COP30 PRESIDENCY ROADMAP

for **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

Implementing the Global Stocktake of the Paris Agreement

COP30 BRASIL AMAZÔNIA
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CONTENTS

FOREWORD 6

INTRODUCTION 8

IMPLEMENTING THE GLOBAL STOCKTAKE ON TRANSITIONING AWAY FROM FOSSIL FUELS: THE BELÉM READINESS APPROACH 14

METHODOLOGY 14

a. Guiding principles 16

DEMAND-SIDE PERSPECTIVE: ACCELERATING FOSSIL FUEL DEMAND REDUCTION ACROSS THE GLOBAL ENERGY SYSTEM 17

a. The relevance of the demand-side transition 17

b. Structural factors shaping the demand-side transition 18

c. Energy Demand Transition Readiness Index: assessing transition preparedness 27

d. Energy Demand Transition Archetypes: identifying common transition profiles 29

e. Differentiated implementation pathways: strengthening demand-side transition readiness 32

SUPPLY-SIDE PERSPECTIVE: REDUCING FOSSIL FUEL SUPPLY AND EXPANDING LOW-EMISSIONS ENERGY SYSTEMS 46

a. The relevance of the supply-side transition 46

b. Structural factors shaping the supply-side transition 47

c. Energy Supply Transition Readiness Index: assessing transition preparedness 56

d. Energy Supply Transition Archetypes: identifying common transition profiles 58

e. Differentiated implementation pathways: strengthening supply-side transition readiness 61

Box 1: The role of the oil and gas industry in transitioning away 74

ECONOMIC TRANSITION PERSPECTIVE: TRANSFORMING ECONOMIC SYSTEMS AND INCENTIVES 78

a. The relevance of the economic transition 78

b. Structural factors shaping the economic transition 79

Box 2: The economics of the transition away from fossil fuels 88

c. Economic Transition Readiness Index: assessing transition preparedness 89

d. Economic Transition Archetypes: identifying common transition profiles 91

e. Differentiated implementation pathways: strengthening economic transition readiness 94

BELÉM READINESS APPROACH TRIPOD: INTEGRATING DEMAND, SUPPLY AND ECONOMIC TRANSITION READINESS 105

THE WAY FORWARD: ACCELERATING ACTION IN THIS CRITICAL DECADE 109

START NOW, FROM WHERE YOU ARE 109

TAFF *MUTIRÃO*: A COLLECTIVE AGENDA FOR THIS CRITICAL DECADE 112

KEEP THE GLOBAL DIALOGUE GOING 114

APPENDICES 116

A. END-USE TRANSFORMATION PATHWAYS 116

Transport 117

Building 135

Industry 140

B. COAL SENSITIVITY ANALYSIS 152

Demand-side 152

Supply-side 153

Economic Transition 155

C. FIRST STEPS BY ARCHETYPE: SEQUENCING PRIORITIES OF SPECIFIC IMPLEMENTATION LEVERS IN THE THREE PILLARS 157

D. GLOSSARY 163

E. ENDNOTES 168

ACKNOWLEDGMENTS AND CONTRIBUTORS 178

FOREWORD

President Luiz Inácio Lula da Silva saw COP30 as the moment when the multilateral climate regime would have to prove that it could deliver: the COP of Truth. "The era of declarations of good intentions has ended: the time for action plans has arrived," he wrote as the conference was about to begin. At the Leaders' Summit in Belém, he went further: "The world needs a clear roadmap to end its dependence on fossil fuels."

That call changed the conversation at COP30. Having listened closely to the intense debate among Parties and non-Party stakeholders, the COP30 Presidency felt bound to pursue the possibility it opened. At the closing plenary, and in the context of the COP being held in the Amazon, I committed to developing, under my responsibility as President of COP30, Roadmaps for implementing two outcomes of the First Global Stocktake, agreed by consensus at COP28 just two years earlier: (i) transitioning away from fossil fuels in energy systems in a just, orderly and equitable manner; and (ii) enhancing efforts toward halting and reversing deforestation and forest degradation by 2030. With their publication, that commitment is fulfilled.

Both transitions depend on finance. The two Roadmaps are therefore presented alongside a third document, *Implementing the Baku to Belém Roadmap to 1.3T*, which sets out how financing to developing countries for climate action can be scaled up from all public and private sources to at least US$ 1.3 trillion per year by 2035. Read together, the three documents describe what has to change and propose ways forward so that change can be financed and sustained.

All three are the result of a year of extensive consultations with governments, regulators, international organizations, experts, civil society and the private sector, with significant contributions from the advisory committees and Circles of the COP30 Presidency. As I said at the time, they are contributions to the implementation of decisions adopted under the UNFCCC, the Kyoto Protocol and the Paris Agreement. Those decisions were all negotiated to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances. As raised in consultations, the principle lies at the heart of the regime, together with other principles enshrined in the 1992 Convention: the specific needs and special circumstances of developing country Parties, especially those that are particularly vulnerable; precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects; the promotion of sustainable development as both a right and a duty; and cooperation to promote a supportive and open international economic system. Far from contradictory, these principles are all mutually supportive.

Common but differentiated responsibilities are often invoked as a line of division between developed and developing countries, yet the record shows that it has not stood in the way of consensus. Year after year, COPs continue to adopt important decisions, many of them with particular attention to the poorest and most vulnerable. As expressed during the consultations, beyond dynamics among countries, common but differentiated responsibilities could also guide implementation *within countries*, where responsibilities

and capabilities are often unequal, given that the climate crisis and wealth inequality are deeply interconnected. Countries and stakeholders can reflect on the domestic application of this principle alongside the consideration of needs and special circumstances of the most vulnerable.

Belém marked a turning point. In the Global *Mutirão* decision, Parties resolved "to decisively transition to a focus on the implementation of the Paris Agreement and decisions adopted since its first session," acknowledging that "the transition toward low greenhouse gas emissions and climate-resilient development is irreversible and represents the trend of the future." With the Paris Rulebook complete and a large body of decisions adopted by consensus, the regime has the mandates and instructions it needs. Refinements will continue to be negotiated, but our shared decisions already allow us to focus on implementation. The purpose of the three documents presented by the COP30 Presidency is to help put into practice what Parties have already agreed. We hope they will inform both the international debate and domestic pathways.

What the regime requires now is accelerated action. This shift opens extraordinary opportunities for cooperation, because negotiation and implementation follow different logics. Negotiation is intergovernmental and requires consensus among Parties. Implementation involves all actors, not only States. At the national level, it rests on the sovereign decision of each country, expressed through Nationally Determined Contributions and National Adaptation Plans. It can also take the form of cooperation among countries and non-State actors willing to move together.

Coalitions of developed countries, of developing countries, and of both are already implementing together, even where they hold different positions in the negotiating room. They are joined by the private sector, subnational governments, civil society, Indigenous Peoples and local communities, and academia, working toward concrete, shared objectives.

The restructured Action Agenda presented in Belém was based on the outcome of the First Global Stocktake, achieved by consensus. With its plurilateral and multistakeholder initiatives, the Action Agenda has shown how much such cooperation can achieve in mitigation, adaptation and finance. By consolidating this approach, Belém allows implementation to advance at the pace the crisis demands, while negotiations continue to build consensus. This two-tier multilateralism has all the elements needed to accelerate action toward the goals of the Paris Agreement.

As President Lula said, the time for action plans has arrived. These three documents are offered in that spirit to Parties, to the incoming Presidencies of COP31 and COP32, and to every government, institution and community ready to take part in our global *Mutirão* against climate change.

André Aranha Corrêa do Lago
President of COP30

INTRODUCTION

Accelerating implementation: the role of the Roadmap

The COP30 Presidency Roadmap for Transitioning Away from Fossil Fuels in Energy Systems was announced at the closing plenary of COP30 in Belém. It responds to the need to support the implementation of the outcomes of the first Global Stocktake, adopted by consensus at COP28 in Dubai, and in particular of its call to transition 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. In Belém, Parties also resolved, in the *Mutirão* decision, to "decisively transition to a focus on the implementation of the Paris Agreement and decisions adopted since its first session"[1].

The Roadmap is the Presidency's voluntary contribution to the shift from negotiation to implementation. It creates no new commitments and is not a negotiated outcome. It brings together evidence, implementation experience and solutions to inform how countries and the partners that support them can accelerate existing efforts through nationally determined action and stronger international cooperation.

The Roadmap draws on an open and participatory process. An open call on the UNFCCC platform drew 267 contributions, including 21 from Parties or groups of Parties representing 115 Parties in total. The Presidency also consulted governments, international organizations, research institutions, civil society, the private sector and financial institutions in every region, importers and exporters of fossil fuels, advanced and developing economies alike[2].

The analysis is organized around three pillars of the transition: energy demand; energy supply; the broader economy. It proposes a methodology, the Belém Readiness Approach, through which countries can assess how exposed they are to the transition away from fossil fuels and how much capacity they have to manage it, and then, according to the readiness archetype that results, select and sequence the levers that fit their circumstances. The Roadmap closes with the way forward, with the COP30 Presidency's proposals for accelerating action in this critical decade.

Aligning the Roadmap with the first Global Stocktake

COP28 marked the first time that fossil fuels were explicitly addressed in the outcome of a UN climate conference. The decision on the first Global Stocktake calls on Parties to contribute, in a nationally determined manner and taking into account the Paris Agreement and their different national circumstances, pathways and approaches, to a set of global efforts in the energy sector: (a) tripling renewable energy capacity globally and doubling the global average annual rate of energy efficiency improvements by 2030; (b) accelerating efforts toward the phase-down of unabated coal power; (c) accelerating efforts globally toward net zero emission energy systems, utilizing zero- and low-carbon fuels well before or by around mid-century; (d) 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; (e) accelerating zero- and low-emission

technologies, including renewables, nuclear, abatement and removal technologies and low-carbon hydrogen production; (f) accelerating and substantially reducing non-carbon-dioxide emissions globally, including in particular methane emissions by 2030; (g) accelerating the reduction of emissions from road transport on a range of pathways; and (h) phasing out inefficient fossil fuel subsidies that do not address energy poverty or just transitions, as soon as possible[3]. The decision also recognizes that transitional fuels can play a role in facilitating the energy transition while ensuring energy security.

The Roadmap takes outcome (d) as its subject. Several of the others, from the expansion of renewables and energy efficiency to the phase-down of unabated coal, methane abatement, road transport and the reform of fossil fuel subsidies, appear throughout its analysis as levers through which that transition is advanced, since the outcomes of paragraph 28 are complementary and were agreed as a whole. Its central focus nonetheless remains outcome (d), and with it the need for countries to plan deliberately and to choose the levers and actions that address this specific challenge of the transition.

The Paris Agreement itself connects the Global Stocktake to national action. Its outcome is meant to inform Parties as they update and strengthen, in a nationally determined manner, their actions and support, and as they enhance international cooperation, and the nationally determined contributions that each Party communicates every five years are to be informed by it[4]. The energy-related outcomes agreed in Dubai therefore already have a route into national plans and contributions, laid down in the Agreement itself, and this Roadmap is intended to support countries in refining and implementing it.

The challenge

Global temperatures are rising at an unprecedented pace, bringing the world close to temperature thresholds associated with widespread climate risks. Human-induced warming reached 1.37°C in 2025 relative to 1850–1900, increasing at around 0.27°C per decade[5]. Looking ahead, there is a 75% chance that global temperatures averaged over 2026–2030 will exceed 1.5°C, as the remaining carbon budget[6] is close to being exhausted. Exceeding 1.5°C increases the risk of crossing climate tipping points[7], making this a critical decade to limit the magnitude and duration of any overshoot[8] and keep the Paris Agreement's long-term goal within reach.

Climate risks increase with every increment of warming, triggering potentially irreversible changes in natural and human systems. Without effective adaptation, global food production is projected to decline by up to 14% by 2050,[9] threatening food security and livelihoods. An additional 5 to 10 cm of sea-level rise expected by 2050[10] can double coastal flooding frequency in tropical regions, undermining the habitability of small island states and low-lying coastal cities.

Additionally, these risks are expected to generate economic costs that fall disproportionately on the most vulnerable. Extreme weather and chronic climate impacts are expected to generate GDP losses at regional and global levels, amplified by cascading effects across economies[11]. Countries with high exposure and limited adaptive capacity are hardest hit, since a single extreme event can erase years of development gains,

as many have already experienced, and most of the damage caused by each additional ton of CO^2 emitted today falls on regions that contributed least to past emissions[12]. The same imbalance holds within countries as much as between them, since the richest tenth of the world's population produces close to half of global emissions and the poorest half little more than a tenth, and the poorest could escape extreme poverty by adding only a few percent to today's emissions, less than the top 1% of emitters already produce[13].

The urgency of acting in this critical decade places global energy systems at the center of climate response, given the continued fundamental role played by fossil fuels. Since the Industrial Revolution, coal, oil and gas have powered industrialization, lifted societies out of poverty and still underpin energy development in many countries. Yet they account for approximately 73% of global greenhouse gas emissions, which reached 57.7 $GtCO^2e$ in 2024, more than 50% above 1990 levels. Atmospheric CO^2 concentrations are now at their highest in approximately two million years[14], which calls urgently for transitioning away from fossil fuels by rethinking the future of energy production and consumption.

A transformation already underway

The technologies needed to transition away from fossil fuels exist, and many of them are now reliable and competitive. Renewables accounted for more than 85% of the power capacity added worldwide in 2025, clean sources met the whole of that year's growth in electricity demand, and electric vehicles, heat pumps and other efficient end-use technologies have reached commercial maturity in many markets, while sustainable fuels and other low-emissions alternatives are available for the uses that are harder to electrify[15]. Over 90% of the large renewable power plants commissioned in 2024 generate electricity more cheaply over their lifetime than any new fossil fuel plant could, and clean energy investment now exceeds investment in fossil fuel supply[16, 17].

The transformation is already underway, and countries now pursue it for energy security and economic advantage as much as for climate reasons. Major fossil fuel supply shocks in the last five years highlighted the risks associated with geographically concentrated production. In 2026, shipping through a single maritime passage that carries a large share of the world's seaborne oil and liquefied natural gas came close to a halt, in the largest disruption in the history of the oil market, and importing economies felt the shortage first and hardest, to the point that several governments rationed fuel and ordered factories to close[18]. Consumers everywhere paid more for fuel and power, since oil and gas are priced on world markets and a shortfall in one region raises prices in all of them, and close to three quarters of the world's population live in countries that are net importers of fossil fuels[19]. Importing countries also discovered the limits of the buffers they had relied on, from spare production capacity to strategic stocks and alternative routes, and many of them, together with households and firms able to act on their own, are turning to electrification and locally produced low-emissions energy as the surest way to reduce their exposure and to contain their energy costs [20].

At the same time, energy demand has reached record levels. Global energy consumption increased by 1.3% in 2025, while electricity demand grew by nearly 3%, above the 2.8% average of the previous decade. This growth reflects the legitimate effort of countries to improve the quality of life of their populations, but it also brings additional challenges[21]. It is expected to continue, driven by rising cooling needs, broader electrification and, more recently, by data centers for artificial intelligence, a demand driver that has emerged in the space of a few years. Meeting this growing demand also means closing persistent energy access gaps, with 655 million people still lacking access to electricity and around 2 billion relying on polluting fuels and technologies for cooking[22].

Demographic projections add a further consideration. The United Nations expects world population to peak at around 10.3 billion in the mid-2080s, a lower and earlier peak than previously projected, as fertility falls below replacement level in a growing number of countries, and recent independent studies suggest that the peak could come sooner and lower still[23]. Plans for energy access, consumption and production over the coming decades will need to be adjusted to this new reality.

For emerging markets and developing economies, the transition is a development question as much as a climate one. They need more energy to raise living standards and are where most future demand will come from, while bearing most of the damage from further warming. Low-emissions energy services can now meet growing demand reliably and at lower cost than fossil fuels, whose apparent affordability often rests on leaving their climate and health externalities unpaid, which eases this tension and makes the transition a way to sustain development.

The policy and implementation gaps

Current policies and announced plans, including the nationally determined contributions submitted to date, still leave the world short of the energy outcomes agreed in Dubai[24]. Countries can close that gap only with a shared sense of direction, since none of them can manage this shift in isolation and fragmented national approaches risk misaligned investment and stranded assets. They have to plan the expansion of low-emissions energy and the decline of fossil fuels in step, at home and with one another, and the multilateral climate process is where they set that common direction and review their progress. That is what Parties did at COP28 in Dubai through the first Global Stocktake.

Translating this collective direction into practical action is now the central challenge of the global transition. Decisions under the Paris Agreement set a common course for all Parties, but delivering them depends on choices that each country makes according to its own circumstances, together with the cooperation among governments, businesses and other actors that turns agreed outcomes into action on the ground. Implementation does not have to be negotiated, but it must be planned, financed and coordinated. It requires cooperation across national, subnational and sectoral levels to set priorities and sequence action, and it requires governments, subnational authorities and companies to understand where their exposure is greatest, where their transition capacity remains constrained and where existing capabilities allow earlier progress, including opportunities to leapfrog.

Building on existing efforts

Encouragingly, implementation is already taking shape, and it builds on a substantial base of existing effort. The transition away from fossil fuels rests on decades of work by governments, international organizations, research institutions, industry, financial institutions, cities and regions and civil society, which have produced the policies, technologies, data, standards and coalitions on which any acceleration will depend. Some countries have recently presented national roadmaps to guide their transitions away from fossil fuels, and others have pledged to follow suit, while subnational governments, companies and communities have moved ahead on their own in the sectors and territories where they have the means to do so. International initiatives, from those that track and support the deployment of renewables, efficiency, electrification and sustainable fuels to those working on methane, coal power, fossil fuel subsidies and the financing of the transition in developing countries, have been at work for years. They are too numerous to list here and are cited throughout the document, whose analysis also draws on the many excellent reports of institutions that have followed energy transitions for decades. The collective task now is to scale up and accelerate these efforts.

The COP30 Presidency has contributed to these efforts through the renewed structure and the Five-Year Vision for the Global Climate Action Agenda, which organizes the voluntary initiatives of national and subnational governments, businesses and other non-state actors around the implementation of the first Global Stocktake through six thematic axes and 30 key objectives. Its first axis, on transitioning energy, industry and transport, draws directly on the energy-related outcomes of paragraph 28. At COP30, 482 initiatives were brought together for the first time and 120 Plans to Accelerate Solutions were published to overcome barriers and deliver those outcomes, with follow-up aligned with the UNFCCC cycle up to the second Global Stocktake in 2028[25]. Through the Action Agenda, the Presidency also launched the Belém 4X Pledge on Sustainable Fuels, endorsed by 32 countries, which aims to quadruple the use of sustainable fuels by 2035 relative to 2024 levels[26].

The COP31 Presidency, for its part, has placed electrification at the center of its Action Agenda, launching the 35-by-35 Global Electrification Pledge in 2026. The pledge seeks to increase electricity's share of global total final energy consumption from just over 20% today to 35% by 2035, complementing efforts to expand renewable energy and improve energy efficiency[27], as one key measure in a broader plan to transition away from fossil fuels.

The COP30 Presidency Roadmap for Transitioning Away from Fossil Fuels is one contribution among these efforts. By connecting structural conditions, readiness assessment and implementation levers, it offers governments at national or subnational level a basis on which to develop, refine and implement national transition roadmaps, and offers the institutions and partners that support them a means of directing finance, technology and capacity-building to the dimension of the transition in which each country's constraints are concentrated. The Belém Readiness Approach on which it rests respects the different circumstances of countries while giving each of them ways to act and to contribute to the shared goal, agreed in Dubai, of transitioning away from fossil fuels.

Purpose and objectives

The purpose of the COP30 Presidency TAFF Roadmap is to support the **accelerated implementation** of the commitment to transition away from fossil fuels in energy systems in a just, orderly and equitable manner, acknowledging that countries face different structural conditions, levels of exposure and transition capacities. To this end, the Roadmap aims to go from diagnosis to implementation by:

- **Provide a common analytical framework** for understanding demand-side, supply-side and economic transition conditions, based on countries' exposure and transition capacity.
- **Support differentiated self-assessment and prioritization**, allowing countries to identify structural factors, readiness conditions, opportunities and implementation needs.
- **Translate assessment into action** through foundational and archetype-specific implementation levers that can be adapted to country-specific circumstances and priorities, with the aim of informing the development, refinement and implementation of national transition roadmaps and strategies.
- **Strengthen coordination, international cooperation and enabling conditions** by allowing the broader supporting ecosystem to better align finance, technology, capacity-building and other forms of support with country-specific needs.

IMPLEMENTING THE GLOBAL STOCKTAKE ON TRANSITIONING AWAY FROM FOSSIL FUELS: THE BELÉM READINESS APPROACH

METHODOLOGY

Transitioning away from fossil fuels is too large a problem to be addressed as a single undertaking. There is no unique solution for this complex puzzle. To make it tractable we must embrace its complexity and break it down into smaller pieces that can be examined and acted upon separately, while considering the effects in the next pieces. This is the purpose of the Belém Readiness Approach, the methodology on which this Roadmap rests. Three pillars of our dependence on fossil fuels, and therefore of the transition, are distinguished but also connected: energy demand, energy supply and the broader economy. Each follows its own dynamics and presents its own constraints, challenges and opportunities. Within each pillar, two questions are asked: how exposed a country is to the transformation under way, and what capacity it has to manage it, the two read together giving an indication of readiness.

The Belém Readiness Approach itself does not single out, assess or classify individual countries; it is written so that each country can recognize its own circumstances in the analysis and carry the exercise out for itself. Its time horizon is nonetheless that of the COP28 decision itself, which calls for action in this critical decade.

In each of the three pillars, the Belém Readiness Approach is applied through the same analytical framework, which leads from diagnosis to implementation in four steps, from the structural factors that shape exposure and capacity to a Readiness Index, a set of archetypes and the levers associated with each of them. The framework uses the same dimensions, indicators and definitions in every pillar, so that the three assessments can later be read together.

The first step identifies, in each pillar, the structural factors that shape countries' exposure to the transition and their capacity to respond. These factors reflect the underlying conditions that can either constrain implementation or create opportunities for faster progress.

The second step is a **Readiness Index** for each pillar, which turns the two questions of the Approach into a measurable assessment. The Energy Demand Transition Readiness Index, Energy Supply Transition Readiness Index and Economic Transition Readiness Index assess the interaction between two core dimensions: **exposure and transition capacity**. Exposure captures the scale and complexity of the transformation required, while transition capacity reflects the capabilities and enabling conditions available to implement that transformation and unlock associated social and economic opportunities.

In the third step, countries position themselves, according to their combination of exposure and transition capacity, within analytical **archetypes**. These archetypes are not intended to rank countries or prescribe uniform pathways. They provide an analytical structure for identifying countries that face similar transition conditions and for understanding how different combinations of exposure and capacity can generate distinct implementation needs and opportunities.

The framework does not prescribe uniform quantitative thresholds or scoring rules, since it is intended to remain a non-prescriptive analytical tool and to avoid introducing methodological parameters that could be read as negotiated classifications or requirements. Consistent self-assessment relies instead on the common structure of the framework, with the same dimensions, indicators and definitions across countries. Where comparable data are available, international benchmarks and reference ranges can provide an indicative basis for interpreting countries' relative levels of exposure and transition capacity, while preserving national ownership and flexibility.

The fourth step moves from assessment to action through two types of implementation levers. **Foundational levers** represent actions that are broadly relevant across countries within each pillar and help to accelerate and strengthen the enabling conditions for transition. **Archetype-specific implementation levers** reflect the differentiated priorities associated with each combination of exposure and transition capacity. Together they translate the readiness assessment into practical implementation options that can be adapted to national circumstances and priorities.

Once the four steps have been completed in each pillar, countries can read the three assessments together, and the **Belém Readiness Approach Tripod** presents this integrated reading graphically, showing their relative readiness across the demand-side, supply-side and economic pillars. The Tripod signals the integration of the three pillars of the transition and the importance of achieving coordinated progress in all three.

The integrated reading can also support more targeted international cooperation. By showing the pillar in which readiness constraints are most concentrated, it can help international organizations, financial institutions, development partners and other supporting actors align finance, technology, capacity-building and technical assistance with country-specific needs and existing capabilities.

Three complementary lenses complete the Belém Readiness Approach. The **within-country lens** examines how just, orderly and equitable considerations inform the design and sequencing of the levers inside each country. The **end-use transformation pathways** (Appendix A) add a sectoral layer for transport, industry and buildings, where fossil fuel demand is reduced in practice, and connect the levers of the three pillars with the solutions available in each sector. A **coal sensitivity analysis** (Appendix B) supports interpretation in countries where coal plays a particularly important role in energy systems or economic activity. It does not establish a separate index or modify the underlying logic; it identifies where coal-specific conditions call for additional attention, disaggregation or interpretation within the existing Readiness Indexes.

The Belém Readiness Approach is also the result of twelve months of consultations. Since Belém, the COP30 Presidency has sought the views of governments, international organizations, financial institutions, research centers, businesses and civil society and constituencies in bilateral meetings, workshops and events held during the Bonn sessions and in the margins of the main climate and energy gatherings of the year. Of particular importance were the written contributions submitted by Parties, admitted organizations and other stakeholders in response to the invitation circulated at the request of the COP30 President, all of which are publicly available on the UNFCCC website.

A document of this nature cannot refer individually to each contribution received, and the Presidency is aware that a synthesis of this kind conveys only part of the range and depth of what it was given. The Roadmap nonetheless rests to a large extent on what the Presidency received in writing and heard in conversation. The Presidency is grateful to all those who took the time to engage with the exercise and to share their experience and expectations.

The COP30 Presidency presents the Belém Readiness Approach as a first iteration. The Readiness Indexes, the archetypes and in particular the Tripod can and should be refined as data improve, as the Approach is tested against national experience and as new aspects are brought in. During the consultations, several contributors asked, for instance, that the social dimension of the transition be more fully captured. The Roadmap is therefore conceived as a living document, and the Presidency has been encouraged by the interest expressed by several governments, institutions and partners in keeping this work alive beyond COP30.

a. Guiding principles

Consistent with the implementation of the outcome of COP28, the transition away from fossil fuels is understood as a process to be advanced in **a just, orderly and equitable manner**, while accelerating action in this critical decade and maintaining alignment with pathways consistent with limiting global warming to 1.5°C. For the purposes of this Roadmap, these concepts are treated as mutually reinforcing considerations for implementation rather than as standalone or prescriptive definitions.

A transition conducted in a just manner places people, workers and communities at the center of implementation. It considers the social and distributional impacts of structural change, including the protection of affected workers and communities, the creation of decent work and quality jobs, the strengthening of skills and social protection, and the importance of meaningful participation. These considerations are reflected across selected Readiness Index indicators, foundational levers and archetype-specific implementation levers.

A transition conducted in an orderly manner emphasizes early planning, sequencing and coordination across the demand-side, supply-side and economic pillars. It seeks to manage risks to reliability, affordability, energy security and economic stability while anticipating infrastructure, investment and institutional needs. This principle is embedded in the readiness assessment, planning-related foundational levers and differentiated implementation pathways.

A transition conducted in an equitable manner recognizes that countries have different histories, different structural conditions, capabilities and development circumstances. It also considers how the costs, benefits and opportunities of the transition are distributed within countries, regions, sectors and population groups, and the role of finance, technology and capacity-building in enabling implementation. This is reflected in the framework's distinction between exposure and capacity, in the archetypes and in the emphasis on targeted international cooperation and means of implementation.

Across all parts of the Roadmap, the analysis is grounded in a common set of principles. It draws on the best available scientific and analytical evidence, recognizes national ownership and circumstances, and reflects the fact that the outcome of the Global Stocktake (GST)

was negotiated under the principle of common but differentiated responsibilities and respective capabilities (CBDR-RC). Equity in this implementation Roadmap is understood in two senses: equity among countries, as expressed in that principle, and equity within countries. Where differences in income between social groups and regions are wide, the transition calls for closer attention to its distributional effects, including at the local level, a concern raised repeatedly during the consultations. It also recognizes that countries face different structural conditions, levels of exposure and implementation capacities. The Roadmap is intended to serve as a practical reference for national planning, international cooperation and coordinated action across national and subnational governments, businesses, financial institutions, international and regional organizations, academia, civil society, Indigenous Peoples and local communities, workers and trade unions, youth and other relevant stakeholders.

Taken together, the evidence and analysis in this Roadmap lead the COP30 Presidency to a clear conclusion that **transitioning away from fossil fuels is urgent, inevitable and yet possible**. Countries start from different positions, but each archetype has a set of implementation levers available according to its characteristics, showing that every country can contribute to the shared goal. Coordinated action across the demand-side, supply-side and economic pillars can turn the commitment of the GST into concrete progress during this critical decade. The COP30 Presidency welcomes proposals to update and improve this Roadmap, which is intended to remain a living document.

DEMAND-SIDE PERSPECTIVE: ACCELERATING FOSSIL FUEL DEMAND REDUCTION ACROSS THE GLOBAL ENERGY SYSTEM

a. The relevance of the demand-side transition

Transitioning away from fossil fuels requires accelerated and sustained reductions in fossil fuel consumption across global energy systems, given their central contribution to GHG emissions and rising global temperatures[28]. Reducing structural dependence on fossil fuels entails fundamental changes in the way energy is used across transport, industry and buildings. As electrification and other low-emissions energy solutions are increasingly deployed at scale and competitively, direct fossil fuel use progressively declines[29].

However, this transformation extends beyond replacing fossil fuels with low-emissions alternatives. It also requires improving the efficiency with which energy is converted into useful services[30], which is one of the benefits of increased electrification. Energy efficiency reduces the amount of energy required to meet energy-service needs, while easing pressure on supply systems and infrastructure requirements[31]. This becomes even more important as population, incomes and demand for energy services continue to grow in many regions.

These changes also strengthen energy security and resilience in the context of heightened geopolitical and market uncertainty[32]. Lower dependence on imported fossil fuels reduces exposure to international price volatility, supply disruptions and geopolitical risks, while diversified low-emissions energy solutions contribute to more resilient energy systems[33].

At the same time, the transition must also support the expansion of modern, reliable and affordable energy services[34], particularly in developing economies. Greater access supports productivity, health, education and living standards, while new technologies and business models expand the role of households and firms in how energy is consumed and managed[35].

The ability to advance such transformations differs substantially across countries and subnational regions[36]. These differences shape both the complexity of reducing fossil fuel demand and the opportunities related to countries' capacity to expand modern, reliable and affordable energy services[37]. Understanding these conditions provides the basis for identifying the factors shaping the demand-side transition, assessing readiness and defining differentiated implementation pathways.

b. Structural factors[38] shaping the demand-side transition

The global energy system is undergoing profound changes in the way energy is consumed, and energy services are delivered. Electrification, digitalization[39] and the deployment of low-emissions energy solutions are reshaping consumption across transport, industry and buildings, while improving efficiency, enabling more decentralized production and management of energy, and expanding the role of consumers and firms in managing energy use[40]. At the same time, rising energy-service needs, including growing cooling demand, data centers for Artificial Intelligence (AI) and new electricity-intensive activities, are increasing the scale, the complexity and the opportunities of the transformation in many countries[41].

The pace of demand-side transformation remains strongly influenced by countries' structural conditions[42], which can create challenges or provide opportunities for accelerating the transition. These factors can be grouped into two complementary sets: those that shape **demand-side exposure**, by influencing the scale and complexity of the transformation required to reduce fossil fuel demand; and those that influence **demand-side transition capacity**, by defining countries' ability to adopt and manage low-emissions alternatives and expand modern energy services[43]. These structural factors provide the analytical foundation for assessing countries' demand-side transition readiness and identifying differentiated implementation pathways.

Structural factors shaping demand-side exposure

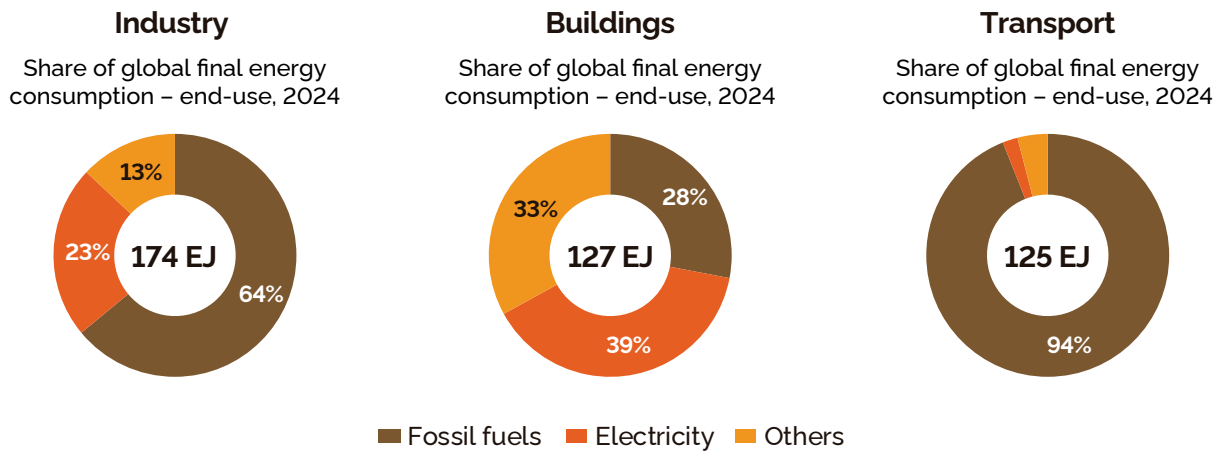
1. Structural factor shaping demand-side exposure:
   fossil fuel dependence in final energy consumption

The share of fossil fuels in final energy consumption is a central factor shaping the scale and complexity of the demand-side. The level of dependence reflects established patterns of fossil fuel use across end-use sectors, shaped by economic and political interests, existing technologies, infrastructure, assets and the practices through which energy services are provided[44]. This dependence is particularly persistent in activities for which mature low-emissions alternatives remain limited or difficult to deploy at scale.

The significance of this factor varies according to countries' final energy demand structure and end-use sector composition. Countries with a greater concentration of fossil-intensive activities naturally face a larger substitution challenge, particularly when energy demand is concentrated in sectors that remain difficult to electrify or shift to low-emissions alternatives [Fig. 1][45]. Economies with more electrified end-use structures or a larger presence of activities for which mature alternatives are already available generally face a less complex substitution process. Countries' level of exposure thus reflects both the scale of fossil fuel use and how deeply fossil-intensive activities are embedded across their end-use systems.

Figure 1: Fossil fuel dependence in final energy consumption

Fossil fuels account for around two-thirds of global final energy consumption, with significant differences across end-use sectors. *Countries' exposure reflects the share of fossil fuels in final energy consumption and the composition of their end-use sectors.*



Fossil fuels remain deeply embedded in end-use energy consumption underscoring the structural inertia of energy systems and the need to accelerate the deployment of low-emissions alternatives. Historically, major energy sources have taken around 50 years to increase their share from roughly 5% to 25% of global energy demand.

Source: IEA. World Energy Outlook. 2025; IEA. Global Energy Review. 2026.
Note: Electricity may be generated from both fossil-fuel and low-emissions sources; therefore, the fossil-fuel shares shown above capture only direct fossil fuel use in end-use sectors and do not include fossil fuels used in electricity generation.

2. Structural factor shaping demand-side exposure: efficiency of final energy use

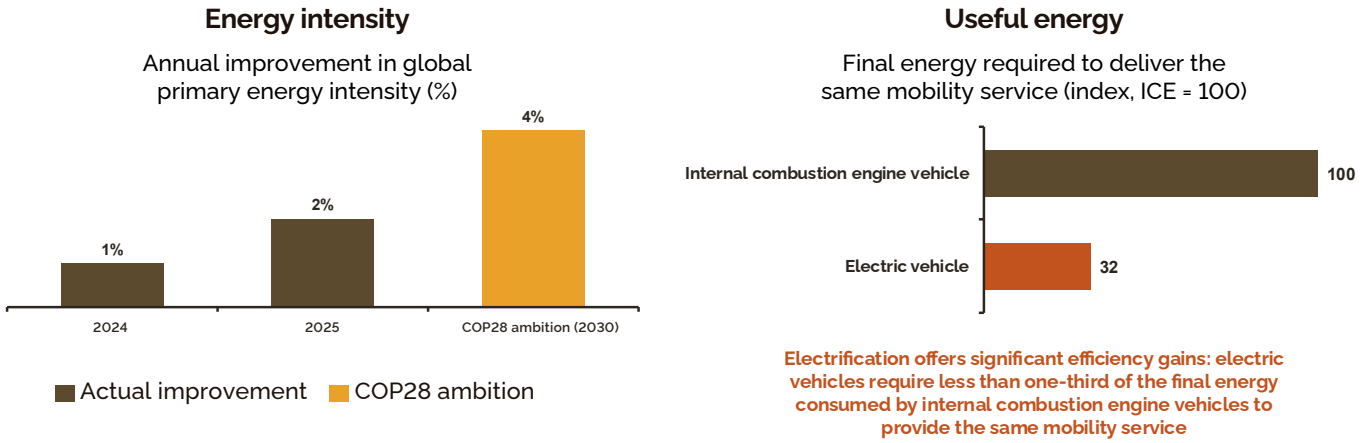
The efficiency of final energy use is a critical factor influencing demand-side exposure, as more efficient systems require less energy to deliver the same level of energy services. Two complementary perspectives support the assessment of this efficiency. Energy intensity measures the amount of energy required to generate a unit of economic output, providing a broad indication of the energy requirements of an economy[46]. Some analysts describe the established practice of treating primary energy as the measure of demand, and hence of the scale of the transition, as the "primary energy fallacy", since roughly two thirds of the primary energy entering fossil fuel-based systems is lost as heat before any service is delivered[47]. Useful energy offers an end-use perspective by assessing how much of the energy delivered to consumers is effectively converted into the services required[48]. The gap between final and useful energy reflects losses in the technologies and processes through which these services are delivered. This perspective becomes particularly relevant in the context of electrification, as electric end-use technologies often convert a larger share of delivered energy into useful services than conventional fossil fuel technologies. As a result, the amount of energy required to provide the same level of mobility, heat or mechanical work can be substantially lower in more electrified systems. Useful energy therefore provides a complementary lens for interpreting the scale of the demand-side transition alongside primary and final energy metrics.

The significance of this factor varies according to countries' existing energy systems, technological capabilities and patterns of energy consumption. Economies with mature building stocks, extensive vehicle fleets and established industrial systems may have greater opportunities to improve efficiency through the modernization or replacement of legacy equipment[49]. In energy systems that are still expanding, the adoption of efficient technologies from the outset offers opportunities to leapfrog and meet growing demand for energy services while avoiding future technological lock-in. Electrification is particularly relevant across both contexts, as electric end-use technologies often deliver equivalent services with substantially lower energy requirements than conventional fossil fuel technologies [Fig. 2].

The efficiency advantage of electric end-use technologies also holds where electricity is still largely generated from fossil fuels. Recent research indicates that electric vehicles and heat pumps supplied by gas-fired generation alone would still consume around half the fossil fuel of the combustion engines and boilers they replace, and that the benefit increases as the carbon intensity of electricity declines[50]. They already cut emissions on almost every power system in the world, including those still heavily reliant on coal, whereas electric industrial heat delivers comparable gains only where electricity is already relatively clean. This suggests that electrification need not wait for power sector decarbonization, and that both may advance in parallel according to national circumstances[51].

Figure 2: Efficiency of final energy use

Energy efficiency improvements reduce the scale of the demand-side transformation. *Countries' exposure reflects both their energy requirements and the efficiency with which energy is converted into useful services.*



Source: IEA. IRENA. Tracking SDG7 Energy Progress. 2026; IEA. World Energy Outlook. 2025; Energy Institute. Statistical Review of World Energy. 2026.

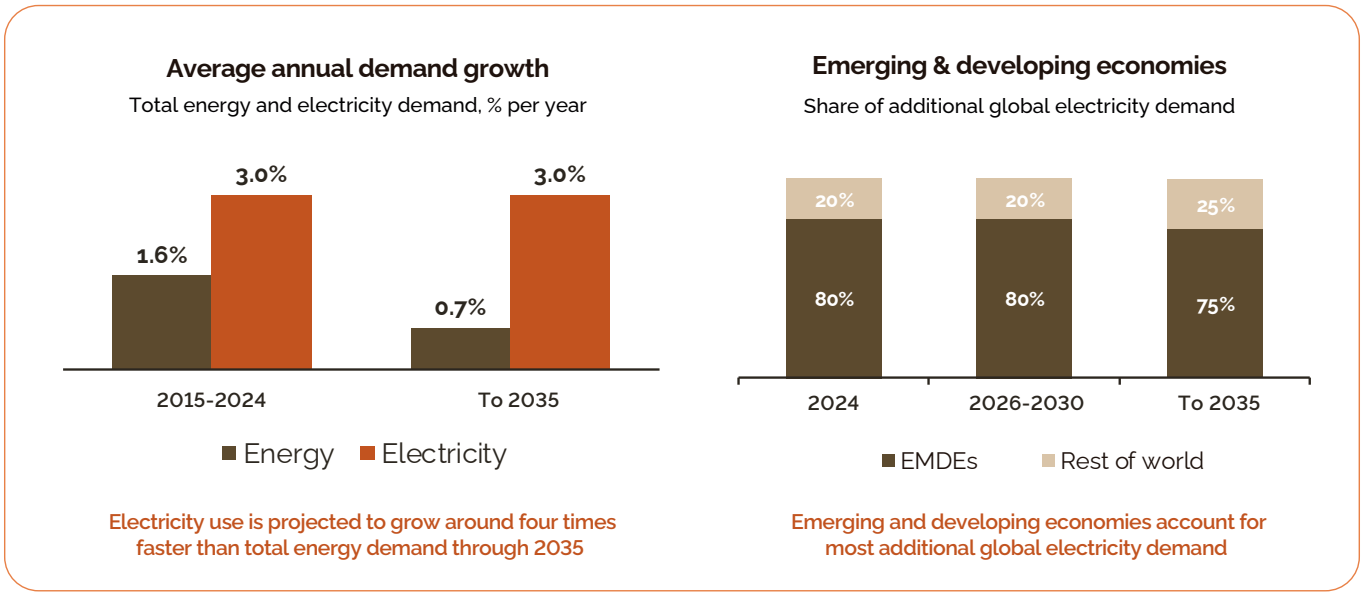
3. Structural factor shaping demand-side exposure: energy and electricity demand growth

Increase in final energy demand is an important factor shaping demand-side exposure. It creates a dual challenge: transforming existing consumption patterns while meeting additional energy-service needs without reinforcing fossil fuel lock-in[52]. The scale of this challenge reflects both the pace of demand growth and the extent to which additional energy services continue to rely on fossil fuels. Electricity-demand growth requires a distinct interpretation. Rising electricity consumption reflects both the growing demand for electricity-based services and the transformation of end-use energy systems through electrification. While this increases electricity requirements, electrification can also reduce overall final energy consumption through efficiency gains and the substitution of direct fossil fuel use[53].

The pace of electricity demand growth differs between economies with relatively stable patterns and those experiencing rapid growth in energy-service needs. Economies with mature demand profiles can focus on transforming existing fossil fuel consumption and replacing fossil fuel-intensive end-use assets[54]. Rapidly expanding systems can meet additional energy-service needs through the direct adoption of efficient and low-emissions technologies, reducing the risk of future fossil fuel lock-in[55] [Fig. 3]. Electricity-demand growth adds a different dimension: it may reflect expanding energy-service needs, including rising cooling demand and electricity-intensive activities such as data centers[56], or the substitution of direct fossil fuel use through electrification. The implications for demand-side exposure depend on the relative contribution of these two drivers and the extent to which electricity substitutes direct fossil fuel consumption[57].

