Source of extraction worker number
	Coal	Oil & gas				
Indonesia	218,000	119,000	2021	135,672,800	0.3%	EITI (2021)
Iraq	-	161,600	2023	11,685,300	1.4%	EITI (2025d)
Nigeria	-	8,700	2023	110,183,300	0.01%	EITI (2024d)
Norway	-	65,000	2024	3,042,200	2.1%	Norsk Petroleum (2025)
South Africa	72,200	-	2025	27,766,000	0.3%	GEM (2025b)
Trinidad & Tobago	-	2,620	2023	652,000	0.4%	EITI (2024e)
United Kingdom	-	30,000	2023	34,950,000	0.1%	UK EITI (2025)
United States	44,000	362,000	2024; 2022	169,494,100	0.2%	EIA (2025); Scott and Bushnell (2025)

Data source for total labour force: World Bank (2025f)

It is important to contextualise the numbers of jobs created or destroyed in the energy transition, as each job can play a larger or smaller social role in different countries' circumstances. In some countries, a larger household depends on the income from each job, because some members of households are engaged in unpaid work in the home (especially women), or are unemployed, or are in (more insecure or lower-paid) informal employment. Again, this can be intensified at the local level: for example, in Mpumalanga, each coal miner typically supports at least three dependents (Burton et al 2019).

Fossil fuel jobs are generally some of the highest-paid. In countries where fossil fuel salaries are higher compared to average incomes, the fossil fuel jobs play a more important economic and social role, as a larger share of total earnings. Coal mining salaries are 50% higher than the average of industrial salaries in South Africa, 60% higher in China, 100% in Indonesia, 200% in Colombia and 300% in India (IEA 2024a). Oil and gas jobs are better-paying still (Figure 5.2). High levels of unionization in Coal India Limited have led to a range of benefits including a provident fund and pension schemes, and employees' entitlement to include five family members on their medical card; conversely Indian renewable energy is being developed by a largely non-unionised, liberalized and weakly regulated private sector (Chhotray 2022).

On the other hand, these benefits of fossil fuel employment do not apply to informal workers, who tend to have low and precarious incomes, dangerous working conditions and few protections of their employment rights. Lahiri-Dutt (2016) estimates that informal employment in coal mining in India may exceed formal employment: not only the subsistence miners who extract coal with hand tools and transport by bicycle for local use, but also large numbers employed in 'contractors' by Coal India Limited, and those working with ill-defined status under the country's settlement with indigenous nations in the northern state of Meghalaya.

5.3 A broader conception of fossil-dependent jobs

When considering just energy transitions, perhaps the image that comes to mind is of coal miners, oil and gas drillers, or power plant operators. This framing would be too narrow. Whilst those workers will be the ones most directly affected by transitions, many others will be more indirectly affected. Jobs that depend on fossil fuels include those in:

1. **Extracting** fossil fuels;
2. **Providing supplies or services** to fossil fuel operations, from engineers to caterers ("backward linkages");
3. **Refining** oil and other processing;
4. Transporting[14], distributing and marketing fossil fuels
5. **Generating power** from fossil fuels (mainly coal and gas);
6. **Energy-consuming sectors**, such as heavy industry and vehicle manufacture and maintenance, using either fossil fuels directly or the electricity from fossil power plants ("forward linkages");
7. "**Induced employment**" in sectors supported by fossil fuel workers' salaries, including lodging, hospitality and transport;
8. **The public sector**, where fiscal revenue from fossil fuels pays their salaries.

To our knowledge, no-one has collected employment data across these categories for multiple countries. The availability and quality of data differ significantly, and definitions are not consistent between countries. However, some examples can help illustrate:

- In the United States, there were 112,700 jobs in oil and gas extraction (category #1) in 2022, 249,200 in drilling and support activities (#2) and 60,300 in refineries (part of #3), according to the Bureau of Labor Statistics (2025a, b). The Texas Independent Producers and Royalty Owners Association (2025) estimates similar numbers in these categories in 2024, plus 47,000 supplying equipment to oil and gas fields, 98,200 in petrochemicals and other downstream processing (part of #3), 341,000 in pipelines and other transportation and distribution (part of #4), and 1,115,600 in gasoline stations and other sales and marketing (#5).
- Worldwide in 2023, there were 13 million jobs in power generation (#5) across all sources, fossil and clean, compared to 19 million in fossil fuel supply (#1, #3 and part of #2), according to the IEA (2024b).
- Another example at national scale is based on a forward-looking study on future skills and job creation through renewable energy in South Africa, including both direct and induced employment (Hartley et al 2019). The study finds that, by 2050, more than 150,000 new jobs would be created in a high-renewables power sector, an increase of 17% in net terms i.e. accounting for job losses in the coal sector. Economy-wide, including induced employment, the study estimates a far greater employment potential, of 1.6 million additional jobs by 2050 through energy transition.
- Estimates of induced employment (#7) vary widely, with differing methodologies and definitions. In the UK, consultancy Experian (2024) estimates 85,100 induced jobs in 2023, compared to 26,000 direct oil and gas workers (#1) and 94,500 supply chain

[14] This can also have wider knock-ons than the share of workforce affected: for example in both India and South Africa, the state-owned railway companies depend economically on coal transport (Viswanathan et al 2022; Burton et al 2019)

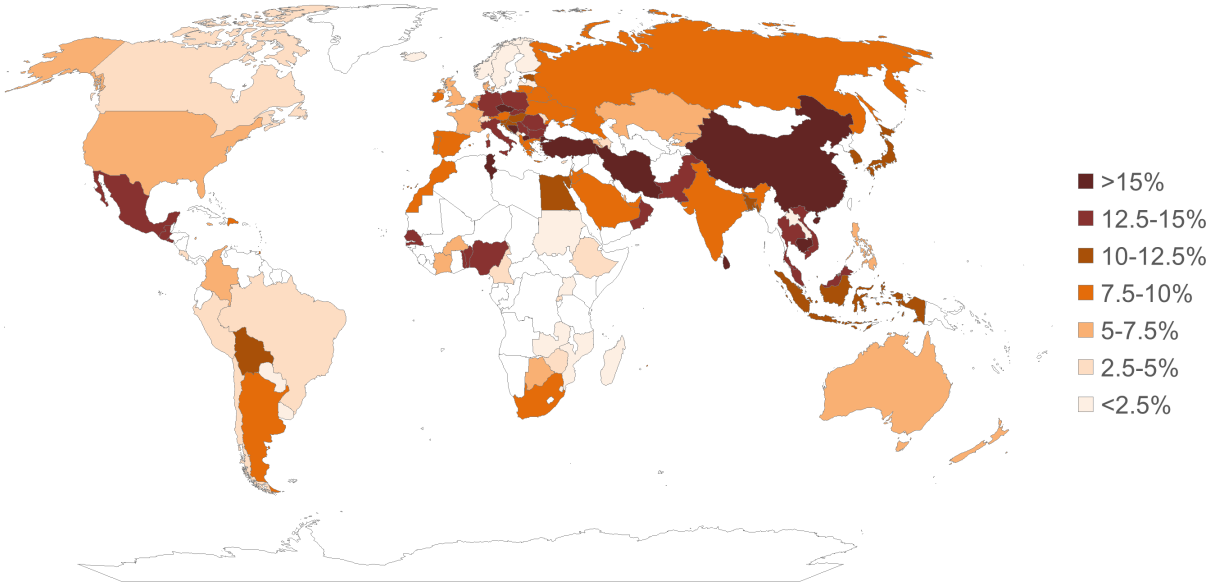
workers (#2), implying a multiplier of 1.7. In the United States, the Texas Independent Producers and Royalty Owners Association (2025) estimates a surprisingly high multiplier of 13-14 for direct extraction and 5-6 for drilling and support services in 2024.

The balance of types of jobs varies according to countries' level of development, technical capability and economic strategy, and also differs between the three fossil fuels. In a new, export-oriented oil producer, production tends to occur in economic enclaves, with jobs for the country's own nationals mainly only in the lower-skilled roles in categories 1 and 2, and in categories 6 and 7. Over time, countries often seek to build technical capacity, and with it the backward and forward linkages with their economies. With fewer technological barriers and lower capital intensity, the coal sector has seen this process of building linkages advance more readily than oil and gas.

However, the most obvious fossil fuel worker categories 1, 3, 4 and 5 are among the smallest categories, whereas the largest numbers of jobs dependent on fossil fuels are in energy-consuming sectors (especially for coal) and fossil-funded public sectors (especially for oil).

Worldwide, 14% of the workforce is employed in manufacturing, according to the United Nations Department of Economic and Social Affairs (2025). While only indicative of the degree to which those jobs depend on fossil fuels, 54% of the energy used in manufacturing worldwide is from oil, gas and coal, with a further 30% from electricity and 9% from heat (the remaining 8% is from biomass and waste) (IEA 2025a). 38 countries depend on fossil-fuelled manufacturing for more than 10% of total employment, defined as the manufacturing sector's share of employment, multiplied by the share of manufacturing's energy provided by fossil fuels or fossil-generated electricity (Figure 5.4 and Table 5.2).

Figure 5.4: Dependence on fossil fuels for manufacturing jobs. *Defined as manufacturing share of employment, multiplied by share of manufacturing energy provided by fossil fuels or fossil-generated electricity. All data 2022 except Cambodia, Pakistan and Oman 2021*



Data sources: United Nations Department of Economic and Social Affairs (2025); IEA (2025a)

Table 5.2: 38 countries exceeding 10% dependence on fossil fuels for manufacturing jobs. *All data 2022 except Cambodia, Pakistan and Oman 2021. Shading indicates the largest fossil fuel in the manufacturing-energy or power mix: grey for coal, yellow for oil, blue for gas.*

	Manufacturing share of employment	Fossil (direct) share of manufacturing energy	Electricity share of manufacturing energy	Fossil share of power generation	Manufacturing job dependence on fossil fuels[15]
China	29%	52%	35%	65%	22%
Tunisia	19%	76%	24%	96%	19%
Iran	18%	100%	0%	n/a	18%
North Macedonia	20%	64%	32%	73%	17%
Sri Lanka	17%	98%	0%	n/a	17%
Czechia	26%	49%	30%	50%	17%
Türkiye	20%	65%	31%	58%	17%
Cambodia	16%	100%	0%	n/a	16%
Bosnia and Herzegovina	18%	63%	37%	68%	16%
Viet Nam	21%	56%	27%	51%	15%
Malaysia	17%	89%	0%	n/a	15%
Italy	18%	58%	36%	63%	15%
Pakistan	15%	100%	0%	n/a	15%
Mexico	17%	75%	18%	70%	15%
El Salvador	15%	100%	0%	n/a	15%
Slovakia	24%	56%	25%	18%	14%
Poland	19%	50%	28%	79%	14%
Nigeria	14%	89%	11%	76%	14%
Senegal	15%	71%	22%	85%	14%
Guatemala	14%	100%	0%	n/a	14%
Romania	20%	57%	29%	38%	13%
Serbia	19%	46%	36%	72%	13%
Oman	13%	100%	0%	n/a	13%
Togo	14%	59%	41%	78%	13%
Benin	14%	75%	16%	97%	13%
Thailand	16%	56%	29%	81%	13%
Germany	19%	50%	33%	49%	13%
Bulgaria	18%	55%	27%	48%	13%
Slovenia	22%	46%	39%	28%	12%
Japan	14%	59%	35%	69%	12%
Egypt	13%	66%	34%	87%	12%
Croatia	18%	57%	27%	37%	12%
Hungary	21%	44%	36%	34%	12%
Bolivia	11%	100%	0%	n/a	11%

[15] Col.6 = Col.2 x (Col.3 + [Col.4 x Col.5])

	Manufacturing share of employment	Fossil (direct) share of manufacturing energy	Electricity share of manufacturing energy	Fossil share of power generation	Manufacturing job dependence on fossil fuels[15]
Estonia	18%	27%	53%	67%	11%
Indonesia	14%	81%	0%	n/a	11%
Bangladesh	11%	100%	0%	n/a	11%
South Korea	16%	34%	54%	64%	11%

Data sources: United Nations Department of Economic and Social Affairs (2025); IEA (2025a)

It is not possible to find systematic data for public sector employment supported by fossil fuel revenues. Table 5.3 calculates this using data compiled from various sources, for some of the largest oil and gas producers. For ten of the eighteen countries shown, more than 5% of the national workforce depend on oil-and-gas-funded public sector jobs, defined as the public sector share of the workforce, multiplied by the oil and gas share of fiscal revenues.

Table 5.3: Dependence on oil and gas for public sector employment. Shown for 18 of the 20 largest oil and gas producers *(data were unavailable for Malaysia and Oman).*

	Oil & gas share of fiscal revenue 2021[16]	Public sector share of workforce 2021[17]	Public sector job dependence on oil & gas[18]
Iraq	88%	37%	33%
Algeria	40%	41%	16%
Kuwait	59%	16%	9%
Norway	29%	31%	9%
Saudi Arabia	58%	13%	7%
Iran	46%	16%	7%
Russia	23%	31%	7%
Kazakhstan	31%	20%	6%
Qatar	52%	11%	6%
UAE	53%	10%	5%
Mexico	19%	11%	2%
Nigeria	38%	4%	1%
Indonesia	8%	9%	1%
Brazil	5%	12%	1%
Canada	2%	21%	0.4%
Australia	1%	29%	0.3%
China	0.5%	23%	0.1%
United States	0%	14%	0.0%

[16] See Section 6.2, Figure 6.2

[17] Except Kuwait 2025; Indonesia, Nigeria and Qatar 2022; Kazakhstan 2018; Russia 2016.

Sources: Arab Times (2025), Chinascope (2023), Gulf Research Centre (2022), IMF (2018, 2019), International Labour Organisation (2025), National Planning Council (2025), OECD (2018, 2023)

[18] Col.4 = Col.2 x Col.3

5.4 Structure of the economy

As the foregoing review of fossi-related employment illustrates, fossil fuels commonly play a far wider role in a country's economy than in direct extraction and use. At stake is a country's economic structure and development strategy. For example, coal has been central to the story of China's rise in the late twentieth and early twenty-first century, where rapid industrialization and economic growth, especially since the late 1990s, lifted China to the world's second largest economy. Coal became a key driver of economic development and a symbol of national identity in both post-independence India and post-apartheid South Africa, and in both cases it was developed with strong support from the trade union movement. In India, coal was embraced to fuel self-sufficient industrialization, including in heavy industry sectors such as iron and steel, and later to achieve electrification of homes (Lahiri-Dutt 2016). South Africa's economy has been shaped by the minerals-energy complex (Fine and Rustomjee, 1996), creating a structure that is highly coal-dependent and capital-intensive, with low employment intensity (Winkler and Marquard, 2009).

Oil too has played a role in shaping national identities, often as a powerful symbol of post-colonial independence, national capability and hope for a thriving future (Turkamani 2025; Gillies et al 2021). Tied to these notions, producer countries have sought to indigenise more of the workforce, in some cases nationalizing production, and to build backward linkages through domestic supply chains. This process has been most successful in countries with high existing capability (e.g. Norway), or with very large reserves and hence long experience of extraction (e.g. Saudi Arabia, Mexico).

Many oil producers have relatively weak forward linkages. Some major exporters of crude oil nonetheless import a significant share of their refined oil products: for instance, Brazil imported 10% of its oil product needs in 2023, Mexico 46%, Angola 61% and Nigeria 99% (IEA 2025a). Other producers have built refining capacity to capture more of the added value. Some, such as the Gulf states, have gone further and adopted economic strategies emphasising downstream use of their oil and gas, as feedstocks in petrochemicals or to fuel energy-intensive heavy industries. Such forward linkages have historically been seen as a means to diversify economies away from reliance on primary commodity exports, by playing to their comparative advantage in cheap fossil fuels (Fattouh and Sen 2021). While such shifts may diversify the economic activities, they increase rather than reducing dependence on fossil fuels, and so are less promising paths in a low-carbon world.