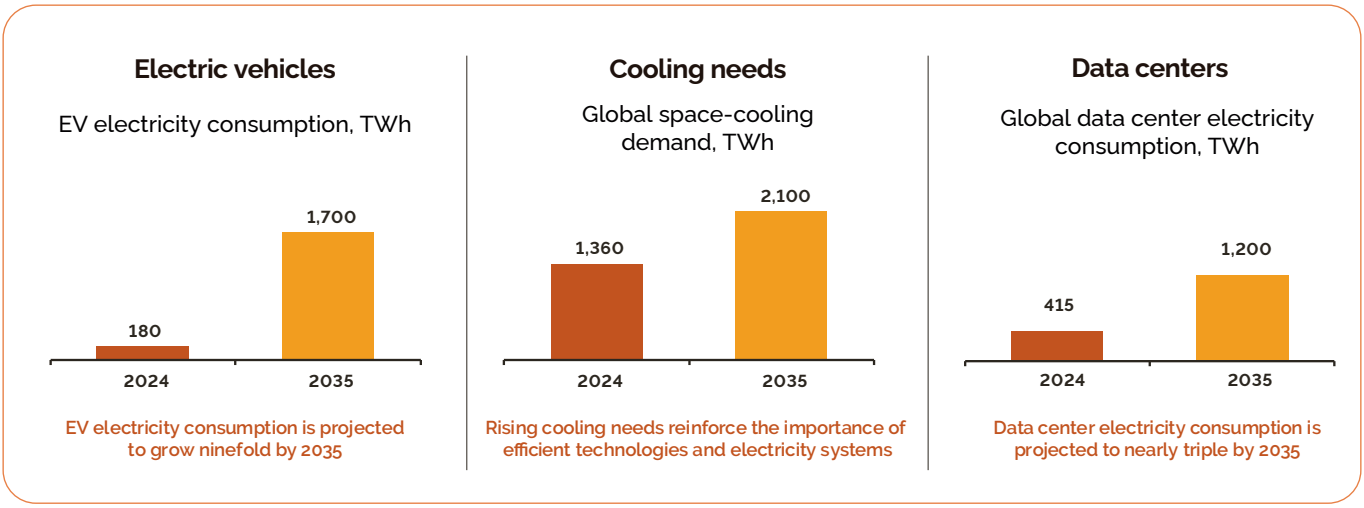
Figure 3: Energy and electricity demand growth

Countries' exposure reflects both the pace of energy demand growth…(part 1 of 2).
Electricity demand is set to outpace total energy demand, driven increasingly by emerging and developing economies.



Source: IEA. World Energy Outlook. 2025; IEA. Electricity. 2026.

… as well as the evolving composition of energy service needs (part 2 of 2).
Electric vehicles, cooling and data centers are emerging as structural drivers of electricity consumption through 2035



Source: IEA. Global EV Outlook. 2025 ; IEA. Global EV Outlook. 2026; IEA. World Energy Outlook. 2025; IEA. Energy and AI. 2025.

Structural factors shaping demand-side transition capacity

While the previous factors determine the scale of the transformation required, the following factors influence countries' capacity to implement the demand-side transformation.

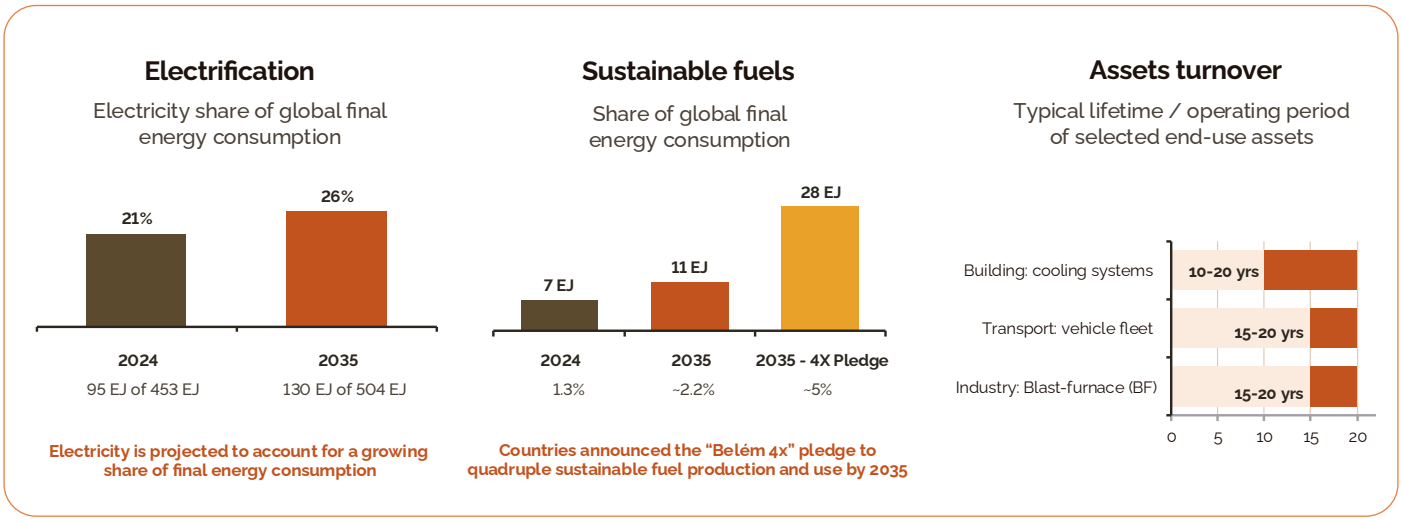
1. Structural factors shaping demand-side transition capacity: adoption of electrification and low emissions end-use technologies

The adoption of electric and other low-emissions solutions is a key factor shaping demand-side transition capacity. It defines the extent to which practical alternatives to reduce fossil fuel demand are already available across end-use sectors. The pace and the maturity of electrification are progressing rapidly, although they still differ considerably across transport, buildings and industry, reflecting differences in technological maturity and the feasibility of replacing direct fossil fuel use across different applications[58]. The Belém 4X Pledge on Sustainable Fuels[59], which aims to quadruple the global use of sustainable fuels by 2035, complements electrification in sectors where direct fossil fuel use is harder to replace. Transition capacity is also influenced by the difference between the deployment of new technologies and the composition of the existing end-use asset stock [Fig. 4]. Technology turnover, that is, the pace at which existing equipment reaches the end of its life and is replaced, is particularly important, as many end-use assets, from vehicles and heating equipment with lifetimes of ten to fifteen years to industrial furnaces and buildings that last several decades, remain operational for extended periods and can slow down reductions in fossil fuel demand even when low-emissions alternatives are commercially available[60].

Countries where electric and other low-emissions solutions already represent a substantial share of new equipment deployment are generally better positioned to progressively transform their end-use systems, reflecting a stronger capacity to adopt and scale alternatives to direct fossil fuel use[61]. Countries with lower levels of adoption and larger stocks of combustion-based assets face a more prolonged substitution challenge, as changes in new technology deployment take time to alter the composition of the overall asset stock[62]. Low levels of electrification can also reflect broader access and service-quality constraints, which should be distinguished from technology-adoption gaps and are addressed separately in the framework.

Figure 4: Adoption of electrification and low emissions end-use technologies

Low-emissions technologies are expanding, but their penetration depends on the pace of technology turnover. *The transformation depends on countries' capacity to adopt new technologies and replace fossil fuel-based assets.*



Source: IEA. World Energy Outlook. 2025; IEA. Global Energy Review. 2026; IRENA. Renewable Energy and Jobs. Annual Review 2025. 2026.

2. Structural factors shaping demand-side transition capacity: access, affordability and quality of modern energy services

Access to reliable, affordable and modern energy services is an important condition improving countries' demand-side transition capacity. The critical issue is whether households and productive sectors are able to access and use modern energy services in ways that support the adoption of efficient and low-emissions end-use technologies[63]. While physical connection is needed to ensure that households and productive sectors are able to adopt and use modern end-use technologies at scale, electricity services also need to be sufficiently reliable and affordable to support growing energy-service needs[64]. Therefore, dealing with gaps in access or service quality is required to allow for greater electrification and the uptake of low-emissions technologies, alongside ensuring affordability is maintained over time. Pursuing universal access to modern energy services[65] adds an important dimension to the equation, as some regions still lack proper access to clean cooking [Fig. 5].

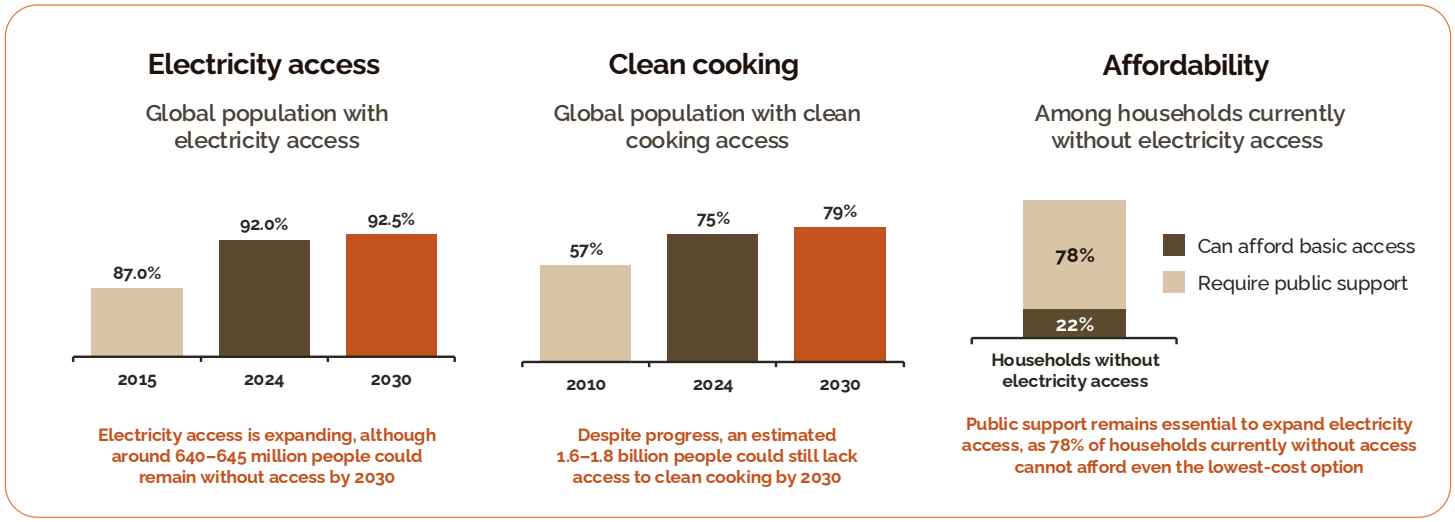
Within countries, households differ widely in how much energy they consume and in their capacity to change the way they consume it. Recent research indicates that the additional emissions required to end extreme poverty remain small when compared with the footprint of the highest emitters, so that expanding access to modern energy services and reducing fossil fuel demand can advance together. Most consumers have limited room to alter their consumption patterns, for lack of resources, information or access to alternatives, whereas higher-income households can change their consumption and reduce their emissions without compromising their living standards. Measures that expand access

and affordability for the many and those that address the consumption and investment patterns of the highest emitters are therefore complementary elements of demand-side transformation[66].

Broader access to reliable and affordable modern energy services strengthens countries' capacity to adopt low-emissions end-use technologies, while persistent service gaps constrain the scale and inclusiveness of their deployment[67]. For demand-side transformation, this means that expanding access to modern energy services and shifting the technologies through which those services are consumed often need to advance in parallel. Choices made during the expansion of electricity, cooking and other energy services can shape consumption patterns for decades[68].

Figure 5: Access, affordability and quality of modern energy services

Access to modern energy services is expanding, while affordability and remaining access gaps shape transition capacity. *Reliable and affordable energy services strengthen countries' capacity to adopt low-emissions end-use technologies.*



Source: IEA. World Energy Outlook. 2025; IEA. IRENA. Tracking SDG7 Energy Progress. 2026; IEA. Clean Cooking in Africa 2026. 2026; IEA. Household Energy Affordability Data and Indicators. 2026.

3. Structural factors shaping demand-side transition capacity: digitalization, use and consumer participation

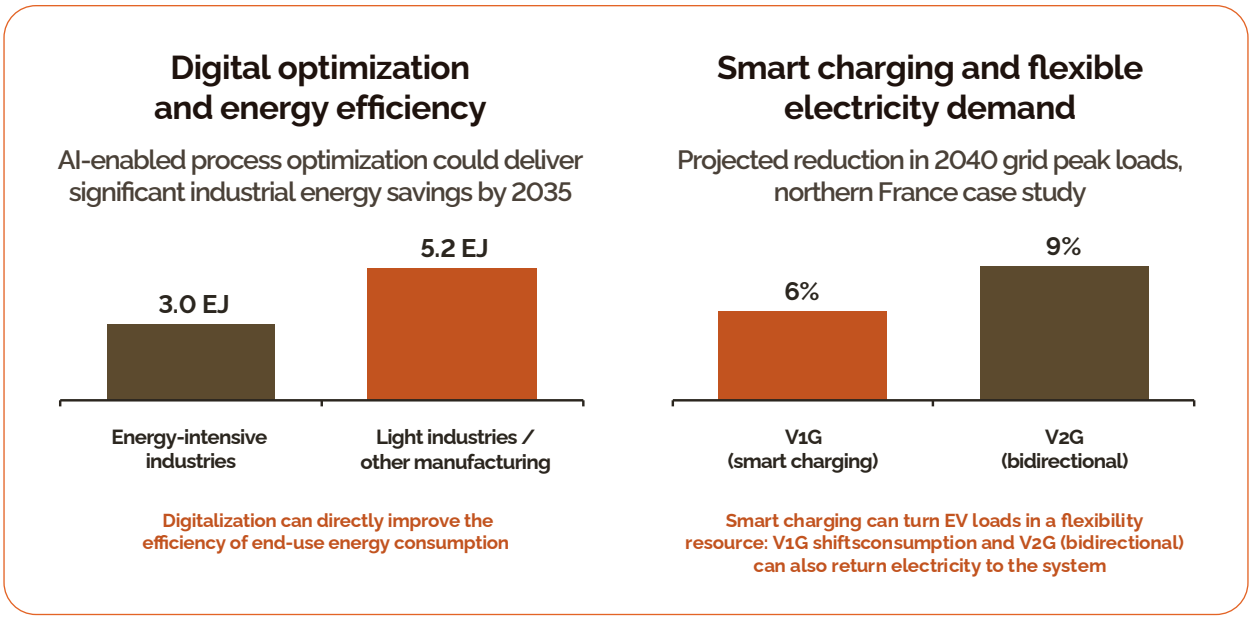
Another condition shaping countries' demand-side transition capacity is their ability to monitor, coordinate and actively manage energy consumption[69]. Digital technologies provide the infrastructure required to make energy consumption more visible and responsive, while demand-side management enables consumers and businesses to adjust when and how energy is used[70]. These capabilities are increasingly important as end-use systems become more electrified, decentralized and interconnected, with a wider range of technologies and energy sources interacting across the system. As energy systems become more decentralized, households and businesses can increasingly interact with distributed technologies such as storage, electric vehicles and flexible loads, expanding both the

number of active participants and the complexity of coordination required. Enhanced digital and demand-management capabilities can leverage the integration of new electric loads, increase opportunities to improve end-use efficiency and expand the participation of consumers—according to their income levels—and businesses in the transformation of energy demand[71] [Fig. 6].

Countries with broader deployment of advanced metering, digital energy-management systems and demand-response mechanisms are generally better positioned to integrate increasingly complex patterns of consumption, coordinate distributed end-use technologies and manage demand more flexibly[72]. Stronger digital capabilities also reinforce the role of households and businesses as active participants in energy systems by enabling them to adjust consumption, optimize energy use and participate in emerging demand-side services[73]. This becomes particularly relevant as distributed energy technologies expand, requiring digital infrastructure, data systems and demand-management capabilities to coordinate a larger number of assets and interactions across the system[74]. Countries with less developed digital infrastructure and demand-management systems face greater constraints on demand-side flexibility and system integration, particularly when electrification and distributed energy technologies expand faster than the capabilities needed to monitor, coordinate and manage their use.

Figure 6: Digitalization, use and consumer participation

Digital capabilities are becoming critical for managing increasingly complex end-use systems. *Stronger digital capabilities improve countries' capacity manage increasingly flexible and decentralized end-use systems.*



Source: IEA. World Energy Outlook. 2025; IEA. Vehicle-to-grid technology. 2026 (peak-load and overload figures); IEA. Key Questions on Energy and AI. 2026V1G refers to unidirectional smart charging, which adjusts when and how quickly electric vehicles charge. V2G (vehicle-to-grid) enables bidirectional electricity flows, allowing electric vehicles to discharge stored electricity back to the grid.

c. Energy Demand Transition Readiness Index: assessing transition preparedness

The analysis presented in the previous sections demonstrates that countries approach the demand-side transition under different structural conditions. These differences reflect two complementary dimensions: the extent to which countries remain exposed to fossil fuel dependence across end-use activities, and their capacity to transform energy consumption while improving energy efficiency and expanding access to affordable and reliable energy services. The interaction between these two dimensions determines countries' readiness and the differentiated implementation priorities associated with their transition profiles[75].

To translate this analysis into a practical assessment tool, the COP30 Presidency proposes the Energy Demand Transition Readiness Index[76] [Table 1]. The Index is designed to support countries in assessing their current level of preparedness to undertake a just, orderly and equitable demand-side transition. The assessment is intended to identify both areas of greater exposure or more limited capacity and existing strengths that can support faster implementation. Together with the Energy Supply Transition Readiness Index and the Economic Transition Readiness Index presented in the following chapters, it provides the basis for the integrated reading presented in Appendix A, which details end-use transformation pathways. A complementary coal sensitivity analysis is provided in Appendix D to support interpretation of the Index in countries where coal plays a particularly significant role, without altering the underlying readiness methodology.

Table 1: Energy Demand Transition Readiness Index: dimensions, indicators and rationale

DIMENSION	INDICATOR	RATIONALE
Demand-side Exposure	Fossil fuel share in final energy consumption	Measures the extent to which end-use sectors remain dependent on fossil fuels, indicating the scale of transformation required to reduce emissions
	Energy intensity and efficiency of final energy use	Reflects how efficiently energy is used across the economy, end-use sectors and energy services
	Growth in final energy and electricity demand	Captures the pace at which energy needs are expanding and the challenge of meeting new demand through clean energy solutions rather than fossil fuels
	End-use sector composition (hard-to-abate sectors)	Assesses the structure of energy demand and the prevalence of sectors where fossil fuel substitution is more complex or costly
Demand-side Transition Capacity	Electrification and adoption of low-emissions end-use technologies	Measures progress in shifting end-use energy consumption toward electricity and low-emissions sources, reflecting countries' ability to reduce fossil fuel dependence
	Access, affordability and quality of modern energy services	Assesses whether households and productive sectors can access and reliably use affordable modern energy services
	Digitalization and demand-side management capabilities	Evaluates the ability to optimize energy use, improve system flexibility and support efficient electrification through digital technologies
	Institutional planning and governance capacity	Assesses institutional capacity to design, coordinate and implement long-term demand-side transition strategies across end-use sectors.

The Index translates the structural conditions identified in the previous section into a set of indicators covering the main dimensions of demand-side exposure and transition capacity. The first one—**"Demand-side Exposure"**—captures the extent to which countries remain structurally dependent on fossil fuels across end-use sectors and the scale and complexity of the transformation required. Its indicators assess complementary sources of exposure, including the share of fossil fuels in final energy consumption, the efficiency of final energy use, the pace of growth in energy and electricity demand, and the composition of end-use sectors, including the prevalence of hard-to-abate[77] activities. End-use sector composition provides an additional perspective by capturing whether fossil fuel demand is concentrated in activities for which substitution is more technologically complex or slower to scale.

The second dimension—**"Demand-side Transition Capacity"**—captures countries' ability to transform energy demand systems by reducing fossil fuel dependence, improving energy efficiency and expanding access to modern, reliable and affordable energy services. Its indicators assess the conditions enabling this transformation, including electrification and end-use technology adoption; access, affordability and quality of modern energy services; digitalization and demand-side management capabilities; and planning and governance capacity. These indicators reflect the technological, service-access, institutional and demand-management capabilities available to support more electrified, efficient and low-emissions demand systems.

Planning and governance capacity is included as a cross-cutting indicator of transition readiness. Although specific planning requirements differ across the demand-side, supply-side and economic pillars, the ability to establish long-term strategies, coordinate implementation across institutions and sectors, and translate objectives into actionable frameworks represents a common enabling condition[78].

The result of the consultations of the COP30 Presidency suggests that readiness assessments be conducted as a self-assessment exercise by countries, subnational governments and sectors, drawing on existing data from international organizations and statistical platforms, while also incorporating national and subnational data where available. To facilitate this process, the table below presents illustrative and non-exhaustive metrics for each indicator [Table 2]. These examples are intended to support implementation rather than provide an exhaustive methodology.

Table 2: Energy Demand Transition Readiness Index: indicators, metrics and potential sources

Dimension	Indicator	Possible metrics
Demand-side Exposure	Fossil fuel share in final energy consumption	Coal, oil, and gas in final energy consumption (%)
	Energy intensity and efficiency of final energy use	Total energy supply per unit of GDP (MJ/US$); Useful-to-final energy ration (%)
	Growth in final energy and electricity demand	5-year CAGR of total final energy consumption and electricity demand (%)
	End-use sector composition (hard-to-abate sectors)	Hard-to-abate sectors (heavy transport and heavy industry) share of final energy consumption (%)
Demand-side Transition Capacity	Electrification and adoption of low-emissions end-use technologies	Electricity and low-emission energy in final energy consumption (%)
	Access, affordability and quality of modern energy services	Access to modern energy (% of population); access to electricity (% of population); Prices (US$/MWh); clean cooking access (% of population)
	Digitalization and demand-side management capabilities	Smart meter penetration (% of customers); Demand-response & dynamic tariffs (% of power demand)
	Institutional planning and governance capacity	Efficiency, access and end-use sector policies (RISE); Alignment with best practices (MEPS's)

Illustrative and non-exhaustive data sources include the IEA and the Energy Institute for final energy consumption, energy intensity, electrification and demand growth; IRENA and the IEA for low-emissions technologies and energy access; the World Bank, World Economic Forum (WEF) and other international datasets for affordability, digitalization and institutional conditions; and national statistics and assessments for country-specific energy, infrastructure, planning and governance conditions.

Recognizing that data availability and quality may vary across countries[79], the Roadmap also stresses the importance of international cooperation among countries and supporting institutions to help address data and information gaps that may limit effective self-assessment and implementation planning.

d. Energy Demand Transition Archetypes: identifying common transition profiles

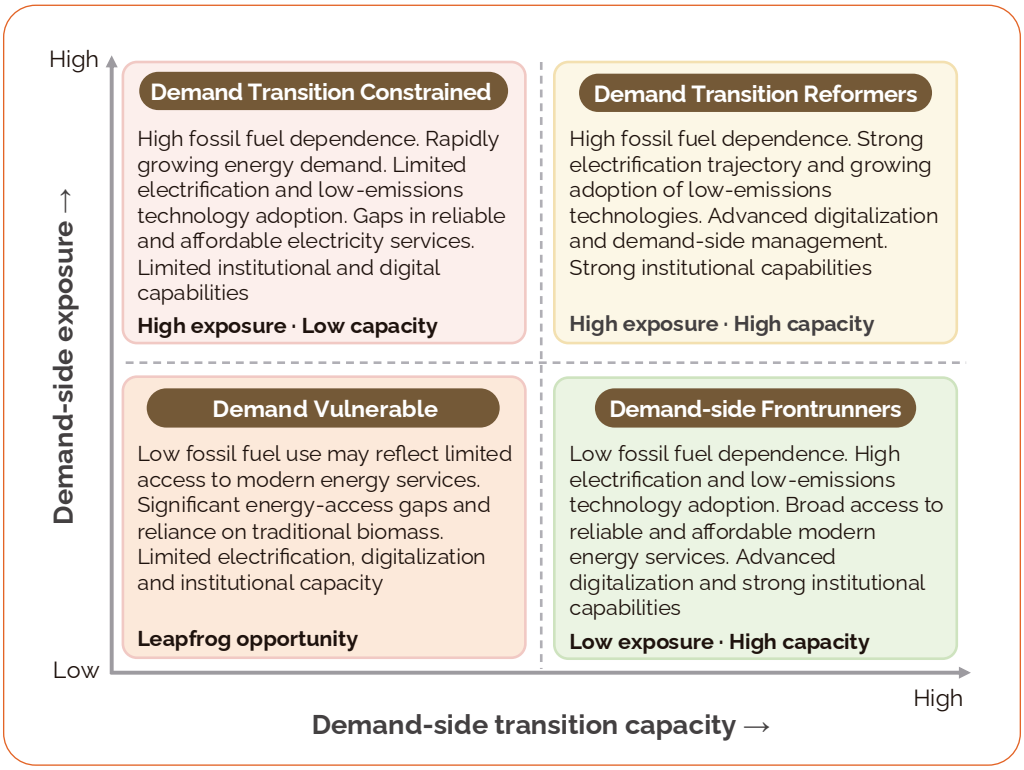
Building on the Energy Demand Transition Readiness Index presented in the previous section, the COP30 Presidency proposes a set of Energy Demand Transition Archetypes. Each archetype shares similar combinations of demand-side exposure and transition capacity. Their purpose is to translate the Index into a practical understanding of the structural conditions shaping countries' demand-side transitions and the transformations required to reduce fossil fuel dependence.

The archetype exercise recognizes that countries face different structural conditions and development realities, resulting in different implementation priorities[80]. Countries with similar readiness profiles may face comparable challenges in reducing fossil fuel dependence

across end-use sectors, improving energy efficiency and expanding access to modern, reliable and affordable energy services. The archetypes provide a basis for identifying common strengths, constraints and opportunities, as well as differentiated implementation priorities, while recognizing that national pathways remain context-specific.

The archetypes are derived by combining the two dimensions of the **Energy Demand Transition Readiness Index** in a two-dimensional matrix. The vertical axis represents the degree of **Demand-side Exposure**, while the horizontal axis represents the level of **Demand-side Transition Capacity**. These dimensions generate four broad archetypes reflecting distinct demand-side transition contexts [Fig. 7].

Figure 7: Energy Demand Transition Archetypes



In positioning themselves within the archetype matrix, countries are encouraged to interpret the results of their self-assessment using the common dimensions and indicators established by the framework. Where comparable data are available, relevant international benchmarks or reference ranges can provide an indicative basis for assessing relative levels of demand-side exposure and transition capacity. These references are intended to support a consistent interpretation of the framework. Therefore, a robust and evidence-based self-assessment is encouraged, as the framework is intended to help countries identify their main challenges, opportunities and implementation priorities.

Countries positioned higher in the matrix exhibit greater exposure to fossil fuel demand, reflecting a larger and more complex transformation challenge, while those located further to the right possess stronger capacity to transform final energy use, improve efficiency and expand access to modern energy services. However, low fossil fuel exposure in final energy consumption does not necessarily indicate an advanced transition and may also reflect limited access to modern energy services or lower levels of energy consumption[81]. Countries in different parts of the matrix combine distinct levels of exposure and transition capacity, resulting in different structural conditions and implementation priorities.

As with any analytical framework, the archetypes are illustrative and not prescriptive. Countries may move across archetypes over time as their demand-side exposure and transition capacity change. The archetype exercise does not intend to assign fixed classifications, but to support strategic planning by identifying common characteristics and differentiated implementation pathways. Within a single country, moreover, subnational governments may fall under different archetypes, reflecting regional differences in energy use, economic structure and institutional capacity.

The main structural characteristics, strengths and constraints associated with the demand-side transition across the four archetypes identified through the framework are summarized below.

Demand Transition Archetypes Description

Demand Transition Constrained Archetype
(High demand-side exposure · Low transition capacity)

These countries combine high demand-side exposure with more limited capacity to transform final energy use. Their energy demand systems remain highly dependent on fossil fuels across transport, industry and buildings, while rapid growth in energy and electricity demand increases the scale of future transformation. At the same time, electrification and the adoption of sustainable fuels and other low-emissions energy solutions remain limited, electricity services are often unreliable or unaffordable, and digital capabilities and institutional coordination are insufficient to support large-scale demand transformation. These countries face the dual challenge of expanding access to modern energy services while avoiding the creation of new fossil fuel lock-in as demand continues to grow.

Demand Transition Reformers Archetype
(High demand-side exposure · High transition capacity)

These countries remain highly dependent on fossil fuels across end-use sectors, reflecting mature transport, industrial and building systems with long-lived capital stock and deeply embedded patterns of energy use. At the same time, they possess strong institutional, technological and management capabilities to accelerate demand-side transformation, including advanced electricity systems, growing electrification, expanding low-emissions energy use, digital demand-management capabilities and robust planning frameworks. Their defining characteristic is the coexistence of high fossil fuel dependence with strong capacity

to transform mature end-use systems. Long-lived assets, established consumption patterns and concerns around costs and industrial competitiveness can nevertheless influence the pace of transformation. Their transition context is shaped by the need to accelerate change while maintaining affordability, reliability and economic competitiveness.

Demand Vulnerable Archetype
(Low demand-side exposure · Low transition capacity)

These countries exhibit relatively low fossil fuel dependence across end-use sectors, often reflecting more limited access to modern energy services and lower levels of industrial activity. Large shares of the population may still rely on traditional biomass or have limited access to reliable electricity, while electrification, low-emissions energy adoption, digital capabilities and institutional capacity remain more limited. Their profile combines low fossil fuel exposure with significant gaps in the capabilities and services required to transform energy demand. More limited legacy fossil fuel infrastructure can also create opportunities to leapfrog toward efficient and low-emissions end-use systems as access, infrastructure and institutional capacity develop.

Demand-side Frontrunners Archetype
(Low demand-side exposure · High transition capacity)

These countries have already transformed a significant share of their energy demand systems. Fossil fuel dependence across end-use sectors is relatively low, reflecting high levels of electrification, widespread adoption of low-emissions energy solutions, sustained improvements in energy efficiency and broad access to modern, reliable and affordable energy services. Strong institutions, advanced digital capabilities and effective planning frameworks further support continued demand-side transformation and increasing system flexibility. Residual fossil fuel use is generally concentrated in activities that remain more difficult to electrify or shift to low-emissions alternatives, while strong structural conditions support further reductions in dependence. Their profile combines low exposure with strong capacity to deepen demand-side transformation while maintaining affordable and reliable energy services.

e. Differentiated implementation pathways: strengthening demand-side transition readiness

Building on the **Energy Demand Transition Archetypes**, the COP30 Presidency suggests a differentiated set of levers to strengthen countries' readiness for a just, orderly and equitable demand-side transition. As countries face different structural conditions, implementation priorities vary according to their levels of demand-side exposure and transition capacity[82].

The strategic actions in the **demand-side pillar** are organized into two complementary categories: foundational levers and archetype-specific implementation levers. **Foundational levers** represent the common enabling conditions required to strengthen countries' demand-side transition readiness, regardless of their archetype. They establish the institutional, regulatory and systemic foundations needed to transform energy demand systems, improve energy efficiency and expand access to modern, reliable and affordable

energy services within the country, focusing on low-income groups. Their implementation depends on coordinated action across multiple actors, with national and subnational governments playing an important role in establishing enabling policy, regulatory and institutional conditions.

Building on these common foundations, archetype-specific implementation levers reflect differentiated priorities associated with the structural factors and readiness conditions of each demand-side archetype. Rather than representing a list of government actions, they identify the key transformations needed to strengthen **Energy Demand Transition Readiness** and explicitly recognize that implementation depends on coordinated action across multiple actors. Accordingly, the framework identifies both the main and supporting actors for each implementation lever, highlighting the complementary roles of different actors in delivering an orderly, secure and equitable demand-side transition.

To support a consistent identification of these roles across the framework, the actors are organized into ten broad categories, with illustrative examples presented in Table 3.

Table 3: Actors Taxonomy for Energy Transition and Illustrative Examples

Actor taxonomy	Illustrative examples
National governments	Ministries of Energy, Finance, Industry, Environment and Transport; national planning agencies; executive offices
Subnational governments	States, provinces, municipalities, metropolitan authorities, regional governments
Regulators and system operators	Energy regulators, electricity market operators, transmission system operators (TSOs), distribution system operators (DSOs), independent system operators (ISOs), gas market regulators
Businesses and industry	Utilities, energy companies, international oil companies (IOCs) / oil majors, national oil companies (NOCs), industrial firms, manufacturers, technology providers, engineering companies, Energy Service Companies (ESCOs), corporate energy users, industry associations
Private financial institutions	Commercial banks, institutional investors, pension funds, insurance companies, asset managers, private equity funds, venture capital funds, green investment funds
National development banks and public financial institutions	National development banks (e.g., BNDES, KfW), green banks, export credit agencies, public investment funds, national infrastructure funds
International financial institutions and climate funds	World Bank Group, International Finance Corporation (IFC), Inter-American Development Bank (IDB), African Development Bank (AfDB), Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), Asian Infrastructure Investment Bank (AIIB), Green Climate Fund (GCF), Climate Investment Funds (CIF), Global Environment Facility (GEF)
International organizations and development partners	UNDP, UNEP, UNIDO, FAO, IRENA, IEA, OECD, Sustainable Energy for All (SEforALL), regional organizations, bilateral development cooperation agencies
Academia and research institutions	Universities, public research institutes, think tanks, technical training institutions, innovation centers
Civil society, consumers and local communities	NGOs, consumer associations, labor unions, community organizations, Indigenous Peoples, households, citizen groups, cooperatives.

In addition to identifying the main and supporting actors, the framework highlights **illustrative implementation instruments**, based largely on the consultation process conducted by the COP30 Presidency throughout the year, that indicate possible mechanisms through which each lever may be operationalized. These instruments are non-exhaustive,

and their relevance and design will vary according to national circumstances, institutional capacity and market conditions. Instruments primarily related to other dimensions of the transition are addressed in the corresponding chapters.

The combined adoption of foundational and implementation levers is essential to strengthen countries' demand-side transition readiness over time. Depending on their structural conditions, countries may reduce their exposure to fossil fuel demand, strengthen their demand-side transition capacity, or advance across both dimensions simultaneously[83]. As readiness improves, countries may progressively evolve toward different archetypes, reflecting changes in final energy consumption patterns, end-use technologies, energy access, digital capabilities and institutional conditions.

Demand-side foundational levers

The foundational levers suggest the enabling conditions that allow governments (national and subnational), businesses, financial institutions, consumers (including low-income households), civil society and international partners to collectively strengthen countries' capacity to transform energy demand systems and reduce fossil fuel dependence across end-use sectors. They provide the institutional, regulatory and system-wide foundations required to accelerate electrification, expand the adoption of low-emissions energy solutions, improve energy efficiency and ensure that demand-side transformation remains reliable, affordable and inclusive. Drawing on consultations and stakeholder engagement, the COP30 Presidency suggests the following foundational levers [Table 4]:

Table 4: Demand-side foundational levers

Archetype	Foundational levers
Demand Transition Constrained (High demand-side exposure Low transition capacity)	1. Strengthen long-term demand-side transition planning and integrated end-use strategies [Institutional planning & governance] 2. Promote institutional coordination, implementation capacity and public-private collaboration [Institutional planning & governance] 3. Expand access to reliable, affordable and modern energy services [Energy access & quality] 4. Strengthen digital energy systems, demand-side management and consumer participation [Digitalization & optimization] 5. Accelerate electrification, low-emissions energy adoption and energy efficiency [Electrification and end-use transformation]
Demand Transition Reformers (High demand-side exposure High transition capacity)	
Demand Vulnerable (Low demand-side exposure Low transition capacity)	
Demand-side Frontrunners (Low demand-side exposure High transition capacity)	

1. Demand-side foundational levers: strengthen long-term demand-side transition planning and integrated end-use strategies

Rationale: long-term planning and integrated strategies across transport, industry and buildings provide the strategic direction needed to transform energy demand while reducing fossil fuel dependence. Robust planning improves policy coherence, aligns public and private investment decisions and helps avoid long-term fossil fuel lock-in as energy demand evolves. While long-term energy and climate strategies have become more widespread[84], demand-side planning often remains fragmented across sectors and institutions, with uneven links between national objectives, infrastructure planning and implementation[85].

Implementation in action[86]: selected initiatives illustrate how this lever is already being operationalized across different geographies and by different actors. The examples are illustrative and primarily drawn from the COP30 Action Agenda, which mobilizes actors and implementation efforts to accelerate delivery of existing climate commitments, building on the outcomes of the first Global Stocktake:

- Global Coalition for Energy Planning (GCEP)**:** launched in June 2025 at the first Energy Planning Summit in Rio de Janeiro, following its establishment under Brazil's 2024 G20 Presidency, GCEP is supported by IRENA as Secretariat and brings together governments, financial institutions and partners to strengthen country-owned energy planning. It supports transparent, evidence-based and integrated energy plans that align energy-system transformation with national development priorities and investment needs. Its integrated planning approach connects demand-side transformation, infrastructure requirements and investment priorities within longer-term energy strategies.

- Deep Decarbonization Pathways (DDP)**:** established in 2014, the initiative originated as the Deep Decarbonization Pathways Project coordinated by IDDRI and the Sustainable Development Solutions Network (SDSN) and is currently led through the DDP network by IDDRI. It develops country-driven long-term pathways that connect deep emissions reductions with national development priorities, supporting countries in translating long-term climate objectives into integrated transition strategies. Its pathway-based approach provides a practical framework for connecting long-term objectives with sectoral transformations across transport, industry and buildings.

2. Demand-side foundational levers: promote institutional coordination, implementation capacity and public-private collaboration

Rationale: effective coordination across public institutions, regulators, businesses, financial institutions and other stakeholders strengthens implementation capacity and ensures that demand-side transformation advances in a coherent and mutually reinforcing manner[87]. Strong collaboration is essential to translate long-term transition objectives into practical actions, accelerate technology adoption and enable active participation across society. Responsibilities for transport, buildings, industry, energy access and efficiency are often distributed across multiple ministries, regulators and levels of government[88], while implementation also depends increasingly on capabilities beyond government institutions, reinforcing the importance of effective coordination and public-private collaboration[89].

Implementation in action[90]:

- Coalition for High Ambition Multilevel Partnerships (CHAMP): launched at COP28 by the COP28 Presidency and Bloomberg Philanthropies, CHAMP supports a multilevel, multisectoral and participatory governance model for implementing the Paris Agreement. It strengthens coordination and capacity across government levels, helping connect national climate objectives with subnational planning and implementation. Its multilevel governance approach provides a practical mechanism for aligning national strategies with locally delivered demand-side action.

- Breakthrough Agenda**:** launched at COP26, the Breakthrough Agenda provides a collaborative framework for countries, businesses and civil society to coordinate and strengthen international action across seven major emitting sectors. Its annual, COP-centred process supports cooperation among public, private and public-private initiatives to accelerate the deployment and accessibility of low-emissions technologies. Its sectoral cooperation model helps connect policy, technology deployment and private-sector action across major areas of energy demand.

- OpenGrid**:** launched in October 2026 under the Linux Foundation, with the support of Breakthrough Energy, Global Grid Catalyst, the Connected Grid Initiative and Google.org, the initiative develops open and shared software infrastructure for power grid planning, including common data standards, interoperable interfaces between commercial and open source tools and a hub of validated datasets, with the aim of giving every country access to high-quality planning tools by 2030. By allowing utilities, regulators, planners and other stakeholders to work from the same data and to inspect the models behind major decisions, it puts forward a model for collaboration among philanthropic, private and research actors that can strengthen the planning capacity on which the integration of new electric loads and the coordination of demand-side and network investments depend.

3. Demand-side foundational levers: expand access to reliable, affordable and modern energy services

Rationale: reliable, affordable and modern energy services are fundamental enabling conditions for improving quality of life, supporting economic development and accelerating the transition away from fossil fuels[91]. Expanding access creates the foundation for electrification, the adoption of low-emissions energy solutions and more efficient energy use across end-use sectors. Progress in modern energy access has been substantial, although significant gaps remain in electricity access, clean cooking, affordability, reliability and service quality[92].

Implementation in action[93]:

- Clean Cooking Alliance (CCA): launched in 2010 as the Global Alliance for Clean Cookstoves and hosted by the International Energy Agency, the initiative works to accelerate universal access to clean cooking by strengthening markets, supporting policy development, mobilizing investment and advancing standards and consumer awareness. Its activities address barriers across the clean-cooking value chain, including affordability, technology quality, supply chains and market development, while also contributing to health, climate and gender objectives. The initiative demonstrates how coordinated market development and enabling policy can expand access to modern cooking services and support the adoption of cleaner and more efficient end-use technologies.

- Summit on Clean Cooking in Africa and the IEA clean cooking agenda: convened by the IEA in Paris in May 2024 with African and partner governments, the Summit mobilized US$ 2.2 billion in public and private commitments and a set of national policy pledges, which the IEA has since tracked in annual progress reports. By mid-2026 about one third of the commitments had been disbursed, more than 120 clean cooking policies and programs had been introduced or announced in over 30 African countries, and a further US$ 900 million in commitments was announced in July 2026, bringing the total above US$ 3.1 billion. In 2026 the IEA launched a Clean Cooking Security Programme to strengthen cooking fuel supply chains after the disruption of LPG shipments through the Strait of Hormuz. IEA analysis indicates that universal access in Africa by 2040 would require investment of about US$ 2 billion a year. The process favors the combination of political convening, systematic tracking of pledges and in-country policy support to keep access on the agenda and help translate financial commitments into delivery[94].

- Mission 300: launched by the World Bank Group and the African Development Bank Group, the initiative aims to provide first-time electricity access to 300 million people in Africa by 2030. It combines grid expansion, distributed renewable-energy solutions, utility reform, regional power-market integration and private-capital mobilization, supported by country-led National Energy Compacts that translate national priorities into policy reforms and investment plans.

4. Demand-side foundational levers: strengthen digital energy systems, demand-side management and consumer participation

Rationale: digital technologies, demand-side management and active participation by consumers and businesses improve the efficiency, flexibility and responsiveness of energy demand systems[95]. They optimize energy use, support the integration of electrified and low-emissions end-use technologies, and enable consumers and firms to play a more active role in managing when and how energy is consumed. Smart metering, automated energy-management systems and demand-response mechanisms are expanding[96]. Artificial intelligence can extend the reach of these digital tools, helping operators, utilities and

consumers to anticipate demand, run equipment closer to its optimum and shift flexible loads to the hours when low-emissions electricity is abundant, and its use is likely to become a prominent feature of energy systems in the years ahead, bringing forward positive tipping points in the adoption of low-emissions technologies. Existing gaps in digital infrastructure, interoperability, data availability and institutional capacity continue to limit the ability of households and businesses to manage consumption more actively as electricity demand becomes increasingly complex, but the rapid progress in developing countries show its potential[97].

Implementation in action[98]:

- Data Center Flexible Load Initiative (DCFlex): launched by EPRI in 2024, DCFlex is a multi-year initiative that brings together technology companies, data-center operators, utilities and other partners to demonstrate how data centers can provide flexible load services. The initiative explores approaches to adjust electricity consumption in response to grid conditions, supporting system stability, more efficient interconnection and improved utilization of electricity infrastructure as AI-driven demand expands. Its demonstration-based approach provides a practical model for integrating large and rapidly growing electricity loads more flexibly into power systems.

- Plan to Accelerate Solutions—Harnessing AI & Digitalization for a Smart, Resilient, and Efficient Energy Infrastructure**:** developed through the COP30 Action Agenda and hosted by the Long-Term Energy Scenarios (LTES) Network, the plan promotes the deployment of AI and digital technologies across energy systems, with particular attention to emerging and developing economies and key end-use sectors. Its activities support digital planning, system optimization and stronger coordination between electricity infrastructure and increasingly distributed and flexible demand-side resources.