Even aside from the need to reduce emissions, economies dependent on fossil energy face growing challenges. As clean energy becomes ever cheaper (Sections 2.3, 4.1), fossil-dependent economies risk becoming uncompetitive. Development strategies based on fossil-fuelled heavy industry are failing to create jobs for growing populations, such as in South Africa (Winkler and Black, 2024). Similarly, in heavily oil dependent countries in the Middle East, the oil sector has too few jobs to absorb the younger generation, while weak private sectors also generate too little growth (Kabbani 2021; IMF 2016). The results are worsening unemployment and stagnation or even decline of per-capita incomes.

At a regional level, economic challenges tend to be even greater than nationally. Often the fossil producing regions have high levels of poverty and inequality, environmental degradation, weak institutions, low productivity and few other sources of income, making them particularly

vulnerable to the transition. For example, the oil-producing Niger Delta region has the highest unemployment rates and lowest development levels in Nigeria (Ukpe 2020; Alakwe 2024). In some cases, such as in Cesar in Colombia and Jharkhand and Chhattisgarh in India, fossil fuel companies provide a large share just only of economic activity but also of social spending (Furnaro and Yanguas Parra 2022; Chhotray 2022). This extensive regional dependence indicates that the solution is not simply to replace fossil jobs with alternative ones, but to transform economies to rest on a more diversified base, with a range of opportunities in alternative economic activities.

Shifting countries' and regions' development pathways towards sustainability can simultaneously achieve emissions reduction and other Sustainable Development Goals (IPCC 2022: Chapter 4; UNEP 2023: Chapter 6). In economies dependent on fossil energy, a paradigm shift in industrial policy can change the composition of the economy away from energy-intensive sectors toward new industries that can sustain development and jobs under carbon constraints (Burton 2011).

However, transforming the composition and structure of an economy is no small task. In the past, the transformation aimed at higher income, through increased productivity. Structural transformation needs to be redefined, meaning not only increased productivity, but more employment and lower emissions. The challenge now is that economic transitions have to create jobs, reduce emissions and build adaptive capacity. Green industrial policy is an important approach, and concepts, policies and national contexts have been increasingly studied internationally (Altenburg & Assmann, 2017). It has been explored for the African context, with expert recommendations on possible pathways (Green Industrial Development Expert Panel 2025) and consideration of political economy (Medinilla & Byiers 2023).

Economic transformation is explored further in Section 6.3.

5.5 Implications for equitable energy-economy transitions away from fossil fuels

We now draw out the key implications of Section 5. Transition progress can be made by capitalising on opportunities and benefits:

- **Greater job creation**: Renewable energy generation employs more people than fossil fuels, per unit of energy and per dollar invested. Energy transitions are net job-creating. Salaries in renewable energy are, on average, higher than in coal but lower than in oil and gas. However, not all employment lost in fossil fuels can be replaced in cleaner energy. Hence in thise transitions, creating employment will also need attention to regional economic development, non-energy sectors (e.g. agriculture, services), and re-skilling.
- **More dynamic clean economies**: Transitioning away from fossil fuels creates and opportunity to build more diverse, prosperous and inclusive economies. In contrast, capital-intensive, fossil-reliant economies can suffer low employment levels and stagnant per-capita income. Fossil-producing regions, such as the Niger Delta in Nigeria, or Jharkhand and Chhattisgarh in India, often have high levels of poverty and inequality, environmental degradation, weak institutions and low productivity.

Dependence on fossil fuel jobs and industries shapes how fast countries can transition:

- **Fossil fuel jobs**: Direct fossil fuel employment is rarely more than 1-2% of the national workforce, but can be up to 8% in fossil-fuel-producing regions. The effect of dependence is greater where fossil fuel jobs are better paid than alternatives, and where larger households depend on each job.
- **Indirect jobs**: The number of jobs indirectly dependent on fossil fuels can be significantly larger. 38 countries rely on fossil-fuelled manufacturing for more than 10% of national employment, with China the highest at 22%. At least 10 countries rely on fossil-funded public sector jobs for more than 5% of national employment, with Iraq the highest at 33%.
- **Economic structure**: Some countries have economic strategies and structures strongly based on fossil energy. For example, the South African and Indian economies rely heavily on coal-fired industry and power generation, while the Saudi and other Gulf economies are built around plentiful local supplies of oil and gas.

Policy interventions can help enable equitable energy-economy transitions:

- **Ensure just transitions for workers and communities**: to address disparities in geography and skills, to sustain livelihoods and ensure the quality of new jobs, to build local and regional economies, and to manage the transition process fairly.
- **Pursue structural transformation**: evolving from a narrow focus on increasing productivity per worker, to also increase employment, reduce fossil fuel dependence and achieve Sustainable Development Goals.

6. Economic transitions and new sources of wealth generation

In some countries, the economic role of fossil fuels goes deeper than powering industry and the economy. While previous sections addressed energy use, for many countries, the contribution of fossil fuels is more about money than energy. This section explores economic transitions away from fossil fuel dependence, and opportunities of more diversified economies. Significant fiscal revenues and export earnings are generated by fossil fuels, especially oil, and to a lesser extent gas and coal (Section 2.2). Oil revenues can play a dominant role within economies: this dominance both necessitates a more fundamental structural transformation, but also makes that transformation more difficult. Building on the previous section's discussion of transforming economies that depend on fossil energy, this section focuses on these deeper aspects of economic dependence (primarily on oil and gas), where their contribution is more about money than energy.

6.1 The economic imperative and resilience

While countries clearly benefit from the fiscal revenues and export earnings from oil and gas, heavy reliance on these can distort a national economy and hold it back from change. For example, resource-dependent economies are vulnerable to fluctuations in international commodity prices, and tend to suffer lower productivity and often stagnant non-resource sectors (Addison and Roe 2024; Gapa 2020). Conversely, diversified economies perform better than those that depend heavily on one or two sectors. Diverse economies can experience faster economic growth, especially in countries at early stages of development, and reductions in poverty and inequality (Delechat et al 2024).

For these reasons, economic diversification has been a key policy priority for major oil and gas exporters since at least the 1970s – well before climate change became a significant international policy issue. The unfolding of energy transitions globally, however, adds urgency to the need to diversify. As reviewed in Section 3.2, demand for coal, oil and gas is set to peak in the coming years, followed by a slow decline under existing policies. Efforts to limit climate change require governments to adopt further policies, which will cause a more rapid decline in fossil fuel demand.

How will these trends affect oil- and gas-exporting countries? Lower demand will lead to lower oil and gas prices, which will in turn reduce fiscal revenues and export earnings.[19] Previous periods of low prices – such as from 2014 to 2016, and in 2020 – illustrate the difficulties these countries can then face. Government services, employment and economy become stressed. In some cases, a fiscal crunch or disrupted balance of payments can in turn provoke wider macroeconomic crisis, including loss of investor confidence, economic contraction, inflation and falling exchange rates (Semieniuk et al 2021; Daumas 2023). Governments may find themselves less able to manage the crisis, as they are fiscally squeezed.

[19] These lower prices arise because the equilibrium point where supply matches demand now occurs at lower volume and lower price: more-expensive supplies are no longer needed. In the short term, OPEC can slow the fall in price by restricting supply (and hence pushing the equilibrium point higher). Over the longer term, doing this reduces OPEC's market share and market power, limiting OPEC's ability to resist structural changes in the oil market (Muttitt 2026, forthcoming).

For example, following the oil price crash due to Covid-19, Iraq's fiscal deficit ballooned to 15% of GDP in 2020 (IMF 2021). The government was unable to pay monthly public sector salaries (Iraq Studies Unit 2020), the population's most important income source, at the same time as the devaluing dinar increased the price of food and other essentials (Arraf 2021). As a result, 4.5 million Iraqis fell below the poverty line, and the child poverty rate nearly doubled to 38% (Unicef 2020). Whereas previous periods of low oil price have been temporary, the global transition away from fossil fuels is systemic and long-term.

The impacts will be greatest in the countries where production costs are highest. In these countries, the margins are smaller, and so are more affected by any reduction in the price. Investments in higher-cost production run the risk of becoming stranded assets, which fail to deliver the expected returns, as markets decline after the capital has been invested.

An assessment by Carbon Tracker Initiative estimates that 29 of the 40 most oil-dependent countries could lose more than half of their expected oil and gas revenues in a moderately-paced transition where the world's governments achieve their net-zero pledges, shown by Carbon Tracker in Figure 6.1. The moderately-paced transition is based on the IEA's (2024d) Announced Pledges Scenario, which leads to 1.7°C of warming. Limiting warming to 1.5°C would have a correspondingly larger impact on government revenues.

Countries' economic vulnerability is greatest in countries that both stand to lose a high proportion of their oil and gas revenues (y-axis) and that rely heavily on oil and gas as a share of total revenues (x-axis) – that is, countries in the top right of Figure 6.1. In nine highly vulnerable states, total fiscal revenues could fall by more than 60% from present levels (Prince et al 2023). Figure 6.1 does not include countries with low dependence on oil and gas revenues such as the United States and Canada (see Figure 6.2), where the relative economic impact of transition will be smaller, compared to the size of the economy.

Figure 6.1: Vulnerability of government revenues to reduction in demand during moderate-paced energy transition

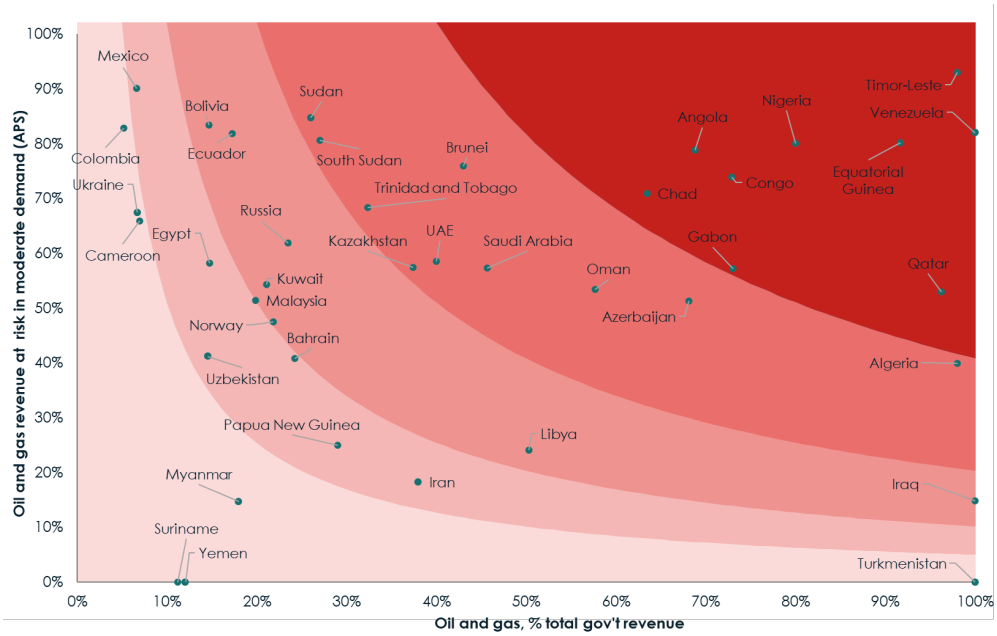


Figure reproduced from Prince et al (2023)

The above analysis assumes that demand for fossil fuels will be met by the lowest-cost (hence most competitive) supply: in other words, it assumes markets play a central role in determining which supply sources are most affected. The uneven distribution of these impacts – disproportionately affecting developing countries – illustrates an aspect of both disorderly and inequitable transitions. A managed and negotiated process of transition can help reallocate the changes to where they can be managed with least social cost (Muttitt and Kartha 2020), rather than leaving it to markets. Countries with costlier production conversely have less to gain from continued production, so may be more open to alternative development pathways.

Even producers with the lowest-cost production – such as in the Middle East – will be affected. Whilst their production is unlikely to become uncompetitive, those governments' budgets will be reduced by any fall in the global oil price, especially where oil provides a large portion of fiscal revenue.[20] In rentier states (Beblawi and Luciani 1987), whose political stability rests on allocation of oil revenues to various groups in society, loss of revenues can also lead to political instability (Gopalakrishnan and Miller 2024).

6.2 Economic dependence on oil and gas

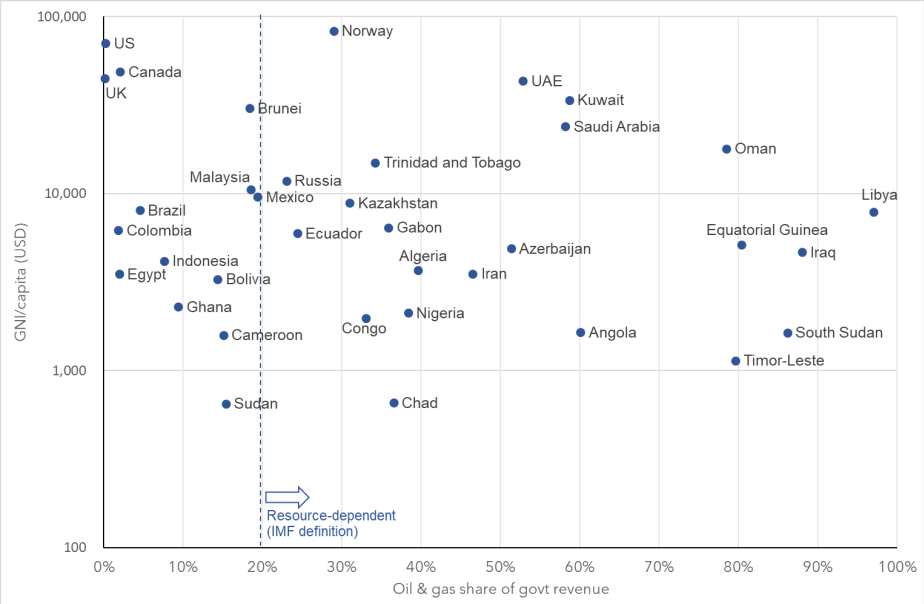
In an unfortunate irony, the countries that most need to increase their economic resilience by transitioning away from oil and gas exports are the countries that will find it hardest. This is because high dependence on fossil revenues creates both economic vulnerability and barriers to reducing it. Under the *status quo*, economies that depend heavily on oil and gas face severe economic risks as the global energy transition unfolds outside their borders. Economic transitions need to be implemented, but will take time if they are not to raise the same issues: loss of fiscal revenue or of export earnings. This is a difficult balance: oil- and gas-dependent countries will need to transition as quickly as possible to reduce their economic vulnerability, but not so fast as to gravely disrupt their economies.

In 22 countries worldwide (data annex), oil and gas generated more than 20% of fiscal revenue in 2021; in about 10 of these countries, it was more than 50%, and in some as high as 80% or 90%: Libya, Iraq, South Sudan, Timor-Leste, Equatorial Guinea and Oman. In such countries, oil and gas revenues not only provide fiscal resources to fund public services, but commonly underpin the wider economy, as public-sector employment and public investment in other sectors are often major elements of the economic structure. Figure 6.2 shows oil and gas share of government revenue on the x-axis, and gross national income (GNI) per capita on the y-axis. Governments' ability to overcome their revenue dependence will be determined by the resources they have to invest in alternative sectors, or to weather any disruptions to oil and gas revenue. Thus transitions will be most difficult for countries in the bottom right of the figure, and least difficult for those in the top left.

Oil and gas' role in exports is even greater: about 20 countries rely on oil and gas for more than half of their exports, some of them at 90% or higher: Iraq, Libya, Algeria, Angola, Nigeria and Azerbaijan (Figure 6.3). In these cases, oil and gas play a powerful role in the balance of trade, currency valuation, credit ratings and macroeconomic prospects.

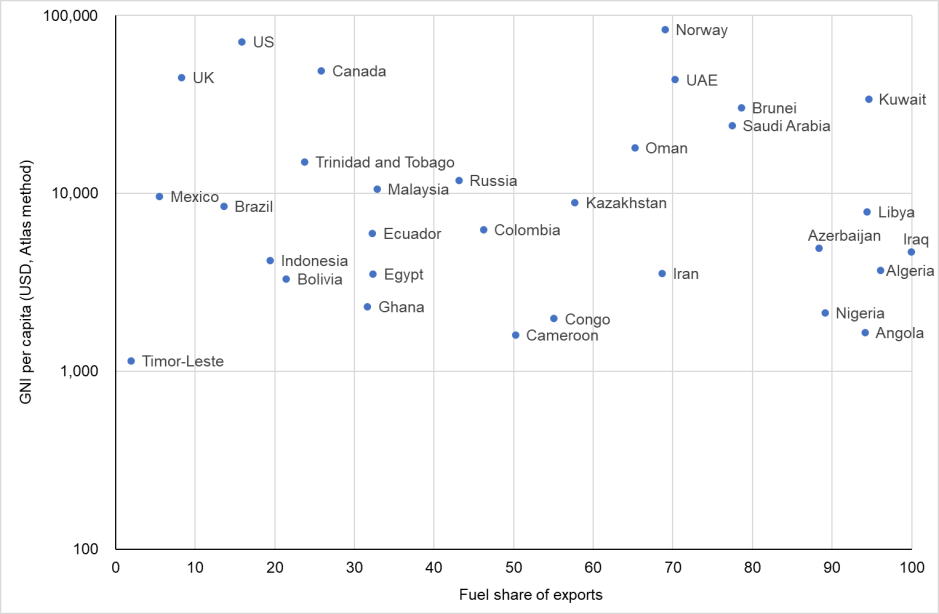
[20] Even where oil is cheap to extract, and so commercially competitive, oil-dependent states rely on a given level of revenue to balance their budgets, indicated by the "fiscal breakeven oil price".

Figure 6.2: Oil and gas share of government revenue,[21] and countries' GNI per capita. *GNI per capita (y-axis) is shown on a logarithmic scale*



Source: Data from World Bank and IMF or national accounts, updating graph from Muttitt & Kartha (2020)

Figure 6.3: Oil and gas share of exports (by value), and countries' gross national income. *GNI per capita (y-axis) is shown on a logarithmic scale*



Data source: World Bank (2025c)

While nowhere is EFFT trivially easy, the challenges of overcoming heavy economic dependence on fossil fuels is perhaps the most significant difference in circumstances

[21] Revenue shares differ in some cases between Figures 6.1 and 6.2 because they are taken from different sources: Figure 6.2 takes the shares directly or indirectly (via IMF reports) from national accounts, whereas Figure 6.1 estimates them from Rystad Energy's UCube model.

between countries. Transforming these highly-dependent economies – without major social costs through loss of public services, unemployment or wider economic collapse – is a vast task. Conversely, the good news is that transition in some major producers such as the United States and Canada will have a very small impact on fiscal revenues, implying that such countries can achieve just, orderly and equitable transitions over a faster timeline. The task of transitioning away from fossil fuels is considerably different where they provide more than 50% of revenues, compared to where they provide less than 2%.

As for coal, only in Mongolia does it constitute a major share of exports, at around 50% of the total (World Integrated Trade Solutions 2022). Data are not available on coal's share of fiscal revenues; the mining sector as a whole (also including gold, copper and iron) accounts for around 30% (Extractive Industries Transparency Initiative 2022). In a few other countries, coal constitutes more than 10% of total exports: Colombia (18%), Australia (17%), Indonesia (11%) and South Africa (10%) (López and Patzy 2021; Edwards et al 2022; Beutel et al 2025; World Bank 2025c). In these cases, the contribution to national fiscal revenues is relatively small: in Colombia, for example, it is estimated at an average of USD 1.75 billion per year between 2013 and 2020 (López and Patzy 2021), equivalent to about 3% of total government revenue (IMF Article IV reports). Apart from Mongolia, fiscal revenues from coal are significant only at a subnational level, and only in a few places. In Colombia's Cesar region, coal mining provides around a third of fiscal revenues for local governments (Furnaro and Yanguas Parra 2022). In Jharkhand, India, coal provides 17% of the state's fiscal revenue (Srivastava 2025).

It is worth noting that governments of oil-importing countries receive greater revenues from the oil than those of oil-exporting countries. The Organisation of the Petroleum Exporting Countries (OPEC 2025) estimates that of the price paid for a litre of fuel in 2024, 46% was taken as fuel taxes and duties by governments in the consuming country, while just 33% reflects the price of crude oil, which is shared between covering the costs of production and providing income to producer governments as the owners of the resource. However, whereas in producing countries this can be a very large proportion of total fiscal revenue as we've seen above, developed economies have a more diversified fiscal base, and so less dependence on revenues fossil fuel consumption. For example, while the United Kingdom took 52% of the price paid for fuel, this amounts to only 1.9% of total fiscal revenues (Office for Budget Responsibility 2025). In some oil-importing emerging economies, revenues from fossil fuel consumption play a larger role than this – 15.6% in India, 8.9% in China and 5.3% in South Africa in 2019 (Laan and Maino 2022) – but still well below that of revenues from production in the most dependent countries.

Conversely, fossil fuel subsidies constitute a cost to governments, often a large share of budget expenditure. Subsidies to fossil fuel consumers amounted to USD 862 billion worldwide in 2024, and subsidies to producers USD 43 billion (IISD and OECD 2025).

6.3 Economic transformation

Achieving greater economic resilience will require efforts to transform the economy. Shifting the development path of an entire economy is a major challenge. As for other types of transitions, creating a shared vision to EFFT, and sustaining institutional momentum for long term change, are key drivers.

In the case of oil, the challenge is heightened by the fact that no other sector – except some types of finance – is generally able to generate economic rents on the same scale. Thus the need is not simply to substitute oil with a single alternative sector, but rather to restructure the economy to rest on a larger number of sectors and a broader base.

There are two main elements to this transformation:

- **Fiscal diversification**: to reduce fiscal reliance on oil and gas, by introducing new or expanding existing sources of government revenue and by improving the effectiveness of collection.
- **Economic diversification**: to broaden the base of the economy (including the export basket), from one dominated by fossil fuels, to one with many sectors.

Both of these are needed, to reduce the respective vulnerabilities. Progress can be made on fiscal diversification in the nearer term, whereas economic diversification entails long-term, structural shifts. The two processes are linked, however: full fiscal diversification will require a broader base of economic activity from which to raise revenues (such as through income and profit taxes), while economic diversification is helped by making fiscal revenues a less central part of the economic structure.

In addition, to make the change politically sustainable, governments will also need to build a national consensus around the country's future economic direction.

A step towards fiscal diversification that doesn't require political trade-offs is to improve the collection rate of existing taxes, an approach Nigeria is presently prioritising (Olorounbi 2024). Some taxes are simpler to administer than others, such as excises and value-added taxes. Saudi Arabia and the UAE introduced value-added taxes in 2018, and Bahrain in 2019; Oman introduced excise taxes on tobacco and soft drinks in 2018 (Magazzino, 2022). Oil-dependent states may see opportunities to target inequality with wealth taxes (Luciani, 2021), or energy over-consumption with vehicle or fuel taxes or with carbon pricing (Laan and Maino, 2022). Other revenue sources, such as business taxes and personal income taxes, may become a strong fiscal backbone once the tax base has grown, in the form of new profitable sectors and private sector employment that do not depend on oil revenues.

As for diversifying the wider economic base, significant investment is required to expand productive capacity beyond extracting and exporting oil and gas. Countries should redirect accumulated revenues to grow other sectors, including manufacturing, services, agriculture and technology. Structural transformation must be socially inclusive, seeking to maintain similar quality of jobs and create opportunities for local communities. Transparent revenue management and dedicated transition funds are important.

There are two schools of thought on how to undergo economic diversification. On one view, the key is to create enabling conditions in which market-driven innovation can thrive and new sectors grow, including physical infrastructure, human capital, and knowledge capital (Peszko et al 2020). On the other, governments adopt deliberate industrial strategy to build the sectors that play to their strengths (Lebdioui 2019). While there are debates about the pros and cons

of governments “picking winners”, most countries will need both to create enabling conditions and pursue industrial strategy.

There have been a few success stories. Indonesia, a former OPEC member, moved from the late 1980s to labour-intensive, export-oriented manufacturing, especially clothing and shoes (Braithwaite and Gerasimchuk 2019). Once oil-dependent, the emirate of Dubai diversified in the 1990s into import/export logistics and trading, and later into finance, luxury property and tourism (Mishrif and Kapetanovic 2018). In both cases, enabling conditions were created through economic reforms, combined with industrial strategies playing to Indonesia’s young workforce and increasing integration into the APEC and world economies, and to Dubai’s mercantile culture and geographical location at the heart of the Gulf.

However, most countries have not managed to significantly reduce their economic dependence on oil, even during many decades when diversification was a high policy priority. Alsharif et al (2017) find that out of 35 major oil exporters in the 1970s, only eleven had reduced their oil dependence forty years later, and some of these only to a small degree. For example, Saudi Arabia consistently increased its non-oil share of exports over the period, but only from 2% in 1974 to 14% in 2014.

Both Dubai and Indonesia were confronted by geological depletion of their reserves, giving them little choice but to build alternative sectors. Similarly, Kabbani (2021) observes that across the Gulf Cooperation Council countries, progress on economic diversification is inversely correlated with remaining reserves. In contrast, economic dangers – whether from reliance on volatile prices or from declining export markets – have so far tended to inspire less consistent efforts: governments have emphasised the importance of diversification while they were feeling the pain of low oil prices, but de-prioritised it when things were more fiscally comfortable during high-price phases (Hvidt 2013). A key to managing the transition will be for governments to internalize the systemic changes happening through the global energy transition, to drive action in the way that depletion has done elsewhere.

The process of diversification generally takes decades. Time is needed to build new capacities, including workers’ skills, competitive companies and underpinning infrastructure. Without these foundations, investments are unlikely to succeed. Success is also likely to require innovation, a process that takes time; initially, a new path is inherently more uncertain, compared to continuation of the status quo. Second, there are structural barriers to change, creating path dependency and inertia. Economically, a dominant oil and gas sector can make other sectors less competitive, by driving up exchange rates and sucking up capital and labour inputs – a problem known as Dutch disease (Hvidt 2013; Stevens, Lahn and Kooroshy 2015). Politically, oil- and gas-exporting countries can develop rent-seeking cultures, where segments of society compete to capture the oil and gas rents, and the beneficiaries of this structure will actively oppose changes that reduce those benefits (Beblawi and Luciani 1987; Ulrichsen 2017).

Given the time it is likely to take, and noting that achieving the Paris temperature goal requires most fossil fuel use to be ended in the next 25 years (Section 3.2, Figure 3.4) governments would be well advised to begin concerted efforts on economic transformation now, in order to make significant progress before their export markets are gone. Economic transitions require

time and sustained commitment, yet the urgency of climate change means investment now is essential.

6.4 Implications for equitable economic transitions away from fossil fuels

Drawing together the lessons of this section, transition progress can be made by capitalising on opportunities and benefits:

- **Stronger economies**: Diversified economies perform better, with faster economic growth, and reductions in poverty and inequality, compared to resource-dependent economies, which are vulnerable to fluctuations in international commodity prices, and tend to suffer lower productivity and often stagnant non-resource sectors.
- **Reducing exposure to transition risks**: Countries that depend on fossil fuel revenues face economic threats as the world transitions and their export markets decrease. The dangers include reduced public services, loss of jobs, and sometimes wider macroeconomic crises. Non-fossil economies will be more resilient.

Dependence on fossil fuel jobs and industries shapes how fast countries can transition:

- **Diversified economies**: Some major producers are not significantly dependent on fossil fuel revenues, and with well-designed policies can achieve just transitions without major economic disruption: for example, in the US and Canada, fossil fuel production provides less than 2% of total fiscal revenues.
- **Revenue and export dependence**: Conversely, some countries' economies are deeply dependent on fossil fuels. Such countries not only need to manage dangers of economic disruption during transitions, they face economic and political barriers that will make just transitions take much longer. In 22 countries, oil and gas generated more than 20% of fiscal revenue in 2021; in about 10 of these countries, it is more than 50%, and in some as high as 80% or 90%: Libya, Iraq, South Sudan, Timor-Leste, Equatorial Guinea and Oman.

Policy interventions can help enable equitable energy-economy transitions:

- **Invest now in long-term transitions**: pursue economic diversification without delay, to stay ahead of changes in global energy markets, and putting in place enablers of long-term sustainable development; .
- **Diversify the economy**: Implement economic diversification including through infrastructure, skills and innovation support; and adopting industrial policies to support and invest in targeted sectors that play to the country's strengths.
- **Diversify fiscal revenue sources**: by introducing new sources such as excise, value-added or income taxes, and by strengthening mechanisms for collection of existing revenue streams.

7. Capability and readiness for transitions

The previous sections have examined how the opportunities and challenges of EFFTs differ between countries, including the ways in which economies depend on fossil fuels. It matters too where a country is on the fossil journey: whether fossil fuel production and consumption are growing or declining, and thus whether transition entails a change of direction or an acceleration of an existing direction. Transitions will be determined not only by these factors, but by countries' capabilities – including financial, institutional and governance, technological and others – to grasp the opportunities, and to manage and overcome fossil fuel dependency. This section assesses countries' capabilities to manage a transition, the role of international cooperation, and how present directions of travel shape readiness for transition, including the situation of new and prospective fossil fuel producers.

7.1 Capability for EFFT

A message from the preceding sections is that overcoming dependence on fossil fuels will require concerted policy efforts and investments. However, countries vary significantly in their capabilities to finance, drive and manage this process.

A simple indicator of economic capability is a country's income: a country with higher income will have more to spend on its EFFT. Some of the figures in this paper this show gross national income on the y-axis (Figures 6.2 and 6.3). A more sophisticated variant of this is to focus on a country's 'discretionary' income, above what is needed to meet people's basic living needs (Holz et al 2018). This is a more progressive measure, as in countries with lower income, more of that income is used to meet basic needs.

A third way to look at economic capability is through the human development index (United Nations Development Program 2025), as an indicator of how much of a country's resources need to be prioritized towards meeting essential human needs: a country with low level of development will find it harder to justify allocating scarce resources to transitioning away from fossil fuels. For developing countries, with typically lower incomes, a differentiated pace is a structural necessity to ensure that the speed of transition does not compromise basic human welfare or the ability to meet Sustainable Development Goals, particularly where financial and institutional resources are limited.

Countries' capacity to undergo equitable fossil fuel transitions is more limited where a significant portion of government budgets are spent on servicing external debts, and conversely greater where a country has a sovereign wealth fund that can be used both for investment and as a buffer against economic disruption.

In addition to economic and financial resources, a country's ability to undergo an EFFT is shaped by the quality of its institutions. The IPCC (2023: SPM) identifies governance as a key enabling condtion, and limited institutional capacity as an obstacle to mitigation. Without skilled people, institutions cannot be effective. Strong institutions are needed to design effective transition strategies, to overcome the inertia associated with vested fossil fuel interests, to manage and minimize negative economic effects, and to deliver a just transition, especially for those most affected. Institutions must also enable building of societal consensus supporting

transition, to avoid and manage political barriers to transition. Various indicators can be used to measure institutional capacity (e.g. World Bank 2024; Fund for Peace 2025; Economist Intelligence Unit 2024).

These differences emphasise the importance of international support in enabling EFFTs. Under the UNFCCC (UNFCCC 1992: Art.4.3) and its Paris Agreement (UNFCCC 2015: Arts.9-11), developed countries have committed to providing finance, technology transfer and capacity-building to developing countries. Where resources are limited, such provision will be crucial.

Indeed, given the challenges outlined in this paper, EFFTs will be far more achievable by countries cooperating together than each acting on their own. Countries in similar circumstances can share lessons on what has worked, and work together to solve common problems, including through creating economies of scale, shared institutions or united diplomatic efforts. At the same time, international cooperation should promote broad coalitions, including countries for whom economic transitions are more challenging and who will need longer. By providing targeted finance and capacity-building, the international community can help weaken the resistance of vested fossil fuel interests and enable highly dependent nations to manage the difficult task of structural transformation (Civil Society Equity Review 2024; Ngwadla 2025).