5. Demand-side foundational levers: accelerate electrification, low-emissions energy adoption and energy efficiency

Rationale: accelerating electrification together with the adoption of renewable electricity, sustainable fuels and other low-emissions energy solutions, while improving energy efficiency across end-use sectors, provides the foundation for reducing fossil fuel dependence[99]. Integrated national strategies help coordinate technology deployment, market development and investment decisions while ensuring that the most appropriate solutions are adopted according to the characteristics of different end-use sectors[100].

Electric and efficient technologies are already commercially available across many applications in transport and buildings, while deployment in other end uses remains at an earlier stage. Differences in technology penetration, existing asset stocks and implementation capabilities continue to shape the pace of adoption, reinforcing the importance of advancing electrification, efficiency and low-emissions energy solutions in a coordinated manner[101].

Implementation in practice[102]:

- Buildings Breakthrough—Plan to Accelerate Near-Zero Emission and Resilient Buildings**:** launched under the broader Breakthrough Agenda and advanced through the COP30 Action Agenda, the initiative supports coordinated action to accelerate near-zero-emission and resilient buildings. Its implementation agenda combines energy efficiency, electrification, low-emissions energy solutions and enabling policy measures to transform building energy use. The initiative advances the coordinated deployment of complementary solutions required to reduce fossil fuel dependence across the buildings sector.

- Road Transport Breakthrough—Plan to Accelerate Road Transport Decarbonization**:** developed under the Breakthrough Agenda and advanced through the COP30 Action Agenda, the initiative supports coordinated implementation to accelerate the transition toward low-emissions road transport. It combines the deployment of zero-emissions vehicles with enabling infrastructure, policy frameworks and market conditions required for wider adoption. The initiative provides a practical mechanism for scaling electrification and associated enabling conditions across road transport.

- COP31 35-by-35 Global Electrification Pledge**:** announced by the COP31 Presidency in June 2026 and formally launched in its Action Agenda priorities in September 2026, the initiative sets a collective objective to increase electricity's share of global final energy consumption to 35% by 2035. The pledge, which fits into the implementation of the GST under Axis 1 of the Action Agenda, seeks to accelerate electrification across buildings, transport and industry, while recognizing differentiated national circumstances and pathways. Its implementation framework emphasizes the expansion of clean power, modern and resilient grids, storage and system flexibility, together with greater access to finance, capacity building and international cooperation, particularly for developing economies. The initiative provides a cross-sectoral framework for translating electrification ambition into coordinated deployment, infrastructure development and implementation at scale.

Demand-side implementation levers: archetype-specific messages

Table 5: Implementation Levers for Demand Transition Constrained Archetype (High demand-side exposure - Low transition capacity)

Demand Transition Constrained (High demand-side exposure · Low transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Accelerate the adoption of competitive electrification and low-emissions energy solutions across end-use sectors [Electrification & end-use transformation]	**Main actor:** National governments **Supporters:** Businesses and industry; Regulators and system operators; National development banks and public financial institutions; International financial institutions and climate funds	• Sectoral technology-deployment programmes and roadmaps • Performance and technology standards • Procurement and buyer commitments for low-emissions technologies
Promote the uptake of energy-efficient technologies and behavioural change across end-use sectors [Digitalization & optimization]	**Main actor:** Businesses and industry; Civil society, consumers and local communities **Supporters:** National governments; Academia and research institutions; International organizations and development partners	• Minimum energy-performance standards (MEPS) • Energy-efficiency labelling and information schemes • Energy-management systems and performance programmes
Align urban development, industrial expansion and transport planning with long-term demand-side transition objectives [Institutional planning & governance]	**Main actor:** National governments; Subnational governments **Supporters:** Regulators and system operators; Businesses and industry; International organizations and development partners	• Integrated spatial and end-use transition planning frameworks • Sustainable mobility and freight-corridor plans • Inter-ministerial and multilevel coordination mechanisms
Improve electricity reliability, affordability and service quality in priority demand growth regions [Energy access & quality]	**Main actors:** National governments; Businesses and industry **Supporters:** Regulators and system operators; National development banks and public financial institutions; International financial institutions and climate funds	• Targeted energy-access and service-quality programmes • Efficient-appliance access and affordability programmes • Access, reliability and service-quality standards and monitoring systems
Develop digital demand management and demand-side flexibility capabilities to improve system efficiency [Digitalization & optimization]	**Main actor:** Businesses and industry; Regulators and system operators **Supporters:** National governments; Academia and research institutions; Civil society, consumers and local communities	• Smart-metering and digital energy-management platforms • Demand-response and flexible-load mechanisms • Smart-charging and interoperability protocols

Sequencing priorities to foster implementation[103]**:** First step, **avoiding new fossil fuel lock-in while meeting rapidly growing energy demand** by directing expanding demand toward electrified and other low-emissions energy solutions wherever they are technically and economically viable. Second step, **building enabling conditions for demand-side transformation** by improving electricity services, strengthening planning capabilities and developing the digital and institutional foundations needed to support modern energy demand systems. Third step, **promoting efficient and sustainable energy use** by accelerating the uptake of energy-efficient technologies, encouraging behavioral change and aligning urban development and industrial expansion with long-term transition objectives. These priorities support the expansion of modern energy services while limiting additional fossil fuel dependence as demand grows.

National and subnational governments play a central role in guiding demand growth, strengthening electricity services and establishing the institutional conditions required for demand-side transformation, including through procurement. Businesses and industry are essential to expand access to modern energy solutions and digital technologies, while regulators and system operators play a central role in improving system performance, establishing minimum standards and creating conditions for reliable service provision. Civil society, consumers and local communities contribute to the adoption of efficient technologies and sustainable energy practices. National development banks and public financial institutions, together with international financial institutions and climate funds, can support technology deployment and improvements in energy access and service quality.

Table 6: Implementation Levers for the Demand Transition Reformers Archetype (High demand-side exposure - High transition capacity)

Demand Transition Reformers (High demand-side exposure · High transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Accelerate the adoption of commercially competitive electrification, renewable electricity and other low-emissions energy solutions across fossil-intensive end-use sectors [Electrification & end-use transformation]	**Main actors**: Businesses and industry; National governments **Supporters**: Regulators and system operators; Private financial institutions; National development banks and public financial institutions	• Sectoral technology-deployment programmes and roadmaps • Performance and technology standards • Procurement and buyer commitments for low-emissions technologies
Develop integrated transition pathways for hard-to-abate sectors combining electrification, energy efficiency and sustainable fuels [Electrification & end-use transformation]	**Main actors**: Businesses and industry; National governments **Supporters**: Academia and research institutions; Regulators and system operators; International organizations and development partners	• Sector-specific decarbonization roadmaps and transition pathways • Technology demonstration and industrial deployment programmes • Product performance and low-emissions technology standards
Optimize highly electrified demand systems through advanced digital energy management and demand-side flexibility [Digitalization & optimization]	**Main actors**: Businesses and industry; Regulators and system operators **Supporters**: National governments; Academia and research institutions; Private financial institutions	• Smart-metering and digital energy-management platforms • Demand-response and flexible-load mechanisms • Smart-charging and interoperability protocols
Accelerate the replacement of fossil fuel-dependent technologies and end-use practices through integrated demand-side transition planning [Institutional planning & governance]	**Main actor**: National governments **Supporters**: Subnational governments; Regulators and system operators; Businesses and industry; International organizations and development partners	• Technology replacement and phase-out programmes • Integrated sectoral transition plans and asset-turnover strategies • Progressively tightening performance standards for new end-use equipment
Strengthen the affordability of low-emissions energy solutions for households and businesses [Energy access & quality]	**Main actors**: National governments; Businesses and industry **Supporters**: Regulators and system operators; National development banks and public financial institutions; Civil society, consumers and local communities	• Targeted technology-access and affordability programmes • Aggregated purchasing and bulk-procurement schemes • Energy-efficiency and appliance replacement programmes for targeted consumers
Enable consumers and businesses to actively participate in smart, flexible and low-emissions energy systems [Energy access & quality]	**Main actors**: Civil society, consumers and local communities; Businesses and industry **Supporters**: National governments; Regulators and system operators; Academia and research institutions; International organizations and development partners	• Demand-response and flexible-consumption programmes • Consumer and prosumer participation frameworks • Digital energy-data access and interoperability mechanisms

Sequencing priorities to foster implementation: First step, **accelerating the replacement of fossil fuel use across mature demand systems** by expanding commercially competitive electrification, low-emissions energy solutions and integrated transition pathways for hard-to-abate sectors. Second step, **optimizing increasingly electrified demand systems** through advanced digital energy management, demand-side flexibility and active consumer participation. Third step, **removing the remaining barriers to widespread adoption** by replacing long-lived fossil fuel technologies and practices, improving the affordability of low-emissions solutions and enabling consumers and businesses to actively participate in demand-side transformation. The transition pathway depends on transforming mature demand systems at sufficient speed while maintaining affordability, reliability and economic competitiveness.

National and subnational governments remain responsible for establishing long-term policy direction, regulatory certainty and integrated transition planning. However, implementation increasingly depends on businesses and industry, which lead the adoption of low-emissions technologies, digital solutions and new business models. Regulators and system operators enable flexible and efficient energy systems, while civil society, consumers and local communities become active participants in energy management and technology adoption. Academia and research institutions, private financial institutions, national development banks and public financial institutions, and international organizations and development partners further accelerate implementation by supporting innovation, investment, technical expertise and the diffusion of emerging solutions. Public procurement, by governments and large companies alike, can create early markets and set standards for low-emissions products, vehicles and buildings, while decentralized digital solutions extend demand-side management to households and small businesses and allow them to contribute to system flexibility.

Table 7: Implementation Levers for the Demand Vulnerable Archetype (Low demand-side exposure - Low transition capacity)

Demand Vulnerable (Low demand-side exposure · Low transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Accelerate the transition from basic electricity access to modern energy services [Energy access & quality]	**Main actors:** National governments; Businesses and industry **Supporters:** Regulators and system operators; National development banks and public financial institutions; International financial institutions and climate funds	• Targeted energy-access and service-quality programmes • Efficient -appliance access and affordability programmes • Service-quality standards and reliability monitoring systems
Guide growing energy demand toward modern electrified and low-emissions end-use applications [Electrification & end-use transformation]	**Main actor:** National governments **Supporters:** Businesses and industry; Regulators and system operators; International organizations and development partners	• End-use electrification deployment programmes • Technology and performance standards for new equipment • Sectoral technology-adoption roadmaps for growing demand
Accelerate the replacement of traditional biomass with modern, efficient and clean energy solutions for households and productive uses [Electrification & end-use transformation]	**Main actors:** National governments; Businesses and industry **Supporters:** Civil society, consumers and local communities; International financial institutions and climate funds; International organizations and development partners	• Clean-cooking transition programmes • Efficient appliance and productive -use technology deployment schemes • Technology standards and certification for modern energy solutions
Promote decentralized digital energy solutions to improve service delivery and system management in underserved areas [Digitalization & optimization]	**Main actors:** Businesses and industry; National governments **Supporters:** Regulators and system operators; Academia and research institutions; International financial institutions and climate funds	• Smart-metering and digital monitoring programmes • Digital platforms for decentralized energy-service management • Remote metering, billing and service-quality monitoring systems
Integrate energy access planning with long-term demand-side transition objectives to avoid future fossil fuel lock-in [Institutional planning & governance]	**Main actor:** National governments **Supporters:** Subnational governments; Businesses and industry; International organizations and development partners	• Integrated energy-access and end-use transition plans • Long-term demand and technology scenario tools • Multilevel coordination mechanisms for access expansion and technology deployment
Stimulate energy efficiency improvements among households and businesses [Electrification & end-use transformation]	**Main actors:** Regulators and system operators; Businesses and industry **Supporters:** National governments; Civil society, consumers and local communities; International organizations and development partners	• Minimum energy-performance standards (MEPS) • Energy-efficiency labelling and information schemes • Efficient -appliance and equipment replacement programmes

Sequencing priorities to foster implementation: First step, **building modern energy demand systems** as access expands by accelerating the transition from basic electricity access to modern energy services and guiding growing demand toward electrified and low-emissions end-use applications. Second step, **avoiding future fossil fuel lock-in** by replacing traditional biomass with modern energy solutions and integrating long-term transition objectives into energy access planning. Third step, **strengthening the quality and efficiency of emerging demand systems** by promoting decentralized digital solutions and encouraging energy efficiency improvements among households and businesses. Affordability will be a relevant precondition for adoption of these steps, since households and small businesses with limited income will only take up modern and efficient solutions whose upfront and running costs they can bear, including through targeted support policies. The transition pathway depends therefore on ensuring that expanding access to modern energy services simultaneously improves living standards and establishes the foundations for a long-term low-emissions demand system.

National and subnational governments lead the expansion of modern energy services and integrate energy access with long-term transition planning. Because domestic implementation capacity and resources remain constrained, international financial institutions and climate funds, national development banks and public financial institutions, and international organizations and development partners play an especially important role in supporting implementation through finance, technical assistance and institutional capacity building. Businesses and industry contribute to deploying decentralized energy solutions and modern technologies, while regulators and system operators support service quality and system performance. Civil society, consumers and local communities are essential to the adoption of modern and efficient energy solutions, while academia and research institutions contribute to technical capabilities and digital innovation.

Table 8: Implementation Levers for the Demand-side Frontrunners Archetype (Low demand-side exposure - High transition capacity)

Demand-side Frontrunners (Low demand-side exposure · High transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Accelerate integrated transition pathways for the remaining hard-to-abate demand sectors [Electrification & end-use transformation]	**Main actors:** Businesses and industry; National governments **Supporters:** Academia and research institutions; Regulators and system operators; Private financial institutions	• Sector-specific decarbonization pathways and technology roadmaps • Demonstration and commercialization programmes for advanced low-emissions technologies • Low-emissions product and technology performance standards
Optimize electrified systems through advanced digital energy management, demand-side flexibility and active consumer participation [Digitalization & optimization]	**Main actors:** Businesses and industry; Civil society, consumers and local communities **Supporters:** National governments; Academia and research institutions; Regulators and system operators	• Advanced demand-response and flexible-load programmes • Smart-charging, V2G and interoperability protocols • Prosumer participation and digital energy-data access frameworks
Ensure reliable, affordable and high-quality electricity services in increasingly electrified economies [Energy access & quality]	**Main actors:** Regulators and system operators; Businesses and industry **Supporters:** National governments; National development banks and public financial institutions	• Service-quality and reliability performance standards • Dynamic tariffs and time-of-use pricing frameworks • Consumer affordability monitoring mechanisms
Address affordability barriers to the widespread adoption of low-emissions technologies [Energy access & quality]	**Main actor:** National governments **Supporters:** Businesses and industry; Civil society, consumers and local communities; National development banks and public financial institutions	• Targeted technology-access and replacement programmes • Aggregated purchasing and bulk-procurement schemes • Performance-based incentive programmes for priority end-use technologies
Create lead markets for next-generation low-emissions energy solutions [Institutional planning & governance]	**Main actors:** National governments; Businesses and industry **Supporters:** Regulators and system operators; Private financial institutions; International organizations and development partners	• Public and corporate procurement commitments • Buyer alliances and demand-aggregation platforms • Product standards and certification schemes for low-emissions solutions
Promote international cooperation and knowledge sharing to accelerate global demand-side transformation [Institutional planning & governance]	**Main actors:** National governments; International organizations and development partners **Supporters:** Businesses and industry; Academia and research institutions; International financial institutions and climate funds	• International technology-cooperation and knowledge-sharing platforms • Common standards, methodologies and interoperability frameworks • Technical-assistance and peer-learning programmes

Sequencing priorities to foster implementation: First step, **completing the remaining demand-side transition** by accelerating integrated pathways for hard-to-abate sectors and addressing the residual barriers to the widespread adoption of low-emissions technologies. Second step, **optimizing mature demand systems** through advanced digital energy management, demand-side flexibility and active consumer participation while maintaining reliable, affordable and high-quality energy services. Third step, **strengthening international leadership** by creating lead markets for next-generation low-emissions energy solutions and promoting international cooperation. These priorities support the continued transformation of advanced demand systems while maintaining efficiency, competitiveness and inclusion and contributing to broader global demand-side progress..

National and subnational governments increasingly focus on shaping markets, strengthening regulatory frameworks and supporting international cooperation. Businesses and industry become the principal drivers of implementation by deploying advanced technologies, creating lead markets and developing innovative business models. Regulators and system operators ensure that increasingly electrified systems remain efficient and responsive, while civil society, consumers and local communities actively participate in energy management and demand flexibility. Academia and research institutions and international organizations and development partners support innovation, knowledge exchange and international collaboration, while private financial institutions, national development banks, public financial institutions, international financial institutions and climate funds can help mobilize resources and support demand-side transformation beyond national borders.

SUPPLY-SIDE PERSPECTIVE: REDUCING FOSSIL FUEL SUPPLY AND EXPANDING LOW-EMISSIONS ENERGY SYSTEMS

a. The relevance of the supply-side transition

The transition away from fossil fuels requires coordinated transformations across the demand and supply sides of the energy system. Supply-side considerations are often perceived to receive comparatively less attention in energy transition policies and planning processes, even as they have gained more attention in government and international discussions in recent years. Greater consideration of the supply side is particularly important given the energy security, economic and social implications that can arise when changes in supply and demand are not adequately aligned. The continued expansion of fossil fuel production as demand declines deepens carbon and infrastructure lock-in, increases stranded asset risks and diverts capital from emerging low-emissions energy systems[104]. Recent scenarios reflecting stated policies and market conditions already point to structural changes in fossil fuel demand. For example, coal demand is projected to peak before 2030, while oil demand is projected to reach a plateau around 2030 before gradually declining. These projections do not capture the potential implications of the recent disruption in the Strait of Hormuz, which affects near-term market conditions. However, the underlying structural drivers of demand reduction remain. Pathways consistent with limiting warming to 1.5°C would require the reduction in fossil fuel demand to occur substantially faster.

In this sense, expected changes in demand need to be reflected in infrastructure planning, investment decisions and the repositioning of energy-related value chains, helping ensure that fossil fuel production and energy assets evolve consistently with long-term transition pathways. When these expected changes are coordinated at the international level, the outcomes can be even more helpful from a producing country's perspective.

Conversely, a premature reduction in fossil fuel supply, ahead of declining demand and the timely expansion of reliable alternatives, generates market imbalances, price volatility and inflationary pressures that disproportionately affect vulnerable households, workers and communities[105], at the risk of losing societal support for the transition. Avoiding these shocks requires careful sequencing, with reductions in fossil fuel supply aligned with declining demand and the accelerated expansion of low-emissions energy alternatives.

Greater international coordination and transparency around evolving fossil fuel demand trajectories, including through credible, science-aligned scenarios, improve investment visibility and support a more orderly adjustment of supply, reducing the risk of abrupt market imbalances and associated economic costs. This coordination is particularly relevant across fossil fuel importing and exporting economies, which face different but interconnected implications as global energy trade and demand patterns evolve.

Additionally, the supply-side transition requires building new energy systems capable of delivering the same level of reliable, secure and affordable energy services to end-use sectors and consumers[106]. This transformation depends on the accelerated deployment of low-emissions energy sources, including renewables, nuclear and sustainable fuels, supported by the enabling infrastructure and system flexibility required for their integration. Transmission and distribution networks, interconnections, storage, demand-responsive resources and other flexibility solutions are essential to ensure that increasingly diversified and intermittent energy systems continue to provide reliable and affordable energy services.

The scale and complexity of this transformation vary according to national and subnational circumstances, reflecting different degrees of fossil fuel exposure and capacities to develop and integrate low-emissions alternatives in a reliable, secure and affordable manner. Understanding these structural differences provides the basis for identifying the factors shaping supply-side transition, assessing countries' readiness and defining differentiated implementation pathways.

b. Structural factors[107] shaping the supply-side transition

The global energy transition is already reshaping the supply side of the energy system. The rapid penetration of low-emissions energy sources and growing electrification are transforming global value chains and the ways in which energy is produced, transported and supplied to markets. At the same time, the world is currently experiencing a phase of energy addition[108] rather than full substitution, as expanding low-emissions supply is primarily meeting rising energy needs and has not yet displaced fossil fuels at the pace required[109]. This dynamic reflects continued growth in global energy demand, the gradual pace of the transition and persistent energy security concerns in the context of geopolitical uncertainty.

The pace of supply-side transformation is strongly influenced by countries' structural conditions. These factors can be grouped into two complementary sets: those that shape **supply-side exposure**, by influencing the scale and complexity of the transformation required as fossil fuel dependence evolves; and those that shape **supply-side transition capacity**, by influencing countries' ability to develop and integrate reliable, secure and affordable low-emissions energy systems. Depending on national circumstances, including the economic and financial dimensions discussed in the next chapter, these factors can increase transition challenges or offer capabilities and opportunities that support faster progress. These structural factors provide the analytical foundation for assessing countries' supply-side transition readiness and identifying differentiated implementation pathways.

Structural factors shaping the supply-side exposure

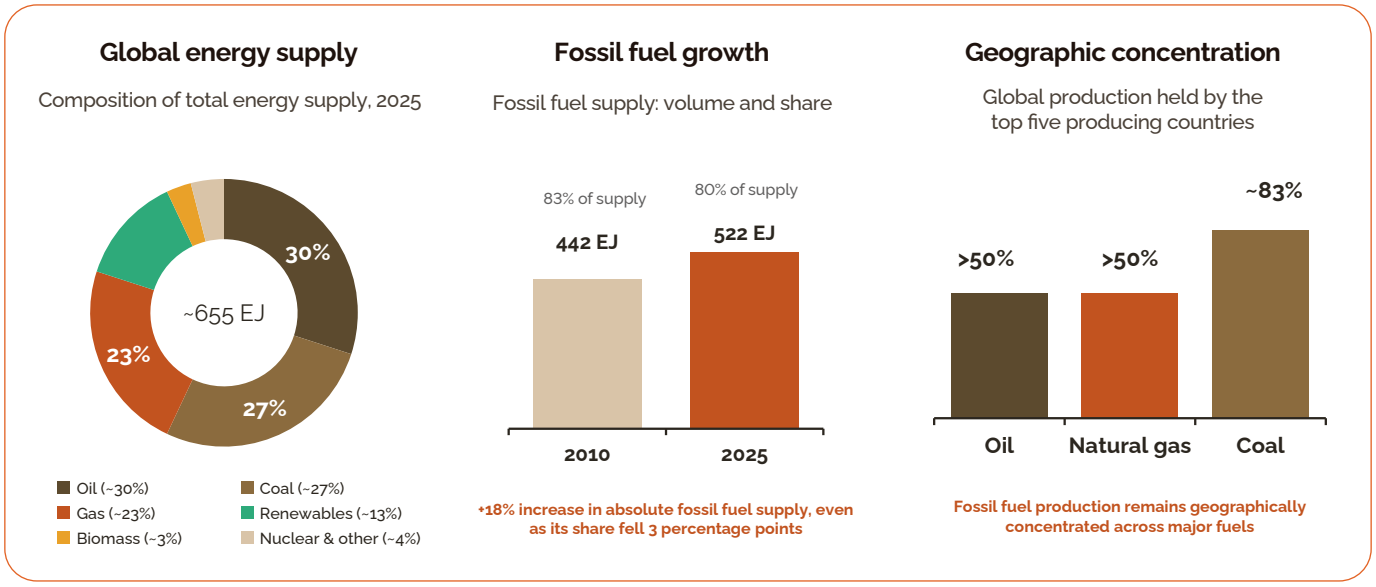
1. Structural factors shaping supply-side exposure: fossil fuel dependence in the supply mix

The share of fossil fuels in primary energy supply is a central factor shaping the scale and complexity of the supply-side transition[110]. Where oil, natural gas and coal account for a large proportion of domestic energy supply, countries should progressively transform or replace this supply with low-emissions energy sources while maintaining reliable, secure and affordable energy services. Transition can require changes across generation assets, supporting infrastructure, distribution networks and operational capabilities that have developed around established fossil fuel supply. This dependence increases the scale of the transformation required across the supply system [Fig. 8].

The significance of this factor differs according to how fossil fuels are embedded within national energy systems[111]. In some countries, fossil fuels play a more limited and concentrated role in the energy supply system and may be replaced more progressively as low-emissions alternatives expand. In others, they remain deeply integrated across multiple supply chains and infrastructure systems, increasing the persistence of existing production and supply patterns. Countries with more diversified energy mixes and a stronger contribution from low-emissions sources generally face a less extensive substitution challenge. In this sense, supply-side exposure reflects both the share of fossil fuels in the energy mix and the extent to which established fossil fuel supply is embedded across the broader energy system.

Figure 8: Fossil fuel dependence in the supply mix

Fossil fuels still account for ~80% of total energy supply (~522 EJ), while low-emissions energy continues to expand. *Countries with a greater concentration of fossil fuels in their energy supply face a more complex supply-side transformation.*



Source: IEA. World Energy Outlook. 2025; IEA. Global Energy Review. 2026.

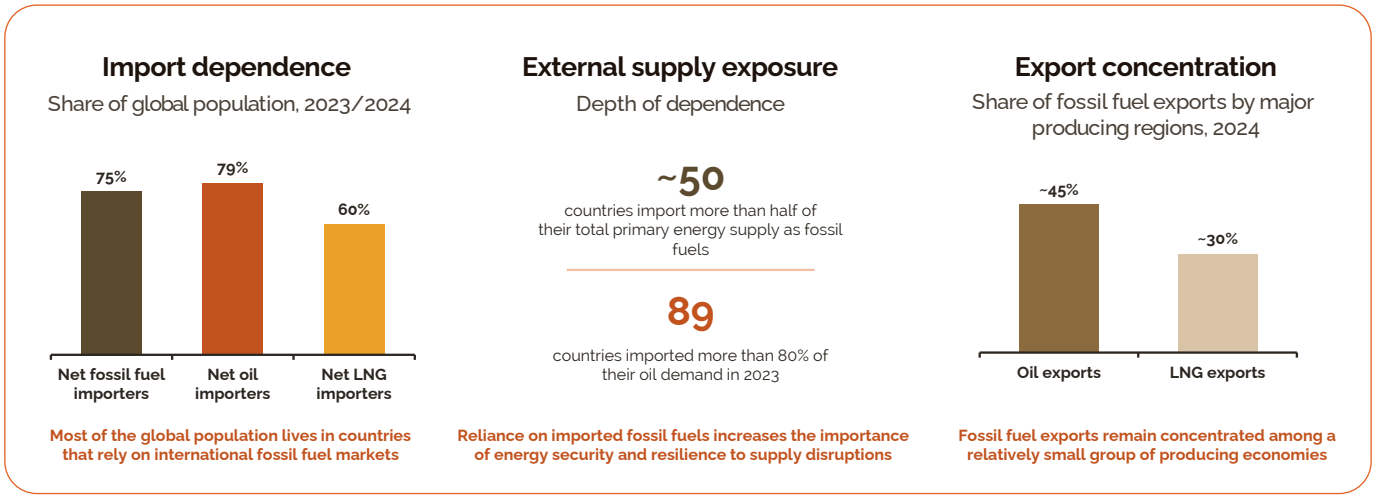
2. Structural factors shaping supply-side exposure: dependence on fossil fuel imports and exports

An additional factor influencing countries' exposure to fossil fuel supply arises from their position in international energy markets, whether as net exporters or net importers[112]. Fossil fuel resources and production capacity are unevenly distributed, creating extensive trade flows between a relatively concentrated group of exporting regions and a much larger number of importing economies. For importing countries, dependence on internationally traded fossil fuels creates structural exposure to supply disruptions, international price volatility and geopolitical tensions. For exporting countries, established production systems, infrastructure, commercial relationships and institutional arrangements tend to entrench the interests built around fossil fuel supply, reinforcing its persistence and increasing the complexity of adjusting production as global demand evolves [Fig. 9].

Therefore, the nature of this challenge differs substantially between importing and exporting economies. Import-dependent countries may have stronger incentives to expand domestic low-emissions energy sources and reduce their exposure to external markets, strengthening energy security and resilience. Exporting economies face a different form of exposure where production capacity, infrastructure and established trade and economic relationships are closely connected to international fossil fuel demand. Adjusting supply can require changes in production strategies, physical assets and long-standing relationships with international markets, confronting established international and domestic interests. Countries' position in fossil fuel trade influences the nature and persistence of their supply-side exposure.

Figure 9: Dependence on fossil fuel imports and exports

Fossil fuel trade is widespread, while exports remain highly concentrated. *Countries' position as fossil fuel importers or exporters shapes distinct supply-side transition conditions.*



Source: Ember, The Energy Security Fall-out: From Fossil Fuel Fragility to Electric Independence, 2026; IEA. World Energy Outlook. 2025; Energy Institute. Statistical Review of World Energy. 2026.

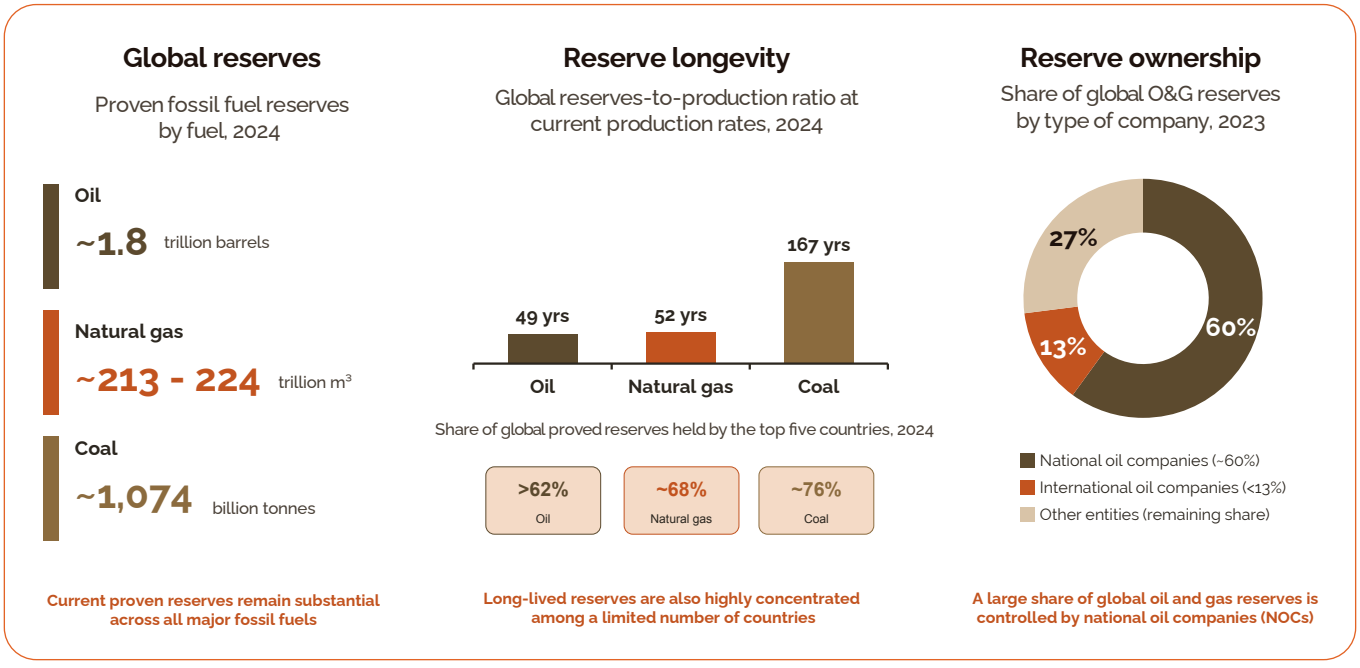
3. Structural factors shaping supply-side exposure: fossil fuel reserve lock-in

The scale and composition of proven fossil fuel reserves represent an important structural factor influencing supply-side transition[113]. Large proven reserves create expectations of significant gains regarding future production, investment and long-term energy planning, reinforcing potential structural lock-in around fossil fuel supply. As global fossil fuel demand peaks and begins to decline, countries with large reserve bases must determine how quickly future production should adjust and which resources can remain viable under changing market conditions. Reserve lock-in shapes the complexity of aligning long-term production strategies with evolving demand, particularly where future production expectations are already embedded in national energy planning and investment decisions [Fig. 10].

The significance of this factor varies according to the scale, longevity, competitiveness and ownership structure of countries' reserve bases[114]. Some major producing regions hold reserves equivalent to several decades of current production, strengthening incentives to preserve established production strategies and continuing resource development. At current production rates, proven oil and gas reserves would last between 40 and 50 years, and the ratio of reserves to production has held steady or risen over the past four decades as extraction technologies improved[115]. Exposure can be particularly persistent where reserves are controlled by national oil companies (NOCs) and closely connected to national energy strategies and government budgets. At the same time, continued development can increase exposure to underutilized resources and stranded assets if demand weakens faster than anticipated. Supply-side exposure is greater where large and long-lived reserve bases reinforce expectations of continued fossil fuel production.

Figure 10: Fossil fuel reserve lock-in

Global fossil fuel reserves remain large and long-lived, shaping expectations around future production. *Larger and longer-lived reserve bases are associated with more persistent supply-side exposure.*



Source: IEA. World Energy Outlook. 2025; IEA. The Oil and Gas Industry in Net Zero Transitions. 2023.

4. Structural factors shaping supply-side exposure: competitiveness of fossil fuel production

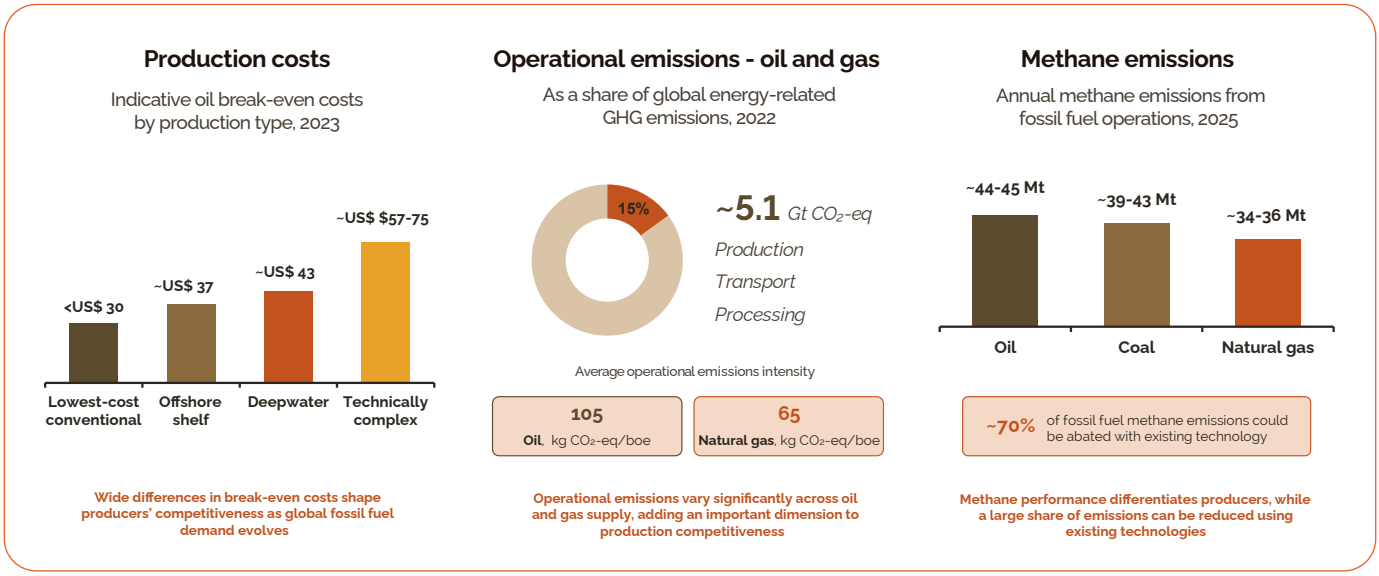
Fossil fuel-producing regions differ considerably in their production competitiveness, which is determined by both break-even costs[116] and the carbon and methane emissions intensity of supply[117]. Operational emissions from oil and gas production, processing and transport amount to around 5 $GtCO_2e$ a year, close to 15% of energy-related emissions, and a substantial part of them can be abated with available technologies[118]. Several companies have shown that this can be done at scale[119]. As global consumption declines, the supply that remains should come preferentially from the lowest-intensity sources, which makes efforts like methane abatement, the elimination of routine flaring, the electrification of operations and the capture of process emissions conditions of competitiveness for producers [Fig. 11]. The role of the industry in operational decarbonization is examined in greater detail in Box 1.

For countries, these differences influence producers' ability to remain viable as global fossil fuel demand evolves. Producers combining low production costs with relatively low operational emissions are generally better positioned to retain market share as higher-cost and more emissions-intensive production becomes less competitive[120]. Greater production competitiveness can sustain incentives for continued production and increase the complexity of aligning fossil fuel supply with evolving global demand.

Well-established production systems, coupled with transport, processing infrastructure and efficient operational practices can support lower break-even costs and lower carbon and methane emissions intensity[121]. Countries with highly competitive production may consequently face more persistent supply-side exposure, as domestic resources remain commercially attractive under a wider range of market conditions. By contrast, higher-cost or more emissions-intensive production is expected to face earlier transition pressures, including declining investment, reduced market access and earlier asset retirement as demand evolves and environmental standards strengthen[122].

Figure 11: Competitiveness of fossil fuel production

Fossil fuel production differs substantially in both cost and emissions performance. *Countries with low-cost production and lower operational emissions can remain competitive under a wider range of market conditions.*



Source: IEA. The Oil and Gas Industry in Net Zero Transitions. 2023; IEA. Global Methane Tracker. 2026.

Structural factors shaping supply-side transition capacity

While the previous factors shape the scale and complexity of the supply-side transformation required, the following factors influence countries' capacity to develop and integrate reliable, secure and affordable low-emissions energy systems.

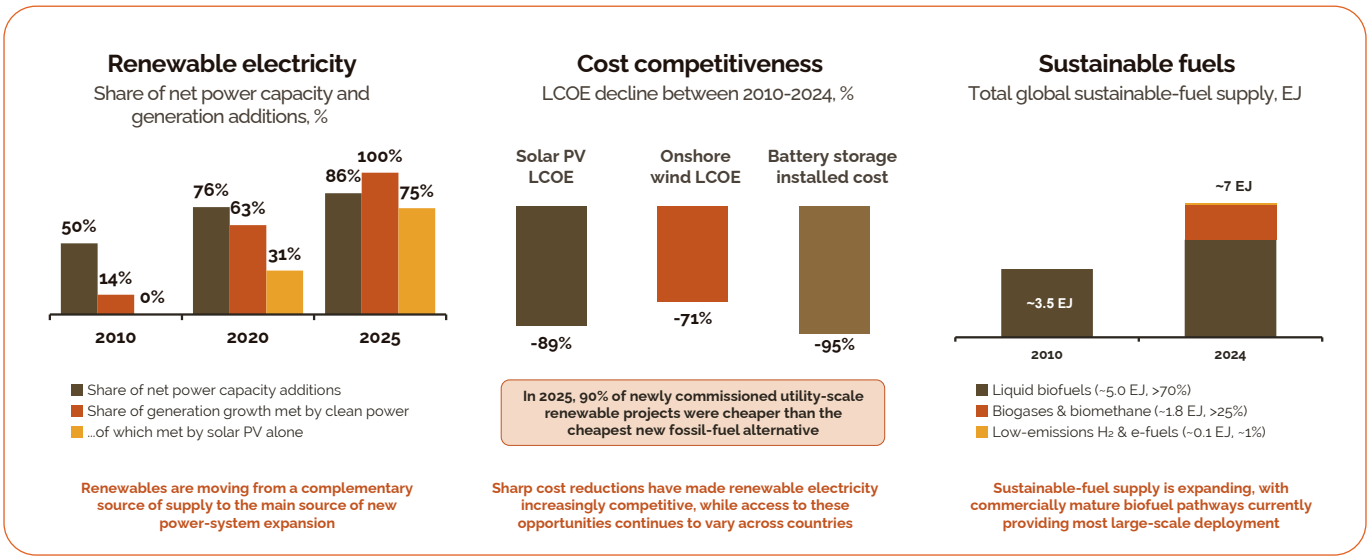
1. Structural factors shaping supply-side transition capacity: competitiveness of low-emissions alternatives

Countries with access to competitive low-emissions energy resources are generally better positioned to transform their supply systems and reduce reliance on fossil fuels[123]. Where these alternatives remain costly, limited or difficult to scale, the development of new energy systems capable of delivering reliable, secure and affordable energy services becomes considerably more complex. Renewable electricity is expected to provide the foundation for increasingly electrified energy systems, while sustainable bioenergy and low-emissions fuels can play a complementary role in sectors that remain difficult to electrify directly. Firm low-emissions technologies, including nuclear power, can also contribute to reliable electricity supply and complement variable renewable generation. The competitiveness and scalability of these alternatives directly influence countries' capacity to replace fossil fuel supply while maintaining energy security, affordability and reliability [Fig. 12].

The ability to diversify sources of energy supply varies according to country-specific resource, technological and enabling conditions[124]. Natural resource endowments such as solar irradiation, wind availability, hydropower potential and sustainable biomass resources positively influence the scale and cost at which low-emissions energy can be developed, while meteorological conditions, land, water, infrastructure and technology availability affect deployment across different energy systems. Renewable power has become increasingly cost-competitive globally, creating significant deployment opportunities where supportive resources and enabling conditions are present. Sustainable fuels such as biofuels and biomethane already constitute drop-in solutions for hard-to-abate sectors with low investment in infrastructure needed, while others like hydrogen remain at earlier stages of commercial deployment. For nuclear power, competitiveness and deployment prospects are particularly influenced by upfront financing costs, construction and project-delivery capabilities, regulatory frameworks and specialized institutional and industrial capacity[125]. Countries with more competitive low-emissions resources and stronger deployment conditions are naturally better positioned to expand reliable alternatives at scale.

Figure 12: Competitiveness of low-emissions alternatives

Low-emissions alternatives are expanding rapidly, with improving competitiveness but uneven deployment across energy systems. *Countries' supply-side transition capacity depends on access to competitive and scalable low-emissions energy alternatives.*



Source: IRENA, Renewable Power Generation Costs in 2025. 2026; IRENA. 24/7 Renewables: The Economics of Firm Solar and Wind. 2026; IEA, Delivering Sustainable Fuels: Pathways to 2035. 2025.

2. Structural factors shaping supply-side transition capacity: power infrastructure and system flexibility

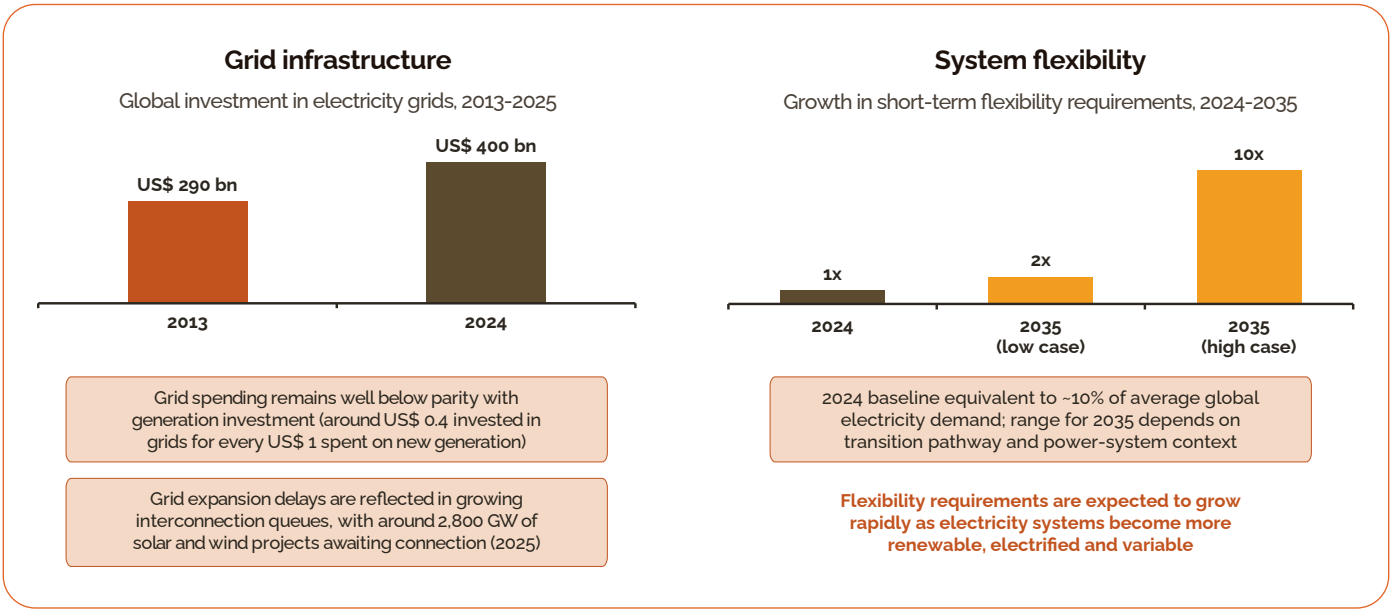
The full transformation of energy supply is accelerated when there is infrastructure capable of converting low-emissions energy potential into electricity that can be connected, transported, balanced and reliably delivered to consumers[126]. Grid infrastructure, interconnections, storage, demand-response resources and firm low-emissions capacity are critical to integrating increasingly diversified and variable power systems. The growing deployment of decentralized generation adds a further dimension to this transformation. Generation located closer to consumption can, in some circumstances, reduce transmission losses, congestion and the need for additional network investment, while also requiring systems to accommodate more dynamic and bidirectional flows and stronger capabilities for monitoring, coordination and flexibility[127]. Where these enabling systems remain underdeveloped, even abundant and competitive renewable resources may not translate into reliable energy supply to domestic markets. Power infrastructure and system flexibility therefore represent critical conditions for translating low-emissions energy potential into reliable, secure and affordable electricity supply [Fig. 13].

Countries with modern networks, sufficient connection capacity and diversified flexibility resources are naturally better positioned to integrate renewable electricity more rapidly and progressively reduce reliance on fossil fuel generation[128]. By contrast, grid congestion, aging assets, insufficient balancing resources and inadequate firm capacity can delay new connections and constrain the integration of variable low-emissions generation. At least 3,000 GW of renewable projects are waiting in grid connection queues, and annual grid investment would need to nearly double, to more than US$ 600 billion by 2030, for countries to meet their stated targets[129]. Storage, demand response, interconnections, hydropower and firm low-emissions generation can provide complementary sources of flexibility, although their availability and suitability vary across energy systems. Transition capacity is stronger where power systems can accommodate growing low-emissions supply while preserving system reliability and security.

Off-grid energy solutions are not merely an alternative to traditional electricity grids; they are a strategic pillar of universal energy access, economic development, and a just energy transition. With approximately 655 million people worldwide still lacking access to electricity in 2024, 86% of them in Sub-Saharan Africa,[130] expanding conventional grids alone will not be sufficient to close the energy access gap. Off-grid solar solutions could provide a cost-effective pathway to electricity access for approximately 398 million people by 2030,[131] bringing clean, affordable, and reliable energy to remote and underserved communities. Beyond providing electricity, these solutions can transform local economies by powering small businesses, improving healthcare and education, creating jobs, and strengthening the economic empowerment of women. Scaling up off-grid solar will require substantial investment, estimated at US$ 95 billion to expand deployment and close the electricity acess gap,[132] making it an important priority for international development and climate finance. Ultimately, investing in off-grid renewable energy is not simply about connecting the last mile; it is about creating the first mile of economic opportunity, strengthening resilience, and ensuring that the global energy transition leaves no one behind.

Figure 13: Power infrastructure and system flexibility

Rapid growth in low-emissions electricity is increasing the need for grid expansion and system flexibility. *Countries with stronger grids and sufficient flexibility are better positioned to integrate growing low-emissions electricity supply.*



Source: IEA. World Energy Outlook. 2025; IEA. World Energy Investment. 2025.

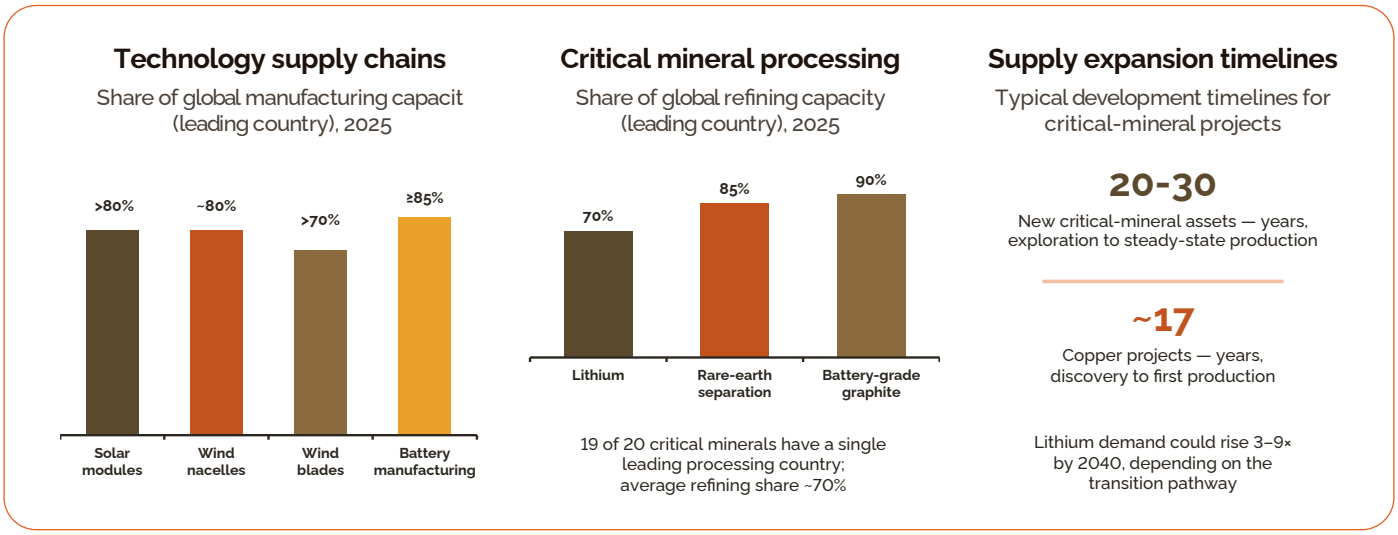
3. Structural factors shaping supply-side transition capacity: low-emission energy supply chains and critical minerals

The development of low-emissions energy systems depends on countries' ability to secure the equipment, components and raw materials required to deploy them at scale[133]. Concentrated supply chains, limited manufacturing capacity and delays in expanding mineral production and processing can impact countries' capacity to transform their energy supply systems, even where renewable resources are competitive. High market concentration also creates risks of supply shortfalls if production from major suppliers is disrupted by extreme weather, technical failures, geopolitical tensions or trade restrictions. These constraints can delay projects, increase technology costs and weaken countries' ability to expand low-emissions supply at the pace required [Fig. 14].

Countries with domestic mineral resources, manufacturing capacity, skilled workforces and established industrial ecosystems are better positioned to participate in selected segments of low-emissions energy value chains. Countries that remain highly dependent on concentrated markets and have limited access to alternative suppliers or technology partnerships may face greater implementation delays and exposure to external disruptions. Supply-side transition capacity is stronger where countries can develop or secure diversified and reliable access to the technologies and materials required for low-emissions deployment.

Figure 14: Low-emission energy supply chains and critical minerals

Clean energy supply chains and critical mineral processing remain concentrated, while expanding supply requires long lead times. *Countries with more diversified access to technologies, minerals and partnerships are better positioned to scale low-emissions supply.*



Source: SAFE. Crowding in Capital to Finance Critical Minerals Supply Chains. 2026; IEA. Critical Minerals Outlook. 2026; IEA. World Energy Outlook. 2025; IEA. World Energy Investment. 2025.

c. Energy Supply Transition Readiness Index: assessing transition preparedness

The analysis presented in the previous sections shows that countries face different supply-side transition conditions, shaped by the structural factors affecting their energy systems beyond finance. These differences can be understood through two complementary dimensions: the extent to which countries are structurally exposed to fossil fuel supply, and their capacity to develop reliable, secure and affordable low-emissions energy systems supported by enabling infrastructure and resilient supply chains. These dimensions shape countries' transition readiness and the implementation pathways available to them.

To translate this analysis into a practical assessment tool, the COP30 Presidency proposes the **Energy Supply Transition Readiness Index** [Table 9]. Following the Belém Readiness Approach, the Index assesses countries' and subnational regions' preparedness to undertake a just, orderly and equitable supply-side transition. A complementary coal sensitivity analysis is provided in Appendix D to support interpretation of the Index in countries where coal plays a particularly significant role, without altering the underlying readiness methodology.

Table 9: Energy Supply Transition Readiness Index: dimensions, indicators and rationale

Dimension	Indicator	Rationale
Supply-side Exposure	Fossil fuel share in primary energy supply	Measures the extent to which energy supply remains dependent on fossil fuels, indicating the scale of transformation required to expand low-emissions alternatives
	Fossil fuel import and export dependence	Assesses how fossil fuel trade shapes supply-side exposure, with exporters facing incentives to sustain production and importers exposed to external supply risks
	Fossil fuel reserves	Captures the scale and longevity of fossil fuel reserves, which can increase production persistence and long-term carbon and infrastructure lock-in
	Production competitiveness	Assesses the cost and emissions competitiveness of fossil fuel production, which influence how long existing supply may remain competitive as demand declines
Supply-side Transition Capacity	Competitiveness of low-emissions alternative	Assesses the competitiveness of low-emissions energy alternatives and their ability to replace fossil fuel supply while maintaining affordability
	Infrastructure readiness and system flexibility	Measures the capacity of energy infrastructure to integrate growing shares of low-emissions energy while maintaining system reliability and flexibility
	Project development and supply chain capacity	Evaluates the capacity of project-development ecosystems and supply chains to support the deployment of low-emissions energy infrastructure at scale
	Institutional planning and governance capacity	Assesses institutional capacity to design, coordinate and implement long-term supply-side transition strategies across energy systems

The Index reflects the structural factors identified in this chapter. **The first dimension—"Supply-side Exposure"—captures the extent to which countries remain structurally exposed to fossil fuel supply.** Its indicators assess complementary sources of exposure, including the role of fossil fuels in domestic primary energy supply, countries' position as importers or exporters in international fossil fuel markets, the scale and longevity of proven reserves, and the competitiveness and emissions intensity of existing production. These indicators provide an assessment of the scale, persistence and complexity of the fossil fuel supply structures that countries must manage as the global energy transition advances.

The second dimension—"Supply-side Transition Capacity"—captures countries' ability to develop reliable, secure and affordable low-emissions energy systems. The economic conditions that influence countries' capacity to deploy new energy systems will be explored in the following chapter. The "Supply-side Transition Capacity" indicators assess the structural conditions that support the deployment and scaling of competitive low-emissions energy sources, their integration through modern infrastructure and system flexibility, access to technologies, industrial capabilities and diversified supply chains, and the planning and governance arrangements required to coordinate implementation. These indicators assess whether countries possess the energy resources, infrastructure, industrial capabilities and institutional conditions needed to translate low-emissions potential into reliable supply and progressively reduce reliance on fossil fuels. As mentioned in the demand chapter, institutional and governance capacity is treated as a cross-cutting condition across the three pillars.

As in the previous chapter, the Index is intended to support self-assessment using internationally available data, complemented by national and subnational information where available. The assessment aims to identify areas of greater exposure or more limited capacity, as well as existing strengths and capabilities that can support faster implementation. The table below presents illustrative metrics and potential data sources [Table 10].

Table 10: Energy Supply Transition Readiness Index: indicators, metrics and potential sources

Dimension	Indicator	Possible metrics
Supply-side Exposure	Fossil fuel share in primary energy supply	Coal, oil, and gas in total energy supply (%)
	Fossil fuel import and export dependence	Coal, oil, and gas production/consumption ratios (%)
	Fossil fuel reserves	Coal (Mt), oil (bn barrels), and gas (tcm) estimated reserves
	Production competitiveness	Average breakeven oil price (US$/bbl); Average emissions intensity ($kgCO_2e$/bbl)
Supply-side Transition Capacity	Competitiveness of low-emissions alternative	Solar, wind, other renewables, and nuclear LCOE (US$/MWh)
	Infrastructure readiness and system flexibility	Transmission & distribution losses (% of output); Storage deployment (GW); Curtailment (% of output)
	Project development and supply chain capacity	Share of clean energy value chains* (% of global); Business & permitting efficiency (B-Ready)
	Institutional planning and governance capacity	Electricity sector governance (RISE); Energy policy stability & effectiveness; International engagement

Illustrative and non-exhaustive data sources include the IEA, OPEC, Energy Institute and Rystad Energy for fossil fuel supply, trade, reserves and production competitiveness; IRENA and the IEA for low-emissions energy alternatives; the IEA and World Bank for infrastructure, flexibility and supply-chain indicators; and national statistics and assessments for country-specific energy, industrial, planning and governance conditions.

Recognizing that data availability and quality vary across countries, **the Roadmap also stresses the importance of international cooperation among countries and supporting institutions to help address data and information gaps** that may constrain effective self-assessment and implementation planning.

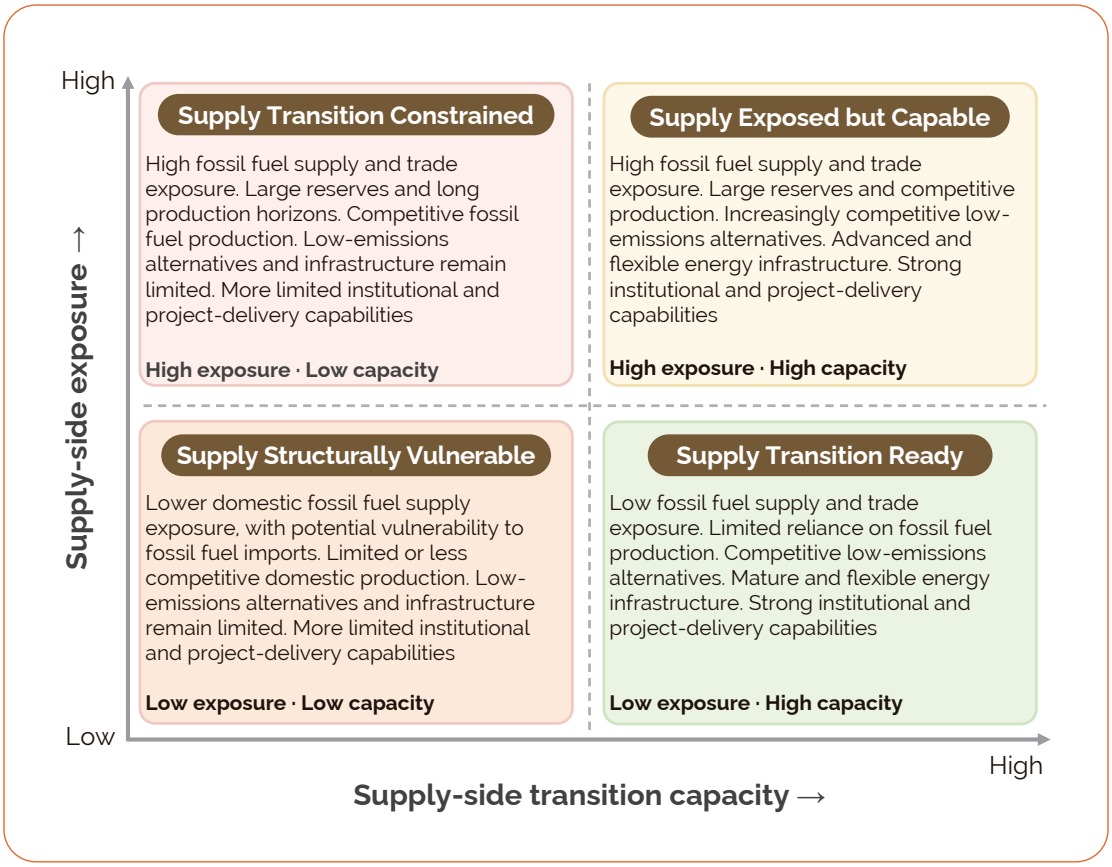
d. Energy Supply Transition Archetypes: identifying common transition profiles

Building on the Energy Supply Transition Readiness Index presented in the previous section, the COP30 Presidency offers a set of **Energy Supply Transition Archetypes**. The archetypes group countries and subnational regions that share similar combinations of supply-side exposure and transition capacity. Their purpose is to translate the Index into a practical understanding of the different supply system transformations countries need to undertake and the structural conditions that shape those transformations.

Countries with similar readiness profiles may face comparable conditions in managing fossil fuel supply, expanding low-emissions alternatives and maintaining reliable, secure and affordable energy services throughout the transition. The archetypes provide a basis for identifying common strengths, constraints, opportunities and differentiated implementation priorities, while recognizing that national pathways remain context-specific. They also offer a basis for cooperation among countries in similar positions, which may exchange experience, coordinate approaches to common challenges and present shared needs to international partners.

The archetypes are derived by combining the two dimensions of the Energy Supply Transition Readiness Index in a two-dimensional matrix [Fig. 15]. The vertical axis represents the degree of "Supply-side Exposure," while the horizontal axis represents the level of "Supply-side Transition Capacity." Their interaction generates four broad archetypes reflecting distinct supply-side transition contexts, ranging from countries facing high fossil fuel exposure and limited transition capacity (upper-left) to those combining lower exposure with stronger capacity to develop and integrate low-emissions alternatives (lower-right).

Figure 15: Energy Supply Transition Archetypes



As in the previous chapter, the archetypes are illustrative and not prescriptive. Countries may share characteristics across groups or evolve over time as their structural conditions and transition capacities change. The exercise is intended to support strategic planning by identifying common characteristics and differentiated implementation pathways rather than assigning fixed classifications.

The main structural characteristics, strengths and constraints associated with the supply-side transition of each of the four archetypes identified through the framework are summarized below.

Supply Transition Archetypes Description

Supply Transition Constrained Archetype
(High supply-side exposure · Low transition capacity)

These countries combine high supply-side exposure with more limited capacity to develop and integrate low-emissions alternatives. Their energy systems are characterized by high dependence on fossil fuel production and supply, often supported by large reserves, established export positions and production that may remain competitive as global demand evolves. At the same time, low-emissions alternatives, enabling infrastructure and system flexibility are less developed or more limited in scale. More limited access to competitive technologies, grid readiness and diversified low-emissions supply chains constrains the pace at which reliable alternatives can be expanded. Fossil fuel supply is therefore deeply embedded in the energy system, while the capabilities required to progressively transform the supply mix remain comparatively limited at the time of assessment.

Supply Exposed but Capable Archetype
(High supply-side exposure · High transition capacity)

These countries represent major fossil fuel producers and exporters, often with competitive resources and significant reserve bases that reinforce long-term production incentives. Their supply systems remain structurally exposed as global demand evolves, particularly where low-cost and lower-emissions production can retain market share for longer. However, they also possess competitive low-emissions resources, relatively modern infrastructure, stronger system flexibility and more developed project and supply-chain capabilities. The defining characteristic of this archetype is the coexistence of high fossil fuel exposure with strong capacity to develop and integrate low-emissions alternatives. Their supply-side transition context is shaped by the scale of existing production, the persistence of reserve and market incentives, and the need to align fossil fuel supply with evolving demand while deploying low-emissions alternatives at scale.

Supply Structurally Vulnerable Archetype
(Low or moderate supply-side exposure · Low transition capacity)

These countries have relatively limited exposure to domestic fossil fuel production and generally face fewer structural incentives to preserve an established fossil fuel export position. However, they face more limited capacity to develop and integrate low-emissions energy systems. Infrastructure, system flexibility, access to competitive low-emissions resources and technologies, project-development capabilities and supply-chain conditions are generally less developed, slowing the deployment of new energy supply. Where fossil fuel import dependence is high, exposure may be driven more by reliance on external supply than by domestic fossil fuel production. More limited legacy fossil fuel infrastructure can create opportunities to leapfrog directly toward low-emissions energy systems, although realizing this potential depends on the development of adequate infrastructure, technologies and institutional capabilities. Their supply-side profile is characterized by lower or moderate fossil fuel exposure combined with more limited capacity to expand reliable, secure and affordable low-emissions energy systems at scale.

Supply Transition Ready Archetype
(Low supply-side exposure · High transition capacity)

These countries face comparatively more favorable structural conditions for transforming their energy supply systems. Fossil fuel production plays a more limited role, while competitive low-emissions resources, modern infrastructure, mature project ecosystems and diversified flexibility solutions provide favorable conditions for the transition. Lower exposure reduces the scale of fossil fuel supply adjustment required, while stronger capacity allows new sources to be integrated while maintaining reliability, security and affordability. Their supply-side profile combines lower fossil fuel exposure with stronger capabilities to expand and integrate low-emissions energy systems at scale. Further progress is shaped primarily by the pace of deployment, infrastructure expansion alongside growing electrification, and the management of emerging supply chain, system integration and technological requirements.

e. Differentiated implementation pathways: strengthening supply-side transition readiness

Building on the Energy Supply Transition Archetypes presented in the previous section, the COP30 Presidency identified a differentiated set of levers to improve countries' readiness to undertake a just, orderly and equitable supply-side transition. Implementation priorities differ according to countries' levels of supply-side exposure and their supply-side transition capacity[134].

The supply-side pillar also distinguishes between foundational levers and archetype-specific implementation levers. **Foundational levers** represent the common enabling conditions required to strengthen supply-side transition readiness across archetypes. They establish the institutional, regulatory and systemic foundations needed to transform energy supply systems, strengthen implementation capacity and enable the deployment of low-emissions energy at scale. National and subnational governments play a central role in establishing these conditions, supported by other critical stakeholders.

Building on these common foundations, implementation levers reflect differentiated priorities associated with the structural factors and readiness conditions of each supply-side archetype. They identify key areas for strengthening Energy Supply Transition Readiness over time and recognize that implementation depends on coordinated action across multiple stakeholders. The framework accordingly identifies main and supporting actors for each implementation lever, reflecting their complementary roles in delivering the supply-side transition.

The combined implementation of foundational and implementation levers is essential to strengthen countries' supply-side transition readiness over time. Countries may reduce their exposure to fossil fuel supply, strengthen their supply-side transition capacity, or advance across both dimensions simultaneously. As readiness improves, countries may progressively evolve toward different archetypes, reflecting changes in the structure of their energy systems, institutional capabilities and transition conditions. **Accordingly, the COP30 Presidency proposes that readiness assessments be periodically updated to monitor progress, inform policy adjustments and refine implementation priorities as countries advance along different transition pathways**.

Supply-side Foundational Levers

Based on extensive consultations and stakeholder engagement, the COP30 Presidency has identified the following foundational levers [Table 11].

Table 11: Supply-side Foundational Levers

Archetype	Foundational levers
Supply Transition Constrained (High supply exposure · Low transition capacity)	1. Strengthen long-term supply-side transition planning and integrated supply strategies [Institutional planning & governance] 2. Promote institutional coordination and public-private collaboration [Institutional planning & governance] 3. Diversify energy supply in line with resource endowments and security objectives [Low-emissions supply transformation] 4. Expand electricity networks, storage, interconnections and system flexibility [Energy infrastructure & system flexibility] 5. Improve project development ecosystems and enabling business environments [Project development and supply chain capacity] 6. Reduce operational emissions from fossil fuel production through methane abatement, flaring reduction and low-emissions technologies [Operational emissions mitigation]
Supply Exposed but Capable (High supply exposure · High transition capacity)	
Supply Structurally Vulnerable (Low supply exposure · Low transition capacity)	
Supply Transition Ready (Low supply exposure · High transition capacity)	

1. Supply-side foundational levers: strengthen long-term supply-side transition planning and integrated supply strategies

Rationale: long-term planning and integrated energy supply strategies provide the basis for transforming energy systems while maintaining reliable, secure and affordable energy services. Coordinated planning helps align infrastructure development, fossil fuel production, low-emissions energy deployment and system modernization, reducing uncertainty and enabling a more orderly and resilient supply-side transition. While long-term energy planning increasingly incorporates low-emissions supply, fossil fuel production, infrastructure development, power-system expansion and low-emissions deployment are still often planned through separate processes and time horizons, limiting integrated decision-making[135].

Implementation in action: selected initiatives illustrate how this lever is already being operationalized across different geographies and by different actors. The examples are illustrative and primarily drawn from the COP30 Action Agenda, which mobilizes actors and implementation efforts to accelerate delivery of existing climate commitments, building on the outcomes of the first Global Stocktake:

- Beyond Oil & Gas Alliance (BOGA): launched at COP26 in 2021, BOGA brings together national and subnational governments committed to managing the transition away from oil and gas production. By supporting restrictions on new licensing and Paris-aligned pathways for existing production, the Alliance promotes the incorporation of future fossil fuel supply into long-term transition planning alongside the development of alternative energy systems and broader transition objectives.

- Powering Past Coal Alliance (PPCA): launched in 2017, the PPCA brings together national and subnational governments, businesses and organizations committed to accelerating the phase-out of unabated coal power. Through peer exchange, transition planning and support for coal-to-clean strategies, the Alliance provides a practical precedent for integrating the managed reduction of fossil fuel-based supply with the expansion of low-emissions alternatives. Its experience provides a practical reference for sequencing the transformation of established fossil fuel-based supply alongside the expansion of low-emissions alternatives within longer-term energy strategies.

2. Supply-side foundational levers: promote institutional coordination and public-private collaboration

Rationale: effective institutional coordination and collaboration across public and private actors are essential to translate long-term supply-side transition objectives into implementation. Coordination across governments, regulators, system operators, utilities, energy producers, investors and other stakeholders helps align energy planning, infrastructure development, regulation, investment and operational decisions as supply systems evolve[136]. Responsibilities across these areas are often distributed among multiple institutions and levels of government, while significant investment and operational decisions are undertaken by state-owned and private companies, increasing the importance of clear mandates and effective coordination mechanisms.

Implementation in practice[137]:

- We Mean Business Coalition—Fossil to Clean**:** the Fossil to Clean campaign mobilizes companies and business networks to accelerate the shift from fossil fuels to clean energy across corporate operations, value chains and policy engagement. It promotes stronger alignment between corporate transition strategies and public policy, while encouraging businesses to support enabling conditions for clean-energy deployment.

- Fossil Fuel Non-Proliferation Treaty Initiative (FFNPT): launched in 2020, the initiative brings together governments, subnational authorities, civil society and other stakeholders to advance international cooperation on the managed transition away from fossil fuel production. Its work includes high-level dialogues, coordination among participating governments and the development of legal, financial and policy pathways to support a just and orderly transition. The initiative showcases cross-country institutional coordination supporting greater alignment around fossil fuel production, transition planning and implementation.

- Santa Marta Process**:** launched through the 1st International Conference on Transitioning Away from Fossil Fuels in April 2026, the process brought together 57 countries and more than 1,000 representatives from governments, sectors and non-state actors to advance dialogue and cooperation on a just, orderly and equitable transition away from fossil fuels. Discussions across 14 sectors created a platform for coordination around implementation priorities, with follow-up efforts aimed at translating dialogue into concrete action and international cooperation ahead of the second conference in 2027[138]. Although broader than the supply-side transition alone, the process provides a relevant example of how cross-country and multi-stakeholder coordination can support alignment across policy, investment and implementation decisions related to transitioning away from fossil fuels. Further information and the final conference report are available here.

3. Supply-side foundational levers: diversify energy supply in line with resource endowments and security objectives

Rationale: diversifying energy supply through the expansion of low-emissions energy sources strengthens energy security, improves system resilience and reduces dependence on fossil fuels. Building on countries' comparative resource endowments enables cost-effective transition pathways while supporting reliable, secure and affordable low-emissions energy systems[139]. Renewable electricity is becoming an increasingly important source of new energy supply[140], while differences in resource availability, infrastructure, technology access and deployment conditions continue to shape countries' ability to diversify across competitive low-emissions alternatives.

Implementation in action[141]:

- Global Renewables Alliance (GRA): established at COP27 in 2022, GRA brings together six major global renewable-energy industry associations covering wind, solar, hydropower, geothermal, green hydrogen and long-duration energy storage. It works with governments, industry, investors and other stakeholders to accelerate renewable deployment and support delivery of the global objective of tripling renewable energy capacity to at least 11,174 GW by 2030[142]. Its cross-technology approach supports the expansion of a more diversified portfolio of renewable energy sources and enabling solutions.

- Belém 4X Pledge on Sustainable Fuels**:** launched at the Pre-COP30 in 2025 and supported by a growing group of governments, the initiative aims to substantially expand the global use of sustainable fuels by 2035. Implementation is anchored in the Clean Energy Ministerial Future Fuels Action Plan, which brings together governments, industry and partner organizations around 20 cross-sector actions covering demand creation, global supply chains, lifecycle carbon accounting and enabling infrastructure. The framework connects policy, markets, infrastructure and supply-chain development to support the scale-up of sustainable fuels across different sectors.

- Nuclear Innovation: Clean Energy Future (NICE Future) Initiative: launched in 2018 under the Clean Energy Ministerial, the initiative brings together governments, international organizations, industry and research institutions to explore the role of nuclear energy in reliable, affordable and secure energy systems. Its work covers advanced reactor deployment, nuclear-renewables integration, financing and economic modeling, non-electric applications and supply-chain development. The initiative broadens the set of low-emissions supply options considered in energy-system planning and supports international cooperation on the conditions required for nuclear deployment.

International Solar Alliance (ISA): conceived by India and France at COP21 in 2015 and established as a treaty-based intergovernmental organization with over 100 member countries, the Alliance works to expand the deployment of solar energy for energy access, energy security and the transition. Its "Towards 1000" strategy aims to mobilize US$ 1 trillion in solar investment, bring energy access to 1 billion people and install 1,000 GW of solar capacity by 2030, through programs on project preparation, capacity building, de-risking instruments such as the Global Solar Facility, and, more recently, the digitalization of power systems and the integration of distributed solar.

4. Supply-side foundational levers: strengthen electricity networks, storage, interconnections and system flexibility

Rationale: modern, resilient and interconnected energy infrastructure constitutes a critical enabling condition for integrating growing shares of variable renewable energy while maintaining system reliability and security[143]. Expanding electricity networks, storage capacity and system flexibility reduces integration constraints, improves energy resilience and enables the large-scale deployment of low-emissions energy technologies. Grid investment has increased, but network expansion, connection capacity and flexibility resources continue to develop at different speeds across countries relative to the rapid growth of renewable generation.

Implementation in action[144]:

- Green Grids Initiative (GGI): launched at COP26 in 2021, the initiative brings together governments, development institutions, businesses, utilities and technical organizations to accelerate the development of modern and interconnected electricity grids. Its activities address grid planning, investment, supply-chain capacity and institutional capabilities, while promoting stronger regional and international power-system connections. Its multi-stakeholder approach connects planning, investment and implementation needs associated with grid expansion and interconnection.

- International Smart Grid Action Network (ISGAN): established in 2010 under the Clean Energy Ministerial and operating as an IEA Technology Collaboration Programme, ISGAN brings together participating governments and technical institutions to advance the development and deployment of smarter and more flexible electricity networks. It facilitates international knowledge exchange on grid technologies, system integration, digitalization, regulatory approaches and flexibility solutions. The network strengthens the technical and institutional capabilities needed to manage increasingly complex and flexible power systems.

- Utilities for Net Zero Alliance (UNEZA): launched at COP28 in 2023, UNEZA brings together leading power utilities and electricity-sector companies, with support from IRENA and the UN Climate Change High-Level Champions, to accelerate power-sector decarbonization and address barriers to grid expansion, renewable integration and electrification. The Alliance focuses on areas such as grid investment, system modernization, renewable deployment, supply chains and access to finance, while facilitating collaboration among utilities and other stakeholders. Its utility-led model places system operators and electricity companies at the centre of network expansion, storage integration and the deployment of flexibility solutions.

5. Supply-side foundational levers: improve project development ecosystems and enabling business environments

Rationale: efficient project development ecosystems, predictable regulatory frameworks and enabling business environments accelerate the deployment of low-emissions energy projects. Streamlined, transparent and predictable permitting processes, underpinned by clear environmental and social safeguards, strong technical capabilities, resilient supply chains and effective project preparation reduce implementation bottlenecks, lower investment risks and strengthen countries' ability to deliver energy infrastructure at scale[145]. Countries differ substantially in project-development capacity, reflecting differences in project preparation, technical capabilities, regulatory certainty and the ability to coordinate permitting, land, infrastructure and supply-chain requirements[146].

Implementation in action[147]:

- IRENA Energy Transition Accelerator Financing Platform (ETAF)**:** launched in 2021 by IRENA and international partners, ETAF supports renewable-energy projects in moving from early development toward implementation through project assessment, technical assistance and project structuring. The platform helps address preparation gaps that can prevent technically viable projects from developing into implementation-ready pipelines, particularly in markets with limited project-development capacity. Its relevance to this lever lies in strengthening project preparation and development capabilities.

- Climate Investment Platform (CIP): established by IRENA, UNDP, Sustainable Energy for All and the Green Climate Fund, CIP supports the development of renewable-energy project pipelines through technical assistance, project assessment and preparation support. Its activities help strengthen local project-development ecosystems and improve the quality and maturity of projects before they reach the financing stage. The platform strengthens local project-development ecosystems by improving project quality and maturity and connecting project preparation with broader implementation and financing needs.

6. Supply-side foundational levers: reduce operational emissions from fossil fuel production through methane abatement, flaring reduction and low-emissions technologies

Rationale: reducing operational emissions from fossil fuel production lowers the emissions (carbon and methane) intensity of energy supply while contributing to near-term climate mitigation. Deploying methane abatement measures, eliminating routine flaring and adopting low-emissions technologies improve the emissions performance of existing production systems and support a more orderly transition as fossil fuel demand gradually declines[148]. Measurement, reporting and mitigation practices have expanded, although significant differences remain across producers in methane management, flaring reduction and the implementation of available mitigation technologies[149].

Implementation in action[150]:

- Oil and Gas Decarbonization Charter (OGDC): launched at COP28 in 2023 and implemented by the Oil and Gas Climate Initiative (OGCI) as its Secretariat, OGDC is a global industry-led initiative bringing together more than 55 oil and gas companies across over 100 countries. Around two-thirds of signatories are national oil companies (NOCs), and participating companies represent approximately 40% of global oil production. The initiative supports companies in accelerating operational emissions reductions through collaboration, knowledge sharing, capacity building and transparent greenhouse gas emissions reporting. Its broad participation across different company types and geographies provides a platform for scaling common decarbonization practices and strengthening operational emissions management across the sector.

- Global Methane Pledge (GMP): launched at COP26 in 2021, the Pledge brings together governments committed to collectively reducing global anthropogenic methane emissions by at least 30% from 2020 levels by 2030. It covers major methane-emitting sectors, including fossil fuel production, and has helped elevate methane abatement within national climate strategies and international cooperation. For this lever, its principal relevance is the establishment of a common political objective that can underpin stronger methane measurement, regulation and mitigation across producing economies.

- UNEP Methane Alert and Response System (MARS): launched at COP27 in 2022 by the United Nations Environment Programme (UNEP) through its International Methane Emissions Observatory (IMEO), MARS is a global satellite-based system that detects major methane emissions and provides actionable information to governments and companies. Using data from more than 30 satellite instruments, combined with scientific analysis and AI-based tools, the system identifies and attributes major emission events, notifies relevant operators and authorities, and tracks subsequent mitigation action. MARS strengthens transparency and accountability by integrating independent methane detection, notification and response, helping turn improved emissions monitoring into concrete mitigation action.

Supply-side Implementation Levers: archetype-specific messages

Table 12: Implementation Levers for the Supply Transition Constrained Archetype (High supply exposure - Low transition capacity)

Supply Transition Constrained (High supply exposure · Low transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Manage an orderly transition of fossil fuel production while expanding competitive low-emissions energy systems [Low-emissions Supply Transformation]	**Main actor:** National governments **Supporters:** Subnational governments; Businesses and industry; Regulators and system operators; International organizations and development partners	• Fossil fuel licensing and production transitioning away frameworks • Coal-to-clean transition plans and project pipelines • Renewable and low-emissions capacity deployment targets and programmes
Expand transmission networks, energy storage and system flexibility to enable the integration of low-emissions electricity [Energy Infrastructure & System Flexibility]	**Main actors:** National governments; Regulators and system operators **Supporters:** Businesses and industry; Subnational governments; International organizations and development partners	• Grid expansion and modernization plans • Grid-connection and interconnection reforms • Storage, smart-grid and flexibility deployment programmes
Strengthen permitting, project delivery ecosystems and domestic industrial capabilities to accelerate clean energy deployment [Project Development & Supply Chain Capacity]	**Main actor:** National governments **Supporters:** Subnational governments; Businesses and industry; Academia and research institutions; International organizations and development partners	• Project-preparation and pipeline-development facilities • Streamlined permitting and project-approval processes • Technical-capacity and supplier-development programmes
Build institutional and coordination capabilities to plan and implement the supply-side transition [Institutional Planning & Governance]	**Main actor:** National governments **Supporters:** Subnational governments; Regulators and system operators; Businesses and industry; Academia and research institutions; International organizations and development partners	• Integrated energy-transition planning frameworks • Inter-ministerial and multilevel coordination mechanisms • Public-private implementation platforms
Deploy best available technologies to minimize operational emissions from fossil fuel production [Operational Emissions Mitigation]	**Main actor:** Businesses and industry **Supporters:** National governments; Regulators and system operators; Academia and research institutions; International organizations and development partners	• Methane measurement, reporting and verification frameworks • Leak detection and repair programmes • Routine-flaring reduction or phase-out requirements
Strengthen public-private partnerships to develop domestic low-emissions energy supply chains [Project Development & Supply Chain Capacity]	**Main actors:** National governments; Businesses and industry **Supporters:** Subnational governments; Academia and research institutions; International organizations and development partners	• Clean-energy manufacturing and supplier-development programmes • Technology-transfer and co-development partnerships • Skills and workforce-development programmes

Sequencing priorities to foster implementation: First step, **transforming the energy supply mix** by gradually reducing dependence on fossil fuels while expanding competitive low-emissions energy systems. Second step, **building the enabling environment for supply-side transformation** through stronger infrastructure, institutional capacity and implementation capabilities that accelerate investment and project delivery. Third step, **enhancing the competitiveness and sustainability of the energy sector** by developing domestic industrial capabilities, strengthening low-emissions supply chains and reducing emissions from remaining fossil fuel production. These priorities support the simultaneous management of existing fossil fuel systems and the development of the infrastructure, technologies and implementation capabilities required to expand reliable low-emissions alternatives.

National and subnational governments play a central role in sequencing the transition of fossil fuel supply, establishing the enabling environment and guiding the expansion of reliable low-emissions energy systems. Where institutional, technical and project-development capabilities are more limited, implementation benefits from coordinated action across a broader supporting ecosystem, including through procurement. Regulators and system operators, businesses and industry, academia and research institutions, and international organizations and development partners can complement domestic efforts by strengthening implementation capacity, accelerating project delivery, expanding access to technology and supporting the development of domestic supply chains.

Table 13: Implementation Levers for the Supply Exposed but Capable Archetype (High supply exposure - High transition capacity)

Supply Exposed but Capable (High supply exposure · High transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Manage an orderly transition of fossil fuel production while accelerating diversified low-emissions energy systems (e.g., utility-scale, distributed renewables and sustainable fuels) [Low-emissions Supply Transformation]	**Main actor:** National governments **Supporters:** Subnational governments; Businesses and industry; Regulators and system operators; International organizations and development partners	• Fossil fuel production transition and licensing frameworks • Renewable capacity auctions and deployment programmes • Sustainable fuel mandates and deployment roadmaps
Expand critical energy infrastructure, energy storage and system flexibility [Energy Infrastructure & System Flexibility]	**Main actors:** Regulators and system operators; Businesses and industry **Supporters:** National governments; Subnational governments; International organizations and development partners	• Transmission expansion and interconnection plans • Storage and flexibility procurement mechanisms • Advanced grid-connection and market-integration rules
Develop competitive low-emissions value chains for emerging technologies [Project Development & Supply Chain Capacity]	**Main actor:** Businesses and industry **Supporters:** National governments; Subnational governments; Academia and research institutions; International organizations and development partners	• Clean-technology manufacturing and supplier-development programmes • Technology demonstration and scaleup programmes • Technology-transfer and industrial partnership frameworks
Align regulatory and market frameworks to accelerate diversified low-emissions energy systems [Institutional Planning & Governance]	**Main actor:** National governments **Supporters:** Regulators and system operators; Businesses and industry; Subnational governments; International organizations and development partners	• Competitive procurement and auction frameworks • Technology and performance standards • Power-market rules supporting low-emissions and flexible resources
Deploy best available technologies to minimize operational emissions from fossil fuel production (e.g., methane emissions and flaring) [Operational Emissions Mitigation]	**Main actor:** Businesses and industry **Supporters:** National governments; Regulators and system operators; Academia and research institutions; International organizations and development partners	• Methane measurement and performance standards • Leak detection and repair requirements • Routine flaring phase-out requirements
Shape market standards that strengthen the competitiveness of low-emissions energy supply [Institutional Planning & Governance]	**Main actor:** National governments **Supporters:** Businesses and industry; Regulators and system operators; International organizations and development partners; Academia and research institutions	• Low-emissions fuel and technology certification schemes • Emissions-intensity standards and benchmarks • International interoperability and sustainability standards

Sequencing priorities to foster implementation: First step, **diversifying the energy supply mix** by managing the orderly transition of fossil fuel production while accelerating the expansion of competitive and diversified low-emissions energy systems. Second step, **redirecting infrastructure and industrial capabilities** toward emerging energy industries and strategic value chains. Third step, **reinforcing the competitiveness of low-emissions energy supply** through supportive market conditions, including targeted subsidies, while reducing operational emissions from remaining fossil fuel production. These economies can build on existing institutional, technical and industrial capabilities to accelerate energy diversification, scale emerging low-emissions industries and align long-term supply strategies with evolving domestic and international demand.

National and subnational governments play a central role in managing the transition of fossil fuel production, aligning regulatory and market frameworks and guiding the diversification of energy systems. Given their relatively strong transition capacity, implementation increasingly relies on coordinated action by businesses and industry, regulators and system operators, and other actors to mobilize investment, expand infrastructure and scale emerging energy technologies. Academia and research institutions, and international organizations and development partners can complement these efforts by supporting innovation, technology cooperation, the development of low-emissions value chains and international market integration.