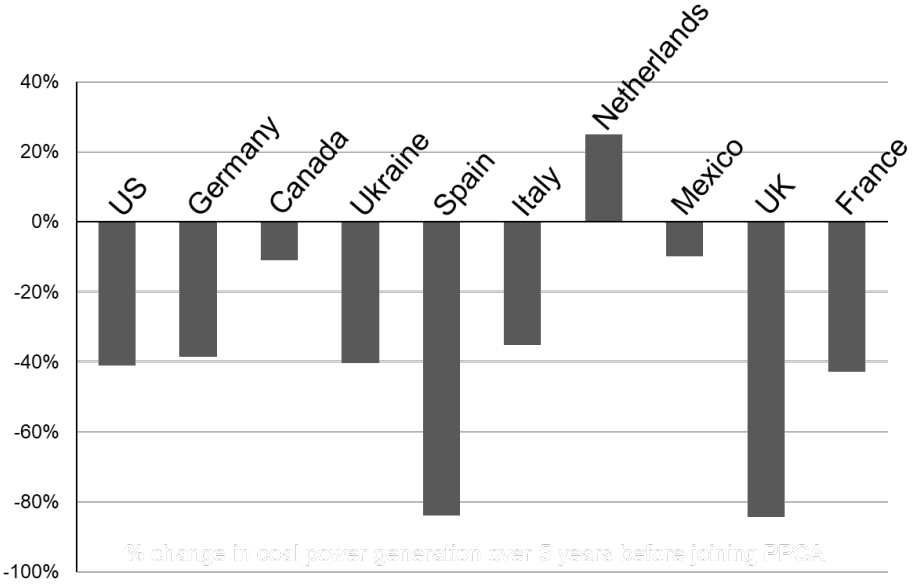
7.2 Progress precedes the pledge

A top-down conception of climate policy-making starts with international commitments, flowing down to governments adopting ‘aligned’ policies, and in turn to national stakeholders to implement them. Often however, an international commitment is made only once a government has resolved domestic political and policy issues and is quite confident it can achieve the goals, when the direction of travel is already clear and even some of the implementation work has been done. Coalitions that promote transitions away from fossil fuels may receive pledges first from those who have already transitioned, or are in the process of doing so.

Lægreid et al (2023) observe that in most countries that have joined the Powering Past Coal Alliance (PPCA), coal power generation has already peaked. Indeed, all but one of the 10 largest generators of coal power to join had seen declines in their coal generation during the 5 years before joining, and most of them quite significant declines (Figure 7.1).

The psychology and politics are quite different between situations of growth and decline. Expansion of fossil fuel infrastructure – whether for production or consumption – tends to thus gain momentum, as it sets a direction of travel and points to a country’s future potential. In contrast, where fossil fuel use or extraction are in decline, the status quo is already recognised as unsustainable, and the government has an incentive to consider what comes next to replace it, while investors and companies turn away, cost of capital rises and profits fall (Bond and Butler-Sloss 2022). Recall that the governments most engaged in economic diversification from oil and gas extraction, such as Indonesia and Dubai, have been those where geological depletion has already determined a future decline.

Figure 7.1: Change in coal power generation over the 5 years before joining PPCA



Data source: Energy Institute (2025)

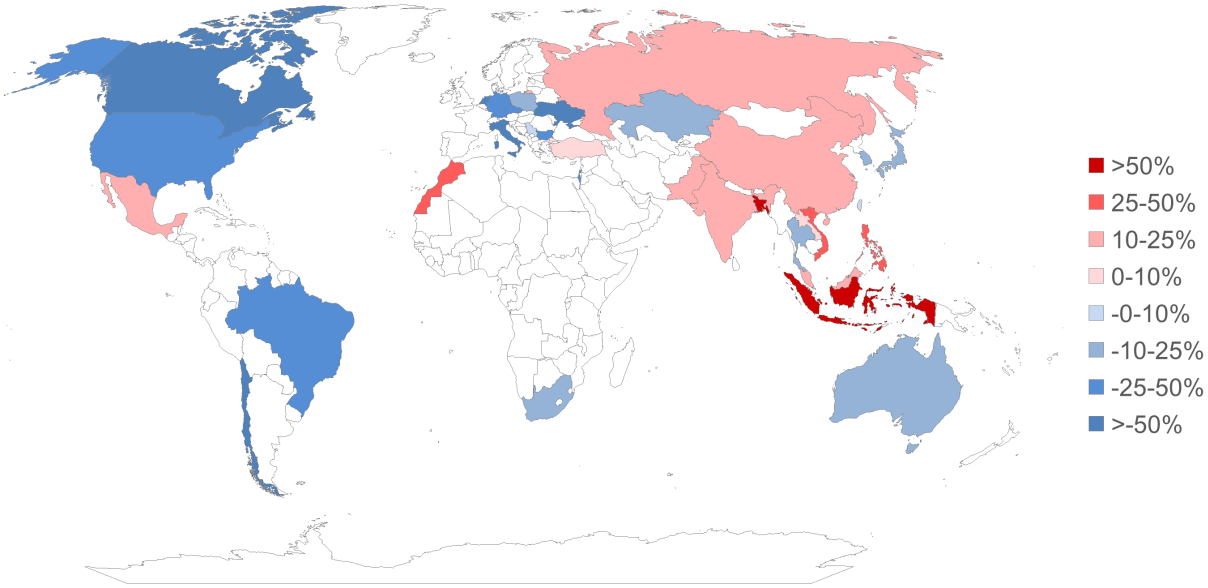
For early wins on EFFT, the lower-hanging fruit may be in accelerating transitions where decline has already begun. As shown in Figure 7.2:

- Of the world's 34 largest generators of coal-fired power, coal generation decreased from 2018 to 2023 in 21 countries, in 12 of them by more than 25%. Conversely, the largest percentage growth over that period was in Bangladesh, Indonesia and the Philippines.
- Of the world's 67 largest producers of oil and gas, production decreased in 41 countries, in 12 of them more than 25%. The largest percentage growth occurred in new producers Guyana and Mozambique (the largest absolute growth occurred in the United States).
- Of the 87 largest consumers of gas, consumption decreased in 41 countries, in 10 of them by more than 25%. The largest percentage growth occurred in Ghana, Turkmenistan and the Dominican Republic (the largest absolute growth occurred in the United States and China).

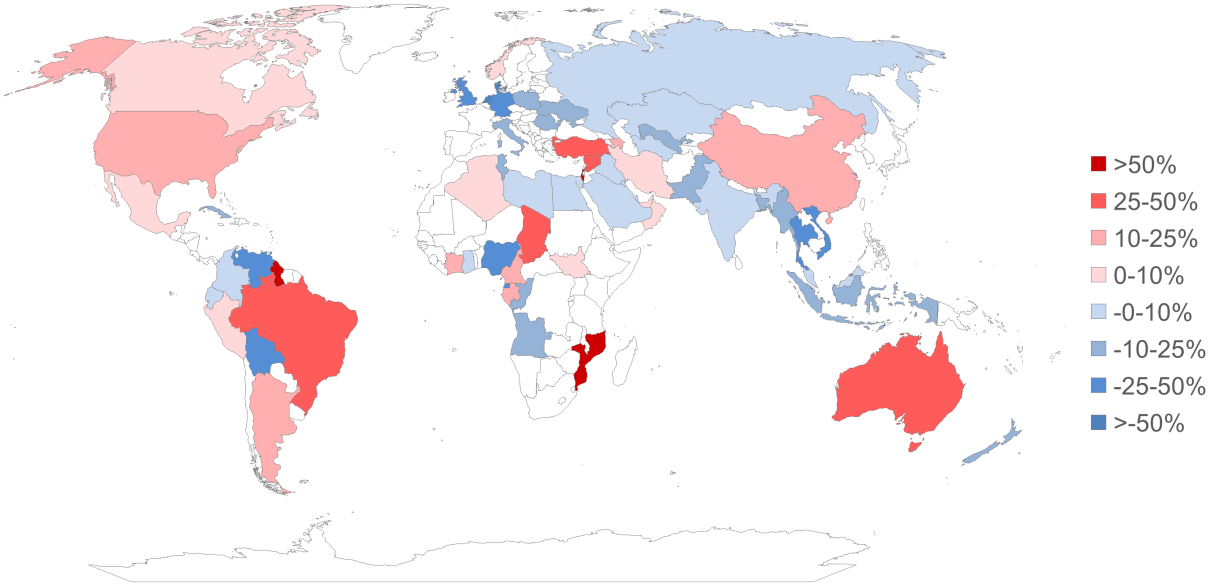
For countries where fossil fuel production and consumption are still growing, a longer process may be needed, beginning with shifting the visions for the countries development pathways (IPCC 2022: Chapter 4). Some countries, such as Gulf Cooperation Council members, are making efforts to diversify their economy even while continuing to increase fossil fuel production (Al-Muwari 2026).

Figure 7.2: Change from 2018 to 2023 in fossil fuel consumption or production. *Declines are shown in blue; increases in red. Countries are shown only if coal generation exceeded 10 TWh, oil and gas extraction exceeded 100 PJ and gas consumption exceeded 50 PJ in 2023.*

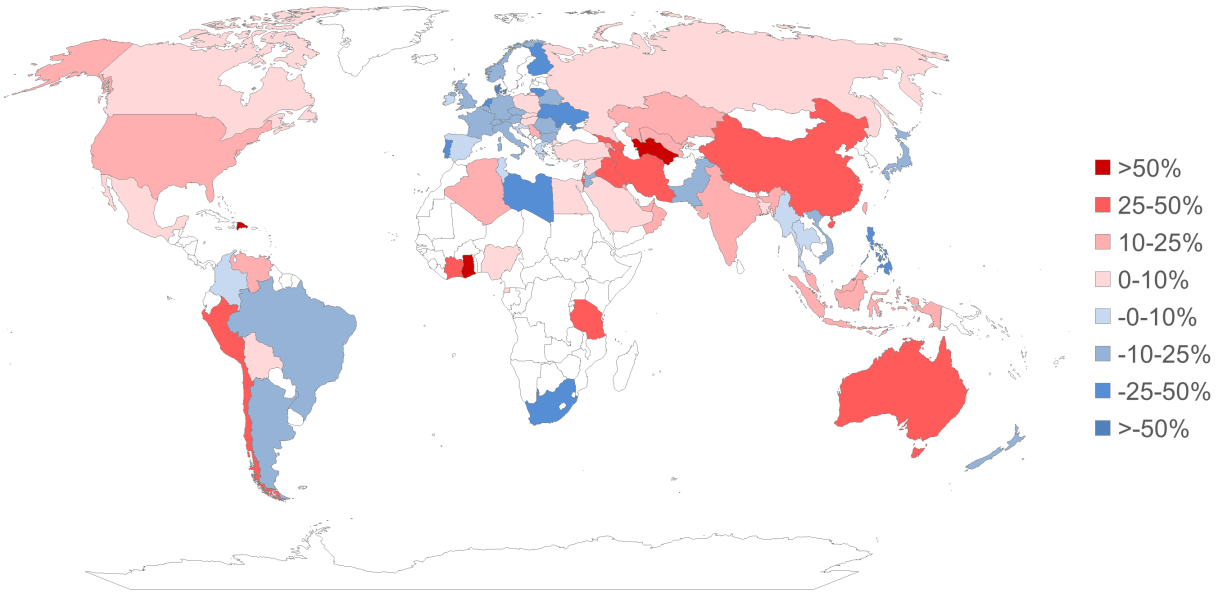
(a) coal power generation



(b) oil and gas extraction



(c) gas consumption



Data source: IEA (2025a)

7.3 International cooperation

Given the challenges of fossil fuel dependence reviewed in the previous sections, countries will be far more likely to succeed by working together than going it alone. Cooperation can take several forms, including international financial and other support, peer learning, momentum-building and coordination.

An important element is the provision and mobilisation of finance, technology transfer and capacity-building from developed to developing countries, as required under the Paris Agreement (UNFCCC 2015: Arts.9-11), to build the capabilities needed to overcome dependence and invest in alternatives (Section 7.1). An exception to this is the high-income developing countries, including those that obtain large fossil fuel revenues, where external support would be hard to justify. Some have built large sovereign wealth funds, which can help invest in the transition process. Indeed, without affordable external finance, many lower-income countries may be unable to fund their transitions, given urgent developmental needs and competing calls on limited budgets. At the same time, domestic resources should cover some portion of the costs, with the possible exception of the very poorest countries: all countries should make domestic finance flows more consistent with climate resilient and low emissions development (UNFCCC 2015: Art.2.1c).

Groupings such as the Powering Past Coal Alliance and Beyond Oil and Gas Alliance contribute to some of the other cooperative functions, including sharing lessons and data among members, encouraging new commitments and policy action, and creating a drumbeat of collective effort and expectation (Koppenborg 2025).

Transition roadmap dialogues can establish fora for governments to understand their different national circumstances, and how those affect the speed and form in which transitions can occur. We have seen in the previous sections how profoundly the circumstances of the most dependent countries differ from the less dependent.

International coalitions promoting EFFTs should be able to include those who find it easier to make commitments and support those who face greater challenges. Coalition-building should aim both to achieve early gains in countries that are less dependent or already decreasing, and also to help enable countries facing greater challenges or still increasing and needing more time. By proactively building these broad coalitions, the international community can foster 'broad front politics' that mediate conflicting interests and provide the necessary finance and capacity-building to weaken resistance and help highly dependent nations manage their specific structural transformations.

7.4 New fossil fuel projects prolong and deepen dependence

We have seen in the preceding sections that economies that depend on fossil fuels face economic and financial risks as global energy systems change. Even aside from their contributions to the shared international process of tackling climate change, governments will want to reduce their exposure to these risks, and to build more diverse and dynamic economies. However, we have also seen that escaping fossil fuel dependence can take decades. One conclusion from this is that more dependent countries should be given more time for EFFTs than those with more diversified economies and energy systems. Another conclusion is that even those dependent countries should actively pursue those transitions without delay, to allow enough time for their transitions.

A first step towards transition away from fossil fuels is to stop investments in new fossil fuel infrastructure. As the saying goes, when in a hole, you should stop digging.

The IPCC Sixth Assessment Report (2022: p.TS-26) warns that:

> Estimates of future CO_2 emissions from existing fossil fuel infrastructures already exceed remaining cumulative net CO_2 emissions in pathways limiting warming to 1.5°C... Decommissioning and reduced utilisation of existing fossil fuel installations in the power sector as well as cancellation of new installations are required.

This excess applies to both the existing facilities used in consuming fossil fuels such as power plants and industrial heating systems (Tong et al 2019) and those used in extracting fossil fuels (Trout et al 2022). As countries reduce emissions to achieve the Paris temperature goal, some of the world's existing fossil fuel facilities will therefore lose money through early closure and reduced utilisation. And the more new fossil fuel projects are added, the greater these losses will be.

The existence of built facilities and sunk investments creates path dependencies that can make changing course more costly and difficult (Green et al 2024). In other words, building more fossil fuel projects deepens and prolongs a country's dependence on fossil fuels, makes it less able to shift its development path, and decreases its economic resilience during the course of its just energy transition. An orderly transition will seek to avoid these excess costs and barriers. The implication is that governments should avoid adding new fossil fuel projects, and instead focus their capital investments on alternatives that reduce their dependence.

7.5 New fossil fuel producers

These questions arise most strongly in relation to the governments that aim to become new producers, especially of oil and gas. They hope that fossil fuel extraction can offer them a chance at future riches. In recent years, Guyana and Senegal have become significant oil and gas producers. Uganda and Mozambique are in the construction process on the way to joining them. And Namibia and Tanzania are hoping to be next.

However, becoming a fossil fuel producer now is a risky course. From the award of licenses and contracts, it commonly takes fifteen or more years of exploration, appraisal and development before new oil and gas start to flow, and even longer before governments start to see meaningful revenues, as in the early stages of production, the investments are being paid off.[22] Even countries starting production now are betting on the energy markets of the 2030s still being fossil-dominated, and those newly pursuing contracts the 2040s. The hope that demand will be sustained over this period and beyond tends to be rooted variously in the observation that fossil fuels have always grown in the past,[23] in noisy government moves to protect fossil fuels, or in new sources of demand such as data centres for artificial intelligence.[24] However, as noted in Section 3.2, fossil fuel demand is already close to peaking, even with the current more pro-fossil fuel policies,[25] and projected supply significantly exceeds projected demand from 2025 to 2050 (Stockholm Environment Institute et al 2025). And if governments adopt new policies to mitigate climate change, demand could decrease significantly.