Table 14: Implementation Levers for the Supply Structurally Vulnerable Archetype (Low supply exposure - Low transition capacity)

Supply Structurally Vulnerable (Low supply exposure · Low transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Accelerate the deployment of renewable energy and sustainable fuels to strengthen reliable, affordable and secure energy supply [Low-emissions Supply Transformation]	**Main actor:** Businesses and industry **Supporters:** National governments; Subnational governments; Regulators and system operators; International organizations and development partners	• Renewable energy deployment programmes • Sustainable-fuel development roadmaps • Competitive procurement and auction schemes
Expand electricity networks, energy storage and system flexibility to improve energy-system reliability and resilience [Energy Infrastructure & System Flexibility]	**Main actors:** National governments; Regulators and system operators; Businesses and industry **Supporters:** Subnational governments; International organizations and development partners	• Grid expansion and modernization plans • Mini-grid and distributed-energy programmes • Storage and flexibility deployment mechanisms
Improve project preparation, permitting and local delivery capabilities to facilitate clean-energy investments [Project Development & Supply Chain Capacity]	**Main actor:** National governments **Supporters:** Subnational governments; Businesses and industry; Academia and research institutions; International organizations and	• Project-preparation and pipeline-development facilities • Streamlined permitting processes • Technical-assistance and local delivery programmes
Build institutional capacity and public-private collaboration to accelerate supply-side transition implementation [Institutional Planning & Governance]	**Main actor:** National governments **Supporters:** Subnational governments; Regulators and system operators; Businesses and industry; Academia and research institutions; International organizations and development partners	• Integrated energy-planning frameworks • Inter-ministerial and multilevel coordination mechanisms • Public-private implementation platforms
Expand regional energy cooperation and cross-border infrastructure to improve energy security and resilience [Energy Infrastructure & System Flexibility]	**Main actors:** National governments; Regulators and system operators **Supporters:** Businesses and industry; International organizations and development partners; International financial institutions and climate funds	• Regional power-pool and interconnection agreements • Cross-border transmission planning frameworks • Regional grid codes and interoperability standards
Manage the orderly retirement and repurposing of ageing or uncompetitive fossil fuel assets, where applicable [Low-emissions Supply Transformation]	**Main actor:** Businesses and industry **Supporters:** National governments; Regulators and system operators; Subnational governments; International organizations and development partners	• Asset-retirement and repurposing plans • Decommissioning standards and timelines • Site-redevelopment and infrastructure-reuse programmes

Sequencing priorities to foster implementation: First step, **strengthening reliable, affordable and secure energy systems** by expanding renewable energy, sustainable fuels and the infrastructure needed to improve energy system resilience. Second step, **building the enabling environment for supply-side transformation** by strengthening institutional capacity, improving project delivery and reinforcing public-private collaboration. Third step, **enhancing long-term energy resilience** through regional cooperation, cross-border infrastructure and the orderly retirement and repurposing of aging or uncompetitive fossil fuel assets, where applicable. For economies with more limited legacy fossil fuel infrastructure, strengthening these conditions can also support the direct development of low-emissions energy systems while reducing the risk of future fossil fuel lock-in. These priorities reinforce the infrastructure, institutional and implementation capabilities needed to expand reliable low-emissions supply and strengthen long-term energy security and resilience.

National and subnational governments play a central role in building the enabling environment, strengthening institutional capacity and promoting regional cooperation. Where domestic implementation capacity and market scale are more limited, coordinated engagement across a broader supporting ecosystem becomes particularly important. Regulators and system operators, businesses and industry, academia and research institutions, international organizations and development partners, and international financial institutions and climate funds can complement domestic efforts by strengthening project preparation, expanding technical capabilities, mobilizing investment and supporting regional energy integration.

Table 15: Implementation Levers for the Supply Transition Ready Archetype (Low supply exposure - High transition capacity)

Supply Transition Ready (Low supply exposure · High transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Accelerate integrated low-emissions energy systems, including renewable energy, sustainable fuels and emerging technologies [Low-emissions Supply Transformation]	**Main actor:** Businesses and industry **Supporters:** National governments; Subnational governments; Regulators and system operators; Academia and research institutions; International organizations and development partners	• Technology-neutral clean-energy deployment programmes • Sustainable-fuel and emerging-technology roadmaps • Integrated renewable, storage and firm-capacity procurement schemes
Optimize electricity networks, energy storage and system flexibility to maximize the integration of low-emissions energy systems [Energy Infrastructure & System Flexibility]	**Main actors:** Regulators and system operators; Businesses and industry **Supporters:** National governments; Subnational governments; Academia and research institutions	• Advanced transmission and interconnection planning • Flexible electricity-market and balancing mechanisms • Storage and demand-response procurement frameworks
Develop globally competitive low-emissions value chains for strategic energy technologies [Project Development & Supply Chain Capacity]	**Main actor:** Businesses and industry **Supporters:** National governments; Subnational governments; Academia and research institutions; International organizations and development partners	• Strategic clean-technology manufacturing programmes • Innovation, demonstration and commercialization programmes • International technology and supply-chain partnerships
Advance regulatory and market frameworks that enable highly integrated low-emissions energy systems [Institutional Planning & Governance]	**Main actors:** National governments; Regulators and system operators **Supporters:** Businesses and industry; Academia and research institutions; International organizations and development partners	• Advanced power-market design and flexibility rules • Interoperability and technology standards • Integrated energy-system planning and regulatory frameworks
Lead international cooperation on regulatory frameworks and market standards that accelerate low-emissions energy systems [Institutional Planning & Governance]	**Main actor:** National governments **Supporters:** Regulators and system operators; Businesses and industry; International organizations and development partners; Academia and research institutions	• International certification and sustainability standards • Cross-border interoperability and technical standards • Mutual-recognition and harmonization frameworks
Promote international collaboration to scale innovation, investment and knowledge sharing for the global supply-side transition [Institutional Planning & Governance]	**Main actors:** National governments; International organizations and development partners **Supporters:** Businesses and industry; Academia and research institutions; Private financial institutions; International financial institutions and climate funds	• International clean-energy innovation partnerships • Joint research, demonstration and knowledge-sharing programmes • Technology-transfer and capacity-building platforms

Sequencing priorities to foster implementation: First step, **expanding low-carbon energy systems** by strengthening system flexibility, expanding sustainable fuels and maximizing the integration of renewable energy. Second step, **optimizing the enabling environment for low-carbon energy systems** through regulatory frameworks, market design and strategic value chains that support long-term system performance and resilience. Third step, **providing international leadership for the supply-side transition** by advancing regulatory cooperation, promoting common market standards and sharing knowledge and implementation experience that accelerate low-emissions energy systems globally. These economies can build on strong domestic energy-system, institutional and technological capabilities to deepen the integration of low-emissions energy, strengthen competitiveness and support implementation beyond national borders.

National and subnational governments play a central role in advancing regulatory frameworks, optimizing energy system performance and strengthening international cooperation. Given their relatively strong transition capacity, implementation can increasingly extend beyond domestic system transformation to international cooperation, technology diffusion and market integration. Regulators and system operators, businesses and industry, academia and research institutions, international organizations and development partners, private financial institutions, and international financial institutions and climate funds can contribute by advancing interoperable regulatory approaches, strengthening strategic value chains, mobilizing investment and supporting the international diffusion of technologies, knowledge and implementation experience.

Box 1: The role of the oil and gas industry in transitioning away[151]

Why the industry matters for the energy transition from the supply-side perspective

The oil and gas (O&G) industry has a central role in the supply-side transition and can contribute on two fronts.

The first is the emissions intensity of its own operations, where the solutions described below are largely available. As O&G continues to meet a large part of global energy demand during the transition, remaining production must be delivered with the lowest operational emissions (scopes 1 and 2) technically and economically achievable. The emissions intensity of fossil fuel production should also increasingly be considered as a differentiating factor in O&G markets, informing purchasing and investment decisions, and strengthening incentives for producers to improve operational emissions performance. This requires reducing emissions across extraction, processing, transport and refining, while accelerating the deployment of technologies that improve the performance of existing supply systems[152].

The second is the diversification of its business, since much of its existing infrastructure, from refineries and pipelines to storage, distribution networks and engineering capacity, can be adapted to produce, refine and distribute low-emissions solutions. Refineries converted into biorefineries producing renewable diesel and sustainable aviation fuel, and gas networks beginning to carry biomethane, show that existing assets, sites and skills can be redirected toward the transition when market and regulatory conditions make it viable.

Reducing emissions from existing operations and building markets for sustainable fuels are therefore complementary pathways and not separate agendas. However large this contribution may be, the industry is unlikely to lead an accelerated transition, whose pace will be set by the policies, markets and technologies described in the rest of this Roadmap.

The industry is diverse, but influence over supply is highly concentrated. Approximately 70% of global O&G production is controlled by around fifty companies[153]. National oil companies (NOCs) and internationally positioned state-owned producers account for more than half of global production[154] and close to 60% of reserves, giving them substantial influence over future production and investment decisions[155]. International oil companies (IOCs) hold smaller shares of reserves and production but also possess strong technical capabilities, experience in complex projects, access to capital and established R&D systems, as well as well-developed institutional and policy-engagement capabilities. Independent producers remain particularly relevant in short-cycle and market-responsive supply, given their significant participation in unconventional production, such as tight oil, and their organizational agility in adjusting investment plans to changing market conditions[156]. These differences shape companies' incentives, implementation capacity and potential contribution to operational decarbonization[157].

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a. Operational emissions profile

O&G production, transport and processing generated approximately 5.1 $GtCO_2e$ in 2022, equivalent to around 15% of energy-related greenhouse gas emissions, excluding end-use combustion. Oil supply accounted for around 3.4 $GtCO_2e$ and natural gas for 1.7 $GtCO_2e$. Methane represented close to half of operational emissions, while the remainder was largely associated with refining, energy use in production, transport, flaring and naturally occurring CO_2 released during gas processing.

This concentration of emissions across a limited number of operational sources creates a substantial mitigation opportunity. Five technology pathways are particularly relevant: methane abatement, elimination of non-emergency flaring, electrification of upstream operations, carbon capture, utilization and storage (CCUS), and low-emissions hydrogen in refining and processing. Their mitigation impact, relative cost and implementation readiness differ considerably, requiring differentiated implementation strategies[158].

b. Readiness across the five decarbonization solutions[159]

1. **Methane abatement** provides the largest immediate opportunity. Approximately 75% of O&G methane emissions could be reduced with existing technologies, including leak detection and repair, continuous monitoring and the replacement of high-emitting equipment. Nearly 47% of upstream methane emissions could be abated at no net cost under 2025 energy prices because the value of recovered gas can exceed implementation costs[160]. These characteristics make methane abatement a high-impact, relatively low-cost and deployment-ready solution[161].

The constraint on methane is therefore one of implementation, not of technology. Measurement and transparency have expanded considerably: the Oil and Gas Methane Partnership 2.0 now covers roughly 45% of global production, direct measurement is carried out across some 6,000 assets, and satellite monitoring through UNEP's Methane Alert and Response System makes major emission events visible to governments and operators[162]. The task is to turn this body of data into faster leak response and accountability for results. First, buyers of oil and gas can create demand for near-zero methane products through procurement expectations, trade relationships and offtake arrangements that reward lower-methane production, giving producers the market certainty to invest in abatement. Second, fiscal and contractual arrangements, including production-sharing agreements and cost-recovery rules, need to recognize methane abatement as a legitimate cost. Third, regulators in many producing countries need the capacity to oversee implementation, as technical expertise on methane management remains concentrated within companies.

2. **Eliminating non-emergency flaring** is also technically mature and capable of delivering rapid reductions. Around 95% of flaring-related emissions could be avoided using existing technologies. Available pathways include gas gathering and processing, reinjection, pipeline delivery, on-site electricity generation and conversion into transportable fuels or industrial products[163]. Deployment is nevertheless constrained where gathering infrastructure, commercial outlets and enforcement mechanisms remain limited.

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3. **Electrification of upstream operations** is a way to substantially reduce emissions associated with on-site energy use when supplied by low-emissions electricity. More than half of global O&G production is located within 10 km of an existing electricity grid, while around three-quarters is situated in regions with strong solar or wind resources. This creates significant technical potential, although large-scale deployment depends on grid expansion, renewable supply, equipment retrofits and supportive regulatory conditions[164].

4. **CCUS** can reduce process-related and residual emissions from gas processing, refining and other energy-intensive operations. It is closely aligned with the industry's capabilities in subsurface management, gas handling and large-scale project delivery. In 2023, O&G companies participated in around 90% of global operational CCUS capacity. In more recent years, CCUS projects have increasingly been developed through hub-based models that share CO_2 transport and storage infrastructure across multiple emitters, helping improve infrastructure utilization and project economics[165]. Large-scale projects are now entering operation. Northern Lights, in Norway, began injecting CO_2 captured from a cement plant in 2025, with a first phase of 1.5 Mt a year fully booked and an expansion to around 5 Mt a year under way, and ExxonMobil started the commercial capture, transport and storage of up to 2 Mt a year from an ammonia plant in Louisiana in 2025, with further projects expected in 2026[166]. However, high capital costs, transport and storage requirements and long development timelines mean that CCUS remains a comparatively high-cost, longer-term solution[167].

5. **Low-emissions hydrogen** can reduce emissions from refining, where hydrogen is already widely used for fuel processing and upgrading. Existing hydrogen demand makes refineries potential anchor users for early low-emissions hydrogen markets. Nevertheless, high production costs, limited infrastructure and the need for reliable low-emissions electricity constrain near-term scalability. Its role is therefore likely to grow gradually as costs decline and supporting infrastructure develops.

c. Levers to accelerate implementation

The comparison across solutions demonstrates that operational decarbonization does not face a uniform readiness challenge, although clear pathways are ready to deliver results. Methane abatement and flaring reduction can be accelerated immediately through stronger measurement and reporting systems, performance standards, enforcement and investment in gas-recovery infrastructure[168]. Electrification requires coordinated grid development, renewable electricity supply and equipment retrofits. CCUS and low-emissions hydrogen depend on longer-term infrastructure planning, stable regulatory frameworks, credible carbon accounting, risk-sharing mechanisms and continued cost reductions[169]. **There is an opportunity for the industry to move faster on mature and cost-effective solutions, while building the conditions required to scale more capital-intensive technologies**[170].



1. R&D and technology development

Operational decarbonization should be accompanied by a stronger R&D contribution in low-emissions technologies and energy solutions. The O&G industry allocated approximately US$ 25–28 billion in corporate R&D in 2024, covering a broad range of technologies, energy sources and operational solutions. In absolute terms, this exceeded the estimated US$ 12–15 billion invested by renewable-energy companies[171]. However, average oil and gas R&D expenditure remains close to 1% of revenues, compared with around 4% in renewable energy and other clean-technology sectors[172], and approximately 75% of sectoral R&D spending is concentrated among fewer than twenty companies[173].

The industry's financial resources, engineering expertise and project-delivery capabilities provide a strong foundation for expanding R&D in methane monitoring, electrification, CCUS, low-emissions hydrogen, advanced materials and other technologies relevant to the broader supply-side transition. Increasing both the scale and strategic orientation of R&D investment can help reduce operational emissions while accelerating the development and commercialization of low-emissions energy solutions.

The industry operates under detailed technical, quality and safety standards, from fuel specifications to operational safety requirements, with a degree of precision that allows its products to be traded and consumed as commodities everywhere in the world, and it has the organizational capacity to apply the same discipline to emissions. The methane and carbon intensity of production can be measured, certified and written into contracts in the same way as sulfur content or calorific value. The COP30 Presidency therefore encourages the industry, together with standard-setting bodies and buyers, to move toward common standards for the emissions performance of oil and gas, so that lower-intensity supply becomes a verifiable product attribute recognized in markets and in trade.

2. Portfolio transformation

Beyond operational decarbonization, portfolio transformation represents a broader and more structural strategic dimension of the transition. The pace and direction of this transformation depends on market conditions, companies' internal capabilities, technology availability and the resource and economic conditions of the countries in which they operate.

Companies' approach to portfolio transformation differs according to their ownership and governance structures. NOCs often operate at the intersection of energy policy, public revenues, energy security and national industrial development. Their investment and diversification strategies can consequently be closely linked to broader national transition priorities, giving them a distinctive role in determining how fossil fuel-producing economies manage changes in energy supply, capital allocation and the development of low-emissions alternatives[174].

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International oil companies, while also influenced by regulatory and policy environments, tend to respond more directly to global market conditions, shareholder expectations and investment opportunities across different markets and technologies. Greater portfolio diversification across the industry depends on the presence of enabling market, regulatory, technological and demand-side conditions that support commercially viable low-emissions activities. Several of these conditions are addressed across the demand-side, supply-side and economic transition chapters of this Roadmap. Differences in governance, capabilities and operating environments can consequently influence the pace and direction of diversification into low-emissions businesses.

ECONOMIC TRANSITION PERSPECTIVE: TRANSFORMING ECONOMIC SYSTEMS AND INCENTIVES

a. The relevance of the economic transition

In addition to the energy-related challenges and opportunities, transitioning away from fossil fuels also requires significant attention to a broader economic transformation[175]. Economic systems play a central role in enabling a just, orderly and equitable transition, as they determine countries' capacity to manage structural economic transformation and ensure that the benefits and costs of the transition are distributed in a socially and economically sustainable manner. The pace, feasibility and costs of the transition depend not only on the characteristics of energy systems, but also on the broader macroeconomic, institutional and geopolitical structures in which they are embedded.

The fiscal dimension of fossil fuel dependence extends well beyond producing countries. Governments of many developing economies that produce little or no fossil fuel rely on excise duties, sales taxes and import levies on fuels as a significant and reliable source of public revenue, often among the largest single contributors to the budget, and in some cases this revenue is shared between national and subnational governments, which deepens the dependence across the whole public sector[176]. Declining consumption therefore poses a question of fiscal transition for importers as well as exporters. At the same time, a growing body of evidence indicates that fossil fuel dependence tends to accentuate inequalities.

Countries differ substantially in their economic exposure to the transition[177]. While some economies remain deeply connected to fossil fuel production, trade and consumption, others have more diversified economic structures, developing new sources of growth associated with the low-emissions economy. These differences help explain why the economic implications of transitioning away from fossil fuels vary considerably across regions and the extent to which countries face differentiated implementation needs and opportunities.

At the same time, countries also differ in their ability to manage structural economic transformation. Mobilizing investment, fostering innovation, strengthening institutions, developing human capital and creating enabling conditions for private sector participation all influence the pace at which new economic activities can emerge and expand[178]. The availability of domestic capabilities, together with access to international finance and cooperation, plays a central role in determining how effectively countries can navigate the economic transition and capture emerging opportunities[179].

These differences influence both the scale of the economic transformation required and the capacity of countries to manage that adjustment over time. Understanding these differences provides an essential foundation for identifying the principal structural factors shaping economic exposure and transition capacity, assessing countries' readiness to advance the transition, and designing differentiated implementation pathways that reflect national circumstances and build on existing strengths and opportunities.

b. Structural factors[180] shaping the economic transition

Over the past decades, the energy transition has advanced significantly, supported by technological progress, expanding deployment of low-emissions solutions and growing policy ambition[181]. However, the broader economic structures within which this transition must occur remain deeply shaped by fossil fuel-based development[182]. International energy trade, fiscal systems, industrial value chains, financial markets and geopolitical relationships have evolved over more than a century around production, consumption and trade of fossil fuels. These structures influence countries' economic exposure to the transition, as well as their capacity to redirect investment, develop new sources of growth and manage structural transformation.

Despite increased international and national efforts, the pace of transition remains well below what is required to achieve pathways consistent with limiting global warming to 1.5°C[183]. Countries face different structural factors that influence both the scale of adjustment required and the capabilities available to manage that transformation.[184] These factors can be grouped into two complementary sets: those that shape economic exposure, by influencing the degree of dependence on fossil fuel-related economic activities and the scale of associated adjustment; and those that shape economic transition capacity, by influencing countries' ability to mobilize investment, diversify economic activity and develop the capabilities required for a low-emissions economy.

Economic exposure is particularly relevant to countries where fossil fuel production, trade, fiscal revenues and related economic activities play a significant role. Lower dependence and greater economic diversification reduce exposure and strengthen countries' ability to absorb structural change. Economic transition capacity is relevant across all economies, including countries with limited fossil fuel production but substantial investment, industrial, institutional and capability needs associated with building a low-emissions economy. Stronger financial, technological, institutional and productive capabilities expand the range of transition opportunities available to countries and support faster progress.

These structural factors provide the analytical foundation for assessing countries' economic transition readiness and identifying differentiated implementation pathways. Their relevance and direction vary across countries according to national circumstances: the same factor can represent a source of exposure, a constraint on implementation or an existing strength that supports transition progress. The sections below identify the key structural factors shaping economic exposure and transition capacity and explain how different conditions influence countries' readiness to advance the transition.

Structural factors shaping economic exposure

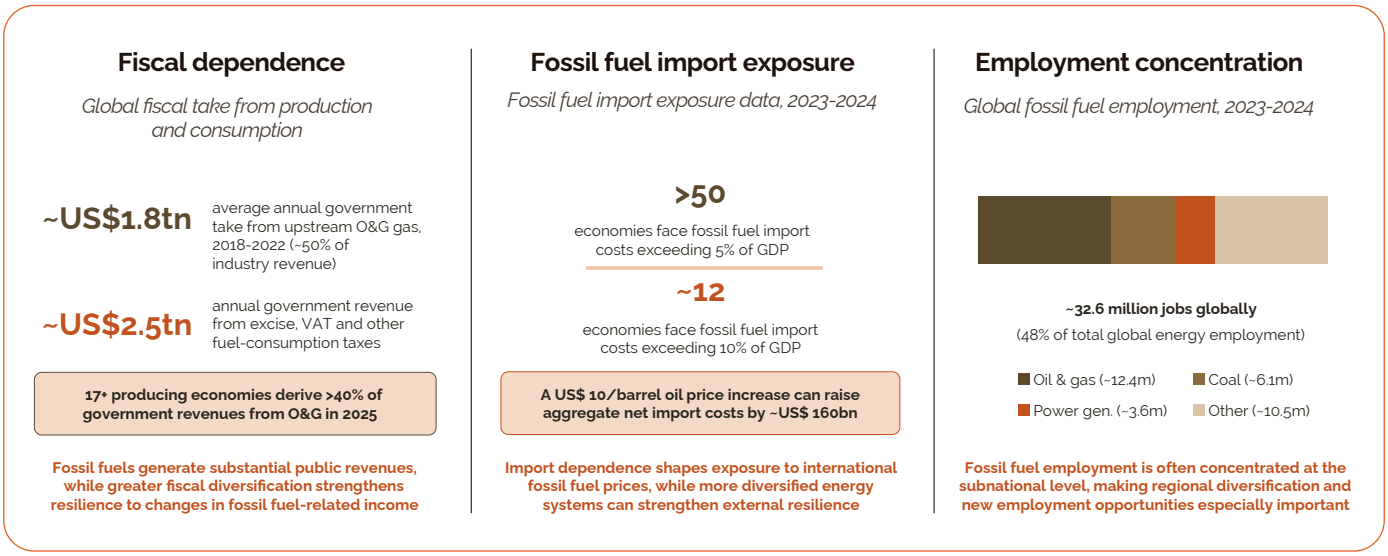
1. Structural factors shaping economic exposure: economic dependence on fossil fuel revenues, trade and employment

One of the main factors influencing economic exposure arises from the central role that fossil fuel activities continue to play in many national economies. Fossil fuel production generates substantial fiscal revenues and export earnings in many economies, supporting public services, investment and broader economic activity, while associated value chains sustain employment and local incomes[185]. High dependence on these activities increases the scale and complexity of economic adjustment as global fossil fuel demand evolves, particularly when public finances, external revenues and labor markets are closely linked to fossil fuel production and trade[186]. Import-dependent economies face a distinct form of exposure, as high fossil fuel import costs can affect external balances, fiscal conditions and domestic energy prices, while increasing sensitivity to international price and supply shocks [Fig. 16].

The nature of economic exposure differs according to countries' position in fossil fuel production and trade and the degree of economic diversification. Producing economies in which fossil fuel income, fiscal revenues and exports account for a large share of overall economic activity generally face greater exposure, particularly when alternative sources of public revenue, exports and employment remain limited[187]. Greater economic diversification strengthens resilience by expanding alternative sources of growth, revenues and employment and improving economies' ability to absorb changes in fossil fuel-related activity. Labor-market exposure also differs across countries: fossil fuel employment is usually more concentrated in specific producing subnational regions, where associated jobs often support wider local economic activity.[188] For importing economies, exposure is greater where fossil fuel purchases represent a significant share of GDP and alternative energy sources remain limited, increasing macroeconomic and energy-security risks associated with supply disruptions. More diversified energy and economic systems strengthen resilience to changes in international fossil fuel markets.

Figure 16: Fossil fuels revenues, trade and employment

Fossil fuel activities continue to shape public finances, external trade and employment across economies. *Economic exposure varies with the degree of dependence on fossil fuel revenues, trade and employment.*



Source: IEA. The Oil and Gas Industry in Net Zero Transitions. 2023; E3G. Playing the Oil Endgame. 2026; Ember. The Energy Security Fallout. 2026; IEA. World Energy Employment. 2025.

2. Structural factors shaping the economic exposure: capital lock-in and stranded-asset exposure

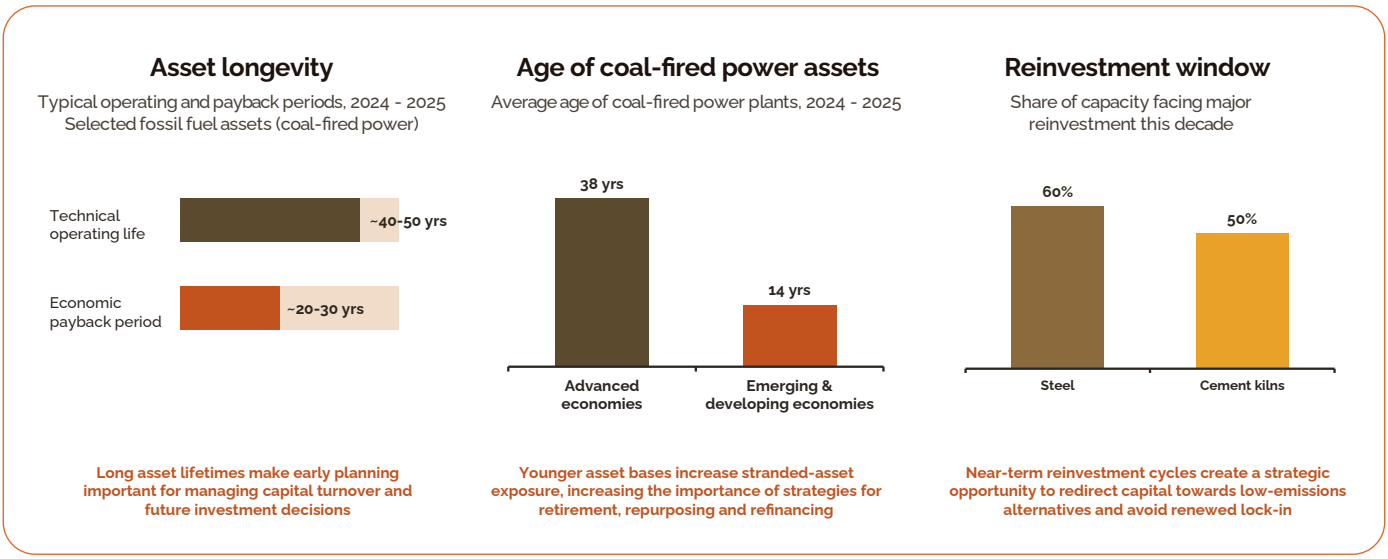
Economic exposure also arises from the stock of capital already committed to long-lived fossil fuel and carbon-intensive assets. These investments are typically designed to operate over several decades and create strong incentives to maintain existing assets until capital costs have been recovered[189]. Accelerated transition may require early retirement, repurposing or refinancing of assets that remain economically valuable, increasing stranded-asset exposure and potential financial losses[190]. Capital lock-in raises the economic cost and complexity of transition, particularly when large shares of national or corporate investment remain tied to assets whose expected operating lives extend well into the transition period. Repurposing can limit these losses where existing assets can be adapted to low-emissions inputs. Coal-fired plants and industrial boilers can be converted to burn biomass pellets, refineries can process biogenic feedstocks into renewable diesel and sustainable aviation fuel, and pipelines and storage can carry biomethane and liquid biofuels, so that part of the capital already invested continues to generate value during the transition, provided that sustainable feedstock is available and the conversion does not prolong the life of assets that should be retired [Fig. 17].

Exposure to capital lock-in depends on the age, composition and reinvestment cycles of the existing capital stock. Economies with relatively young fossil fuel infrastructure and carbon-intensive industrial assets generally have a larger share of unrecovered capital

and face greater financial exposure from accelerated retirement, while older asset bases create greater opportunities for replacement and modernization[191]. Major refurbishment and reinvestment decisions represent important transition opportunities, as they can either extend existing production systems or redirect capital toward low-emissions alternatives. Well-timed investment decisions can reduce future lock-in, support repurposing and accelerate the modernization of existing assets[192]. Economies with more limited legacy fossil fuel infrastructure face lower lock-in and have greater scope to expand energy and productive systems directly around low-emissions technologies, provided that adequate finance, infrastructure and institutional capabilities are available.

Figure 17: Capital lock-in and stranded-asset exposure

Age of existing assets and reinvestment cycles shape capital lock-in and transition opportunities. *Younger carbon-intensive assets increase exposure, while reinvestment cycles create opportunities to redirect capital.*



Source: IEA. Scaling up Transition Finance. 2025; IEA. Coal in Net Zero Transitions. 2022; IEA. World Energy Outlook. 2025.

Structural factors shaping economic transition capacity

While the previous factors shape the scale and complexity of economic adjustment, the following factors influence countries' capacity to mobilize investment, diversify economic activity and build the capabilities required for a low-emissions economy.

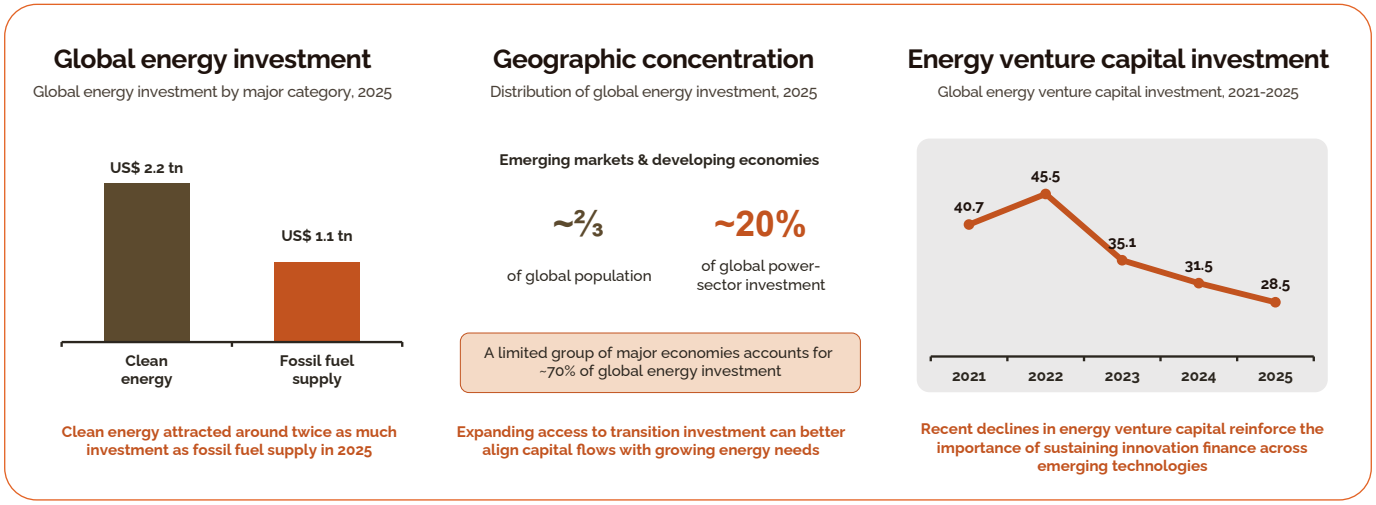
1. Structural factors shaping economic transition capacity: transition investment flows

Global energy investment is shifting rapidly toward low-emissions technologies, even though the scale and distribution of capital remain uneven and significantly concentrated on developed countries and large emerging economies. Clean energy investment[193] now exceeds investment in fossil fuel supply, reflecting the greater economic attractiveness of renewable power, grids, storage, electrification and energy efficiency[194]. However, aggregate growth in investment does not necessarily translate into sufficient capital flows across all countries, technologies and stages of development. Stronger and more broadly distributed investment flows could accelerate the development of infrastructure, productive capabilities and innovation required for low-emissions economies[195] [Fig. 18].

Countries' ability to attract transition-related investment depends on their access to domestic and international capital and their position in global investment flows[196]. Global energy investment remains highly concentrated, while many emerging markets and developing economies receive a comparatively limited share despite substantial energy and development needs. Investment allocation is also influenced by geopolitical priorities, changing electricity-demand patterns and investors' appetite for different technologies, markets and stages of maturity. Countries that attract greater transition investment are better positioned to expand low-emissions systems, strengthen productive capabilities and develop new sources of economic growth, particularly where strong resource potential and development opportunities are present.

Figure 18: Transition investment flows

Clean energy investment is rising rapidly, while broader access to transition capital remains critical for scaling implementation. *Greater access to transition investment strengthens countries' capacity to expand low-emissions infrastructure and productive capabilities.*



Source: IEA. World Energy Investment. 2025; IEA. World Energy Outlook. 2025; IEA. World Energy Investment. 2026.

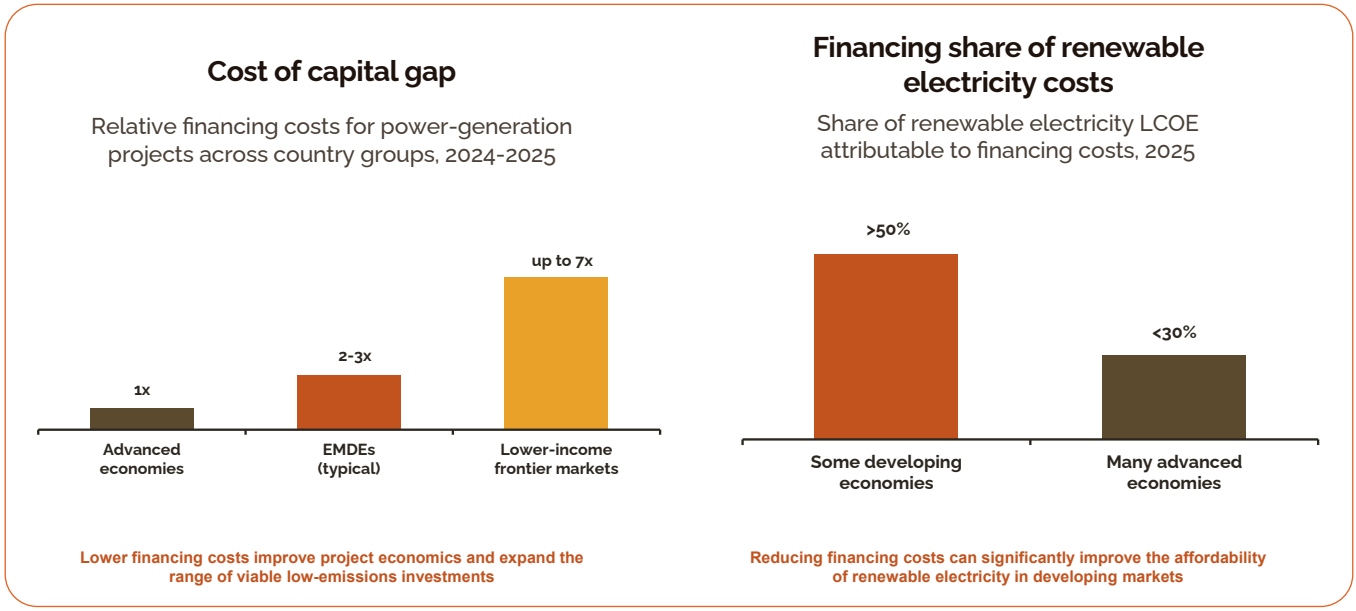
2. Structural factors shaping economic transition capacity: cost of capital and access to finance

The cost and availability of finance are fundamental determinants of countries' transition capacity. Low-emissions technologies, particularly renewable power and storage, require higher upfront capital expenditure than fossil fuel-based alternatives, making their competitiveness particularly sensitive to financing conditions[197]. More affordable financing reduces project costs, improves investment viability and accelerates deployment of low-emissions technologies. Differences in financing conditions influence both the pace and the cost of the transition across countries [Fig. 19].

Financing conditions depend on macroeconomic conditions, sovereign risk, financial market development and the broader investment environment. Financing costs for energy projects are typically higher in emerging markets and developing economies, reflecting factors such as inflation, currency risk, sovereign credit conditions, regulatory uncertainty and investors' perceptions of risk[198]. These differences can materially increase the levelized cost of renewable electricity and constrain access to affordable capital for governments, firms and project developers. In many cases the defining factor for building solar capacity is financing conditions, more than resource endowments. Across countries, installed capacity is negatively correlated with solar potential, whereas within countries, and even more within regions of the same country, installations follow the resource closely[199]. Stronger financial systems, lower financing costs and improved access to capital expand countries' ability to translate viable low-emissions investment opportunities into implementation.

Figure 19: Cost of capital and access to finance

Financing conditions strongly shape the affordability and scalability of low-emissions investment. *More affordable financing strengthens countries' ability to translate competitive low-emissions technologies into viable investment.*



Source: IEA. World Energy Outlook. 2025; IEA. World Energy Investment. 2025; COP29 Presidency. Baku to Belém Roadmap. 2025.

3. Structural factors shaping economic transition capacity: fossil fuel subsidies and distorted price signals

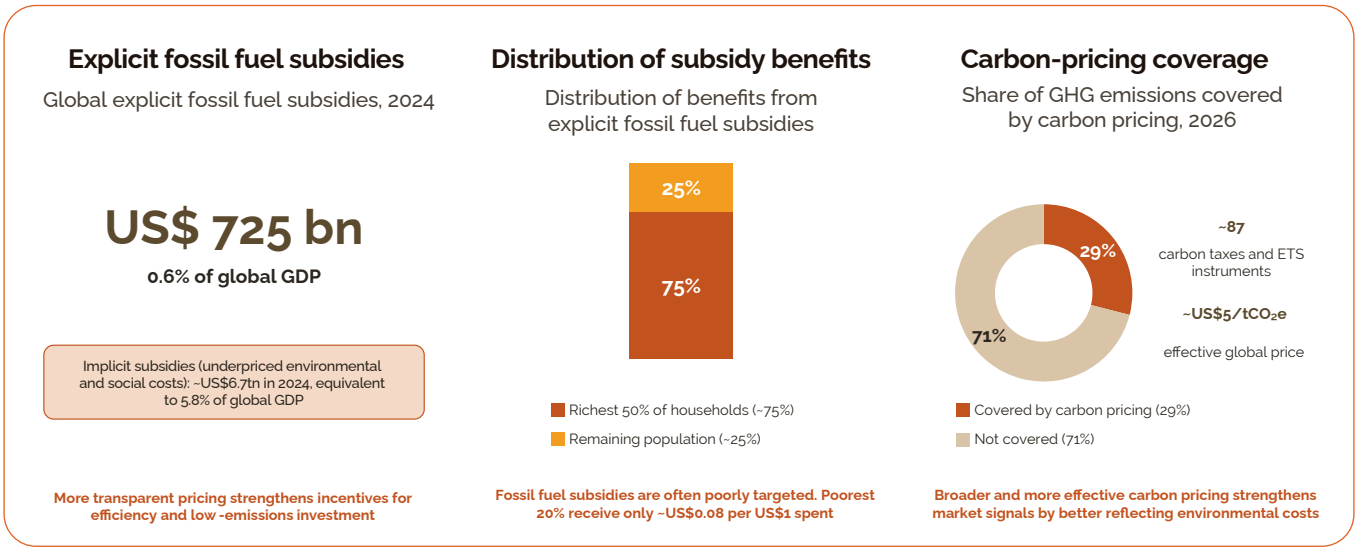
Fossil fuel subsidies and the inadequate pricing of environmental and social costs distort economic incentives and weaken the competitiveness of low-emissions alternatives[200]. Explicit subsidies lower the effective price of fossil fuel consumption through direct fiscal support or the underpricing of energy supply costs, reducing incentives for efficiency, electrification and investment in cleaner technologies. A second source of distortion arises when the environmental and social costs of fossil fuel use are not adequately reflected in market prices, creating implicit support for fossil fuel consumption and production[201] [Fig. 20].

The counterpart of this implicit support is that the costs of climate impacts are largely borne by public budgets. Governments finance emergency response, reconstruction and adaptation, often through additional borrowing, and increasingly act as insurers of last resort as private insurers raise premiums or withdraw from exposed areas: insured losses from natural catastrophes have exceeded US$ 100 billion a year since 2020 and still cover only a minority of total losses, with the protection gap estimated at more than half of losses worldwide and widening over time[202]. Recent work by central banks and supervisors on the macroeconomic and financial consequences of extreme weather shows that these costs are no longer marginal for public finances, financial stability or the affordability of insurance for households[203]. The damage caused by each additional ton of emissions is thus paid in the end by taxpayers and the uninsured, while those who produce and consume fossil fuels are at present rarely called upon to contribute. Correcting this asymmetry, through pricing frameworks and risk-sharing arrangements that reflect the costs of fossil fuel use, is one of the clearest ways to align incentives with the transition.

The effects of distorted price signals depend on countries' energy pricing systems, fiscal structures and capacity to protect vulnerable households through targeted measures. Broad-based fossil fuel subsidies are often expanded during periods of high energy prices or geopolitical disruption, but prolonged or poorly targeted support can reinforce fossil fuel dependence, generate fiscal pressures and disproportionately benefit higher-income consumers. Explicit subsidies amounted to about US$ 725 billion in 2024, roughly ten times the support directed to clean technology deployment, and they reach the poorest fifth of households only marginally, at about eight cents of every dollar, while the richest half captures close to three quarters[204]. Better-targeted support and clearer energy price signals reinforce incentives for efficiency, electrification and low-emissions investment while preserving protection for vulnerable consumers. Carbon pricing mechanisms also strengthen price signals by reflecting environmental and social costs more directly in economic decisions, although coverage and price levels remain uneven: in 2025, 87 carbon taxes and emissions trading systems covered about 29% of global emissions at an average price of around US$ 21 per ton, which amounts to roughly US$ 5 per ton once unpriced emissions are included[205]. Transition capacity is stronger where pricing frameworks support low-emissions investment and social protection mechanisms address affordability and distributional impacts.

Figure 20: Fossil fuel subsidies and distorted price signals

Fossil fuel prices remain distorted by substantial explicit subsidies and the inadequate pricing of environmental and social costs. *Clearer pricing signals and targeted support strengthen incentives for low-emissions investment while protecting vulnerable consumers.*



Source: IMF. Underpriced and Overused: Fossil Fuel Subsidies Data 2025 Update. 2025; World Bank. State and Trends of Carbon Pricing. 2026.