There is a danger then that new producers could find their export markets have dried up by the time production starts to flow, leaving the countries with stranded assets and deeper in debt (Ruzzante and Sobrinho 2022). Countries in the global South face particular dilemmas of stranded resources and assets, given the need to provide access to energy services and generally develop their economies (Heras & Gupta 2023).

This creates a significant dilemma. While scholars have debated whether oil and gas development helps or harms economies (whether there is a “resource curse”), one point on which there is consensus is that countries fare better when they have stronger institutions (Ovadia 2020). Countries thus achieve better outcomes when they develop fossil fuels slowly, allowing time not only to strengthen institutions but also to build domestic supply chains and skilled workforces to carry out some of the extraction activities. Norway is widely seen as the

[22] Production of “tight” oil and gas through hydraulic fracturing involves much shorter timelines of decision, investment and return, but requires establishment of significant infrastructure. The vast majority of such production occurs in the United States, with smaller amounts in Canada and Argentina.

[23] Philosopher Bertrand Russell warned against such reasoning with his story of a chicken, who observes that every single morning of its experience, the farmer has brought food, and concludes that therefore this is therefore the established structure of mornings, until one morning the pattern is fatally broken with the wringing of its neck (cited in Taleb 2007: 40).

[24] In reality, data centres accounted for just 1.5% of global electricity consumption in 2024. While the rise of artificial intelligence is set to double this by 2030, the global share is still small (IEA 2025f).

[25] The reason the outlook has not changed much with the new political landscape is that the biggest driver of change is China, whose transition prospects have rather accelerated, whereas the slow-down of transition in the United States has a smaller impact compared to previous expectations (Muttitt 2025).

most significant success story from oil and gas development, prior to the climate crisis[26]: after discovering oil in the 1960s, it adopted a policy to deliberately keep it slow, including maximum production quotas (Wicken 2017).

New producers risk getting caught between these conflicting time pressures: to develop slowly in order to avoid the resource curse, versus to develop quickly before global fossil fuel demand falls (Stevens, Lahn and Kooroshy 2015; Muttitt and Kartha 2020).

7.6 Implications for equitable transitions

We now summarise the key lessons from this section. In addition to countries' dependence on fossil fuels, a key determinant of transitions is their capabilities to overcome that dependence:

- **Economic capabilities** include the availability of resources to invest in alternative energy sources and infrastructure, in alternative economic sectors and in funding a just transition. A simple measure of this is a country's gross national income per capita.
- **Institutional capabilities** include the ability to manage a process of change, technically, politically and economically. Various indices aim to capture institutional capabilities. They are generally well correlated with economic capabilities.

Where fossil fuel production and use are already declining, governments can more readily engage in questions of what comes next. The largest consumers and producers in decline from 2018 to 2023 are:

- **Coal power generation**: United States, Japan, Korea and South Africa.
- **Oil and gas production** (other than Russia and OPEC members): Qatar, Kazakhstan, Malaysia and Indonesia.
- **Gas consumption**: Japan, Germany and United Kingdom.

Where production and use are growing, they shape expectations and hopes for the future, requiring a more concerted policy shift to engage with transitions. The largest absolute increases from 2018 to 2023 were in:

- **Coal power generation**: China, India and Indonesia.
- **Oil and gas production**: United States, followed by China, Brazil, Australia and Canada.
- **Gas consumption**: United States, China and Iran.

A potent area of focus is the new investment frontier, where capital has not yet been committed:

- **New fossil fuel projects deepen dependence**: Building more fossil-fuel-consuming or -producing facilities and infrastructure creates lock-in effects that will make a country less able to shape its transition path, and decrease its economic resilience during the

[26] On the other hand, Norway has not meaningfully engaged with the climate implications of its oil and gas production (Rendon-Betancur and Dyer 2026).

global energy transition, potentially losing money through early closure and reduced utilisation. An orderly transition will seek to avoid these excess costs and barriers.

- **New fossil fuel producers face competing time pressures and risks**: Guyana and Senegal recently became significant oil and gas producers, Uganda and Mozambique are in the process of doing so, and prospective future producers include Namibia and Tanzania. Such countries will need to carefully manage the risks of declining export markets, while also avoiding the converse problem of failing to benefit economically from a rushed process of expansion.

Policy interventions can help enable equitable transitions:

- **Provide and mobilise finance and capacity-building** to enable equitable transitions in low- and middle-income countries.
- **Stop building new fossil projects**: to focus capital investments instead on alternatives that reduce dependence.
- **Assess and manage economic risk**: while initiating transitions, hedge economic risks through economic diversification to build alternative sectors and sources of fiscal revenue.

8. Conclusion: Overcoming dependencies, grasping opportunities and implementing equitable transitions

At the end of each of the country-comparison Sections 4-7, we have summarised the key implications and policy recommendations, which are also captured in the Executive Summary, so there is no need to repeat them here. Instead, we conclude by drawing together the key themes of the paper and the high-level guidance they suggest for strategies on equitable transitions.

A first observation is that there are many benefits to be gained from equitable fossil fuel transitions, beyond climate mitigation. These include reducing energy costs, improving energy security and reducing harmful air pollution, as well as creating jobs and thriving economies, and making economies more resilient to global changes. To build momentum and achieve near-term progress, capturing these opportunities is a good place to start. Early wins are also possible where fossil fuel production and use are already in decline: as we saw in Section 7, governments in such circumstances are more ready to engage in transitions, as there is generally less political and societal belief in or expectation from fossil futures.

Secondly, we have also seen how many countries depend on fossil fuels in ways that will take longer to change: their infrastructure is fossil-dominated, their economic development strategies fossil-fuelled or their economies built on fossil fuel exports and revenues. In these contexts, transition entails investing now in a structural transformation of the energy system and/or economy, understanding that such transformations take time. It requires a clear strategy, creation of enabling conditions (such as investing in skills and infrastructure, and adopting supportive policies) and targeted investments.

Third, timing is a key way of differentiating transitions. There are countries with relatively low dependence on fossil fuels, for whom a more rapid transition is possible, and others where entrenched dependences will take time to overcome. Put differently, if all countries moved at the same pace, transitions would incur greater economic and social cost in the countries most dependent on fossil fuels: it would be a less just, less orderly, less equitable transition for such countries. The lesson, then, is that the language of the Global Stocktake decision implies a differentiated timeline for transitions, where less-dependent countries transition faster than more-dependent countries. All should move as fast as possible, but some transitions will take longer to overcome challenges and change entire economies.

Fourth, countries differ not only in their degree of dependence on fossil fuels, but also in their capabilities. Countries with greater economic, institutional and technological resources will be more capable of overcoming the challenges of dependence, while ensuring a transition is just, orderly and equitable. In relation to most of the challenges considered in this paper, developed countries are more able to transition away from fossil fuels: their economies, energy systems and workforces are generally more diversified, their infrastructure stronger and their cost of capital lower. To build their economic and institutional capabilities to enable transitions, developing countries will need financial support and capacity-building (to varying degrees). Without international support, countries with limited budgets and pressing developmental priorities may be unable to transition, beyond strengthening their own economic resilience, and in some cases not even that.

Fifth, international cooperation can also take the form of coalitions, where lessons and resources are shared, and other structures of mutual assistance enabled. Such coalitions will be most effective if they can accommodate countries that differ in their circumstances and readiness for transition, enabling simultaneous cooperation on both the shorter and longer timescales described above. A key step towards international cooperation is for countries to understand respects in which their circumstances are similar – allowing sharing of experiences – or different, implying different approaches or pace of transitions. We hope this report helps contribute to such shared understanding.

Coalitions are important at the domestic level too, as means to build broad societal support for transitions, and to develop transition strategies together with the stakeholders most affected. Facilitated stakeholder processes that develop a shared vision and framework for en equitable fossil fuel transition are important. An EFFT framework will need to address the specific and different national circumstances. Identifying socio-economic and local environmental co-benefits (such as cheaper energy or reduced air pollution) will help make the case. Impmenting an EFFT framework will need investment, both to realise any near-term opportunitities and to put in place enablers for the longer term.

Finally, having observed the difficulties created by dependence on fossil fuels, and the ways in which it reduces governments' ability to manage transitions, a key first step is for governments to stop deepening their dependence. In particular, one of the most achievable and least costly elements is to stop building new fossil fuel projects, and instead focus all investments on alternatives that reduce dependence.

Based on these reflections, we make six high-level recommendations on how to implement equitable fossil fuel transitions:

- **Seek early wins where there are greater opportunities and benefits** from transitioning, such as cheaper energy or improved energy security.
- In parallel, **invest now to overcome entrenched dependence on fossil fuels**, as economic diversification and structural transformation take time.
- **Differentiate timelines between countries**, such that every country moves as fast as it can, understanding more time is needed in countries with greater dependence.
- **Provide and mobilise** finance and capacity-building **support for low- and middle-income countries**, to boost their capabilities to invest in and manage transitions.
- **Build inclusive international coalitions** to provide peer learning and gain momentum, including both early-movers and those that need more time. **Build domestic coalitions** to create political support and engage stakeholders.
- **Avoid building new fossil** fuel-consuming or -producing facilities and infrastructure, and instead focus investments on alternatives that reduce dependence.

Pulling together the quantitative analysis from this paper, Table 8.1 illustrates how some of these principles can be applied in practice, in the case of key countries. Green cells show where governments can capitalise on opportunities from transitions. Orange shows aspects of dependence that will require time and long-term investments. Blue shows where fossil fuel production and use are declining, indicating greater readiness to engage in transitions;

conversely red shows growth where fossil fuels shape visions for countries' futures and greater efforts are needed to think about a change of direction and alternative path.

Our overarching message is that the opportunities and challenges of equitably transitioning away from fossil fuels depend fundamentally on countries' different national circumstances. It is hoped that this paper usefully shines light on those circumstances, to help inform efforts to advance transitions.

Table 8.1: Indicators of dependence and barriers (orange), transition opportunities (green) and increase/decrease (red/blue) for selected countries

Country	Power generation					Fossil imports share of GDP (2023)	Fossil air pollution deaths /100,000 population (2023)	Share of workforce			Oil and gas of fiscal revenues (2021)	Fossil share of gross exports (2023)	Change 2018-23		
	Coal share (2023)	Fossil share (2023)	Average age of coal plants, years (2024)	Solar PV cost of capital (2024)	Cheapest LCOE source of generation (2024)			Fossil extraction (2023)	Fossil-fuelled manufacturing[c] (2022)	Fossil-funded public sector[d] (2023)			Coal generation	Oil & gas extraction	Gas consumption
Argentina	1%	53%	n/a	17%	wind	0.3%	29	0.3%	10%	4%	20%	3%	n/a	+13%	-11%
Australia	47%	66%	35.5	4%	solar	exp	11	0.5%	8%	0.3%	0.3%	28%	-19%	+34%	+31%
Brazil	2%	9%	n/a	8%	wind	exp	24	no data	4%	1%	5%	14%	-31%	+25%	-17%
Canada	4%	20%	n/a	5%	wind	exp	13	0.3%	4%	0.4%	2%	26%	-53%	+9%	+7%
China	62%	65%	12.6	4%	wind	2.6%	121	0.5%	22%	0.1%	0.5%	1%	+23%	+25%	+39%
France	1%	7%	n/a	3%	solar	2.4%	39	-	6%	-	-	3%	n/a	n/a	-24%
Germany	27%	44%	29.6	2%	solar	2%	55	0.1%	13%	-	-	3%	-44%	n/a	-16%
India	74%	78%	14.3	7%	solar	3.7%	88	0.4%	9%	0.1%	2.4%	14%	+23%	-5%	+11%
Indonesia	69%	84%	9.5	8%	coal	exp	46	0.2%	11%	1%	8%	19%	+62%	-11%	+12%
Italy	5%	55%	n/a	5%	solar	3%	82	-	15%	-	-	3%	-54%	-19%	-15%
Japan	29%	65%	22.8	3%	solar	4.5%	59	-	12%	-	-	1%	-15%	n/a	-20%
Mexico	9%	77%	n/a	9%	solar	0.7%	36	no data	15%	2%	19%	6%	+21%	+3%	+8%
Russia	18%	63%	42.1	11%	gas	exp	66	no data	8%	7%	23%	43%	+19%	-9%	+2%
Saudi Arabia	0%	99%	n/a	6%	no data	exp	6	no data	8%	7%	58%	77%	n/a	-5%	+10%

Country	Power generation					Fossil imports share of GDP (2023)	Fossil air pollution deaths /100,000 population (2023)	Share of workforce			Oil and gas share of fiscal revenues (2021)	Fossil share of gross exports (2021)	Change 2018-23		
	Coal share (2023)	Fossil share (2023)	Average age of coal plants (2024)	Solar PV cost of capital (2024)	Cheapest LCOE power generation (2024)			Fossil extraction (2023)	Fossil-fuelled manufacturing (2023)	Fossil-funded public sector (2021)			Coal generation	Oil & gas extraction	Gas consumption
South Africa	83%	87%	32.8	7%	solar	4.1%	50	0.4%	9%	-	0.2%	9%	-17%	n/a	-27%
South Korea	34%	62%	14.6	5%	coal	6.4%	70	-	11%	-	-	6%	-22%	n/a	-0%
Türkiye	36%	57%	19.0	11%	wind	1.2%	55	-	17%	-	-	4%	+5%	+44%	+1%
UK	2%	37%	n/a	3%	wind	1.4%	49	0.1%	6%	0.01%	0.2%	8%	n/a	-27%	-20%
US	17%	60%	43.2	5%	wind	exp	22	0.2%	7%	0.03%	0.2%	16%	-42%	+24%	+13%
Other countries	BWA 99% XKK 87% MNG 85%	BHR 100% BRN 100% KWT 100% LBY 100% TMN 100% TTO 100% DZA 99%	VNM 8	GHA 16%; PAK 16%; TUN 16%		CPV 34% LBN 22% MRT 16% LBR 15%	BGR 192 SRB 160 BIH 151	NOR 2.1% IRQ 1.4%	TUN 19% IRN 18%	IRQ 33% DZA 16%	LBY 97% IRQ 88% SSD 86% TLS 80% GNQ 80%	KWT 95% AGO 94% NGA 89% AZE 88%			
Sources and details	Figure 4.6	Figure 4.6	Table 4.1	Figure 4.2	Figure 4.1	Figure 4.3	Figure 4.5	Table 5.1	Figure 5.4	Table 5.3	Figure 6.2	Figure 6.3	Figure 7.2a	Figure 7.2b	Figure 7.2c

[c] Manufacturing share of workforce, multiplied by direct and indirect fossil share of manufacturing energy

[d] Public sector share of workforce, multiplied by oil and gas share of fiscal revenue

References

Addison, T. and Roe, A. (2024). *Extractive industries: enclaves or a means to transform economies?* UN University World Institute for Development Economics Research, WIDER Working Paper, No. 2024/28. https://doi.org/10.35188/UNU-WIDER/2024/486-1

AEP (2024). Key Statistics 2024. Australian Energy Producers. https://energyproducers.au/wp-content/uploads/2024/06/AEP_KS24_Web2.pdf

African Development Bank (2021). *O Mercado de Trabalho em Angola e os Impactos da Pandemia da Covid-19*. https://www.afdb.org/sites/default/files/2022/09/27/o_mercado_de_trabalho_em_angola_002.pdf

African Expert Panel (2025). *Growth, Debt and Development: Opportunities for a New African Partnership*, Report of the South Africa G20 Africa Expert Panel for the G20 Leaders' Summit, November 2025, https://g20.org/wp-content/uploads/2025/11/FINAL-AEP_Report_Individual_Pages_v251115.pdf.

Alakwe, K.O. (2024). The Paradox of the Niger Delta: Examining the Principal Determinants of Poverty and Underdevelopment. *Journal of Developing Societies*, *40*(1), 94-115. https://doi.org/10.1177/0169796X241226571

Al-Kuwari, M. (2026). Escaping the Oil Curse: The Road to Economic Diversification in the GCC Region. In: Qarmout, T., Zaidan, E., Joyce, P. (eds), *Public Policy in Gulf States*, Gulf Studies vol 14, Singapore: Springer. https://doi.org/10.1007/978-981-95-2050-3_3

Alsharif, N., Bhattacharyya, S., & Intartaglia, M. (2017). Economic diversification in resource rich countries: History, state of knowledge and research agenda. *Resources Policy,* 52, 154–164. https://doi.org/10.1016/j.resourpol.2017.02.007

Altenburg, T., & Assmann, C. (2017). *Green industrial policy: Concept, policies, country experiences*. UN Environment and German Development Institute. http://un-page.org/files/public/green_industrial_policy_book_aw_web.pdf

Altieri, K.E., Trollip, H., Caetano, T., Hughes, A., Merven, B. and Winkler, H. (2016). Achieving Development and Mitigation Objectives through a Decarbonization Development Pathway in South Africa. *Climate Policy* 16 (sup1): S78–91. https://doi.org/10.1080/14693062.2016.1150250

Arab Times (2025). Kuwait sees growth in labor market, Indians remain largest workforce group. https://www.zawya.com/en/economy/gcc/kuwait-sees-growth-in-labor-market-indians-remain-largest-workforce-group-m19jhgd9

Argus (2022). Survey: US VLCC rates highest since 2020. 18 November. https://www.argusmedia.com/en/news-and-insights/latest-market-news/2392696-survey-us-vlcc-rates-highest-since-2020

Arndt, C., Arent, D., Hartley, F., Merven, B., & Mondal, A. H. (2019). Faster than you think: Renewable energy and developing countries. *Annual Review of Resource Economics,* 11, 149–68. http://doi.org/10.1146/annurev-resource-100518-093759

Arraf, J. (2021). Iraq, Struggling to Pay Debts and Salaries, Plunges Into Economic Crisis. *New York Times*, 4 January. https://www.nytimes.com/2021/01/04/world/middleeast/iraq-economy-debt-oil.html

Ayaburi, J., Bazilian, M., Kincer, J. and Moss, T. (2020). Measuring "Reasonably Reliable" access to electricity services. *The Electricity Journal* 33(7). https://doi.org/10.1016/j.tej.2020.106828

Beblawi, H., & Luciani, G. (Eds.). (1987). *The Rentier State.* Abingdon and New York: Routledge. https://doi-org.libproxy.ucl.ac.uk/10.4324/9781315684864

Bertram, R. (2020, January 27). *Uruguay, Latin America's renewable champion*. Heinrich Böll Foundation. https://energytransition.org/2020/01/uruguay-latin-americas-renewablechampion/

Beutel, J., Avallone, A., Gallego Herrera, E., Klingen, J., Kurwan, J., Mohr, K., Vasudha, V., Wallenta, A., Wehnert, T. and Yetano, M. (2025). *Status Report of the Coal Sector in Indonesia: Pathways and barriers towards a Just Energy Transition*. Wuppertal Institute. https://www.jetknowledge.org/wp-content/uploads/2025/02/Status-Report-Coal-Sector-Indonesia.pdf

Bhatia, M. and Angelou, N. (2015). *Beyond Connections: Energy Access Redefined*. ESMAP Technical Report 008/15, World Bank. http://hdl.handle.net/10986/24368

Le Billon, P. and Kristoffersen, B. (2019). Just cuts for fossil fuels? Supply-side carbon constraints and energy transition. *Environment and Planning A: Economy and Space*, *52*(6), pp.1072-1092. https://doi.org/10.1177/0308518X18816702

BloombergNEF (2023a). Cost of Clean Energy Technologies Drop as Expensive Debt Offset by Cooling Commodity Prices. 7 June. https://about.bnef.com/insights/commodities/cost-of-clean-energy-technologies-drop-as-expensivedebt-offset-by-cooling-commodity-prices/

BloombergNEF (2023b). The Race to Localize Clean Technology Supply Chains. 7 September. https://about.bnef.com/insights/finance/the-race-to-localize-clean-technology-supply-chains/

Bond, K. and Butler-Sloss, S. (2022) *Why Peaks Matter: The Turning Point from Growth to Decline*. Rocky Mountain Institute. https://rmi.org/insight/peaks-why-they-matter/

Bond, K., Walter, D. and Butler-Sloss, S. (2025). *The Electrotech Revolution*. Ember. https://ember-energy.org/latest-insights/the-electrotech-revolution/

Braithwaite, D. and Gerasimchuk, I. (2019). *Beyond Fossil Fuels: Indonesia's fiscal transition*, IISD. https://www.iisd.org/system/files/publications/beyond-fossil-fuels-indonesia-fiscal-transition.pdf

Brazil Government (2025). Speech by President Lula at the opening of the COP30 Leaders' Summit in Belém, 6 November. https://www.gov.br/planalto/en/follow-the-government/speeches-statements/2025/11/speech-by-president-lula-at-the-opening-of-the-cop30-leaders2019-summit-in-belem-para

Bureau of Labor Statistics (2025a). Describing the U.S. oil and gas extraction workforce with public data, *Monthly Labor Review*, May. https://www.bls.gov/opub/mlr/2025/article/describing-the-us-oil-and-gas-extraction-workforce-with-public-data.htm

Bureau of Labor Statistics (2025b). Quarterly Census of Employment and Wages, Employment and Wages Data Viewer - Private, NAICS 32411 Petroleum refineries, All Counties, 2022 Annual Averages, All establishment sizes. https://data.bls.gov/cew/apps/table_maker/v4/table_maker.htm#type=1&year=2022&qtr=A&own=5&ind=32411&supp=0

Burton, J. (2011). The Role of Industrial Policy in Pursuing Climate Change Mitigation Objectives in South Africa: Industrial Energy Demand and the Minerals-Energy Complex in Post-Apartheid South Africa. Publishable Paper (Summary of MSc Thesis), Energy Research Centre, University of Cape Town, http://hdl.handle.net/11427/10175.

Burton, J., Marquard, A. and McCall, B. (2019). *Socio-economic Considerations for a Paris Agreement-Compatible Coal Transition in South Africa*. Energy Research Centre, University of Cape Town. https://lifeaftercoal.org.za/wp-content/uploads/2020/05/Burton-Marquard-McCall-JT_Paris_South-Africa-Final.pdf

Byers, E., Krey, V., Kriegler, E., Riahi, K., Schaeffer, R. et al (2022). *AR6 Scenarios Database hosted by IIASA.* International Institute for Applied Systems Analysis. https://doi.org/10.5281/zenodo.5886911

Caldecott, B., Sartor, O. and Spencer, T. (2017). *Lessons from Previous Coal Transitions*, part of 'Coal Transitions: Research and Dialogue on the Future of Coal' Project, IDDRI and Climate Strategies, https://www.iddri.org/sites/default/files/import/publications/coal_synthesisreport_v04.pdf

Calverley, D. & Anderson, K. (2022). *Phaseout pathways for fossil fuel production within Paris-compliant carbon budgets*. Tyndall Centre, University of Manchester. https://research.manchester.ac.uk/en/publications/phaseout-pathways-for-fossil-fuel-production-within-paris-complia/

Carello, F. (2024). *Examining Total Cost of Ownership: Battery electric vs internal combustion engine vehicles*. Ayvens. https://www.ayvens.com/-/media/ayvens/public/cp/files/white-papers/examining-the-tco-of-bev-vs-icevehicles---may-2024.pdf

Chhotray, V. (2022). Extractive Regimes in the Coal Heartlands of India: Difficult Questions for a Just Energy Transition, in Kashwan, P. (ed.), *Climate Justice in India* (Vol. 1, pp. 74-97), Cambridge University Press. https://doi.org/10.1017/9781009171908.005

Chinascope (2023). One in Four People in China's Work in Public Sector. https://chinascope.org/archives/32095

Civil Society Equity Review (2023). *An Equitable Phase Out of Fossil Fuel Extraction*. https://www.equityreview.org/extraction-equity-2023

Civil Society Equity Review (2024). Fair Shares, Finance, Transformation: Fair Shares Assessment, Equitable Fossil Fuel Phaseout, and Public Finance for Just Global Climate Stabilization. https://equityreview.org/report2024

Cui, H. and Wei, P. (2017). Analysis of thermal coal pricing and the coal price distortion in China from the perspective of market forces. *Energy Policy* 106, pp.148-154. http://dx.doi.org/10.1016/j.enpol.2017.03.049

Daumas, L. (2023). Financial stability, stranded assets and the low-carbon transition – A critical review of the theoretical and applied literatures. *Journal of Economic Surveys, 38*(3), 601–716. https://doi.org/10.1111/joes.12551

Delechat, C.C., Melina, G., Newiak, M., Papageorgiou, C. and Spatafora, N. (2024). *Economic Diversification in Developing Countries: Lessons from Country Experiences with Broad-Based and Industrial Policies*. IMF Departmental Paper No 2024/006. https://doi.org/10.5089/9798400240201.087

Diluiso, F., Walk, P., Manych, N., Cerutti, ZN., Chipiga, V., Workman, A., Ayas, C., Cui, R.Y., Cui, D., Song, K. 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. *Environmental Research Letters* 16(11). http://doi.org/10.1088/1748-9326/ac1b58

Economist Intelligence Unit (2024). Democracy Index 2024. https://www.eiu.com/n/campaigns/democracy-index-2024/

Edwards, G.A.S., Hanmer, C., Park, S., MacNeil, R., Bojovic, M., Kucic-Riker, J., Musil, D. and Viney, G. (2022). *Towards a Just Transition from Coal in Australia?* British Academy. https://doi.org/10.5871/just-transitions-a-p/G-E

EIA (2025). *Annual Coal Report*. Energy Information Administration. https://www.eia.gov/coal/annual/

EITI (2021). *EITI Indonesia 10th report: 2021 fiscal year*. https://eiti.org/sites/default/files/2024-02/Indonesia%20EITI%202021%20report.pdf?hash=1772103600

EITI (2022). Mongolia. https://eiti.org/ru/node/22037

EITI (2024a). *Argentina 2022-2023 EITI Report*. https://eiti.org/documents/argentina-2022-2023-eiti-report

EITI (2024b). *Gabon 2022 EITI Report*. https://eiti.org/documents/gabon-2022-eiti-report

EITI (2024c). *Ghana 2021-2022 EITI Report - Oil and gas*. https://eiti.org/documents/ghana-2021-2022-eiti-report-oil-and-gas

EITI (2024d). *Nigeria 2023 EITI Report - Oil & Gas*. https://eiti.org/documents/nigeria-2023-eiti-report-oil-gas

EITI (2024e). *Trinidad and Tobago 2022 EITI Report*. https://eiti.org/documents/trinidad-and-tobago-2022-eiti-report

EITI (2025a). *Angola 2023 EITI Report*. https://eiti.org/documents/angola-2023-eiti-report

EITI (2025b). *Chad 2023 EITI Report*. https://eiti.org/documents/chad-2023-eiti-report

EITI (2025c). *Republic of the Congo 2023 EITI Report*. https://eiti.org/documents/republic-congo-2023-eiti-report

EITI (2025d). *Iraq 2023 EITI Report*. https://eiti.org/documents/iraq-2023-eiti-report

Energy Institute (2024). *Statistical Review of World Energy 2024*. https://www.energyinst.org/statistical-review

Energy Institute (2025). *Statistical Review of World Energy 2025*. https://www.energyinst.org/statistical-review

Experian (2024). Estimating Employment and GVA impact of the UK Oil and Gas Industry. Available at https://www.ukeiti.org/sites/default/files/Experian-Oil-and-Gas-Economic-Impact-Summary-Final-1%20(1).pdf

European Heat Pump Association (2024). *Heat pumps versus boilers: taxes and running costs*. https://www.ehpa.org/wp-content/uploads/2024/12/EHPA_VAT-report_Heat-pumps-versus-boilers-taxes-and-running-costs-1.pdf

Faridzad, A., Sim, C. H., Chang Siak Gek, J., & Khai Yeo, K. H. (2026). Energy Transition and Governance: A Systematic Literature Review. Progress in Energy and Environment, 32(1). https://doi.org/10.37934/progee.32.1.1029

Fattouh, B., and Sen, A. (2021). Economic Diversification in Arab Oil-Exporting Countries in the Context of Peak Oil and the Energy Transition, in Luciani, G. and Moerenhout, T. (eds), *When Can Oil Economies Be Deemed Sustainable?* (pp. 73-98). Palgave Macmillan.

Fine, B. and Rustomjee, Z. (1996). The Political Economy of South Africa: From Minerals-Energy Complex to Industrialization. London: C. Hurst.

Foster, V., Trotter, P.A., Werner, S., Niedermeyer, M., Mulugetta, Y. et al. (2024) Development transitions for fossil fuel-producing low and lower–middle income countries in a carbon-constrained world. *Nature Energy* 9, pp.242–250. https://doi.org/10.1038/s41560-023-01440-3

Friedlingstein, P., O'Sullivan, M., Jones, M.W., Andrew, R.M., Hauck, J., Landschützer, P., Le Quéré, C., Li, H., Luijkx, I.T., Olsen, A., Peters, G.P., Peters, W., Pongratz, J., Schwingshackl, C., Sitch, S., Canadell, J.G., Ciais, P., Jackson, R.B. et al (2025). Global Carbon Budget 2024. *Earth System Science Data* 17, pp.965-1039. https://doi.org/10.5194/essd-17-965-2025

Fund for Peace (2025). State Resilience Index. https://fundforpeace.org/SRI/about.html

Furnaro, A. and Yanguas-Parra, P. (2022). A Global South Perspective on Stranded Regions: Insights from the Decline of Coal Mining in Cesar, Colombia. *Economics of Energy & Environmental Policy* 11(2). https://doi.org/10.5547/21605890.11.2.afur

Gapa, A. (2020). Natural Resources and African Economies: Turning Liability to Asset, in Oloruntoba, S.O. and Falola, T. (eds), *The Palgrave Handbook of African Political Economy*, pp.667-677, https://doi.org/10.1007/978-3-030-38922-2

Ge, M., Friedrich, J. and Vigna, L. (2024). 4 Charts Explain Greenhouse Gas Emissions by Sector. World Resources Institute, 5 December. https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors

GEM (2025a). Global Coal Plant Tracker, October 2025 Supplement release. Global Energy Monitor https://globalenergymonitor.org/projects/global-coal-plant-tracker/

GEM (2025b). Global Coal Mine Tracker, May 2025 v2 release. Global Energy Monitor. https://globalenergymonitor.org/projects/global-coal-mine-tracker/download-data/

Gillies, A., Heller, P.R.P., Mahdavi, P., Manley, D., Marcel, V., Melgar, L., Monaldi, F., Muttitt, G., Picciariello, A. and Roth, J. (2021). *National Oil Companies and Climate Change: Insights for Advocates*. Natural Resource Governance Institute and International Institute for Sustainable Development. https://resourcegovernance.org/publications/national-oil-companies-and-climate-change-insights-advocates

Goodall, C. (2016). *The Switch: How solar, storage and new tech means cheap power for all*. Profile Books.