4. Structural factors shaping economic transition capacity: green premiums[206] and market formation for low-emissions alternatives

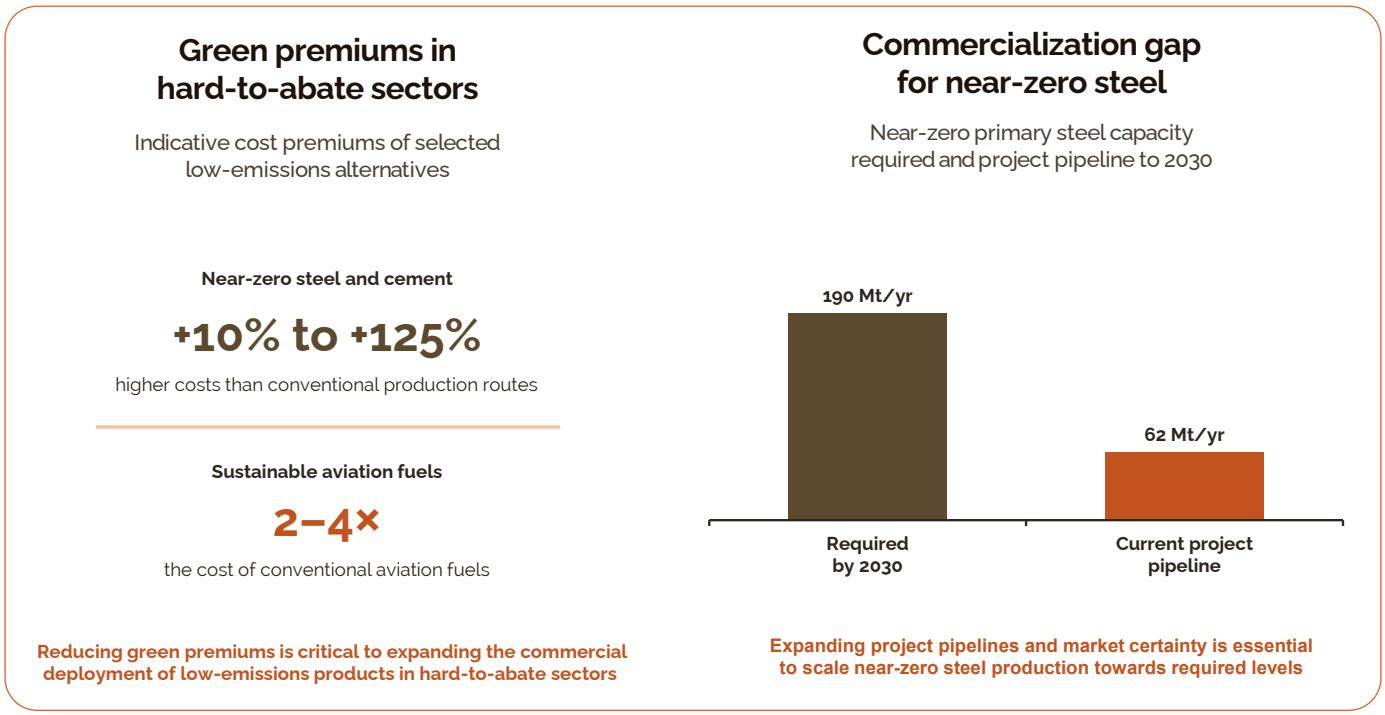
Cost differential and market-formation conditions influence the commercial deployment of low-emissions alternatives, particularly in sectors where technologies remain at earlier stages of maturity[207]. While sustained innovation and deployment have significantly reduced the costs of technologies such as solar photovoltaics, wind power and batteries, green premiums remain for several products and processes in hard-to-abate sectors, including steel, cement, aviation and shipping[208]. These premiums reflect limited economies of scale, less mature technologies and supply chains, high capital requirements and the advantages accumulated by established production systems [Fig. 21]. Stronger innovation and productive capabilities accelerate technological maturation, reduce costs and expand the range of commercially viable low-emissions alternatives.

Market formation is shaped by the scale and maturity of domestic markets, the capacity to aggregate demand, the strength of industrial and innovation ecosystems, and the availability of credible standards and product-level emissions information[209]. Countries with larger or more developed markets, stronger buyer demand and established systems for certification and emissions accounting are better positioned to provide producers with visibility over future revenues and support investment and scale-up. Where demand remains fragmented, purchasing capacity is limited and market infrastructure is less developed, low-emissions products face greater difficulty differentiating themselves from conventional alternatives and capturing the value associated with lower emissions[210]. More mature market conditions strengthen commercialization and support the progressive reduction of green premiums.

These conditions also explain why transitions tend to accelerate once a threshold is crossed. Technology costs fall with cumulative deployment, deployment grows as costs fall, and when a low-emissions alternative reaches cost parity with the incumbent the process becomes self-reinforcing, following the S-shaped adoption curve observed for earlier technologies[211]. Research on these positive tipping points shows that progress in one sector lowers costs in others, as the battery costs driven down by electric cars make electric trucks and grid storage competitive clean electricity improves the economics of low-emissions hydrogen for industry, and that clear mandates with set timeframes bring tipping points forward by more than subsidies or carbon prices alone, because they give investors certainty about the direction of the market[212]. Several sectors once described as hard to abate are following this path, as trucks near cost parity, low-emissions steel moves to its first commercial plants and vessels able to run on sustainable fuels enter the order books, which suggests that green premiums are a stage in market formation and not a permanent condition, provided that demand signals, standards and finance are in place to carry the early market across the threshold.

Figure 21: Green premiums and market formation

Green premiums and market formation strongly shape the commercialization of low-emissions products. Stronger innovation capabilities and market formation accelerate the scale-up of low-emissions alternatives.



Source: MPP. Making net-zero steel possible. 2022; ETC. Energy Transition Monitor. 2026; IEA. Delivering Sustainable Fuels. 2025; IEA. Demand and Supply Side Measures for the Industry Transition. 2026.

Box 2: The economics of the transition away from fossil fuels

Contribution of the Economics of Climate Organisation (ECO)[213]

At the request of the COP30 Presidency, the Economics of Climate Organisation (ECO), a new global initiative hosted at the London School of Economics, which serves to bridge frontier economic research with climate policy, prepared an economic analysis of the transition away from fossil fuels as an input to this Roadmap. Led by Professors Robin Burgess and Michael Greenstone, it combines new estimates of climate damages, a country-level dataset of renewable energy costs provided by IRENA, and an integrated assessment model recalibrated with that data. Its main findings are the following.

Climate damages are large and unequal, and current policies fall far short of addressing them. Each additional tonne of CO2 emitted today causes an estimated USD 336 of damage worldwide over its lifetime. These damages are not shared equally: 95% are concentrated in non-OECD regions whose populations have contributed least to historical emissions. Under current policies, the report's modelling puts the world on track for roughly 3°C of warming by 2100, consistent with broader projections of 2.8–3.2°C and far above the 1.5–2°C goals of the Paris Agreement.

Two market failures hold the transition back. First, fossil fuels are too cheap: their prices do not reflect the damage they cause, which falls particularly on low- and middle-income countries. Second, clean innovation is underfunded. Innovators weigh only their private gains, but the benefits of new technology spill over to firms and countries that did not pay for it, so private actors take on too little of this risky investment.

Each failure calls for its own instrument: (I) carbon pricing, so that prices reflect the full cost of fossil fuels, and (II) increased public investment and subsidies to spur clean innovation. The common thread is getting the prices right. Carbon pricing raises the price of fossil fuels while innovation policy lowers the price of clean energy, opening a price wedge that can accelerate the shift to clean energy and sustain it. Neither instrument is sufficient on its own. The carbon price level required to reach the Paris goals is far higher than any government has been willing to set to date. On the innovation side, even if clean technology costs continue to fall as they have over the last fifteen years, the report's modelling still points to warming of about 2.5°C by 2100 without a carbon price.

However, together, the two instruments can deliver cost-effective and meaningful emissions reduction. Cheaper clean technology lowers the carbon price required for a given reduction in emissions, and a credible, rising carbon price enlarges the market for clean technologies. In the report's modelling, sustained declines in clean energy costs combined with a carbon price starting at US$ 50 per tonne and rising 3% a year limit warming to about 1.9°C by 2100. Used in tandem, the two instruments will also enable developing countries grow sustainably and meet growing energy demands. But complementary policies to speed the diffusion of clean energy will be needed to achieve this.



The central message emerging from this report is that innovation policy is climate policy. Directed technical innovation paired with pricing carbon broadly allows countries to have a secure energy supply and limit temperature increases to targeted levels. International climate negotiations should credit not only a country's domestic emissions cuts but also its role in driving down the cost of clean technology, which makes abatement easier for every other country.

These findings are consistent with the structural factors and foundational levers identified in this chapter, in particular on price signals, fossil fuel subsidies, cost of capital and innovation, and they give those levers a quantitative foundation. They do not translate into uniform prescriptions: the choice and sequencing of instruments remain a matter for each country, according to its circumstances and in line with the differentiated approach of this Roadmap.

The COP30 Presidency regards this analysis as a valuable contribution to the Roadmap and ECO itself, whose work will continue beyond COP31, as one of the lasting legacies of the Roadmap process. Independent economic analysis of this kind, available to all Parties and capable of being updated as data and policies evolve, deserves the support of governments, research funders and international institutions, and the Presidency hopes it will be recognized and built upon in the years ahead.

Source: Burgess, R. and Greenstone, M. (2026), The Economics of Transitioning Away from Fossil Fuels: a contribution to the COP30 Presidency Roadmap, Economics of Climate Organisation.

c. Economic Transition Readiness Index: assessing transition preparedness

The analysis presented in the previous sections shows that countries face different economic transition conditions, shaped by the structural factors affecting their economies. These differences reflect both the degree to which economies remain exposed to fossil fuel activities and their capacity to diversify economic structures, mobilize investment, foster innovation and develop new sources of sustainable growth[214]. These dimensions shape countries' economic transition readiness and the implementation pathways available to them.

To translate this analysis into a practical assessment tool, the COP30 Presidency proposes the Economic Transition Readiness Index [Table 16]. Following the Belém Readiness Approach, the Index assesses countries' and subnational[215] regions' preparedness to undertake a just, orderly and equitable economic transition. A complementary coal sensitivity analysis is provided in Appendix D to support interpretation of the Index in countries where coal plays a particularly significant role in energy systems or economic activity.

Table 16: Economic Transition Readiness Index: dimensions, indicators and rationale

Dimension	Indicator	Rationale
Economic Exposure	Dependence on fossil fuel revenues	Measures countries' fiscal exposure to declining fossil fuel revenues and the need to diversify public finances
	Dependence on fossil fuel trade	Measures the extent to which external accounts depend on fossil fuel trade, whether through export earnings or import requirements
	Employment dependence	Captures the socioeconomic risks associated with employment concentrated in fossil fuel value chains, including regional vulnerabilities
	Exposure to stranded assets	Measures the risk that fossil fuel infrastructure and investments lose economic value during the transition
Economic Transition Capacity	Access to affordable finance	Assesses countries' ability to mobilize affordable capital for economic diversification and transition investments
	Macroeconomic and fiscal stability	Reflects the macroeconomic resilience and fiscal capacity required to support a sustained economic transition
	Innovation and productive capabilities	Captures countries' capacity to diversify their economies through innovation, industrial development and new sources of sustainable growth
	Institutional planning and governance capacity	Assesses institutional capacity to design, coordinate and implement long-term economic transition strategies across relevant sectors and institutions

The structure of the Index reflects the structural factors identified in this chapter. The first dimension—**"Economic Exposure"**—captures the extent to which countries remain structurally exposed to fossil fuel activities. Its indicators assess complementary sources of exposure, including dependence on fiscal revenues, trade, employment and capital embedded in long-lived fossil fuel assets and infrastructure. These indicators capture the scale and persistence of economic adjustment associated with changes in fossil fuel demand and related activities. Economic Exposure is particularly relevant to countries where fossil fuel production, trade, fiscal revenues and related activities play a significant role in the economy, while greater diversification across these areas reduces exposure and strengthens economic resilience.

The second dimension—**"Economic Transition Capacity"**—captures countries' capacity to manage structural transformation and build new sources of sustainable growth. Its indicators assess the structural conditions that strengthen economic diversification and transition capacity, including investment conditions, access to finance, institutional and governance frameworks, and innovation capacity. These indicators assess countries' ability to mobilize investment, develop new economic activities, strengthen innovation and institutional capabilities[216], and manage the distributional and fiscal implications of structural transformation. Unlike economic exposure, this dimension is relevant across all economies, including countries with limited fossil fuel production but substantial investment, industrial and capability needs associated with building a low-emissions economy. Stronger capacity across these areas expands countries' ability to capture emerging economic, technological and development opportunities associated with the transition.

As in the previous chapters, the Economic Transition Readiness Index is intended to support self-assessment using internationally available data, complemented by national and subnational information where available. The table below presents illustrative indicators and possible metrics [Table 17].

Table 17: Economic Transition Readiness Index: indicators and potential metrics

Dimension	Indicator	Possible metrics
Economic Exposure	Dependence on fossil fuel revenues	Fossil fuel rents (% of GDP); Fossil fuels revenues (% of govt. revenues); Fiscal breakeven (US$/boe)
	Dependence on fossil fuel trade	Fossil fuel exports (% of total exports); Fossil fuel imports (% of GDP)
	Employment dependence	Fossil fuel supply chain jobs (% of employment); Fossil fuel jobs (% of energy sector employment)
	Exposure to stranded assets	Weighed-avg. age of coal fleets (years); Weighed- avg. breakeven cost of O&G reserves (US$/boe)
Economic Transition Capacity	Access to affordable finance	Average cost of capital of clean energy projects (%); domestic credit to private sector (% of GDP)
	Macroeconomic and fiscal stability	Sovereign risk rating; Interest payments (% of govt. revenues); Economic vulnerability index (MVI)
	Innovation and productive capabilities	R&D expenditure (% of GDP); Public energy R&D (% of GDP); Economic complexity index (ECI)
	Institutional planning and governance capacity	Governance indicators (World Governance Index); Transparency and revenue allocation (RISE)

Illustrative and non-exhaustive data sources include the World Bank, OECD and IMF for fossil fuel revenues and macroeconomic indicators; the UN and national statistics for fossil fuel trade; the IEA, IRENA and national employment statistics for employment-related indicators; Global Energy Monitor, Rystad Energy and the IEA for asset-related metrics; and the World Bank, IEA, Harvard Growth Lab and other international and national sources for finance, institutional and innovation indicators.

Recognizing that data availability and quality vary across countries, **the Roadmap also stresses the importance of international cooperation among countries and supporting institutions to help address data and information gaps** that may constrain effective self-assessment and implementation planning.

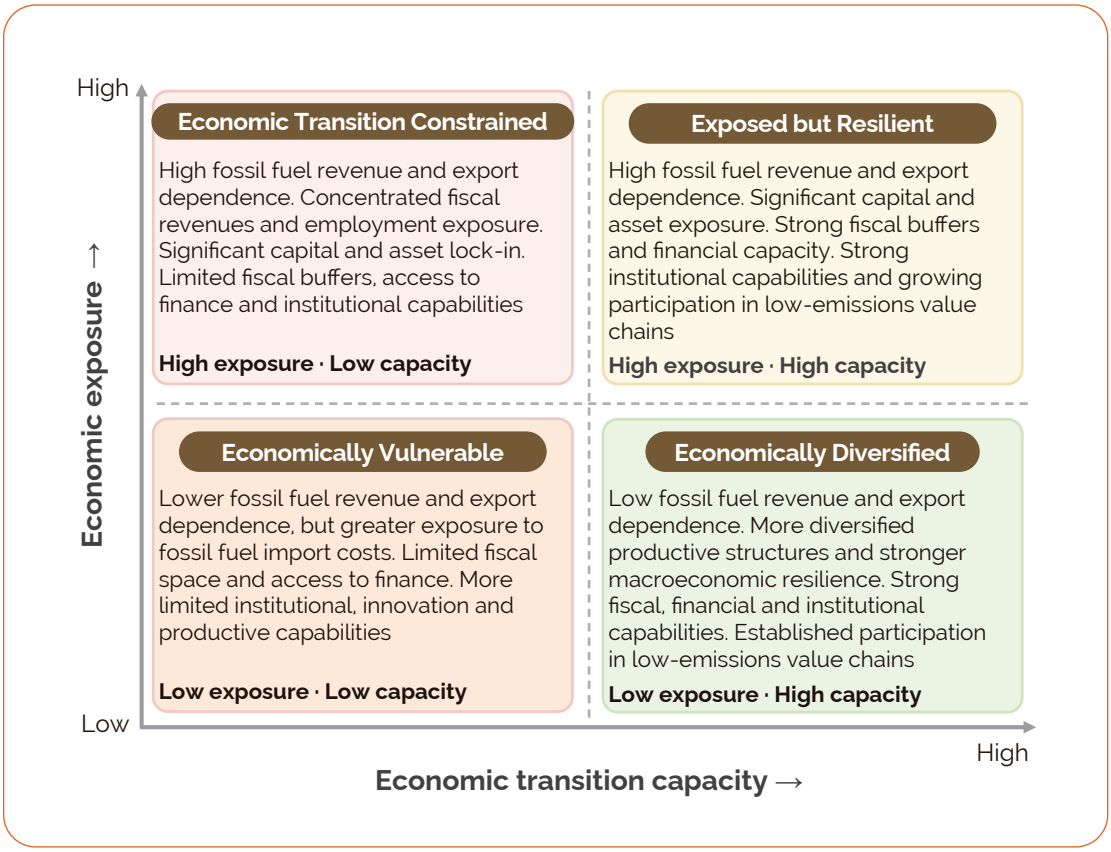
d. Economic Transition Archetypes: identifying common transition profiles

Building on the Economic Transition Readiness Index presented in the previous section, the COP30 Presidency proposes a set of **Economic Transition Archetypes**. The archetypes group countries that share similar combinations of economic exposure and transition capacity. Their purpose is to translate the Index into a practical understanding of the different economic transformations countries may need to manage and the opportunities they may be positioned to capture.

Countries with similar readiness profiles may face comparable economic transition challenges, opportunities and implementation priorities despite different national circumstances. The archetypes are intended to support the identification of differentiated implementation pathways aligned with countries' structural conditions rather than rank countries along a single dimension.

The archetypes are derived by combining the two dimensions of the Economic Transition Readiness Index in a two-dimensional matrix [Fig. 22]. The vertical axis represents the degree of "Economic Exposure", while the horizontal axis represents the level of "Economic Transition Capacity". Their interaction generates four broad archetypes reflecting distinct economic transition contexts, ranging from countries facing high fossil fuel-related economic exposure and limited transition capacity (upper-left) to those combining lower exposure with stronger conditions for diversification and sustainable growth (lower-right).

Figure 22: Economic Transition Archetypes



As in the previous chapters, the archetypes are illustrative rather than prescriptive. Countries may share characteristics across groups or evolve over time as their economic structures and transition capacities change. The exercise supports strategic planning by helping identify common strengths, constraints and differentiated implementation priorities rather than assigning fixed classifications.

The main **structural characteristics, strengths and constraints** associated with the economic transition of each of the four archetypes identified through the framework are summarized below.

Economic Transition Archetypes Description

Economic Transition Constrained Archetype
(High economic exposure · Low diversification and transition capacity)

These economies combine high exposure to fossil fuel-related revenues and activities with more limited diversification and transition capacity. Dependence can span multiple channels simultaneously, including fiscal revenues from oil and gas, export concentration, long-lived fossil fuel assets and employment concentrated in producing regions. More limited fiscal buffers, access to finance, institutional capacity and innovation capabilities can increase the complexity of adjustment and reduce the resources available to absorb structural change. Fiscal exposure is particularly significant where recurrent public expenditure is closely linked to volatile fossil fuel revenues, increasing sensitivity to commodity-price cycles and sudden revenue declines.

Economically Exposed but Resilient Archetype
(High economic exposure · High diversification and transition capacity)

These economies share significant fossil fuel-related economic exposure but possess stronger fiscal, institutional, financial and industrial capabilities to manage structural transformation. Fiscal buffers, sovereign wealth funds, revenue-stabilization mechanisms and more diversified productive structures strengthen their ability to absorb commodity-price volatility and preserve fiscal space. Their exposure remains significant where public revenues, exports and productive assets are closely linked to fossil fuel activities, but stronger domestic capabilities provide greater flexibility to manage adjustment over time.

Economically Vulnerable Archetype
(Low or moderate economic exposure · Low diversification and transition capacity)

These economies generally have more limited direct dependence on fossil fuel production but remain exposed through other economic channels. High fossil fuel import costs can place pressure on current accounts, public finances and broader macroeconomic stability, while more limited fiscal space, institutional capacity, financial depth and productive capabilities can constrain the ability to manage structural transformation. This economic vulnerability can, however, stimulate change. More limited legacy fossil fuel infrastructure also implies lower capital lock-in than in more fossil-intensive economies. Their economic exposure is primarily linked to fossil fuel import dependence and to more limited capacity to absorb and manage broader transition-related adjustment.

Economically Diversified Archetype
(Low economic exposure · High diversification and transition capacity)

These economies combine lower fossil fuel-related economic exposure with stronger diversification and transition capacity. Fossil fuel revenues and exports represent a more limited share of economic activity, while stronger fiscal and macroeconomic conditions, institutional depth, financial systems and participation in low-emissions and strategic value chains provide greater resilience to structural change. Where fossil fuel import exposure

remains relevant, it is generally moderated by broader economic diversification, stronger institutions and greater capacity to absorb external shocks and investment needs. Limited legacy fossil fuel infrastructure, combined with stronger institutional and productive capabilities, supports the direct development of low-emissions energy and productive systems (leapfrog).

e. Differentiated implementation pathways: strengthening economic transition readiness

Building on the Economic Transition Archetypes presented in the previous section, the COP30 Presidency identified a differentiated set of levers to strengthen countries' readiness to undertake a just, orderly and equitable economic transition. Implementation priorities differ according to countries' levels of economic exposure and transition capacity.

As in the previous chapters, the **economic pillar** distinguishes between foundational levers and archetype-specific implementation levers. **Foundational levers** establish common macroeconomic, financial, institutional, innovation and social conditions required to strengthen economic transition readiness across archetypes. National and subnational governments play a central role in establishing these conditions, supported by other critical stakeholders[217].

Building on these common foundations, **implementation levers** define differentiated strategic priorities that reflect the structural factors associated with each readiness profile. **They are designed to address constraints, reinforce existing capabilities and advance implementation** according to countries' specific conditions. Implementation depends on coordinated action across multiple stakeholders, and the framework identifies main and supporting actors for each lever according to their respective roles in strengthening economic transition readiness.

The combined implementation of foundational and archetype-specific implementation levers strengthens economic transition readiness over time. Countries can reduce their economic exposure, reinforce their transition capacity, or advance across both dimensions as their economic structures and capabilities evolve. Readiness assessments can be periodically updated to track progress, capture changes in structural conditions and refine implementation priorities as the transition advances.

Economic Foundational Levers

Based on extensive consultations and stakeholder engagement, the COP30 Presidency has identified the following foundational levers [Table 18]:

Table 18: Economic Foundational Levers

Archetype	Foundational levers
Fiscally constrained (High economic exposure · Low diversification and transition capacity)	1. Strengthen long-term transition governance and planning [Institutional planning & governance] 2. Promote institutional coordination, implementation capacity and public-private collaboration [Institutional planning & governance] 3. Align fiscal incentives, public spending and market signals, including through fossil fuel subsidy reform, green public procurement and carbon pricing [Macroeconomic & fiscal] 4. Strengthen transparency, carbon accounting and sustainable finance taxonomies [Financial & investment systems] 5. Develop national innovation and diversification strategies, including through low-carbon R&D [Innovation & productive capabilities] 6. Reinforce social dialogue and regional transition planning [Social & territorial transition]
Exposed but resilient (High economic exposure · High diversification and transition capacity)	
Economically vulnerable (Lower structural fossil dependence · Low diversification and transition capacity)	
Economically diversified (Low economic exposure · High diversification and transition capacity)	

1. Economic foundational levers: strengthen long-term transition governance and planning

Rationale: long-term governance and integrated transition planning provide the basis for restructuring fiscal systems, labor markets and productive sectors throughout the transition. Robust planning reduces economic uncertainty, allows for policy coherence and supports a more orderly, predictable and equitable transition. This is particularly important where the transition requires coordination across multiple ministries, levels of government and economic actors, or where changes in fossil fuel-related activity may have concentrated fiscal, employment or territorial implications[218]. While long-term climate and energy planning has expanded substantially, broader economic transition considerations (e.g.: fiscal resilience, economic diversification) remain unevenly integrated across planning processes and institutional responsibilities[219].

Implementation in action: selected initiatives illustrate how this lever is already being operationalized across different geographies and by different actors. The examples are illustrative and primarily drawn from the COP30 Action Agenda, which mobilizes actors and implementation efforts to accelerate delivery of existing climate commitments, building on the outcomes of the first Global Stocktake:

- Just and Inclusive Planning of the Energy Transition**:** presented at COP30 in 2025 through the COP30 Action Agenda and hosted by the Global Coalition for Energy Planning, the initiative supports the development of just-transition indicators, inclusive data systems and gender-responsive approaches to transition planning. Its contribution lies in incorporating social and distributional considerations into long-term planning, broadening transition strategies beyond energy-system transformation to include employment, equity and development considerations.

- 2050 Pathways Platform**:** launched at COP22 in 2016 by the High-Level Climate Champions, the platform supports governments and other actors in developing long-term low-emissions, climate-resilient and sustainable-development pathways, including through knowledge exchange, capacity building and collective problem-solving. The platform fosters long-term transition objectives that can be translated into integrated development pathways extending across economic sectors.

2. Economic foundational levers: promote institutional coordination, implementation capacity and public-private collaboration

Rationale: effective institutional coordination, implementation capacity and collaboration across public and private actors, both within and across countries, help align policy design, financial mobilization and workforce transition and translate long-term transition objectives into implementation. These capabilities are essential for translating long-term transition objectives into effective short-term implementation[220]. Countries differ in the availability of technical resources, clarity of institutional mandates, coordination mechanisms and the maturity of public-private engagement, shaping their ability to implement transition strategies effectively.

Implementation in action[221]:

- High-level global dialogue on economic enablers and aligning financial flows**:** presented through the COP30 Action Agenda in 2025 hosted by the Clean Energy Transition Partnership, the initiative convenes public and private actors around the economic and financial conditions required to accelerate the transition away from fossil fuels. It facilitates international cooperation and coordination across transition-related economic and financial priorities and connects policy, finance and implementation considerations within a shared coordination platform.

- NDC Partnership**:** launched at COP22 in 2016, the partnership brings together governments, international institutions and other partners to coordinate technical assistance, expertise and finance for implementation of national climate and development priorities. Its country-engagement model supports coordination across ministries, implementing partners and development institutions, illustrating how implementation capacity can be strengthened through structured cooperation between domestic institutions and external partners.

- Collaborative Exporter-Importer Governance for Shared Prosperity Post-Fossil Fuels (CEIG)**:** hosted by the Equitable Framework and Finance for Extractive-based Countries in Transition (EFFECT), CEIG promotes structured cooperation between fossil fuel exporting and importing economies to better align transition interests and manage the implications of declining fossil fuel dependence. The initiative seeks to develop governance arrangements that support coordinated approaches to trade, investment and capital reallocation as energy systems evolve. By creating a platform for cooperation between economies occupying different positions in fossil fuel markets, CEIG promotes cross-border institutional coordination in support of more orderly economic adjustment and investment decisions.

3. Economic foundational levers:
align fiscal incentives, public spending and market signals

Rationale: well-designed fiscal policies and market signals help correct structural distortions that discourage low-emissions investment and innovation. Aligning incentives, public expenditure and pricing mechanisms with transition objectives improves resource allocation, mobilizes private investment and supports long-term fiscal sustainability[222]. Market and pricing frameworks that increasingly reflect the emissions intensity of products can also influence relative competitiveness and investment decisions across domestic and international markets. Implementation remains uneven, with fossil fuel subsidies[223], limited carbon-pricing coverage[224] and inconsistent integration of transition objectives into public spending continuing to generate mixed economic signals across countries. Price signals and innovation support reinforce each other: as low-emissions technologies become cheaper, a lower carbon price achieves the same reduction in emissions, and clearer and more predictable price signals enlarge the expected market for clean innovation[225].

Implementation in action[226]:

- Coalition on Phasing Out Fossil Fuel Incentives including Subsidies (COFFIS): launched at COP28 in 2023, and supported by the International Institute for Sustainable Development, the coalition brings together governments committed to increasing transparency around fossil fuel subsidies, identifying barriers to reform and advancing national approaches to phase out inefficient fossil fuel incentives. Its work addresses one of the principal fiscal distortions affecting relative energy prices and provides a platform for cooperation on the fiscal and distributional dimensions of subsidy reform.

- Harnessing Public Procurement in High-Impact Sectors to Drive Climate Action and a Just Transition: advanced through the COP30 Action Agenda in 2025, and hosted by UNEP, MGI Brazil and UNIDO's Industrial Deep Decarbonization Initiative, the initiative seeks to scale sustainable public procurement in high-impact sectors and use government purchasing power to support more sustainable production. Public expenditure is positioned as a demand and market-formation mechanism, creating clearer signals for low-emissions products while supporting innovation, resilience and broader transition objectives.

4. Economic foundational levers: strengthen transparency, carbon accounting and sustainable finance taxonomies

Rationale: robust carbon accounting, transparent governance and sustainable finance taxonomies provide the information, regulatory certainty and market confidence needed to mobilize investments at scale. Clear and comparable information can improve investment decision-making, reduce greenwashing risks, strengthen accountability and facilitate more efficient capital allocation toward activities aligned with transition objectives[227]. Comparable product-level emissions information can also support market differentiation, facilitate trade in low-emissions products and enable carbon intensity to be reflected more consistently in purchasing and market decisions. Implementation has expanded significantly, although differences in methodologies, classification systems, data availability and reporting capacity continue to limit comparability across markets and jurisdictions[228].

Implementation in action[229]:

- Super Taxonomy**:** launched at COP30 in 2025 under the COP30 Action Agenda to advance greater interoperability across sustainable finance taxonomies and classification systems. The initiative seeks to improve comparability and consistency across markets while supporting clearer identification of activities aligned with climate and transition objectives. Greater interoperability can reduce fragmentation for investors and financial institutions operating across jurisdictions and strengthen confidence in sustainable finance classifications.

- Open Coalition on Compliance Carbon Markets**:** officially launched in 2026, building on a declaration endorsed at COP30 in 2025, the coalition aims to establish shared standards and improve connections across carbon-credit trading systems, supporting greater liquidity, predictability and transparency in carbon markets. The initiative strengthens the market infrastructure needed for more consistent carbon accounting and clearer recognition of emissions outcomes across jurisdictions.

- GHG Protocol–ISO harmonization of global carbon accounting standards: launched under the COP30 Action Agenda in 2025, following the strategic partnership established between the Greenhouse Gas Protocol and the International Organization for Standardization, the initiative seeks to harmonize corporate, product and project-level greenhouse gas accounting standards. In 2026, the organizations advanced plans to consolidate their corporate standards into a single co-branded global standard. The initiative aims to improve consistency and comparability across jurisdictions and value chains, reducing duplication and strengthening the reliability of emissions information used by businesses, investors and policymakers.

5. Economic foundational levers: develop national innovation and economic diversification strategies, including through low-emissions R&D

Rationale: innovation, technological development and economic diversification create new sources of productivity, competitiveness and economic growth while reducing long-term dependence on fossil fuel industries[230]. Early investment in low-emissions research and development, as well as productive capabilities, can strengthen industrial competitiveness, expand economic diversification opportunities and reduce long-term dependence on fossil fuel activities. Differences in R&D expenditure, technological capabilities and advanced manufacturing capacity shape countries' ability to develop, adapt and commercialize emerging technologies, with stronger innovation ecosystems supporting faster technological diffusion and industrial diversification. Public effort remains modest, with IEA member countries devoting about 0.05% of GDP to energy research and development in 2025, half the level reached after the oil shocks of the 1970s. Recent studies attribute close to half of the fall in solar module prices over the past two decades to public support for production and innovation, with benefits that exceeded costs in the countries that provided it and cost reductions shared by every country deploying the technology[231].

Implementation in action[232]:

- IEA Technology Collaboration Programme (TCP): established in 1975, the program brings together governments, industry and research institutions to collaborate on the research, development and commercialization of energy technologies. With dozens of active technology collaborations spanning areas such as renewables, grids, hydrogen, industrial technologies and next-generation fuels, the program supports knowledge exchange, coordinated R&D and technology diffusion across participating economies.

- Africa Green Industrialization Initiative (AGII)**:** launched at COP28 in 2023, the pan-African initiative promotes green industrial development through investment in manufacturing, value-added processing and large-scale industrial and infrastructure opportunities. It seeks to strengthen domestic value creation around renewable energy, critical resources and emerging low-emissions industries. It focuses on local value addition and industrial capability of transition-related investment contributing to broader productive diversification and new sources of economic growth.

6. Economic foundational levers: strengthen social dialogue and territorial transition planning

Rationale: inclusive social dialogue and place-based transition planning are essential for addressing the localized socioeconomic impacts of the transition. Meaningful and transparent engagement with businesses, workers, communities and other stakeholders enhances policy legitimacy, facilitates consensus-building and promotes a better general understanding of the energy transition trade-offs[233]. Transition planning does not always fully capture localized employment and economic impacts, while workforce information, skills assessments and stakeholder participation mechanisms remain limited in many contexts.

Implementation in action:

- Global Initiative on Jobs & Skills for the New Economy**:** launched at COP30 in 2025, with analytical support from Systemiq and the World Resources Institute, the initiative works through Country Action Partnerships to support governments in developing employment and skills strategies for the emerging economy. Ministries responsible for labor, education and environment participate alongside local governments, businesses and other stakeholders. The model connects national workforce strategies with local implementation and helps anticipate the employment and skills implications of structural economic change.

- Global Commission on People-Centered Clean Energy Transitions**:** convened by the International Energy Agency (IEA) in 2021, the Commission brought together government representatives, labor organizations and other stakeholders to develop recommendations for clean energy transitions that address employment, affordability, participation and distributional impacts. Its work subsequently informed the IEA's broader people-centered transition activities. The framework highlights social dialogue and stakeholder participation as core elements of transition design, with particular attention to workers and communities affected by structural change.

Economic Transition Implementation Levers: archetype-specific messages

Table 19: Implementation Levers for the Economic Transition Constrained Archetype (High economic exposure—Low diversification capacity)

Economic Transition Constrained (High economic exposure · Low diversification and transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Diversify fiscal revenues and redirect public resources towards productive and transition-related investment [Macroeconomic & Fiscal]	**Main actor:** National governments **Supporters:** Subnational governments; National development banks and public financial institutions; International organizations and development partners	• Resource-revenue stabilization and transition funds • Public investment prioritization frameworks • Sustainable public procurement programmes
Strengthen domestic revenue mobilization and fiscal resilience [Macroeconomic & Fiscal]	**Main actor:** National governments **Supporters:** Subnational governments; International financial institutions and climate funds; International organizations and development partners	• Tax-base broadening and revenue-administration reforms • Medium-term fiscal and fiscal-risk frameworks • Fossil-fuel subsidy reform programmes
Scale concessional finance, guarantees and risk-sharing mechanisms [Financial & Investment Systems]	**Main actors:** International financial institutions and climate funds; National development banks and public financial institutions **Supporters:** National governments; Private financial institutions	Concessional and blended-finance facilities Credit-guarantee and enhancement mechanisms Foreign-exchange hedging and risk-sharing facilities
Expand fiscal space and debt resilience through innovative sovereign financing instruments [Financial & Investment Systems]	**Main actor:** National governments **Supporters:** International financial institutions and climate funds; Private financial institutions; National development banks and public financial institutions	• Sustainability-linked sovereign financing instruments • Debt-for-climate or sustainability swaps • MDB-backed sovereign credit-enhancement mechanisms
Develop credible corporate transition strategies and strengthen technology adoption, innovation and productive diversification [Innovation & Productive Capabilities]	**Main actor:** Businesses and industry **Supporters:** National governments; Academia and research institutions; Private financial institutions; International organizations and development partners	• Corporate transition planning frameworks • Technology demonstration and commercialization programmes • Supplier-development and productive-diversification programmes
Implement workforce reskilling and regional economic diversification programmes [Social & Territorial Transition]	**Main actors:** National governments; Subnational governments **Supporters:** Businesses and industry; Academia and research institutions; Civil society, consumers and local communities; International organizations and development partners	• Regional just-transition and diversification plans • Worker reskilling and job-placement programmes • Local enterprise and livelihood-development programmes

Sequencing priorities to foster implementation: First step, **strengthening fiscal resilience** through better management of existing revenues, domestic revenue mobilization and expanded fiscal space. Second step, **mobilizing investment and productive diversification** by drawing on concessional finance, private capital, technology adoption and innovation. Third step, **enabling an inclusive structural transition** by promoting workforce reskilling and regional economic diversification to reduce long-term dependence on fossil fuels. Progress depends on expanding available resources while simultaneously strengthening domestic capabilities.

National and subnational governments play a central role in reinforcing fiscal resilience, improving the enabling environment and guiding economic diversification. Where public financial capacity is more constrained, implementation benefits from coordinated action across a broader supporting ecosystem, including national development banks and public financial institutions, international financial institutions and climate funds, international organizations and development partners, private financial institutions, businesses and industry, academia and research institutions, and civil society, consumers and local communities. These actors complement domestic efforts by helping mobilize investment, expand access to technology and innovation, and accelerate the development of new productive sectors that underpin long-term economic diversification.

Table 20: Implementation Levers for the Economically Exposed but Resilient Archetype (High economic exposure - High diversification and transition capacity)

Economically Exposed but Resilient (High economic exposure · High diversification and transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Accelerate fiscal diversification beyond fossil fuel revenues [Macroeconomic & Fiscal]	**Main actor:** National governments **Supporters:** Subnational governments; National development banks and public financial institutions; International organizations and development partners	• Medium-term fiscal diversification strategies • Non-fossil revenue mobilization frameworks • Fossil-revenue stabilization and savings rules
Redirect sovereign wealth and public investment towards transition priorities [Financial & Investment Systems]	**Main actor:** National governments **Supporters:** National development banks and public financial institutions; Private financial institutions	• Sovereign wealth fund transition mandates • Strategic public-investment allocation frameworks • Public co-investment vehicles for low-emissions industries
Develop sovereign transition funds to catalyse strategic public and private investment [Financial & Investment Systems]	**Main actor:** National governments **Supporters:** National development banks and public financial institutions; Private financial institutions; International financial institutions and climate funds	• Sovereign transition and diversification funds • First-loss and catalytic capital facilities • Public-private co-investment platforms
Strengthen domestic financial systems and capital markets for transition finance [Financial & Investment Systems]	**Main actor:** Private financial institutions **Supporters:** National governments; Regulators and system operators; National development banks and public financial institutions	• Green and transition bond frameworks • Securitization and asset-recycling mechanisms • Institutional-investor participation frameworks
Strengthen productive capabilities and participation in low-emissions and strategic value chains [Innovation & Productive Capabilities]	**Main actor:** Businesses and industry **Supporters:** National governments; Academia and research institutions; Private financial institutions; International organizations and development partners	• Strategic industrial-development programmes • R&D, demonstration and commercialization support • Supplier-development and technology-partnership programmes
Create markets for low-emissions products through certification, green public procurement and private-sector collaboration [Innovation & Productive Capabilities]	**Main actor:** National governments **Supporters:** Businesses and industry; Regulators and system operators; Private financial institutions; International organizations and development partners	• Green public procurement requirements • Low-emissions product certification and labelling schemes • Corporate procurement and buyer-commitment programmes
Implement just transition programmes for fossil-dependent regions [Social & Territorial Transition]	**Main actors:** National governments; Subnational governments **Supporters:** Businesses and industry; Civil society, consumers and local communities; Academia and research institutions; International organizations and development partners	• Regional economic diversification plans • Worker reskilling and redeployment programmes • Regional transition and community-development funds

Sequencing priorities to foster implementation: First step, **reallocating existing financial resources** by redirecting fossil fuel revenues, sovereign wealth and public investment toward future growth sectors. Second step, **accelerating industrial transformation** through stronger capital markets, innovation ecosystems and participation in low-emissions and strategic value chains. Third step, **managing an orderly transition** by supporting fossil-dependent workers and regions while maintaining long-term competitiveness. These economies can build on existing public and private capital to support emerging low-emissions industries and new sources of growth.

National and subnational governments play a central role in redirecting public investment, aligning policy incentives and creating the conditions for long-term economic diversification. Given their relatively strong institutional and financial capacity, implementation increasingly relies on coordinated capital reallocation by private financial institutions and businesses and industry, including through scaling investment in emerging industries and strengthening participation in low-emissions value chains. Academia and research institutions support this transformation by strengthening innovation ecosystems and technology development, while national development banks and public financial institutions, international financial institutions and climate funds, and international organizations and development partners help de-risk strategic investments, mobilize additional resources and strengthen international cooperation. Regulators and system operators also contribute to the development of market frameworks and standards that support emerging low-emissions products and industries.

Table 21: Implementation Levers for the Economically Vulnerable Archetype (Low structural fossil dependence - Low diversification and transition capacity)

Economically Vulnerable (Low structural fossil dependence · Low diversification and transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Build macroeconomic resilience and fiscal capacity [Macroeconomic & Fiscal]	**Main actor:** National governments **Supporters:** Subnational governments; International financial institutions and climate funds; International organizations and development partners	• Medium-term fiscal frameworks • Domestic revenue mobilization reforms • Fiscal-risk and contingency planning mechanisms
Improve the enabling environment for transition-related investment [Financial & Investment Systems]	**Main actor:** National governments **Supporters:** Private financial institutions; National development banks and public financial institutions; International organizations and development partners	• Investment-facilitation and one-stop-shop mechanisms • Predictable regulatory and permitting frameworks • Public-private project-development platforms
Scale concessional finance, guarantees and risk-sharing mechanisms [Financial & Investment Systems]	**Main actors:** International financial institutions and climate funds; National development banks and public financial institutions **Supporters:** National governments; Private financial institutions	• Concessional and blended-finance facilities • Credit-guarantee and enhancement mechanisms • Foreign-exchange and political-risk mitigation instruments
Strengthen domestic financial systems to expand access to transition finance [Financial & Investment Systems]	**Main actor:** Private financial institutions **Supporters:** National governments; National development banks and public financial institutions; International financial institutions and climate funds	• Green lending and transition-finance frameworks • Local-currency financing facilities • Small and medium-sized enterprise and project-finance credit lines
Develop innovation ecosystems, productive capabilities and absorptive capacity for low-emissions technologies [Innovation & Productive Capabilities]	**Main actor:** Academia and research institutions **Supporters:** National governments; Businesses and industry; International organizations and development partners	• Technology-transfer and demonstration programmes • Innovation hubs and applied research partnerships • Supplier-development and technology-adoption programmes
Invest in foundational human capital, STEM education and vocational training [Social & Territorial Transition]	**Main actor:** National governments **Supporters:** Academia and research institutions; Businesses and industry; Civil society, consumers and local communities; International organizations and development partners	• STEM education and technical-training programmes • Vocational training and apprenticeship schemes • Skills-forecasting and workforce-development systems

Sequencing priorities to foster implementation: First step, **strengthening the enabling conditions** for investment through greater macroeconomic resilience, fiscal capacity, stronger domestic financial systems and an improved investment climate. Second step, **building domestic capabilities** by fostering innovation ecosystems, productive capabilities, technology absorption and human capital. Third step, **expanding access to finance** and knowledge through concessional finance, technology transfer and international partnerships that support productive transformation. These priorities reinforce the institutional, financial and productive foundations needed for the economic transition. International finance, technology and knowledge can complement domestic capacity-building efforts and accelerate implementation through the direct deployment of low-emissions energy systems, reducing the risk of future fossil fuel lock-in.

National and subnational governments play a central role in strengthening macroeconomic resilience, improving investment conditions and investing in human capital. Where domestic implementation capacity and financial resources are more constrained, coordinated engagement with international financial institutions and climate funds, national development banks and public financial institutions, and international organizations and development partners becomes particularly important to expand access to finance, strengthen domestic financial systems and build institutional and productive capabilities. At the same time, private financial institutions, businesses and industry, academia and research institutions, and civil society, consumers and local communities play a critical role in fostering innovation, developing workforce skills and enabling the emergence of competitive low-emissions industries.