Gopalakrishnan, T., & Miller, J. (2024). New climate dis-economies: The political economy of energy transitions in fragile fossil fuel producers. *Environment and Security*, *2*(3), 348-374. https://doi.org/10.1177/27538796241272361

Green, F., Bois von Kursk, O., Muttitt, G., & Pye, S. (2024). No new fossil fuel projects: The norm we need. *Science, 384*(6699), 954–957. https://doi.org/10.1126/science.adn6533

Green Industrial Development Expert Panel (2025). *Pathways to Green African Industrialisation.* Position paper. https://commerce.uct.ac.za/media/730024

Grubb, M., Drummond, P. and Hughes, N. (2020). *The shape and pace of change in the electricity transition: sectoral dynamics and indicators of progress*. We Mean Business Coalition. https://www.wemeanbusinesscoalition.org/blog/shape-and-pace-of-change-in-the-electricity-transition/

Grubert, E. and Hastings-Simon, S. (2022). Designing the mid-transition: A review of medium-term challenges for coordinated decarbonization in the United States. *WIREs Climate Change* 13(3). https://doi.org/10.1002/wcc.768

Gulf Research Centre (2022). Saudi Arabia: Workers employed in the public and private sectors by country of citizenship (2021). https://gulfmigration.grc.net/saudi-arabia-workers-employed-in-the-public-and-private-sectors-by-country-of-citizenship-2021/

Hanna, R., Heptonstall, P. & Gross, R. (2024). Job creation in a low carbon transition to renewables and energy efficiency: a review of international evidence. *Sustainability Science* 19, pp.125–150. https://doi.org/10.1007/s11625-023-01440-y

Hartley, F., Burton, J., Cunliffe, G., McCall, B., Caetano, T., Ntuli, N., Fourie, R. and Chiloane, L. (2019). Future Skills and Job Creation through Renewable Energy in South Africa: Assessing the Co-Benefits of Decarbonising the Power Sector, https://doi.org/10.2312/Iass.2019.009. In Okunlola, A., Jacobs, D., Ntuli, N., Fourie, R., Borbonus, S., Nagel, L. and Helgenberger, S. (eds), *Future skills and job creation through renewable energy in South Africa. Assessing the co-benefits of decarbonising the power sector*, Pretoria and Potsdam: Council for Scientific and Industrial Research and Institute for Advanced Sustainability Studies, https://doi.org/10.2312/iass.2019.009

He, G., Lin, J., Zhang, Y., Zhang, W., Larangeira, G., Zhang, C., Peng, W., Liu, M., Yang, F. (2020). Enabling a Rapid and Just Transition away from Coal in China. *One Earth* 3(2), pp.187 – 194. https://doi.org/10.1016/j.oneear.2020.07.012

Heras, Augusto, and Joyeeta Gupta. 2024. “Fossil Fuels, Stranded Assets, and the Energy Transition in the Global South: A Systematic Literature Review.” *WIREs Climate Change* 15 (1). https://doi.org/10.1002/wcc.866

Holz, C., Kartha, S. & Athanasiou, T. (2018). Fairly sharing 1.5: national fair shares of a 1.5 °C-compliant global mitigation effort. *International Environmental Agreements* 18, pp.117–134. https://doi.org/10.1007/s10784-017-9371-z

Hvidt, M. (2013). *Economic diversification in GCC countries: Past record and future trends.* London School of Economics & Political Science, Kuwait Programme on Development, Governance and Globalisation in the Gulf States. https://researchonline.lse.ac.uk/id/eprint/55252/

IDDRI. 2025. “What Are the Development Narratives Surrounding a Global Transition Away from Fossil Fuel Production ? Domestic Perspectives and International Cooperation Chair’s Summary.” Paris.

IEA (2021a). *Net zero by 2050: A roadmap for the global energy sector.* https://www.iea.org/reports/net-zero-by-2050

IEA (2021b). *Financing Clean Energy Transitions in Emerging and Developing Economies*. https://www.iea.org/reports/financing-clean-energy-transitions-in-emerging-and-developing-economies

IEA (2023). *World Energy Outlook 2023*. https://www.iea.org/reports/world-energy-outlook-2023

IEA (2024a). *Accelerating Just Transitions for the Coal Sector*. https://www.iea.org/reports/accelerating-just-transitions-for-the-coal-sector

IEA (2024b). *World Energy Employment 2024*. https://www.iea.org/reports/world-energy-employment-2024

IEA (2024c). *Integrating Solar and Wind: Global experience and emerging challenges*. https://www.iea.org/reports/integrating-solar-and-wind

IEA (2024d). *World Energy Outlook*. https://www.iea.org/reports/world-energy-outlook-2024

IEA (2025a). *World Energy Balances: Summary edition*. Dataset. https://www.iea.org/data-and-statistics/data-product/world-energy-balances

IEA (2025b). *Global Electric Vehicle Outlook 2025*. https://iea.blob.core.windows.net/assets/7ea38b60-3033-42a6-9589-71134f4229f4/GlobalEVOutlook2025.pdf

IEA (2025c). Global EV Data Explorer. https://www.iea.org/data-and-statistics/datatools/global-ev-data-explorer

IEA (2025d). Greenhouse Gas Emissions from Energy Data Explorer. https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer

IEA (2025e). *World Energy Outlook*. https://www.iea.org/reports/world-energy-outlook-2025

IEA (2025f). *Energy and AI: World Energy Outlook Special Report*. https://www.iea.org/reports/energy-and-ai

IEA, IRENA, UN Statistics Division, World Bank and World Health Organisation (2025). *Tracking SDG 7: The Energy Progress Report*. https://trackingsdg7.esmap.org/downloads

IEA and OECD (2000). *Experience Curves for Energy Technology Policy*, https://www.iea.org/reports/experience-curves-for-energy-technology-policy.

IISD and OECD (2025). Fossil Fuel Subsidy Tracker: Country data. https://fossilfuelsubsidytracker.org/country/

IMF (2016). *Economic Diversification in Oil-Exporting Arab Countries*, report for Annual Meeting of Arab Ministers of Finance, April 2016, Manama, Bahrain. https://www.imf.org/external/np/pp/eng/2016/042916.pdf

IMF (2018). *Algeria, Selected issues*, Country Report No. 18/169. https://www.elibrary.imf.org/view/journals/002/2018/169/002.2018.issue-169-en.xml?cid=lk-com-dsp-imf.org

IMF (2019). *The Russian State’s Size and its Footprint: Have They Increased?* https://www.elibrary.imf.org/view/journals/001/2019/053/001.2019.issue-053-en.xml?cid=lk-com-dsp-imf.org

IMF (2021). *Iraq: 2020 Article IV Consultation—Press Release; Staff Report; and Statement by the Executive Director for Iraq*. https://www.elibrary.imf.org/view/journals/002/2021/038/article-A002-en.xml

India Ministry of Statistics and Program Implementation (2025). *Energy Statistics India 2025*, https://www.mospi.gov.in/sites/default/files/publication_reports/Energy_Statistics_2025/Energy%20Statistics%20India%202025_27032025.pdf

International Labour Organisation (2023). Resolution concerning a just transition towards environmentally sustainable economies and societies for all. International Labour Conference – 111th Session, Geneva, 16 June

2023. https://www.ilo.org/resource/ilc/111/resolution-concerning-just-transition-towards-environmentally-sustainable

International Labour Organisation (2025). ILOSTAT data explorer – Employment by sex, age and public/private sector – annual. https://rshiny.ilo.org/dataexplorer37/?lang=en&segment=indicator&id=EMP_TEMP_SEX_AGE_INS_NB_A

IPCC (2013). *Climate Change 2013: The physical science basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar5/wg1/

IPCC (2014). *Climate Change 2014: Mitigation of climate change.* Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar5/wg3/

IPCC (2022). *Climate Change 2022: Mitigation of climate change.* Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg3/

IPCC. (2023). Climate Change 2023: Synthesis Report: Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. https://doi.org/10.59327/IPCC/AR6-9789291691647.001

Iraq Studies Unit (2020). Crisis of Salaries in Iraq and its Political Consequences. Emirates Policy Center, 13 December. https://epc.ae/en/details/brief/crisis-of-salaries-in-iraq-and-its-political-consequences

IRENA (2025). *Renewable Power Generation Costs in 2024*, data download. https://www.irena.org/Publications/2025/Jun/Renewable-Power-Generation-Costs-in-2024

Jewell, J., Vinichenko, V., Nacke, L. and Cherp, A. (2019): "Prospects for powering past coal", *Nature Climate Change* 9, pp.592–597. https://doi.org/10.1038/s41558-019-0509-6

Joshi, S., Sharma, M., Kumar, A., Joshi, T., Johri, A., & Alfehaid, M. (2025). Sustainable energy transition towards decarbonization among developing countries: a systematic literature review. Frontiers in Sustainability, 6. https://doi.org/10.3389/frsus.2025.1641299

Kabbani, N. (2021). The Long Road to Economic Transformation in the Gulf. *Cairo Review of Global Affairs*, Spring 2021. https://www.thecairoreview.com/essays/the-long-road-to-economic-transformation-in-the-gulf/

Kearney (2025). Rethinking infrastructure: the utilization challenge in electrification investing, 22 September 2025. https://www.kearney.com/industry/energy/article/rethinking-infrastructure-the-utilization-challenge-in-electrification-investing

Kersey, J., Massa, C.K., Lukuyu, J., Mbabazi, J., Taneja, J., Kammen, D.M. and Jacome, V. (2025). Grid connections and inequitable access to electricity in African cities. *Nature Cities* 2, 413–421. https://doi.org/10.1038/s44284-025-00221-1

Khennas, S., & Sokona, Y. (2020, July). Pathways for leapfrogging to reconcile development and climate change imperatives in Africa. *Climate Policy Brief, 24*. South Centre. https://www.southcentre.int/climate-policy-brief-24-july-2020/

Koppenborg, F. (2025). Phase-out clubs: an effective tool for global climate governance? *Environmental Politics*, 1–23. https://doi.org/10.1080/09644016.2025.2483070

Kueter, T. (2024). Renewable Energy: The Path Through the Energy Trilemma, *Energy Manager*, 1 February. https://www.energymanagermagazine.co.uk/renewable-energy-the-path-through-the-energy-trilemma/

Laan, T., and Maino, A.G. (2022). *Boom and Bust: The fiscal implications of fossil fuel phase-out in six large emerging economies*, Winnipeg: IISD, July. https://www.iisd.org/system/files/2022-07/fossil-fuel-phase-out-briics-economies.pdf

Lægreid, O.M., Cherp, A. and Jewell, J. (2023). Coal phase-out pledges follow peak coal: Evidence from 60 years of growth and decline in coal power capacity worldwide. *Oxford Open Energy* 2. https://doi.org/10.1093/ooenergy/oiad009

Lamb, W.F., Mattioli, G., Levi, S., Roberts, J.T., Capstick, S., Creutzig, F., Minx, J.C., Müller-Hansen, F., Culhane, T. and Steinberger, J.K. (2020). Discourses of climate delay. *Global Sustainability*, 3, p. e17. https://doi.org/10.1017/sus.2020.13

Lazard (2025). *2025 LCOE+ Report*. https://www.lazard.com/research-insights/levelized-cost-of-energyplus-lcoeplus/

Lebdioui, A. (2019). Chile's Export Diversification since 1960: A Free Market Miracle or Mirage? *Development and Change* 50(6), pp.1624-1663. https://doi.org/10.1111/dech.12545

Lelieveld, J., Haines, A., Burnett, R., Tonne, C., Klingmüller, K., Münzel, T., and Pozzer, A. (2023). Air pollution deaths attributable to fossil fuels: observational and modelling study, *BMJ* 383. https://doi.org/10.1136/bmj-2023-077784

Lenferna, G.A. (2018). Can we equitably manage the end of the fossil fuel era? *Energy Research & Social Science* 35, pp.217-223, https://doi.org/10.1016/j.erss.2017.11.007

Lins, C., Ferreira, G., Bastos, L. and Correa, B. (2024). *Rethinking Transitioning Away From Oil and Gas in a Just, Orderly and Equitable Manner*. Catavento. https://catavento.biz/wp-content/uploads/2024/12/2024_Catavento_Rethinking-transitioning-away-from-OG.pdf

Lins, C., Ferreira, G., Bastos, L. and Correa, B. (2025). *Transitioning Away From Fossil Fuels: A Broader Perspective to Drive Implementation*. Catavento. https://catavento.biz/wp-content/uploads/2025/09/2025_Catavento_Transitioning-away-from-fossil-fuels_a-broader-perspective.pdf

López, S. and Patzy, F. (2021). *Thermal Coal in Colombia: Perspectives and Risks for the Economies of La Guajira and Cesar Departments*. Natural Resource Governance Institute. https://resourcegovernance.org/sites/default/files/documents/summary_thermal_coal_in_colombia_perspectives_and_risks_for_the_economies_of_la_guajira_and_cesar.pdf

Luciani, G. (2021). Framing the Economic Sustainability of Oil Economies, in Luciani, G. and Moerenhout, T. (eds.), *When Can Oil Economies Be Deemed Sustainable? The Political Economy of the Middle East*. Cambridge: Gulf Research Centre. https://doi.org/10.1007/978-981-15-5728-6

Magazzino, C. (2022) Fiscal sustainability in the GCC countries. *International Journal of Economic Policy Studies* 16, pp.389–408. https://doi.org/10.1007/s42495-022-00082-9

Marchetti, C. and Nakicenovic, N. (1979). *The Dynamics of Energy Systems and the Logistic Substitution Model*. International Institute for Applied Systems Analysis. http://pure.iiasa.ac.at/id/eprint/1024/

MCA (2025). Coal: building Australia's future. Minerals Council of Australia. https://minerals.org.au/about/mining-facts/mineral-coal/

Medinilla, A., & Byiers, B. (2023). *The political economy of green industrialisation in Africa.* https://ecdpm.org/work/political-economy-green-industrialisation-africa

Mishrif, A. and Kapetanovic, H. (2018), Dubai's Model of Economic Diversification, in: Mishrif, A. and Al-Balushi, Y. (eds), *Economic Diversification in the Gulf Region, Volume II. The Political Economy of the Middle East*, Singapore: Palgrave Macmillan, https://doi.org/10.1007/978-981-10-5786-1_5

Mogess, Y.K. and Winkler , H. (2025). *Equitable transitions away from fossil fuels: A systemic and narrative literature review*. University of Cape Town Policy Research on International Services and Manufacturing (PRISM) Working Paper number 2025-1. https://commerce.uct.ac.za/sites/default/files/media/documents/commerce_uct_ac_za/869/prism-working-paper-2025-1-mogess-winkler-updated.pdf

Mulugetta, Y., Sokona, Y., Trotter, P.A., Fankhauser, S., Omukuti, J., Somavilla Croxatto, L., Steffen, B., Tesfamichael, M. et al. (2022). Africa needs context-relevant evidence to shape its clean energy future. *Nature Energy* 7, pp.1015–1022. https://doi.org/10.1038/s41560-022-01152-0

Muttitt, G. (2025). *Trends in Oil and Gas Demand and their Implications for Exporting Countries*. Lead Report - Policy Dialogue on Just Energy Transitions 2.0: Identifying Pathways to Prosperity Post-Fossil Fuels, Climate Strategies and Salzburg Global Dialogue. https://climatestrategies.org/publication/trends-oil-gas-demand/

Muttitt, G. (2026, forthcoming). *Oil prices and climate action*. IISD.

Muttitt, G. and Kartha, S. (2020). Equity, climate justice and fossil fuel extraction: Principles for a managed phaseout, *Climate Policy* 20(8). https://doi.org/10.1080/14693062.2020.1763900

Muttitt, G., Price, J., Pye, S. and Welsby, D. (2023). Socio-political feasibility of coal power phase-out and its role in mitigation pathways. *Nature Climate Change,* 13(2). https://doi.org/10.1038/s41558-022-01576-2

Muttitt, G., Sharma, S., Mostafa, M., Kühne, K., Doukas, A., Gerasimchuk, I., & Roth, J. (2021). *Step off the gas: International public finance, natural gas, and clean alternatives in the Global South.* IISD. https://www.iisd.org/system/files/2021-06/natural-gas-finance-clean-alternatives-global-south.pdf

Myllyvirta, L. (2025). Clean energy just put China's CO2 emissions into reverse for first time. *CarbonBrief*, 22 May. https://www.carbonbrief.org/analysis-clean-energy-just-put-chinas-co2-emissions-into-reverse-for-first-time/?utm_source=cbnewsletter&utm_medium=email&utm_term=2025-07-29&utm_campaign=Daily+Briefing+15+05+2025

Nakhle, C. (2009). Petroleum taxation. In: Evans, J. and Hunt, L., *International Handbook on the Economics of Energy*. Cheltenham and Northampton: Edward Elgar. pp.401-419.

National Planning Council, Qatar (2025). Number of Labor Force by Sector. https://www.data.gov.qa/explore/dataset/number-of-labor-force-by-sector-thousand/information/?flg=en-gb&disjunctive.sector

Ngwadla, X., Pérez Català, A. and Torres Gunfaus, M. (2025). *Enhancing international cooperation for climate action in Africa: A grounded theory analysis*. IDDRI. https://www.iddri.org/sites/default/files/PDF/Publications/Catalogue%20Iddri/Etude/202509-ST0225-cooperation%20africa.pdf

Nishikanta Mangang, N., Swarnakar, P. and Pai, S. (2024). Transitioning away from coal: Perspectives of Indian coal unions on achieving a just transition. *Energy Research & Social Science*. 118: 103812. https://doi.org/10.1016/j.erss.2024.103812

Norsk Petroleum (2025). Employment in the petroleum industry. https://www.norskpetroleum.no/en/economy/employment/

OECD (2018). *Benchmarking Civil Service Reform in Kazakhstan*. https://www.oecd.org/content/dam/oecd/en/publications/reports/2018/06/benchmarking-civil-service-reform-in-kazakhstan_g1g876f7/9789264288096-en.pdf

OECD (2023). *Government at a Glance Country Notes: Norway*. https://www.oecd.org/content/dam/oecd/en/publications/reports/2023/06/government-at-a-glance-2023-country-notes_a95d10b5/norway_52d434d6/2d302411-en.pdf

Office for Budget Responsibility (2025). Fuel duties. Webpage. https://obr.uk/forecasts-in-depth/tax-by-tax-spend-by-spend/fuel-duties/

Olurounbi, R. (2024). Nigeria Aims to Boost Tax Collections by 57% in 2024. Bloomberg, 15 January, https://www.bloomberg.com/news/articles/2024-01-15/nigeria-aims-to-boost-tax-collections-by-57-in-2024-asreforms-take-hold

OPEC (2025). *Who gets what from imported oil?* Factsheet, October. https://www.opec.org/assets/assetdb/who-gets-what-from-oil-2025.pdf

Ordonez, J.A., Jakob, M., Steckel, J.C. and Ward, H. (2023). India's just energy transition: Political economy challenges across states and regions. *Energy Policy* 179: 113621, https://doi.org/10.1016/j.enpol.2023.113621

Ovadia, J.S. (2020). Natural Resources and African Economies: Asset or Liability? in Oloruntoba, S.O. and Falola, T. (eds), *The Palgrave Handbook of African Political Economy*, pp.667-677. https://doi.org/10.1007/978-3-030-38922-2

Pai, S., Harrison, K. and Zerriffi, H. (2020). *A Systematic Review of the Key Elements of a Just Transition For Fossil Fuel Workers*. Smart Prosperity Institute, Clean economy working paper series WP 20-04. https://institute.smartprosperity.ca/transition-for-fossil-fuel-workers

Peszko, G., Van Der Mensbrugghe, D., Golub, A., Ward, J., Zenghelis, D., Marijs, C., Schopp, A., Rogers, J.A., Midgley, A. (2020). *Diversification and Cooperation in a Decarbonizing World : Climate Strategies of Fossil Fuel-Dependent Countries.* World Bank Group. http://documents.worldbank.org/curated/en/469241593746087038

Pirani, S. (2025). Pakistan's rush for rooftop solar brings dreams and nightmares. *People and Nature*, 7 February. https://peopleandnature.wordpress.com/2025/02/07/pakistans-rush-for-rooftop-solar-brings-dreams-and-nightmares/

Prince, G., Muttitt, G., Collett-White, R. and Coffin, M. (2023). *PetroStates of Decline*. Carbon Tracker Initiative. https://carbontracker.org/reports/petrostates-of-decline/

Rajamani, L. (2016) 'Ambition and differentiation in the 2015 Paris Agreement: Interpretative possibilities and underlying politics', *International and Comparative Law Quarterly*, 65(2), pp. 493–514. https://doi.org/10.1017/S0020589316000130

Rempel, A. and Gupta, J. (2021). Equitable, effective, and feasible approaches for a prospective fossil fuel transition. *WIREs Climate Change* 13(2). https://doi.org/10.1002/wcc.756

Rendon-Betancur, J.P. and Dyer, C.M. (2026) Green oil? Arctic melting and Norway's climate change obstruction discourses. *Polar Record*, 62, p.e1. https://doi.org/10.1017/S003224742510017X

Renewables First (2025). *Pakistan Electricity Review 2025*. https://uploads.renewablesfirst.org/Pakistan_Electricity_Review_2025_89f0b613d6.pdf

Ruzzante, M. and Sobrinho, N. (2022). *The 'Fiscal Presource Curse': Giant Discoveries and Debt Sustainability*. IMF Working Paper 010. https://doi.org/10.5089/9781616358990.001

Santos, M., O'Connor, J., Guzzardi, M., Ashiq, M., Rehan, R., Ahmed, M. and Tahir, S. (2025). Shedding light on Pakistan's distributed solar revolution. TransitionZero and Policy Research Institute for Equitable Development. https://www.transitionzero.org/shedding-light-on-pakistans-distributed-solar-revolution

Scott, K. and Bushnell, T. (2025). Describing the U.S. oil and gas extraction workforce with public data. *Monthly Labor Review*, May 2025. https://doi.org/10.21916/mlr.2025.11

Semieniuk, G., Campiglio, E., Mercure, J-F., Volz, U., & Edwards, N. R. (2021). Low-carbon transition risks for finance. *WIREs Climate Change, 12*(1), Article e678. https://doi.org/10.1002/wcc.678

Sengupta, T. (2024). *Equitable Fossil Fuel Phaseout: Science and Responsibility*. Centre for Science and Environment. https://www.cseindia.org/equitable-fossil-fuel-phaseout-12490

Seto, K. C., Davis, S. J., Mitchell, R. B., Stokes, E. C., Unruh, G., & Ürge-Vorsatz, D. (2016). Carbon lock-in: Types, causes, and policy implications. *Annual Review of Environment and Resources, 41*(1), 425–452. https://doi.org/10.1146/annurev-environ-110615-085934

Speelman, L. and Numata, Y. (2022). *A Theory of Rapid Transition: How S-Curves work and what we can do to accelerate them*. Rocky Mountain Institute. https://rockymnt.wpenginepowered.com/wpcontent/uploads/2022/10/theory_of_rapid_transition_how_s_curves_work.pdf

Srivastava, S., Tiwari, S. and Jena, L.P. (2025). *Transforming Jharkhand's economy in line with India's net-zero ambitions*, IEEFA, 3 November. https://ieefa.org/resources/transforming-jharkhands-economy-line-indias-net-zero-ambitions

Statistics Canada (2025). Employment by industry, monthly, unadjusted for seasonality, energy. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1410020102

Stevens, P., Lahn, G. and Kooroshy, J. (2015). *The resource curse revisited*. Chatham House. https://www.chathamhouse.org/sites/default/files/publications/research/20150804ResourceCurseRevisitedStevensLahnKooroshyFinal.pdf

Stockholm Environment Institute, Climate Analytics, and International Institute for Sustainable Development. (2025). *The Production Gap Report 2025*. http://productiongap.org/2025report

Taleb, N.N. (2007). The Black Swan: The impact of the highly improbable. London: Penguin.

Texas Independent Producers and Royalty Owners Association (2025). *State of Energy 2025*. https://tipro.org/2025-state-of-energy/

Tong, D., Zhang, Q., Zheng, Y., Caldeira, K., Shearer, C., Hong, C., Qin, Y. & Davis, S.J. (2019). Committed emissions from existing energy infrastructure jeopardize 1.5°C climate target. *Nature* 572: 373-377. https://doi.org/10.1038/s41586-019-1364-3

Trout, K., Muttitt, G., Lafleur, D., van de Graaf, T., Mendelevitch, R., Mei, L. & Meinshausen, M. (2022). Existing fossil fuel extraction would warm the world beyond 1.5 °C. *Environmental Research Letters*, 17(6), 064010. https://doi.org/10.1088/1748-9326/ac6228

Turkamani, H.S. (2025). The challenge of phasing out fossil fuels for highly fossil fuel-dependent countries in international law. *Leiden Journal of International Law*, pp. 1–20. https://doi.org/10.1017/S0922156525100319

UK EITI (2025). Oil & Gas in the UK. https://www.ukeiti.org/oil-gas

Ukpe, W. (2020). South South States lead in Nigerian unemployment. *Nairametrics*, 16 August. https://nairametrics.com/2020/08/16/south-south-states-lead-in-nigerian-unemployment/

United Nations Department of Economic and Social Affairs (2025). SDG Indicators database - Indicator 9.2.2, Series : Manufacturing employment as a proportion of total employment - 13th ICLS (%) SL_TLF_MANF. https://unstats.un.org/sdgs/dataportal/database

United Nations Development Program (2025). Human Development Index. https://hdr.undp.org/data-center/human-development-index#/indicies/HDI

UNEP(2023). *Emissions Gap Report 2023: Broken Record – Temperatures hit new highs, yet world fails to cut emissions (again).* United Nations Environment Program, Nairobi. https://doi.org/10.59117/20.500.11822/43922

UNEP(2025). *Emissions Gap Report 2025: Off target: Continued collective inaction puts global temperature goal at risk.* United Nations Environment Program, Nairobi. https://wedocs.unep.org/handle/20.500.11822/48854

UNFCCC (1992). United Nations Framework Convention on Climate Change. https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

UNFCCC (2015). Paris Agreement. https://unfccc.int/sites/default/files/english_paris_agreement.pdf

UNFCCC (2023). Outcome of the first global stocktake. Conference of the Parties serving as the meeting of the Parties to the Paris Agreement, Fifth session. https://unfccc.int/sites/default/files/resource/cma2023_L17_adv.pdf

Unicef (2020). *Assessment of COVID-19 Impact on Poverty and Vulnerability in Iraq*. https://www.unicef.org/iraq/reports/assessment-covid-19-impact-poverty-and-vulnerability-iraq

Unruh, G. C. (2000). Understanding carbon lock-in. *Energy Policy, 28*(12), 817–830. https://doi.org/10.1016/S0301-4215(00)00070-7

Unruh, G.C. (2002). Escaping carbon lock-in. *Energy Policy* 30, pp.317–325. https://doi.org/10.1016/S0301-4215(01)00098-2

Van Rossum, H., Torres-Gunfaus, M., Lins, C., Ferreira, G. and Correa, B. (2025). *Implementing the Global Stocktake's energy goals: Why economic transition matters for COP30*. IDDRI and Catavento. https://www.iddri.org/en/publications-and-events/policy-brief/implementing-global-stocktakes-energy-goals-why-economic

Victor, D.G., Geels, F.W. and Sharpe, S. (2019). *Accelerating the Low Carbon Transition: The case for stronger, more targeted and coordinated international action*. Brookings Institution. https://www.brookings.edu/wpcontent/uploads/2019/12/Coordinatedactionreport.pdf

Vinichenko, V., Cherp, A. and Jewell, J. (2021). Historical precedents and feasibility of rapid coal and gas decline required for the 1.5°C target. *One Earth* 4(10), pp.1477-1490. https://doi.org/10.1016/j.oneear.2021.09.012

Viswanathan, B., Raizada, S., Bassi, A.M., Pallaske, G. and Beaton, C. (2022). *India's State-Owned Energy Enterprises, 2020–2050: Identifying evidence-based diversification strategies*, IISD. https://www.iisd.org/publications/report/india-state-owned-energy-enterprises

Walker, B. and Pastukhova, M. (2024). *An orderly and equitable global transition away from fossil fuels*. E3G. https://www.e3g.org/publications/an-orderly-and-equitable-global-transition-away-from-fossil-fuels/

Walter, D., Butler-Sloss, S. and Bond, K. (2024). Energy after Fire: The shift from primitive heat to modern work, Rocky Mountain Institute, 10 September. https://rmi.org/energy-after-fire/

Wang, X. and Lo, K. (2021). Just transition: A conceptual review. *Energy Research & Social Science* 82: 102291, https://doi.org/10.1016/j.erss.2021.102291

Way, R., Ives, M.C., Mealy, P. and Farmer, J.D. (2022). Empirically grounded technology forecasts and the energy transition. *Joule* 6(9), 2057-2082. https://doi.org/10.1016/j.joule.2022.08.009

WeMake Consultores (2023). Electrification: the limping pillar of the energy transition, 2 November. https://wemakeconsultores.com/en/electrification-the-limping-pillar-of-the-energy-transition/

Wicken, O. (2017). Industrial diversification processes and strategies in an oil economy, pp.304-307. In Mahroum, S. & al-Saleh, Y. (Eds.), Economic diversification policies in natural resource rich economies, Abingdon and New York: Routledge.

Wilke, T. (2024). Available Mechanisms to Finance the Early Retirement of Coal-Fired Power Plants. Columbia Center on Sustainable Investment blog, 18 November. https://ccsi.columbia.edu/news/available-mechanisms-finance-early-retirement-coal-fired-power-plants

Winkler, H. and Marquard, A. (2009). Changing Development Paths: From an Energy-Intensive to Low-Carbon Economy in South Africa. *Climate and Development* 1 (1): 47–65. https://doi.org/10.3763/cdev.2009.0003 .

Winkler, H. and Black, A. (2024). "Creating Employment and Reducing Emissions: Options for South Africa. *Development Southern Africa* 41. https://doi.org/10.1080/0376835X.2024.2380716

World Integrated Trade Solutions database (2022). Mongolia Trade Summary. https://wits.worldbank.org/CountrySnapshot/en/MNG/textview

World Bank (2021a). Doing Business Index: System average interruption duration index. https://databank.worldbank.org/source/doing-business/Series/IC.ELC.SAID.XD.DB1619

World Bank (2021b). Doing Business Index: System average interruption frequency index. https://databank.worldbank.org/source/doing-business/Series/IC.ELC.SAIF.XD.DB1619

World Bank (2024). Worldwide Governance Indicators, updated 11/05/2024. https://databank.worldbank.org/id/98e680fc#

World Bank (2025a). World Development Indicators: Population: total, https://data.worldbank.org/indicator/SP.POP.TOTL

World Bank (2025b). World Development Indicators: Fuel imports (% of merchandise imports). https://data.worldbank.org/indicator/TX.VAL.FUEL.ZS.UN

World Bank (2025c). World Development Indicators: Fuel exports (% of merchandise exports), https://data.worldbank.org/indicator/TX.VAL.FUEL.ZS.UN

World Bank (2025d). World Development Indicators: Merchandise imports (current US$), https://data.worldbank.org/indicator/TM.VAL.MRCH.CD.WT

World Bank (2025e). World Development Indicators: Merchandise exports (current US$), https://data.worldbank.org/indicator/TX.VAL.MRCH.CD.WT

World Bank (2025f). World Development Indicators: GDP (current US$), https://data.worldbank.org/indicator/NY.GDP.MKTP.CD

World Bank (2025f). World Development Indicators: Labor force, total. https://data.worldbank.org/indicator/SL.TLF.TOTL.IN

World Bank (2025g). Coal rents (% of GDP). https://data.worldbank.org/indicator/NY.GDP.COAL.RT.ZS?locations=1W

World Bank (2025h). Oil rents (% of GDP). https://data.worldbank.org/indicator/NY.GDP.PETR.RT.ZS

World Bank (2025i). Natural gas rents (% of GDP). https://data.worldbank.org/indicator/NY.GDP.NGAS.RT.ZS

WLGA (2025). Where does LPG come from? https://www.worldliquidgas.org/about-liquid-gas/what-is-liquid-gas/where-does-lpg-come-from/

Yang, M., Yang, B., Butler-Sloss, S. and Graham, E. (2025). *China Energy Transition Review 2025*, Ember. https://ember-energy.org/latest-insights/china-energy-transition-review-2025/

Yanguas Parra, P. (2024). Closing the supply-side gap: using a novel vulnerability index to identify the right policy mix for coal producing countries. *Sustainability Nexus Forum* 31:3–24. https://doi.org/10.1007/s00550-024-00530-4

Yanguas Parra, P., Furnaro, A., Malz, N., Wijayani, L., & Oei, P.Y. (2025). Supply-side policies in coal transitions and country vulnerabilities: a systematic literature review. *Environmental Politics*, pp.1–37. https://doi.org/10.1080/09644016.2025.2538324