Table 22: Implementation Levers for the Economically Diversified Archetype (Low economic exposure - High diversification and transition capacity)

Economically Diversified (Low economic exposure · High diversification and transition capacity)		
Implementation levers [Category]	**Main actor and supporters**	**Readiness policies and instruments (illustrative)**
Maintain macroeconomic resilience and fiscal sustainability [Macroeconomic & Fiscal]	**Main actor:** National governments **Supporters:** Subnational governments; National development banks and public financial institutions; International organizations and development partners	• Medium-term fiscal and expenditure frameworks • Fiscal-risk and stress-testing mechanisms • Public investment prioritization frameworks
Mobilize institutional investors and international transition finance to support developing and emerging countries [Financial & Investment Systems]	**Main actor:** Private financial institutions **Supporters:** International financial institutions and climate funds; National governments; National development banks and public financial institutions; Regulators and system operators	• Institutional-investor mobilization platforms • Blended-finance and credit-enhancement facilities • Cross-border transition investment vehicles
Strengthen advanced manufacturing, innovation capabilities and participation in low-emissions and strategic value chains [Innovation & Productive Capabilities]	**Main actor:** Businesses and industry **Supporters:** National governments; Academia and research institutions; Private financial institutions; International organizations and development partners	• Advanced manufacturing and industrial innovation programmes • R&D, demonstration and commercialization support • Strategic technology and supply-chain partnerships
Create international markets for low-emissions products through certification, green procurement partnerships and industrial cooperation [Innovation & Productive Capabilities]	**Main actor:** National governments **Supporters:** Businesses and industry; Regulators and system operators; Private financial institutions; International organizations and development partners	• International certification and product-standard frameworks • Green public procurement partnerships • Buyer alliances and advance market commitments
Support international just transition partnerships, regional cooperation and frameworks for legacy fossil regions [Social & Territorial Transition]	**Main actors:** National governments; International organizations and **Supporters:** Subnational governments; International financial institutions and climate funds; Civil society, consumers and local communities; Academia and research institutions	• International just-transition partnership frameworks • Regional diversification and redevelopment programmes • Technical-assistance and knowledge-sharing platforms

Sequencing priorities to foster implementation: First step, **maintaining domestic leadership** by sustaining macroeconomic resilience, advanced manufacturing and innovation capabilities. Second step, **shaping international markets** through certification, green public procurement partnerships, standards and industrial cooperation that expand demand for low-emissions products. Third step, **supporting the global transition** by mobilizing international finance, technology, innovation and partnerships for developing and emerging economies. These economies can build on strong domestic capabilities to sustain competitiveness, shape international markets, scale innovation and support implementation beyond national borders.

National and subnational governments play a central role in providing long-term strategic direction, shaping international market frameworks and strengthening cooperation with developing and emerging economies. Implementation increasingly relies on coordinated action by private financial institutions and businesses and industry to mobilize international investment, scale advanced industries and accelerate innovation. Academia and research institutions, national development banks and public financial institutions, international financial institutions and climate funds, international organizations and development partners, and regulators and system operators contribute by supporting technology development, international partnerships, market frameworks and the diffusion of implementation experience across countries and regions.

BELÉM READINESS APPROACH TRIPOD: INTEGRATING DEMAND, SUPPLY AND ECONOMIC TRANSITION READINESS

The Belém Readiness Approach Tripod is a visual tool for synthesis, to help countries to have an overall view of its own readiness. This integrated assessment combines the Energy Demand Transition Readiness Index, the Energy Supply Transition Readiness Index and the Economic Transition Readiness Index, providing countries with an integrated basis for self-assessing their preparedness to manage the transition away from fossil fuels in a just, orderly and equitable manner [Fig. 23].

Figure 23: The three Readiness Indexes: dimensions and indicators

Energy Demand Transition Readiness Index		Energy Supply Transition Readiness Index		Economic Transition Readiness Index	
Dimension	**Indicator**	**Dimension**	**Indicator**	**Dimension**	**Indicator**
Demand-side Exposure	Fossil fuel share in final energy consumption	**Supply-side Exposure**	Fossil fuel share in primary energy supply	**Economic Exposure**	Dependence on fossil fuel revenues
	Energy intensity and efficiency of final energy use		Fossil fuel import and export dependence		Dependence on fossil fuel trade
	Growth in final energy and electricity demand		Fossil fuel reserves		Employment dependence
	End-use sector composition (hard-to-abate sectors)		Production competitiveness		Exposure to stranded assets
Demand-side Transition Capacity	Electrification and adoption of low-emissions end-use technologies	**Supply-side Transition Capacity**	Competitiveness of low-emissions alternative	**Economic Transition Capacity**	Access to affordable finance
	Access, affordability and quality of modern energy services		Infrastructure readiness and system flexibility		Macroeconomic and fiscal stability
	Digitalization and demand-side management capabilities		Project development and supply chain capacity		Innovation and productive capabilities
	Institutional planning and governance capacity		Institutional planning and governance capacity		Institutional planning and governance capacity

The integrated assessment supports countries to identify where structural exposure is greatest, and where existing capabilities and comparative advantages can support faster progress across the demand, supply and economic pillars. Considering the three assessments jointly can provide a more complete picture of the conditions affecting transition readiness and allow for the identification of the structural factors that require greatest attention. The integrated reading can then inform the selection and sequencing of the foundational and archetype-specific implementation levers presented throughout the Roadmap.

Each vertex represents one pillar — demand, supply or economic — and reflects the readiness level resulting from the interaction between exposure and transition capacity within the corresponding Index. As set out in the previous sections, exposure reflects the scale and complexity of the transformation required, based on the extent to which fossil fuels remain embedded in the energy or economic system. Transition capacity reflects the enabling conditions available to manage and implement that transformation [Fig. 24]. When those countries' assessments are shown as a single figure, the overall picture can be read immediately, and the pillar in which constraints are concentrated stands out. The figure is deliberately simple: it shows one readiness level per pillar. Since every Tripod rests on a country's own terms and evaluation, the figure describes one specific profile and should not be used to rank countries.

Figure 24: Readiness scoring logic and the Belém Readiness Approach Tripod

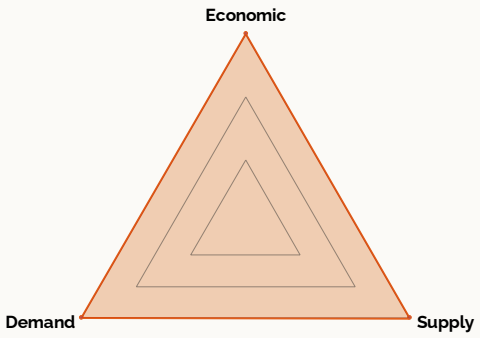
Readiness scoring logic

Exposure to fossil fuels	Capacity to transition	Readiness
Low	High	**High**
High	High	**Medium**
Low	Low	**Medium**
High	Low	**Low**

Note: A **Medium** can arise two ways — high capacity offset by high exposure (exposed but capable), or low exposure with low capacity (structurally vulnerable). The readiness level is the same, but the underlying transition challenge differs.

Ideal profile

Maximum readiness in all dimensions



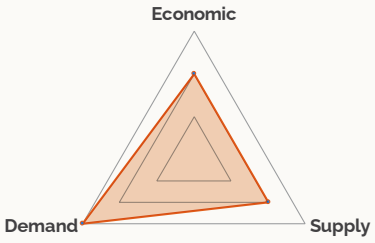
Note: Readiness increases from the inner to the outer triangle: the inner triangle represents **low readiness**, the middle triangle **medium readiness**, and the outer triangle **high readiness** across the three pillars.

*The COP30 Presidency will avoid referring to specific countries. This slide is provided solely as an illustrative example

Figure 25: Illustrative readiness profiles

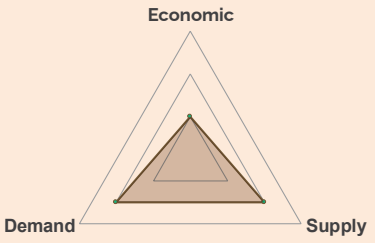
Advanced fossil producer

High production and demand exposure, offset by strong capacity across all dimensions



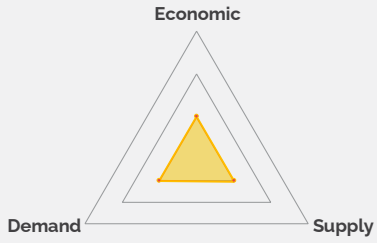
Emerging producer with economic constraints

Moderate exposure with capable energy systems but less consolidated economic capacity



Structurally constrained economy

High exposure combined with limited capacity across all dimensions



The readiness scoring logic preserves an important distinction between exposure and capacity. High transition capacity combined with low exposure results in higher readiness, while high exposure combined with limited capacity indicates lower readiness. Intermediate readiness can emerge through different structural configurations: high capacity may offset comparatively high exposure, while low exposure may partially offset weaker capacity. Countries with similar aggregate readiness levels may consequently face substantially different transition challenges and require different implementation responses.

Illustrative profiles demonstrate how different combinations can emerge. An economy with significant fossil fuel production may combine relatively high supply and economic exposure with strong institutional, technological and economic capacity. Another fossil fuel-producing economy may possess capable energy systems while facing more constrained economic diversification capacity. A structurally constrained economy may face limited transition capacity across all three pillars, even when its direct exposure to fossil fuel production is comparatively lower. These profiles are illustrative and can evolve as exposure declines and transition capabilities strengthen.

The integrated reading reinforces three key messages:

1. **Demand, supply and economic transformation need to be considered jointly.** Progress in one pillar cannot fully compensate for persistent constraints in another. Demand reduction without adequate low-emissions supply can create reliability and affordability pressures; supply transformation without corresponding changes in end-use demand can generate misalignment and stranded assets; and both depend on economic conditions that enable investment, diversification and structural adjustment. The three pillars are complementary components of an orderly transition rather than independent pathways.

2. **Differentiated implementation should reflect countries' underlying structural conditions.** Similar readiness levels can result from different combinations of exposure and transition capacity. A medium readiness profile, for example, may reflect comparatively high exposure offset by strong capacity, or lower exposure combined with weaker capacity. The integrated assessment preserves these differences and can help countries identify where foundational conditions need to be strengthened, where more targeted implementation levers are required, and where existing capabilities can support faster progress and local ownership of the transition.

3. **Integrated assessment can help target international cooperation and supporting ecosystems.** When readiness constraints are concentrated in a particular pillar, international cooperation can be reinforced toward the areas where additional capacity, finance or technical support is most needed. For example, an economy with relatively strong demand- and supply-side capacity but weaker economic transition capacity may benefit more from support focused on institutional capabilities, innovation and technological capabilities, and access to finance than from broader energy-system assistance. This can help international financial institutions and climate funds, international organizations and development partners, and other supporting actors to better align cooperation with countries' nationally determined priorities.

THE WAY FORWARD: ACCELERATING ACTION IN THIS CRITICAL DECADE

"The world is formed not only by what already exists, but by what can actually exist."

Milton Santos[234]

"I am myself and my circumstance."

José Ortega y Gasset[235]

At COP30 in Belém, President Lula put the transition away from fossil fuels at the center of the political conversation, and several other leaders from every region joined it, importers and exporters alike, developed and developing. At the closing plenary, the COP30 Presidency announced the task to prepare, under its own responsibility, a roadmap to help implement what Parties had agreed by consensus at COP28. In this context, the COP30 Presidency prepared this document outside the negotiations process, in dialogue with all who wished to take part, as a voluntary contribution to the implementation of the first Global Stocktake. The Roadmap sets no targets or timelines for any country and replaces no national decision. What it offers is **a possible common language for a conversation that has begun**.

From the evidence gathered during the consultation process and the resulting document, the COP30 Presidency draws three final messages. First, countries, subnational governments and sectors can **all start now, from where they are**, by assessing their exposure and capacity to transition away from fossil fuels and choosing the levers that fit their circumstances. Second, as some levers require a global coordinated action, the Presidency proposes **a 'TAFF *Mutirão*', a collective agenda for accelerating action in this critical decade**. Third, the **global dialogue opened in Belém has to continue if we want to achieve the Paris Agreement Goals**, so that implementation by countries informs the next collective assessments.

START NOW, FROM WHERE YOU ARE

Human-induced warming reached 1.37°C in 2025 and the remaining carbon budget consistent with 1.5°C is close to exhausted. Science informs us that some overshoot of that limit is now inevitable. We can still keep the overshoot small and short, and that depends on how fast emissions fall in this critical decade and on the cost of bringing temperatures back down later, a cost that rises with every year of delayed action.

The Belém Readiness Approach, on which this Roadmap rests, proposes breaking the big challenge of transitioning away from fossil fuels into smaller, actionable pieces for each country to choose its own path. The Approach is structured in three pillars: i) energy demand; ii) energy supply; and iii) the broader economy, and asks two questions: how exposed a country is to the transformation under way, and what capacity a country has to accelerate and manage it. A Transition Readiness Index for each pillar translates the

replies to these two questions into a measurable assessment. Their combination places a country, a subnational government in one of four archetypes per pillar. The foundational levers, relevant across all archetypes, and archetype-specific levers, are identified and ordered in a suggested sequencing . Finally, the Tripod supports the case that the three pillars are connected.

The Belém Readiness Approach is a tool for voluntary self-assessment; each country finds in it a way to locate itself and a set of actions suited to its position. It is not a single template and it can naturally be improved and refined. It shows that **every archetype has levers and that countries can use them to start now**. For instance, economies with high exposure and limited capacity have most to gain from avoiding new lock-in and stranded assets as their demand for energy services grows. Economies with strong capacity have the means to move first and to create market competitiveness with technologies that will be needed.

Countries differ in how fast they can move and in the support they need, but **every country gains from immediatelly planning its transition away from fossil fuels**. Assets, infrastructure and institutions last for decades, so the decisions taken today will define what remains possible tomorrow. Those who start early keep more room to sequence the transition on their own terms, increase their energy security and protect the workers, communities and assets exposed to it.

Having located themselves in the framework, countries and subnational governments can turn to the **foundational levers** that apply across all archetypes and to the **archetype-specific implementation levers** that correspond to their profile. In choosing among the levers, it helps to distinguish a policy gap, where a lever has yet to be adopted, from an implementation gap, where it has been adopted but is not yet delivering because institutional capacity, financing, enforcement or coordination across levels of government fall short.

The COP30 Presidency invites willing national and subnational governments, where the Approach applies, to **conduct their readiness self-assessment as soon as possible.** Following the Belém Readiness Approach and using the three Readiness Indexes (demand, supply and economic) according to their priorities and circumstances is a possible first step toward actionable roadmaps. Actors can begin with the data that international organizations already publish, complemented by national and subnational sources. Where data is thin, international cooperation through existing institutions and mechanisms can support countries in this exercise.

Figure 26 brings together, for the twelve archetypes of the three pillars, the priorities of the three archetype-specific implementation levers that the chapters identify for each archetype, in the order in which attention is most needed. A full version of this frame is available in the Appendix C. Figure 26 is a summary of the archetypes, the proposed sequencing and the implementation levers behind it. The steps overlap in practice, and are to be understood as a possible pathway among many others which countries may decide to take.

Figure 26: First steps by archetype: sequencing priorities of specific implementation levers in the three pillars

DEMAND-SIDE PILLAR Energy Demand Transition Archetypes

Demand Transition Constrained
High demand-side exposure · Low transition capacity

1. Avoid new fossil fuel lock-in while meeting rapidly growing energy demand
2. Build enabling conditions for demand-side transformation
3. Promote efficient and sustainable energy use

Demand Transition Reformers
High demand-side exposure · High transition capacity

1. Accelerate the replacement of fossil fuel use across mature demand systems
2. Optimize increasingly electrified demand systems
3. Remove remaining barriers to widespread adoption

Demand Vulnerable
Low demand-side exposure · Low transition capacity

1. Build modern energy demand systems as access expands
2. Avoid future fossil fuel lock-in
3. Strengthen the quality and efficiency of emerging demand systems

Demand-side Frontrunners
Low demand-side exposure · High transition capacity

1. Complete the remaining demand-side transition
2. Optimize mature demand systems
3. Strengthen international leadership

SUPPLY-SIDE PILLAR Energy Supply Transition Archetypes

Supply Transition Constrained
High supply-side exposure · Low transition capacity

1. Transform the energy supply mix
2. Build the enabling environment for supply-side transformation
3. Enhance the competitiveness and sustainability of the energy sector

Supply Exposed but Capable
High supply-side exposure · High transition capacity

1. Diversify the energy supply mix
2. Redirect infrastructure and industrial capabilities
3. Reinforce the competitiveness of low-emissions energy supply

Supply Structurally Vulnerable
Low supply-side exposure · Low transition capacity

1. Strengthen reliable, affordable and secure energy systems
2. Build the enabling environment for supply-side transformation
3. Enhance long-term energy resilience

Supply Transition Ready
Low supply-side exposure · High transition capacity

1. Expand low-carbon energy systems
2. Optimize the enabling environment for low-carbon energy systems
3. Provide international leadership for the supply-side transition

ECONOMIC PILLAR Economic Transition Archetypes

Economic Transition Constrained
High economic exposure · Low transition capacity

1. Strengthen fiscal resilience
2. Mobilize investment and productive diversification
3. Enable an inclusive structural transition

Economically Exposed but Resilient
High economic exposure · High transition capacity

1. Reallocate existing financial resources
2. Accelerate industrial transformation
3. Manage an orderly transition

Economically Vulnerable
Low economic exposure · Low transition capacity

1. Strengthen enabling conditions for investment
2. Build domestic capabilities
3. Expand access to finance and knowledge

Economically Diversified
Low economic exposure · High transition capacity

1. Maintain domestic leadership
2. Shape international markets
3. Support the global transition

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order. The full sequences, and the foundational and archetype-specific levers behind them, are set out in the demand-side, supply-side and economic chapters.

The COP30 Presidency encourages countries to carry the results of their self-assessment and both foundational levers and archetype-specific implementation levers they select into some of the **instruments they already plan and report**: nationally determined contributions, long-term low-emission development strategies, national energy and development plans, or a dedicated national roadmap for transitioning away from fossil fuels, as some countries have already prepared or are beginning to do so. The approach applies equally to subnational governments and to sectors, for which the end-use transformation pathways in Appendix A provide a direct point of entry, and the self-assessment is worth repeating as exposure and capacity change.

The COP30 Presidency encourages governments and other actors to **make their assessments known**, in the form and through the channels they may choose. Shared openly, the assessments let partners aim their cooperation at the pillar where constraints are concentrated and let countries with similar profiles learn from one another. Together they help to build the picture of where the world stands for the second Global Stocktake.

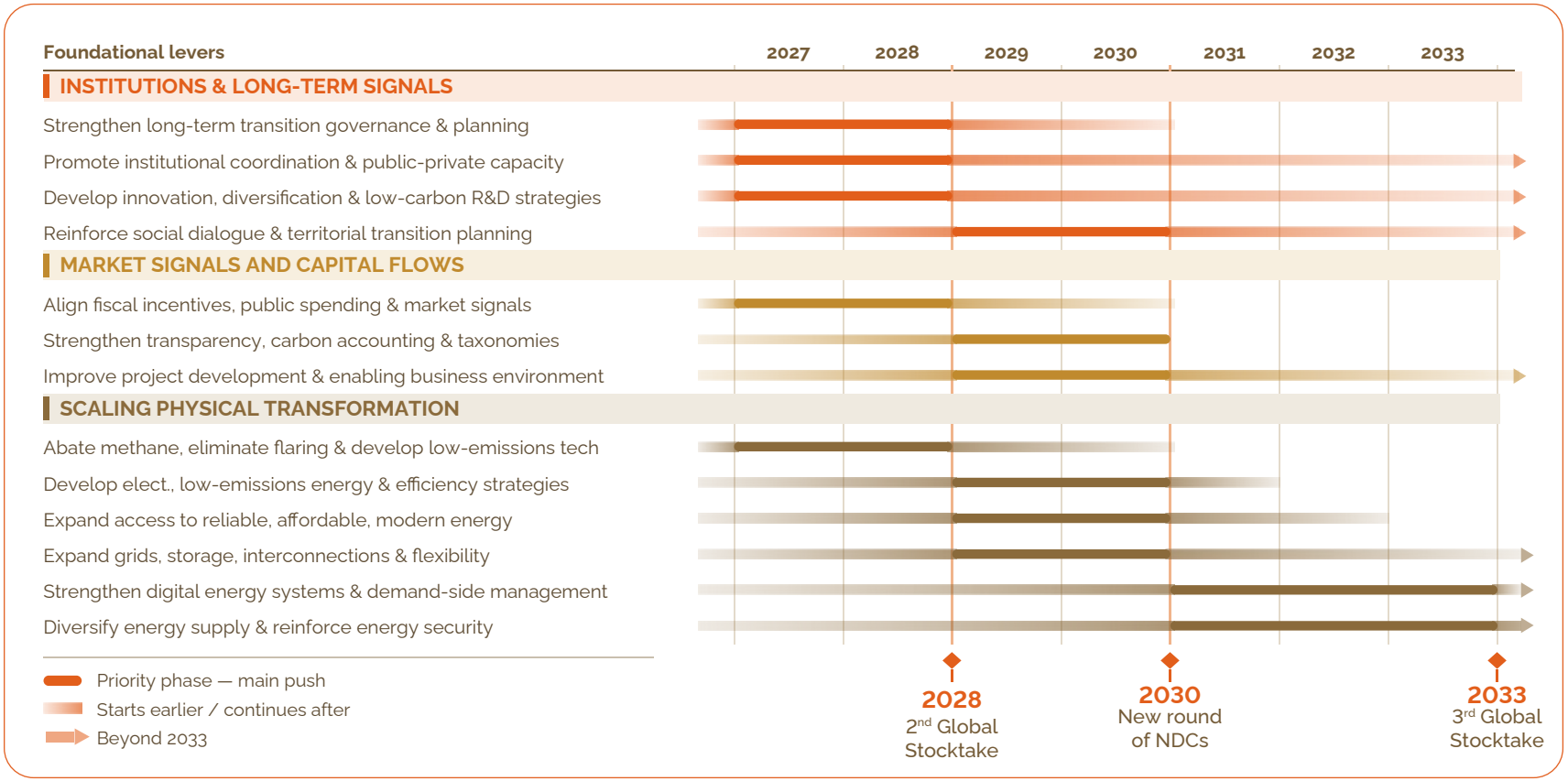
TAFF *MUTIRÃO*: A COLLECTIVE AGENDA FOR THIS CRITICAL DECADE

This proposed collective agenda that sets out what we can collectively prioritize. The foundational levers of the three pillars are enabling conditions that stay relevant throughout the decade and across all archetypes, and constitute the common ground on which countries, partners and stakeholders can work. Within that continuous effort, some foundational levers have a larger immediate effect or unlock others, and some depend on technologies and markets still in a scaling phase, with broad deployment expected by around 2035.

The COP30 Presidency therefore proposes **a collective agenda in three phases**, anchored on critical moments for the multilateral process: 2028 and the second Global Stocktake; 2030, when the collective goals agreed at COP28 fall due, and the next Nationally Determined Contributions are submitted; and 2033, the third Global Stocktake, when Parties will assess progress over the critical decade since Dubai in full.

Figure 27 represents the TAFF *Mutirão* and brings the foundational levers of the three pillars together (so the planning and coordination levers common to all three appear once), and groups them into three fronts: institutions and long-term signals, market signals and capital flows, and the physical transformation of energy systems. For each lever, it distinguishes the phase of concentrated international attention from the longer period over which work continues. Some levers have a foreseeable end point, such as subsidy reform or the end of routine flaring; others, such as institutional coordination or innovation, constitute longer-term features of the transition. The main push of each lever reflects its urgency, understood as readiness for deployment combined with potential impact, its place in the chain, since some levers unlock others, and the limit to how many workstreams a government can carry at once.

Figure 27: TAFF *Mutirão*: priority phases within a continuous effort, 2027 to 2033



In the first phase, to 2028, the main push goes to institutions and long-term signals. Countries can conduct the self-assessments and the planning described in this Roadmap, including national roadmaps, institutional coordination and public-private collaboration, and innovation and diversification strategies, and so lay the foundations on which later transformation can scale. They also act on the two levers that deliver results at once and on which the debate is mature: the reform of fossil fuel incentives, with targeted protection for vulnerable consumers, and the abatement of methane and the end of routine flaring, where operators can cut around three-quarters of oil and gas methane emissions with existing technologies and avoid some 95% of flaring-related emissions (see the box on the oil and gas industry in the supply-side chapter). The plans completed in this phase can feed the second Global Stocktake.

In the second phase, 2029 to 2030, the main push moves to the physical transformation of energy systems: electrification, low-emissions energy and efficiency, modern energy services, and the networks, storage, interconnections and flexibility that make them reliable substitutes for fossil fuels. The 2030 goals of tripling renewable capacity and doubling the rate of energy efficiency improvement fall due in this phase and

the next nationally determined contributions are submitted, so credible trajectories should be in place. In the same phase countries complete the work on market signals and capital flows, through transparency, carbon accounting and taxonomies and through project development ecosystems, and they take forward the social dialogue and territorial planning that prepare the ground for adjusting supply in a just, orderly and equitable manner in the phase that follows.

In the third phase, 2031 to 2033, the main push can go to the supply side and to the solutions in the scaling phase. With market reforms, planning and social dialogue in place, fossil fuel demand declining and low-emissions supply built out, producers and governments can adjust and diversify supply in step with demand, and system operators can integrate increasingly electrified end uses through digital energy systems and demand-side management. Industry can bring the fuels and technologies from a scaling phase to broad deployment. Supply-side action starts earlier, with planning, methane and flaring in the first phase and with social dialogue and territorial planning in the second, and reaches scale here.

The agenda proposes priorities for concentrated international attention and leaves the pace and pathway of each country to the country itself. Work proceeds in parallel on every lever throughout the period, and many countries are already advancing in many of those. Some are further along in building institutions and reforming markets and can anticipate the later phases; others will reorder the priorities to their circumstances, giving earlier weight to energy access where it remains a persistent challenge, or to supply diversification and territorial planning where fiscal and employment dependence on fossil fuels is high. Therefore, it is fundamental that all countries consider the TAFF Mutirão in this critical decade.

KEEP THE GLOBAL DIALOGUE GOING

The conversation opened in Belém has been constructive because it stayed focused on implementation, based on direction given by consensus in Dubai and open to all, importers and exporters, advanced and developing economies alike. As previously mentioned, in preparing this Roadmap the COP30 Presidency received contributions through the open call hosted on the UNFCCC platform, consulted Parties and observers at the sessions of the subsidiary bodies in Bonn in June 2026 and carried the discussion into energy, finance and climate conferences in every region, with governments, companies, financial institutions, researchers and civil society and other constituencies. We recognize that those who decide to use, adapt or improve this Roadmap will give it its meaning, and **the political space for a frank conversation on implementing the transition away from fossil fuels** should stay **open**.

In this context, the COP30 Presidency invites those best placed to continue this global dialogue to keep that space open. During the consultations, important suggestions came: that **future COP Presidencies and the High-Level Climate Champions** can continue to hold dialogues on implementing the transition away from fossil fuels at each COP and at the sessions of the subsidiary bodies in Bonn, and sustain the Action Agenda's axis on transitioning energy, industry and transport, its Plans to Accelerate Solutions and the coalitions of businesses, financial institutions, subnational governments and civil society behind them. **Future G20 leaderships**, and the finance and energy tracks that serve them, can take up the economic pillar in particular: the cost of capital and access to finance, fiscal resilience in exposed economies, fossil fuel subsidies and price signals, and the interoperability of carbon accounting and sustainable finance taxonomies, barriers that no single country removes on its own. **The United Nations system, other international organizations and financial**

institutions, whose work provides the analytical foundations of this Roadmap, can keep the readiness instruments current, help close the data gaps identified in the Readiness Indexes, refine the interpretation of Index results and archetype positioning, and draw on the Belém Readiness Approach in the country work they already do, from energy planning and support to nationally determined contributions to the monitoring of methane, flaring and energy access. **The platforms through which countries prepare their transition plans**, among them the **Santa Marta process,** ahead of its second conference in 2027, may find useful this Approach, its indexes, archetypes and levers, and the TAFF *Mutirão* agenda, material that the Presidency believes can be useful to national and regional roadmaps, to be improved with their own experience.

The second Global Stocktake, to be concluded in 2028, will be the first collective assessment of progress since Parties agreed to transition away from fossil fuels. Those taking part in this conversation may wish to bring to it a shared reading, by pillar and by readiness profile, of where the world stands: how widely readiness has been assessed, which levers have gained most ground, where constraints remain concentrated and where cooperation has made a difference.

A final message

When I accepted the COP30 Presidency, I wrote that change is inevitable, by choice or by catastrophe, and that we still hold the choice. Almost two years later, I believe it more firmly. In Belém we opened a conversation that many considered impossible, on how to put into practice what all of us agreed at COP28, and we kept it open with respect for every point of view. Governments, companies, scientists, workers and communities from every region answered our call for contributions, and the partners who worked with us on this Roadmap gave it their time and their best judgment. We listened to them and we learned from them, and this Roadmap is the result.

Transitioning away from fossil fuels is inevitable and has already begun, even if countries start from very different positions. A country that still lacks electricity for part of its people faces a different task from a country that built part of its prosperity on oil and gas, and both face a different task from a country that already produces most of its energy from low-emissions sources. My hope is that each of them can find in this Roadmap a way to look at its own situation and a set of levers it can use.

Many of the messages in this Roadmap may sound addressed to national governments. But governments will move faster and in a just, orderly and equitable manner where states, provinces and cities, companies, investors, workers and civil society take up their part of the work, as so many of them have done in recent years. The Presidencies that will follow ours, the G20, the agencies of the United Nations and the many platforms where countries prepare their plans can keep this conversation going and bring what they learn to the second Global Stocktake in 2028. And all of us can work, in this critical decade, on the obstacles we can only remove together. In my very first letter I asked the world to pull the levers together. We now know which levers they are.

This document leaves much still to be discussed, and those who decide to use it will improve it. We prepared it in the spirit of *mutirão*, in which neighbors join to build what none of them could build alone, and I offer it in the same spirit, with gratitude to everyone who helped and with an open door to everyone who wishes to join. I hope it helps us deliver what we agreed together in Dubai. The Paris Agreement is working, and there is much more to do. Let us do it together, by choice.

APPENDICES

APPENDIX A. END-USE TRANSFORMATION PATHWAYS

Beyond examining how countries can strengthen their readiness to implement the transition away from fossil fuels, the COP30 Presidency complements the Belém Readiness Approach with an additional analytical layer focused on the main end-use sectors: transport, industry and buildings. This sectoral lens extends the country-level readiness analysis by examining how fossil fuel demand can be reduced within specific end uses and which conditions are required to accelerate the deployment of available solutions. To ensure consistency across sectors, the analysis follows a common four-step sequence linking current fossil fuel dependence, key transition solutions and their deployment conditions, solution impact and adoption readiness, and implementation levers.

First, the analysis assesses each sector's current dependence on fossil fuels. This includes the composition of energy use, the prevalence of fossil fuel-based technologies and the characteristics of sectoral activities that influence the complexity of substitution.

Second, it identifies selected technological and other demand-side solutions available to reduce fossil fuel consumption and examines the main conditions affecting their deployment. These may include electrification, energy efficiency, low-emissions fuels, changes in production or consumption practices and other sector-specific solutions, depending on the characteristics of each end use. The solutions identified are illustrative rather than exhaustive and are intended to capture those with significant relevance to reducing fossil fuel demand within each sector. For each solution, the analysis also highlights key technological, infrastructure, market, financial, behavioral or institutional constraints that may influence the pace and scale of adoption.

Third, the identified solutions are assessed across two complementary dimensions: their relative impact on fossil fuel demand reduction and their adoption readiness. Relative impact is assessed within each end-use sector, comparing the potential contribution of each solution to reducing fossil fuel demand relative to other solutions available within that sector. Therefore, the assessment is sector-specific and should not be interpreted as a direct comparison of absolute fossil fuel reductions across sectors.

Adoption readiness assesses the extent to which each solution can be deployed at scale, considering technology maturity, the infrastructure and enabling conditions required for implementation. Solutions are classified into three broad readiness categories:

1. "Ready now", scalable within the current decade, by 2030;
2. "Scaling phase", requiring further infrastructure and capacity development, with broader deployment by around 2035;
3. "Long-term transformation", requiring further technological and system maturation toward 2050.

The assessments of relative impact and adoption readiness are intended as global-level reference assessments. Actual conditions may differ significantly across countries and regions depending on factors such as existing infrastructure, technology availability and market conditions.

The investment requirements associated with each demand-side solution are not assessed as a separate analytical dimension, given the substantial variation across technologies, applications and country-specific conditions[236]. Nevertheless, cost-related considerations are reflected indirectly in the adoption-readiness assessment, alongside technological maturity, degree of commercialization, market development and the enabling conditions required for deployment at scale.

Fourth, the analysis identifies the implementation levers required to accelerate deployment of the selected solutions and address the principal constraints identified. End-use implementation levers describe the strategic actions and enabling changes needed to support the adoption and scaling of specific solutions across end-use sectors. They are grouped into five categories: Infrastructure & Supply Chains; Innovation & Technology; Market & Finance; Behavioral & Demand Optimization; and Institutional Planning & Coordination. Implementation levers describe what needs to change to enable deployment at scale, rather than prescribing specific delivery mechanisms.

Transport sector

The transport sector accounts for approximately 28% of total final energy consumption and close to a quarter of global fossil fuel consumption, including some 60% of oil consumption [237]. This consumption is highly dominated by fossil fuels, which supply about 94% of the sector's energy use. Oil represents the largest share, accounting for roughly 90% of transport energy consumption, highlighting the sector's strong dependence on petroleum products. Natural gas accounts for around 4%, while bioenergy contributes approximately 4% and electricity the remaining 2%[238]. As a result of this high reliance on fossil fuels, the transport sector is a major contributor to global energy-related emissions. In 2024, transport accounted for approximately 22% of global CO_2 emissions from fossil fuel combustion, totaling around 7 Gt CO_2.

The transport sector comprises four main modes: road, aviation, shipping and rail. Road transport consumed approximately 93 EJ (75%) in 2024, aviation around 14 EJ (11%) and shipping approximately 11 EJ (9%), while rail accounted for around 7 EJ (5%). When considering fossil fuels, the modes differ substantially in their level of dependence, the scale and composition of fossil fuel demand, technological alternatives and transition pathways. The analysis considers these modes separately to reflect their distinct fossil fuel dependence, transition solutions, deployment conditions and implementation levers.

Road transport

a. Current dependence

Road transport remains heavily dependent on fossil fuels and accounts for around 45% to 50% of global oil demand. **Oil dominates the sector's energy mix, accounting for approximately 92% of road transport energy consumption** [239], while electricity currently supplies less than 1%.

This dependence is unevenly distributed across road transport segments. Passenger cars represent a major source of gasoline demand, while medium- and heavy-duty vehicles remain particularly dependent on diesel since they hold higher energy requirements, longer operating distances and more demanding vehicle-performance needs. Two- and three-wheelers and buses represent smaller shares of total energy demand but offer important opportunities for early electrification, particularly in urban areas. Dependence is also reinforced by the size and turnover of the existing vehicle fleet, as changes in new vehicle sales take time to translate into reductions in fleet-wide fossil fuel consumption.

b. Key demand-side solutions and deployment conditions

Reducing fossil fuel demand in road transport can be supported by three key macro demand-side solutions: electrification, efficiency and mobility optimization, and sustainable and low-emissions fuels.

1. **Electrification**: it represents a particularly important near-term opportunity to displace gasoline and diesel in road transport. Electric passenger vehicles, two- and three-wheelers and buses already rely on commercially mature technologies in many markets, supported by declining battery costs and substantially higher energy efficiency than internal combustion engine vehicles. These solutions present relatively strong conditions for near-term scale-up where supporting infrastructure and market conditions are in place. Under current policies, electric vehicles are expected to reach around 50% of global car sales by 2035, contributing to oil demand savings of approximately 10 mb/d[240]. Further scale-up continues to depend on the expansion of charging infrastructure, improved vehicle affordability and stable policy and regulatory signals, while concentrated battery and critical-mineral supply chains remain a source of cost and supply risk[241].

Electrification also has significant potential to reduce diesel demand in freight transport. Even if adoption remains less mature than in passenger and urban applications, particularly for long-distance and high-utilization operations, the rate of adoption in some markets and the continuous progress of the technology and cost reduction indicate similar progress to EVs. In these segments, wider deployment should occur as vehicle performance, charging infrastructure and operating economics continue to improve.

2. **Efficiency and mobility optimization:** vehicle efficiency improvements have already reduced fuel consumption immediately across new vehicle sales and progressively affect the overall fleet, while modal shift, public transport expansion, logistics optimization and demand-management measures can generate deeper structural reductions in energy demand over time. Fuel economy of internal

combustion engine vehicles is expected to continue improving through 2035, broadly in line with historical trends under current policies. Many vehicle-efficiency measures are already technically mature and can be adopted in the near term, although slow fleet turnover and consumer preferences for larger and heavier vehicles in some markets can reduce the pace at which these gains translate into lower fleet-wide fuel consumption. Broader mobility optimization measures often depend on longer-term changes in infrastructure, urban planning and transport systems, including stronger public transport networks, supportive land-use patterns and policy frameworks that enable modal shift and more efficient mobility. Their effectiveness can also depend on behavioral change and sustained investment in public transport infrastructure and urban development[242].

3. **Sustainable and low-emissions fuels**: two groups of fuels reduce fossil fuel demand in road transport in segments and contexts where direct electrification remains more difficult, and they are at very different stages of readiness[243]. Sustainable biofuels and biomethane are already being deployed at scale. Ethanol, biodiesel and renewable diesel are commercially competitive in specific markets and applications, and can in some cases make use of existing vehicle and fuel-distribution infrastructure[244]. Where blending mandates have been sustained over time, national experience shows that they can create stable demand, attract investment along the agricultural and industrial value chain and raise agricultural productivity, so that the fuel policy also serves rural development and energy security objectives. Broader deployment depends on cost competitiveness across fuel pathways and markets, on sustainable feedstock availability and competing uses of biomass, and on the ability to demonstrate sustainability. Robust and comparable carbon accounting is needed to distinguish low-emissions fuels from the rest, but it must be designed so that certification does not become a burden that excludes smaller producers or raises costs for consumers. The large demand potential of sustainable fuels in aviation and shipping, where few alternatives exist and willingness to pay is higher, may also draw producers toward those markets as they grow, which could tighten supply for road transport over time.

Low-emissions hydrogen and other synthetic fuels are at an earlier stage. Low-emissions hydrogen faces additional challenges related to production costs, limited refueling infrastructure and the availability of low-emissions supply[245].

Overall, most assessments identify electrification as an exceptionally important pathway for reducing fossil fuel demand in road transport, especially in passenger transport, urban fleets and two- and three-wheelers. Road transport accounts for close to half of global oil demand, and a large part of it could already be electrified competitively with available technologies, a share that grows as battery costs continue to fall. Electric vehicles across all segments, from two- and three-wheelers to cars, buses and trucks, are therefore the single largest lever for reducing oil consumption, and their progressive adoption could in time remove most of the oil demand of the sector[246]. Efficiency and mobility optimization provide complementary reductions by lowering energy requirements within vehicles and across mobility systems. Sustainable and low-emissions fuels can contribute in selected contexts and harder-to-electrify applications, with sustainable biofuels potentially playing a larger role where established supply chains and deployment experience already exist. At the global level, however, their contribution to road transport is likely to remain more targeted than that of direct electrification[247].

c. Levers to accelerate implementation

Based on the assessment so far, the tables below consolidate the specific demand-side solutions, their relative impact on fossil fuel demand reduction and adoption readiness, as well as the implementation levers required to accelerate deployment across the three macro solution areas: electrification [Table A.1]; efficiency and mobility optimization [Table A.2]; and sustainable and low-emissions fuels [Table A.3].

Table A.1: Road transport - Electrification: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Electrification			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Passenger electric vehicles (EVs)	**Very high** - largest contributor to oil demand reduction in road transport	**Ready now** – commercially mature and scalable, although adoption conditions differ significantly across markets	**Expand public, workplace and residential charging infrastructure** [Infrastructure & Supply Chains]
			Scale competitive EV and battery supply chains [Infrastructure & Supply Chains]
			Improve vehicle affordability and financing conditions for EV adoption [Market & Finance]
Electric buses and urban fleets	**High** – rapid potential to displace diesel consumption in high-utilization urban fleets	**Ready now** – technologies are commercially mature, but scaling depends on charging availability, fleet economics and operational capabilities	**Expand depot and urban fast-charging infrastructure** [Infrastructure & Supply Chains]
			Adapt fleet operations, route planning and charging management [Behavioural & Demand Optimization]
			Strengthen coordinated fleet transition planning [Institutional Planning & Coordination]
Heavy-duty freight electrification	**High,** particularly over the longer term - substantial potential to reduce diesel demand in road freight	**Scaling phase** – deployment remains constrained by vehicle costs, high-power charging requirements, grid capacity and operational conditions	**Develop high-power charging corridors and logistics hubs** [Infrastructure & Supply Chains]
			Reinforce grid capacity in priority freight locations [Infrastructure & Supply Chains]
			Improve battery performance, charging speed and fleet logistics [Innovation & Technology]

Table A.2: Road transport - Efficiency and Mobility Optimization: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Energy Efficiency			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Vehicle efficiency improvements	**High** – potential to reduce fuel consumption across conventional and hybrid vehicle fleets	**Ready now** – mature technologies and operational practices can be deployed within the current decade, although fleet turnover affects the pace of impact	**Improve vehicle powertrains, lightweighting and aerodynamic performance** [Innovation & Technology]
			Accelerate fleet renewal toward more energy-efficient vehicles [Market & Finance]
			Promote efficient driving, fleet management and digital route optimization [Behavioural & Demand Optimization]
Modal shift and optimization	**Moderate near term / High long term** – structural reduction in transport energy demand through more efficient mobility patterns and modal choices	**Long-term transformation** – technologies and mobility solutions are mature, but scaling depends on urban development, transport systems, institutional coordination and behavioural change	**Expand high-capacity public transport, rail and multimodal mobility systems** [Infrastructure & Supply Chains]
			Integrate land-use and mobility planning around efficient transport modes [Institutional Planning & Coordination]
			Promote shared mobility, active mobility and travel-demand optimization [Behavioural & Demand Optimization]

Table A.3: Road transport - Sustainable Fuels: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Sustainable and low-emission fuels			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Sustainable biofuels for road transport	**Moderate** – can reduce fossil fuel use across existing vehicle fleets, particularly where electrification progresses more slowly, although their overall contribution is constrained by sustainable feedstock availability and competing uses	**Ready now –** commercially established biofuel pathways are already deployed in several markets and can use existing vehicle and fuel-distribution systems, although broader scale-up depends on sustainable feedstock availability, market conditions and additional production capacity	**Scale sustainable feedstock supply chains** (Infrastructure & Supply Chains)
			Expand sustainable biofuel production and distribution capacity where required (Infrastructure & Supply Chains)
			Advance higher-performance and lower-emissions biofuel production pathways (Innovation & Technology)
Low-emission hydrogen for heavy transport	**Moderate** – can reduce fossil fuel use in selected heavy-duty and long-distance transport applications where direct electrification is more constrained	**Scaling phase** – vehicle technologies are entering commercial deployment, but broader adoption depends on low-emissions hydrogen availability, refuelling infrastructure and coordinated development of vehicles and fuel supply	**Develop hydrogen production, transport and refuelling infrastructure for priority transport corridors** (Infrastructure & Supply Chains)
			Scale hydrogen-ready heavy-duty vehicle and storage technologies (Innovation & Technology)
			Improve cost competitiveness and financing conditions for hydrogen fleet adoption (Institutional Planning & Coordination)

Aviation

a. Current dependence

Aviation accounted for approximately 7% of global oil demand in 2024 and remains almost entirely dependent on fossil fuels. Oil supplied more than 99% of aviation energy demand (14 EJ)[248]. Aviation demand is also expected to continue growing, particularly in emerging markets and developing economies, supported by rising incomes and expanding air travel. Some projections indicate that oil could still meet around 90% of the sector's energy needs by 2050 under current policies, corresponding to roughly 10 million barrels per day (mb/d).

Aviation is considered one of the harder-to-abate transport segments, as the high energy-density requirements of commercial flight constrain the scope for direct electrification[249]. Current battery energy density is insufficient for most medium- and long-distance commercial aviation applications, making it difficult for the sector to move away from energy-dense liquid fuels. Existing aircraft fleets, long asset lifetimes and infrastructure designed around liquid fuels further reinforce the persistence of conventional jet fuel use, particularly in medium- and long-haul aviation.

b. Key demand-side solutions and deployment conditions

Key demand-side solutions for reducing fossil fuel demand in aviation include sustainable and low-emissions fuels and efficiency and optimization[250].

1. **Sustainable and low-emissions fuels: these represent a particularly important pathway for reducing fossil fuel dependence in aviation, given the continued need for energy-dense fuels across most commercial aviation applications[251].** Bio-based sustainable aviation fuels are expected to play a particularly important role in the near to medium term, as several production pathways are already technically established and can be integrated into existing aircraft and fuel systems. Sustainable aviation fuels (SAF), including bio-based and alcohol-to-jet pathways, can substitute conventional jet fuel while making use of established liquid-fuel infrastructure and operational practices. However, their wider deployment continues to depend on improvements in cost competitiveness, expansion of production capacity and access to affordable and sustainable feedstocks. SAF remains more expensive than conventional jet fuel in many markets, while feedstocks can account for more than 80% of production costs for some established commercial biofuel pathways.

Synthetic aviation fuels, including e-fuels produced using low-emissions hydrogen, could provide an additional pathway, particularly over the longer term, but remain at an earlier stage of technological and commercial maturity. Their scale-up requires substantial expansion of low-emissions hydrogen production, access to suitable sources of captured CO_2, fuel-conversion capacity and associated infrastructure, alongside further cost reductions[252]. Long-term policy signals, fuel standards and sustainability frameworks can strengthen investment conditions and support the development of new production capacity[253].

At the international level, aviation stands out as the one sector where a multilateral process has created demand. At the International Civil Aviation Organization (ICAO), governments have adopted a long-term aspirational goal of net zero emissions by 2050 and a global framework for cleaner aviation energy by 2030, while mechanisms such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) provide market and regulatory signals by recognizing eligible fuels that meet defined lifecycle-emissions and sustainability criteria, including the requirement that feedstocks do not compete with food production or displace ecosystems of high conservation value. Few low-emissions products enjoy a demand signal of this clarity, and the question for producers, investors and governments is now how to bring sustainable supply to market at the price and in the volumes the sector will require[254].

2. **Efficiency and optimization: they provide an important complementary pathway for limiting fossil fuel aviation demand by reducing the amount of energy required to deliver air transport services.** This includes aircraft efficiency improvements alongside operational and demand-side optimization measures. Fuel efficiency improvements in aviation have averaged around 2.5% per year over the past decade[255]. More efficient aircraft and engines, fleet renewal, improved air traffic management, route optimization and higher fleet utilization can further reduce fuel consumption per unit of transport activity. Many of these measures are already technically mature and can be deployed in the near term, particularly operational measures that do not depend on fleet replacement. However, their contribution to reducing absolute fossil fuel demand remains constrained by slow fleet turnover, long aircraft-development cycles and continued growth in aviation activity.

The long operational lifetime of commercial aircraft limits the pace at which improvements in aircraft and engine efficiency can penetrate the overall fleet, while the development and introduction of new aircraft platforms occur over long technology cycles[256]. Operational measures, including improved air traffic management, route optimization and higher fleet utilization, can provide more immediate efficiency gains, but their effectiveness depends on coordination across airlines, airports and air-navigation systems. Some projections indicate that annual aircraft fuel-efficiency improvements could slow to around 0.9% through 2035, compared with approximately 2.5% per year over the past decade[257]. At the same time, continued growth in passenger air travel can offset part of the energy savings achieved through efficiency improvements, meaning that efficiency and optimization may moderate growth in fossil fuel demand without necessarily reducing absolute consumption on their own.

Overall, aviation presents a more constrained transition pathway than road transport because commercially mature options for direct fossil fuel substitution remain limited. Near- to medium-term reductions in oil dependence will rely primarily on scaling SAF, particularly bio-based pathways, alongside continued improvements in aircraft and operational efficiency. Over the longer term, additional fossil fuel displacement may be supported by the development and commercialization of synthetic aviation fuels, including e-fuels produced using low-emissions hydrogen, and other advanced fuel pathways, although their future contribution will depend on technological progress, commercial viability and the development of supporting infrastructure.

c. Levers to accelerate implementation

Based on the assessment above, the tables below consolidate the specific demand-side solutions, their relative impact on fossil fuel demand reduction and adoption readiness, and the implementation levers required to accelerate deployment across the two macro solution areas: sustainable and low-emissions fuels [Table A.4] and efficiency and optimization [Table A.5].

Table A.4: Aviation - Sustainable and Low-emissions Fuels: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Sustainable and low-emission fuels			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Sustainable aviation fuels (SAF)	**Very high –** key near- to medium-term pathway for substituting conventional jet fuel across the existing aviation fleet	**Scaling phase** — some production pathways are technically established, but substantial expansion of production capacity and sustainable feedstock supply is required	**Expand SAF production capacity and sustainable feedstock supply chains** Supply Chains]
			Strengthen market and investment conditions to support long-term SAF production and uptake [Market & Finance]
			Develop coordinated sustainability and certification conditions for SAF [Institutional Planning & Coordination]
Synthetic aviation fuels, including e-fuels produced using low-emissions hydrogen	**Moderate –** could provide an additional pathway for fossil fuel substitution over the longer term, particularly where sustainable biofuel supply is constrained	**Long-term transformation** — production pathways remain at an early stage of commercialization and require expansion of low-emissions hydrogen, captured CO_2 and fuel-conversion infrastructure	**Develop low-emissions hydrogen production, conversion and airport distribution infrastructure** [Infrastructure & Supply Chains]
			Accelerate innovation in hydrogen-based aviation fuels, aircraft and propulsion technologies [Innovation & Technology]
			Strengthen certification, sustainability and market conditions for commercial deployment [Institutional Planning & Coordination]

Table A.5: Aviation - Efficiency and Optimization: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Energy efficiency and optimization			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Aircraft efficiency improvements	**Moderate to high** – can deliver significant near-term reductions in fuel use per unit of aviation activity, although fleet turnover limits the pace of fleet-wide gains	**Ready now** — efficient aircraft, engines and aerodynamic technologies are commercially available, but fleet-wide deployment depends on aircraft replacement cycles	**Accelerate innovation and deployment of high-efficiency aircraft, engines, aerodynamics and lightweight materials** [Innovation & Technology]
			Support fleet renewal and the uptake of more fuel-efficient aircraft [Behavioural & Demand Optimization]
			Strengthen long-term efficiency requirements and planning signals for aircraft performance improvements [Institutional Planning & Coordination]
Demand optimization and operational efficiency	**Moderate –** can reduce fuel consumption and energy use per unit of aviation activity, but is unlikely to deliver deep absolute fossil fuel reductions on its own	**Ready now** — many digital and operational measures are technically mature, although deployment depends on coordination across airlines, airports and air-navigation systems	**Expand digital air-traffic, route and flight -operations optimization systems** [Innovation & Technology]
			Optimize fleet utilization, passenger load factors and operational practices across aviation systems [Behavioural & Demand Optimization]
			Strengthen coordination across airlines, airports and air-navigation systems, including integration with alternative modes where viable [Institutional Planning & Coordination]

Shipping

a. Current dependence

Shipping accounted for approximately 5% of global oil demand in 2024[258]. The sector remains heavily dependent on oil, which currently meets more than 90% of its energy demand (11 EJ). Some projections indicate that oil could remain the dominant fuel over the coming decades even as the shipping fuel mix gradually diversifies. Shipping activity could increase by around 45% by 2050, while oil could still account for about 80% of sectoral energy demand by 2035 and around 70% by 2050. Shipping accounted for approximately 847 Mt CO^2, representing around 2.2% of global energy-related CO_2 emissions95. This combination of persistent oil dependence and expanding transport activity increases the scale and complexity of the fossil fuel substitution challenge[259].

Direct electrification remains challenging for several shipping applications, particularly long-distance and deep-sea shipping, given long operating distances, high energy requirements and the limited energy density of current battery technologies[260]. Long vessel lifetimes and existing fuel and bunkering infrastructure can further reinforce dependence on energy-dense liquid fuels.

b. Key demand-side solutions and deployment conditions

Key demand-side solutions for reducing fossil fuel demand in shipping include sustainable and low-emissions fuels and energy efficiency and optimization[261].

1. **Sustainable and low-emissions fuels: they represent a particularly important pathway for substituting conventional oil-based marine fuels, especially in long-distance shipping applications[262].** These include sustainable biofuels, as well as low-emissions ammonia, synthetic methanol and hydrogen. Sustainable biofuels are a near- to medium-term option, as they can be used as drop-in fuels in existing vessels with limited modifications. Several biofuel pathways are comparatively more mature for near-term deployment, although their broader scalability depends on sustainable feedstock availability, production capacity and cost competitiveness. Their deployment at scale also depends on sufficient fuel availability across major ports and trade routes, given the internationally distributed nature of maritime bunkering networks.

In addition, low-emissions ammonia, synthetic methanol and hydrogen could enable deeper fossil fuel substitution over time, but generally require greater modifications in vessels, fuel-production systems, storage and bunkering infrastructure[263]. Their technological and commercial readiness remains lower than that of established biofuel pathways. Scaling these fuels requires coordinated investment across shipowners, fuel producers, ports and infrastructure providers, as fuel supply, vessel deployment and bunkering capacity need to develop in parallel. Safety requirements, fuel standards, sustainability criteria and lifecycle-emissions methodologies also need sufficient consistency across jurisdictions to support internationally operating fleets and long-lived vessel investments. Some projections indicate that alternative fuels together could supply around one-quarter of shipping energy demand by 2035[264].

At the international level, shipping had been moving in the same direction as aviation. The International Maritime Organization (IMO) approved a Net-Zero Framework combining a global fuel intensity standard with a pricing mechanism for emissions above it, the first arrangement of its kind for an entire global sector, which was expected to create the demand signal that sustainable marine fuels require. Its formal adoption was subsequently postponed, and the framework is currently under renewed negotiation, including proposals that would reduce the stringency of the standard or weaken its pricing element[265]. Greater regulatory clarity and internationally consistent standards can strengthen long-term demand signals and provide greater visibility for investment across the maritime value chain[266].

2. **Energy efficiency and optimization provide an important complementary pathway for reducing the amount of fuel required to deliver maritime transport services[267].** Relevant measures include improvements in vessel design and propulsion systems, speed and route optimization, digitalization, logistics optimization and more efficient fleet operations. These measures improve the energy efficiency of maritime transport by reducing fuel use per unit of shipping activity, including as transport volumes increase. For example, the deployment of technical efficiency upgrades in new ships can moderate baseline energy demand growth. Many technical and operational efficiency measures are already mature and can be deployed in the near term, although the long operational lifetime of vessels and associated fleet turnover limit the pace at which improvements in new ships translate into fleet-wide reductions.

Operational and digital measures, including speed and route optimization, logistics improvements and more efficient fleet utilization, can generally be implemented more rapidly than vessel replacement or major technical retrofits. However, their effectiveness depends on coordination across shipowners, operators, ports and other actors in maritime transport systems[268]. Some projections indicate that cost-effective efficiency technologies could reduce shipping energy use per ton-kilometer by around 4% by 2035[269]. As shipping activity expands, these measures can reduce fuel intensity, although they are unlikely to deliver deep absolute reductions on their own[270].

Overall, shipping combines a high dependence on oil with comparatively limited options for direct electrification across long-distance applications. Sustainable and low-emissions fuels provide one of the main pathways for deeper fossil fuel substitution, with sustainable biofuels offering comparatively more mature near-term options and ammonia, synthetic methanol and hydrogen potentially contributing more substantially as technologies and supporting fuel systems scale[271]. Energy efficiency and optimization can deliver earlier reductions in fuel intensity and moderate growth in energy demand but are unlikely to achieve deep fossil fuel displacement on their own. The transition depends on deploying mature efficiency measures, as well as scaling and commercializing the alternative fuel pathways required for more structural reductions in oil dependence.

c. Levers to accelerate implementation

Based on the assessment above, the tables below consolidate the specific demand-side solutions, their relative impact on fossil fuel demand reduction and adoption readiness, and the implementation levers required to accelerate deployment across the two macro solution areas: sustainable and low-emissions fuels [Table A.6] and efficiency and optimization [Table A.7].

Table A.6: Shipping - Sustainable and Low-emissions Fuels: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Sustainable and low-emission fuels			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Sustainable biofuels	**Moderate** – can substitute fossil marine fuels in existing vessels and support near- to medium-term fossil fuel reductions, but overall contribution is constrained by sustainable feedstock availability	**Scaling phase** — technically established pathways exist, but broader deployment requires expansion of sustainable feedstock supply and production capacity	**Expand sustainable marine biofuel production capacity and diversified feedstock supply chains** [Infrastructure & Supply Chains]
			Improve market and investment conditions for sustainable marine biofuel production and uptake [Market & Finance]
			Establish robust sustainability and fuel-certification conditions for marine biofuel scale-up [Institutional Planning & Coordination]
Low-emissions ammonia and	**Limited in the near term / High in the longer term** – potential pathway for deep fossil fuel substitution in long-distance and deep-sea shipping	**Long-term transformation** — fuel production, vessel technologies, storage and bunkering systems require further maturation and scale-up	**Develop low-emissions ammonia and hydrogen production, port bunkering, storage and fuel-handling infrastructure** [Infrastructure & Supply Chains]
			Accelerate development and deployment of compatible marine propulsion and onboard fuel systems [Innovation & Technology]
			Advance international coordination on safety, fuel standards and certification for low-emissions marine fuels [Institutional Planning & Coordination]
Synthetic marine fuels	**Limited in the near term / potentially high in the longer term** – could provide deeper fossil fuel substitution where energy-dense fuels remain required	**Long-term transformation** — production technologies, low-emissions hydrogen supply and associated fuel infrastructure remain at an early stage of large-scale deployment	**Develop low-emissions hydrogen, synthetic-fuel production and associated marine fuel supply chains** [Infrastructure & Supply Chains]
			Accelerate innovation and commercialization of synthetic marine fuel production technologies
			Strengthen investment conditions and coordinated demand signals for early commercial deployment [Market & Finance]

Table A.7: Shipping - Efficiency and Optimization: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Energy efficiency and optimization			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Vessel efficiency improvements	**Moderate** – can reduce fuel use per unit of maritime transport activity, but does not directly substitute fossil fuels and fleet-wide impacts depend on vessel turnover and operational uptake	**Ready now** — many vessel-design, propulsion and energy-saving technologies are commercially available, although fleet-wide deployment depends on retrofit opportunities and vessel replacement cycles	**Accelerate deployment of high-efficiency hull, propulsion and energy -saving technologies across new and existing vessels** [Innovation & Technology]
			Scale digital voyage optimization, slow steaming and other operational efficiency practices [Behavioural & Demand Optimization]
			Strengthen long-term vessel-efficiency and carbon -intensity requirements to support continued performance improvements [Institutional Planning & Coordination]
Port and logistics optimization	**Moderate** – can reduce fuel use across maritime operations and logistics chains by improving routing, cargo handling, port calls and intermodal coordination	**Ready now** — many digital, logistics and operational solutions are mature, but wider deployment depends on coordination across ports, shipping companies and freight networks	**Expand smart port, cargo-management and logistics optimization systems** [Innovation & Technology]
			Improve route, port-call, cargo and intermodal coordination across maritime logistics chains [Behavioural & Demand Optimization]
			Strengthen coordination and data-sharing arrangements across ports, carriers and logistics operators [Institutional Planning & Coordination]

Rail

a. Current dependence

Oil demand from rail was slightly below 0.6 million barrels per day (mb/d) in 2024, considerably lower than in road transport, aviation and shipping. However, rail relies significantly on oil, primarily diesel, for its energy needs, accounting for nearly 50% of its total final energy consumption[272]. At the same time, rail is the most electrified transport mode, with electricity and biofuels accounting for the remaining share of energy use. Rail transport accounts for approximately 261 Mt CO_2, representing around 3% of total transport emissions and around 0.7% of total energy-related CO_2 emissions. Compared with other transport modes, rail combines relatively low overall energy demand with a comparatively high level of electrification.

Remaining fossil fuel dependence is concentrated primarily in diesel-operated rail networks and applications where electrification remains limited or less economically viable. The persistence of this dependence varies substantially across rail systems, reflecting differences in network characteristics, traffic density, infrastructure and the economics of electrification.

b. Key demand-side solutions: relative impact and adoption readiness

Given the comparatively high level of electrification already achieved in rail, key demand-side solutions for further reducing fossil fuel demand include additional electrification and the use of sustainable and low-emissions fuels in applications where full electrification is less practical[273].

1. **Electrification: further electrification provides a pathway for displacing diesel use in rail networks where traffic density, infrastructure conditions and operating patterns support economically viable deployment.** Rail electrification is a technically mature solution and is already commercially deployed in many rail systems, making it one of the most adoption-ready options for reducing residual fossil fuel use in the sector. However, its further expansion depends strongly on network characteristics and investment requirements[274]. Extending overhead catenary or third-rail systems across remote, geographically challenging or low-traffic routes can require substantial infrastructure investment and may be less economically attractive than electrification of high-density corridors.

Rail electrification also requires coordinated investment in catenary systems, traction substations and associated electricity connections, often over relatively long planning, permitting and construction periods[275]. Battery-electric trains can provide an alternative in some applications, particularly where full network electrification is less practical, although current battery characteristics can constrain deployment over longer distances and in heavy-duty operations. Differences in technical standards, voltage systems and equipment specifications can create additional integration and interoperability challenges, particularly across interconnected or cross-border networks[276]. Some projections indicate that the combined share of electricity and sustainable fuels could continue to increase over the coming decades, progressively reducing the role of oil in the rail energy mix.

2. **Sustainable and low-emissions fuels: sustainable fuels can provide a complementary pathway for reducing diesel demand in rail applications where network electrification is less technically viable or economically attractive.** Biofuels can be used in existing diesel fleets with relatively limited modifications, making them a comparatively mature option for selected non-electrified rail applications.

Other low-emissions fuel pathways, including hydrogen-based solutions, may become relevant in selected applications over time but require additional production, storage, distribution and refueling infrastructure and remain less mature for widespread rail deployment. Given rail's already high level of electrification in several markets, sustainable and low-emissions fuels are likely to play a more targeted role than electrification, particularly in applications where network electrification remains less practical.

Overall, rail differs from road, aviation and shipping because much of the core technology required for fossil fuel substitution is already mature and commercially viable. The principal transition opportunity is to reduce remaining diesel dependence through further electrification and targeted use of sustainable and low-emissions fuels[277]. At the same time, the broader expansion and utilization of rail can contribute to fossil fuel reduction across the transport system where it provides a viable alternative to more oil-intensive passenger and freight modes.

c. Critical structural barriers to adoption

The barriers to reducing remaining fossil fuel demand in rail differ across demand-side solutions and reflect infrastructure, economic and financial, technological, policy and institutional, and supply-chain constraints. Given the comparatively high maturity of rail electrification, the main barriers relate to the conditions required to extend them across remaining diesel-dependent applications.

d. Levers to accelerate implementation

Based on the assessment above, the tables below consolidate the specific demand-side solutions, their relative impact on fossil fuel demand reduction and adoption readiness, and the implementation levers required to accelerate deployment across the two macro solution areas: electrification [Table A.8] and sustainable and low-emissions fuels [Table A.9].

Table A.8: Rail - Electrification: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Electrification			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Rail network electrification	**High** – direct pathway for displacing diesel across remaining high-traffic and technically suitable rail corridors	**Ready now / Scaling phase** — technology is mature and commercially deployed, but expansion to new corridors can require infrastructure investment and long-term planning	**Expand rail electrification infrastructure, including overhead systems, substations and required electricity connections** [Infrastructure & Supply Chains]
			Accelerate deployment of advanced electric rail technologies and energy-recovery systems [Innovation & Technology]
			Strengthen long-term rail electrification planning, technical standards and interoperability [Institutional Planning & Coordination]
Battery-electric and hybrid regional rail	**Moderate** – can reduce diesel use in selected non-electrified regional and lower-traffic applications where full network electrification is less practical	**Ready now** — technologies are commercially available for selected applications, although deployment remains dependent on route characteristics, charging infrastructure and battery performance	**Develop charging and supporting electricity infrastructure for suitable regional rail corridors** [Infrastructure & Supply Chains]
			Advance battery performance, lightweight rolling stock and hybrid-electric propulsion technologies [Innovation & Technology]
			Integrate battery-electric and hybrid fleets into rail operations, scheduling and interoperability requirements [Behavioural & Demand Optimization / Institutional Planning & Coordination]

Table A.9: Rail - Sustainable and Low-emissions Fuels: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Sustainable and low-emission fuels			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Sustainable biofuels for non-electrified rail	**Moderate** – can directly substitute diesel in selected non-electrified rail applications, but broader impact is constrained by feedstock availability	**Ready now** – commercially established and compatible with existing diesel fleets, although scale-up depends on sustainable feedstock supply	**Expand and diversify sustainable biofuel feedstock supply and production capacity** [Infrastructure & Supply Chains]
			Strengthen market and investment conditions for biofuel uptake in suitable rail applications [Market & Finance]
			Advance waste- and residue-based biofuel pathways and refinery integration [Innovation & Technology]
Low-emissions hydrogen rail systems	**Limited** – potential contribution is concentrated in selected non-electrified regional and freight applications where direct electrification or battery-electric alternatives are less practical	**Scaling phase** – technologies are commercially available for selected applications, but wider deployment requires hydrogen supply and refuelling infrastructure	**Develop low-emissions hydrogen production, storage and refuelling infrastructure for suitable rail corridors** [Infrastructure & Supply Chains]
			Advance hydrogen fuel-cell train technologies and performance [Innovation & Technology]
			Establish safety, certification and operational conditions for deployment [Institutional Planning & Coordination]

Building

a. Current dependence

Buildings account for approximately 19%–20% of global direct natural gas demand and 5%–6% of global direct oil demand in 2024[278]. Direct fossil fuels account for around 35% of total final energy consumption in buildings, equivalent to approximately 45 EJ in 2024, and remain particularly important for space heating, water heating and cooking[279]. At the same time, electricity accounts for the largest share of building energy consumption, at approximately 39%. This makes buildings the most electrified of the end-use sectors. The sector's overall emissions profile therefore reflects both direct fossil fuel consumption within buildings and the emissions intensity of the electricity supplied to them. The building sector accounted for nearly 7.3% of global CO_2 emissions from fossil fuel combustion, totaling approximately 2.8 $GtCO_2$.

The transition challenge differs considerably across building stocks and energy services. Existing buildings can remain in use for several decades, meaning that heating systems, building envelopes and appliances installed today can influence energy consumption over long periods. At the same time, rapidly expanding building stocks and growing demand for cooling, appliances and data centers create an opportunity to integrate efficient and low-emissions technologies from the outset.

b. Key demand-side solutions and deployment conditions

Key demand-side solutions for reducing fossil fuel dependence and improving energy use in buildings include electrification, energy efficiency and optimization, and expanded access to clean cooking solutions.

1. **Electrification provides a particularly important pathway for directly substituting fossil fuel use in building energy services, especially space and water heating and, where applicable, cooking.** The deployment of heat pumps is a critical element of this transition, as they are typically three to five times more efficient than conventional fossil fuel-based heating systems[280], enabling the same level of energy service while significantly reducing final energy consumption. As such, heat pumps are a key technology for displacing natural gas and oil use in space and water heating. Electric technologies for heating, cooling and cooking are already commercially mature across many applications, although adoption readiness varies according to building characteristics, climate, electricity-service conditions and the existing stock of fossil fuel-based equipment[281].

Their wider deployment depends on upfront equipment and installation costs, the characteristics of existing buildings and the availability of skilled workers. In older or less efficient buildings, electrification may need to be accompanied by building-envelope upgrades or adaptations to internal heating systems to maintain performance and affordability[282]. Large-scale deployment also requires sufficient installation and maintenance capacity, including electricians, heating, ventilation and air-conditioning technicians and other skilled workers. These conditions are particularly relevant for retrofitting existing buildings, while new construction can provide greater opportunities to integrate electric technologies and efficient building design from the outset[283].

2. **Energy efficiency and optimization provide a complementary pathway by reducing the amount of energy required to deliver heating, cooling and other building services, while also improving how and when energy is consumed**[284]**.** Building energy codes can establish higher levels of efficiency from the outset, while retrofits can reduce energy requirements through improvements in building envelopes and the replacement of inefficient equipment and systems[285]. Appliance and equipment efficiency also represents an important component of this pathway, particularly as rising temperatures, incomes and appliance ownership increase demand for cooling and other energy services. Minimum energy performance standards (MEPS) and more efficient cooling technologies can therefore reduce the amount of electricity required to provide these expanding services. Deployment across existing building stocks remains influenced by renovation rates, upfront retrofit costs, split incentives and the effectiveness of building codes and efficiency standards.

Optimization measures can further improve the performance of increasingly electrified buildings by enabling energy consumption to respond more flexibly to changing system conditions. Smart meters, connected heating and cooling systems, automated controls and other digital technologies can help households and commercial buildings adjust the timing of electricity use without reducing the energy services provided[286]. Flexible loads such as water heating, heat pumps and air conditioning can be shifted across different periods, while digital aggregation can support more coordinated demand management across multiple buildings. Wider adoption depends mainly on digital infrastructure, interoperability and the ability of consumers, building operators and utilities to participate in demand-side management[287].

3. **Clean cooking access: expanding access to modern and clean cooking solutions is a critical component of a just and equitable transition in buildings**[288]**.** A significant share of the global population still relies on traditional biomass, such as firewood. Transitioning to modern clean cooking technologies can reduce overall energy demand, improve health outcomes, and significantly lower indoor air pollution and deforestation pressures. Available solutions include electric cooking and other modern cooking technologies, such as ethanol cookstoves, with their suitability varying according to local energy-access conditions, affordability and available infrastructure. Several clean cooking technologies are already commercially mature, but sustained adoption depends on more than technology availability[289]. Upfront appliance costs, recurring fuel or electricity costs, reliable access to modern energy services and distribution networks can limit uptake, particularly in underserved and dispersed communities. Where these conditions remain weak, households may continue relying on traditional biomass and other polluting fuels even when cleaner alternatives are available. International cooperation on clean cooking has strengthened in recent years, with the IEA playing a central role in mobilizing commitments, tracking their delivery and bringing governments, industry and development partners together[290].

Overall, buildings present a comparatively broad set of mature technological options for transforming energy demand. Electrification can directly substitute fossil fuel use in key building services, while energy efficiency and optimization can substantially reduce the amount of energy required to provide heating, cooling and other energy services. Clean cooking access addresses a distinct transition challenge by expanding modern energy services while reducing reliance on traditional and polluting fuels. One of the most relevant challenges is increasingly the scale and pace of adoption across highly diverse building stocks and development contexts[291].

c. Levers to accelerate implementation

Based on the assessment so far, the tables below consolidate the specific demand-side solutions, their relative impact on fossil fuel demand reduction and adoption readiness, and the implementation levers required to accelerate deployment across the three macro solution areas: electrification [Table A.10]; energy efficiency and optimization [Table A.11] and clean cooking access [Table A.12].

Table A.10: Building - Electrification: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Electrification			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Electrification of space and water heating	**High** - can directly displace natural gas and oil use in major building heating applications, particularly through heat pumps	**Ready now** - heat pumps and other electric heating technologies are commercially mature, although adoption depends on building characteristics, installation capacity and electricity-service conditions	**Upgrade building-level and local electricity infrastructure required for large-scale heating electrification** [Infrastructure & Supply Chains]
			Expand installer capacity and technical capabilities for heat pump deployment and building-system integration [Infrastructure & Supply Chains]
			Strengthen market and regulatory conditions that improve the competitiveness and uptake of electric heating technologies [Market & Finance / Institutional Planning & Coordination]

Table A.11: Building - Energy Efficiency and Optimization: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Energy efficiency and optimization			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Building envelope and thermal performance improvements	**High** – can reduce heating and cooling energy requirements across existing and new buildings while improving the conditions for electrification	**Ready now** – insulation, envelope and building-system technologies are mature, although large-scale adoption depends on retrofit rates, workforce capacity and building characteristics	**Scale standardized and industrialized approaches to building renovation and retrofit delivery** [Infrastructure & Supply Chains]
			Advance deployment of high-performance building materials and integrated efficiency technologies [Innovation & Technology]
			Strengthen market and financing conditions for large-scale building retrofit investment [Market & Finance]
High-efficiency appliances and cooling equipment	**Moderate** – can materially reduce electricity and energy requirements for rapidly growing cooling and appliance services	**Ready now** – high-efficiency appliances and cooling technologies are commercially mature, although adoption remains uneven across markets	**Accelerate innovation and deployment of high-efficiency cooling and appliance technologies** [Innovation & Technology]
			Scale manufacturing and supply chains for high-efficiency equipment [Infrastructure & Supply Chains]
			Strengthen product-performance and market conditions that accelerate uptake of efficient equipment [Institutional Planning & Coordination]
Demand-side flexibility and smart energy management	**Moderate** – can optimize electricity use, reduce peak pressures and facilitate the integration of increasingly electrified building loads, but its direct fossil fuel displacement is more indirect	**Scaling phase** – many digital and control technologies are mature, but wider adoption requires smart infrastructure, interoperability and mechanisms for coordinated demand management	**Expand smart metering, connected devices and digital infrastructure for flexible building loads** [Infrastructure & Supply Chains]
			Advance automation, control systems and interoperable smart-building technologies [Innovation & Technology]
			Enable consumer and building-operator participation in coordinated demand-side management [Behavioural & Demand Optimization]

Table A.12: Building - Clean Cooking Access: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Clean cooking access			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Transition to modern clean cooking technologies and fuels	**High** – can substantially reduce reliance on traditional biomass and polluting cooking fuels while lowering the energy required to provide cooking services	**Ready now** – multiple clean cooking technologies are commercially available, although large-scale adoption depends on affordability, reliable energy access and last-mile delivery systems	**Expand last-mile distribution and service networks for clean cooking technologies and fuels** [Infrastructure & Supply Chains]
			Strengthen affordability and financing conditions for sustained household adoption of clean cooking solutions [Market & Finance]
			Integrate clean cooking into broader energy-access planning and support adoption and sustained use [Institutional Planning & Coordination / Behavioural & Demand Optimization]

Industry

Industry accounts for approximately 30% of global coal demand, 22% of global natural gas demand and 20% of global oil demand in 2024[292]. Fossil fuels together account for around 61% of total final energy consumption in the sector, equivalent to approximately 105 EJ. Coal represents the single largest share, accounting for approximately 25% of industrial energy consumption, while oil and natural gas contribute approximately 19% and 17%, respectively. Electricity accounts for around 23%, while modern solid bioenergy and heat supply the remaining shares, at around 6% and 5%.

This energy mix results in a significant emissions footprint, reflecting both direct fossil fuel combustion and industrial process emissions, as well as the emissions intensity of electricity supply. In 2024, industry accounted for nearly 24% of global CO_2 emissions from fossil fuel combustion and industrial processes, totaling approximately 9.1 $GtCO_2$.

Given the significant differences in energy intensity, process requirements and technological substitution options across industrial activities, the analysis distinguishes between light and heavy industry. Light industry comprises less energy-intensive manufacturing and production activities, including food and tobacco, machinery, textiles, construction, mining and quarrying, transport equipment and wood processing. Heavy industry comprises energy-intensive activities such as iron and steel, chemicals, cement and other non-metallic minerals, aluminum and other non-ferrous metals, and paper and pulp. This distinction allows the analysis to reflect the different technological pathways, deployment conditions and implementation requirements associated with each group[293].

Light industry

a. Current dependence

Light industry remains dependent on fossil fuels across several thermal and combustion-based applications, although this dependence is lower than in heavy industry and more concentrated in lower-temperature processes[294]. Fossil fuels account for almost 60% of light industry energy needs, while electricity accounts for most of the remaining share.

Compared with heavy industry, light industrial activities generally have a larger share of mechanical energy use and low- to medium-temperature heat requirements. This makes a larger portion of residual fossil fuel demand technically accessible to substitution through mature electric technologies and other low-emissions solutions[295].

b. Key demand-side solutions and deployment conditions

Key demand-side solutions for reducing fossil fuel demand in light industry include electrification, energy efficiency and optimization, and sustainable and low-emissions fuels[296].

1. **Electrification provides an important pathway for directly substituting fossil fuel use in mechanical applications and low- to medium-temperature industrial heat.** Industrial heat pumps are a key enabling technology, as they can efficiently replace fossil fuels in many low- and medium-temperature heat applications, while electric boilers and other advanced electric heating technologies can address process requirements that are less suitable for heat pumps[297]. Electric motors and other electric process technologies provide additional substitution opportunities depending on production requirements. Many electrification technologies relevant to light industry are already commercially mature, although adoption readiness varies according to process-temperature requirements, plant configuration and electricity-service conditions and the relative competitiveness of electricity and fossil fuels[298].

Wider deployment depends on the ability to integrate electric technologies into existing facilities, which require modifications to process equipment, heat-distribution systems and site-level electricity infrastructure. These requirements can increase upfront investment, particularly where production systems were designed around fossil fuel-based equipment. Adoption also depends on sufficient electricity-connection capacity, relative energy prices and the availability of engineering and technical skills required to design, install and operate electrified industrial systems[299].

2. **Energy efficiency and optimization can reduce the amount of energy required to deliver industrial output while improving the performance and flexibility of existing production systems[300].** Upgrading equipment, including the adoption of high-efficiency electric motors, variable-speed drives, waste-heat recovery systems, process controls and other energy-management measures, can significantly reduce energy requirements and associated fossil fuel consumption. Digital monitoring and process optimization can provide additional gains by improving equipment utilization and identifying inefficient energy use. As industrial electrification expands, demand-side flexibility and smart electricity management can also enable suitable processes to adjust the timing of electricity consumption without reducing industrial output, supporting more efficient integration of electrified loads. Many of these technologies and measures are already mature and deployable in the near term, although uptake depends on equipment turnover, investment capacity and plant-level implementation capabilities.

Wider deployment can remain limited where firms prioritize investments with very short payback periods, energy represents a relatively small share of total production costs, or efficiency upgrades compete with core production investments for capital[301]. Potential production downtime can further delay projects requiring equipment replacement or process integration. Smaller industrial firms may face additional constraints related to access to finance, technical expertise and project-development capacity. Energy-performance requirements and their enforcement can also influence the pace of adoption. Demand-side flexibility and smart electricity management depend on digital infrastructure, automation capabilities and the ability of industrial processes to adjust operating schedules without affecting production requirements[302].

3. **Sustainable and low-emissions fuels: sustainable bioenergy, biogases and other low-emissions fuels can provide a complementary pathway for thermal applications**[303]**.** Modern bioenergy is already used in several light industrial activities, particularly where biomass residues or other sustainable feedstocks are locally available, while biomethane can substitute natural gas in compatible applications. These solutions are generally more targeted than direct electrification, and their broader contribution depends on sustainable fuel availability, supply-chain conditions and competition for low-emissions fuels from other sectors. Their adoption can also require modifications to burners, fuel-handling systems or production processes, depending on the fuel and application.

The role of sustainable bioenergy and biogases is growing, supported by established supply chains for biomass residues, pellets and biomethane that are already serving industrial and power markets at scale. Biomass residues and pellets can be burned in boilers originally designed for coal, in co-firing or after full conversion, and where feedstock comes from residues and supply chains are efficient they can significantly reduce lifecycle emissions relative to coal; biomethane can be injected into existing gas networks and used without modification in compatible processes; and ethanol, biodiesel and renewable diesel already displace fuel oil and diesel in on-site generation and process heat in several industries. These pathways share the advantage of displacing fossil fuels while making use of existing infrastructure. Their contribution depends on the availability, logistics and competitiveness of sustainable feedstocks and on the design of the supply chain, since emissions savings narrow where feedstock travels long distances or is sourced in ways that affect carbon stocks. Demand for sustainable feedstocks from aviation, shipping and other sectors where electrification is harder is likely to concentrate their use in industry in the applications where they add most value, which argues for planning bioenergy supply alongside electrification and not as a substitute for it.

Overall, light industry presents comparatively broad opportunities for near-term fossil fuel reduction because many relevant electrification and efficiency technologies are already mature. Electrification can directly substitute fossil fuels across a significant range of mechanical and low- to medium-temperature applications, while efficiency and optimization can reduce the energy required for production. Sustainable and low-emissions fuels provide a more targeted complementary pathway where direct electrification is more expensive or its infrastructure more complex. The main challenge is related to the pace and scale at which mature solutions are integrated into diverse industrial processes and existing production assets.

c. Levers to accelerate implementation

Based on the assessment so far, the tables below consolidate the specific demand-side solutions, their relative impact on fossil fuel demand reduction and adoption readiness, and the implementation levers required to accelerate deployment across the three macro solution areas: electrification [Table A.13]; energy efficiency and optimization [Table A.14] and sustainable and low-emissions fuels [Table A.15].

Table A.13: Light industry - Electrification: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Electrification			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Electric heat for low- and medium-temperature processes	**High** – can directly displace fossil fuel use across a broad range of low- and medium-temperature industrial heat applications	**Ready now** – industrial heat pumps, electric boilers and other electric heat technologies are commercially mature, although adoption depends on process integration, electricity-connection capacity and relative energy competitiveness	**Upgrade industrial electricity connections and site-level infrastructure required for large-scale process electrification** [Infrastructure & Supply Chains]
			Accelerate deployment and integration of industrial heat pumps, electric boilers and advanced electric heating technologies [Innovation & Technology]
			Strengthen market, grid-access and planning conditions that improve the competitiveness and integration of industrial electrification [Market & Finance / Institutional Planning & Coordination]

Table A.14: Light industry - Energy Efficiency and Optimization: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Energy efficiency and optimization			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Industrial process and equipment efficiency improvements	**Moderate** – can materially reduce energy and fossil fuel use across a broad range of industrial processes, although it does not directly substitute fossil fuels	**Ready now** – high-efficiency motors, drives, waste-heat recovery and process optimization technologies are commercially mature, although uptake depends on equipment turnover, investment priorities and operational integration	**Accelerate deployment of high-efficiency motors, drives, waste -heat recovery and other process-efficiency technologies** [Innovation & Technology]
			Deploy digital energy-management systems to identify and reduce process energy losses [Innovation & Technology]
			Strengthen investment and performance conditions that accelerate industrial efficiency upgrades [Market & Finance]
Material efficiency and circularity	**Moderate** – can reduce energy and feedstock requirements by increasing material recovery, reuse and resource productivity, although impacts vary considerably across light-industry activities	**Ready now** – many recycling, recovery and resource-efficiency practices are established, although adoption depends on collection systems, material quality and integration across supply chains	**Expand material recovery, recycling and circular supply-chain infrastructure** [Infrastructure & Supply Chains]
			Advance circular processing technologies, product redesign and resource optimization [Innovation & Technology]
			Strengthen coordination and market conditions for recycled-material use and industrial circularity [Institutional Planning & Coordination]
Industrial demand flexibility and load optimization	**Limited** – can improve the integration of electrified industrial loads and reduce peak-related system pressures, but its direct contribution to fossil fuel demand reduction is comparatively indirect	**Ready now** – digital controls, automation and flexible load-management technologies are mature for suitable industrial processes, although participation depends on process flexibility and market arrangements	**Expand smart metering, automation and digital load-management systems** [Innovation & Technology]
			Enable flexible production scheduling and active industrial demand management where operationally viable [Behavioural & Demand Optimization]
			Strengthen market arrangements that enable industrial loads to participate in demand-side flexibility [Market & Finance]

Table A.15: Light industry - Sustainable and Low-emissions Fuels: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Sustainable and low-emission fuels			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Sustainable bioenergy for industrial heat	**Moderate –** sustainable biofuels and biogases can substitute fossil fuels in selected thermal applications where direct electrification is less viable, but broader impact is constrained by sustainable feedstock availability.	**Ready now** – commercially established bioenergy and biofuel pathways can be deployed in compatible industrial heat applications, although broader scale-up depends on sustainable feedstock supply, logistics and plant-level integration	**Expand sustainable biomass supply chains, processing capacity and logistics for industrial applications** [Infrastructure & Supply Chains]
			Advance bioenergy conversion technologies and integration with existing industrial heat systems [Innovation & Technology]
			Establish robust sustainability and certification conditions for industrial bioenergy deployment [Institutional Planning & Coordination]

Heavy industry

a. Current dependence

Heavy industry remains highly dependent on fossil fuels, particularly coal, across several energy-intensive production processes. Fossil fuels represent approximately 70%–75% of total final energy demand in heavy industry, with coal accounting for 35%–40%[304]. The end-use sector accounts for approximately 20%–25% of global fossil fuel demand, including 25%–30% of global coal demand[305].

This dependence varies across subsectors and production processes. In the iron and steel industry, coking coal plays a critical role, serving both as a high-temperature heat source and as a chemical reductant to remove oxygen from iron ore. Currently, around 90% of global primary iron production relies on traditional coal-based blast furnace routes[306].

Cement production presents a different challenge, as fossil fuels are used to provide the high-temperature heat required by kilns while a significant share of sectoral emissions arises directly from the chemical transformation of limestone during clinker production[307]. For aluminum, despite being highly electricity-intensive, other stages of the production process still depend on fossil fuels for high-temperature heat, particularly in alumina refining[308]. These differences mean that fossil fuel dependence in heavy industry is embedded not only in energy supply but also in process technologies, feedstocks and long-lived production assets.

Heavy industries are considered hard-to-abate because they require high-temperature heat and, in several processes, rely on chemical reactions or feedstocks that generate process emissions independently of energy combustion. This makes fossil fuel substitution more complex than in many other end-use sectors and increases the importance of multiple transition pathways, including fuel substitution, process innovation, material and energy efficiency, and solutions for residual process emissions[309].

b. Key demand-side solutions and deployment conditions

Key demand-side solutions for reducing fossil fuel dependence in heavy industry include sustainable and low-emissions fuels, energy efficiency and optimization, and electrification[310]**. These macro-solutions encompass different technological pathways and levels of maturity across industrial subsectors.** Unlike in many light-industry applications, achieving deeper fossil fuel substitution in heavy industry will also depend on continued innovation, demonstration and commercialization of emerging production technologies.

1. **Sustainable and low-emissions fuels: low-emissions hydrogen and sustainable bioenergy can provide important fuel- and feedstock-substitution pathways in heavy industrial processes where direct electrification is more difficult**[311]**.** Low-emissions hydrogen is particularly relevant in primary steelmaking through hydrogen-based direct reduced iron (H_2-DRI), where it can replace coal-based reduction pathways. It can also substitute

unabated fossil-based hydrogen used as a chemical feedstock, including in the production of ammonia and other chemical products. Several hydrogen-based applications are technically demonstrated, although wider adoption remains in a scaling phase and depends on the availability of low-emissions hydrogen, supporting infrastructure and compatible industrial equipment[312]. Deployment is further constrained by the still-limited supply and commercial competitiveness of low-emissions hydrogen, infrastructure requirements and the need for continued innovation and industrial demonstration to improve process integration and viability at scale. Low-emissions hydrogen currently represents less than 1% of global hydrogen demand, while electrolytic hydrogen and hydrogen-derived fuels remain substantially less competitive than fossil-based alternatives, making adoption highly sensitive to electricity and fuel costs.

Sustainable bioenergy can provide a complementary pathway for selected high-temperature heat applications and industrial boilers and kilns. However, its role is likely to remain more targeted given sustainable feedstock constraints and competing uses across sectors[313]. More broadly, adoption of low-emissions fuels can be particularly challenging in globally traded heavy industries, where producers may have limited ability to pass higher production costs through to final markets and where uncertain demand or willingness to pay a premium for lower-emissions products can weaken the business case for investment in new production pathways[314].

2. **Energy efficiency and optimization: material efficiency, circularity and improvements in process performance can reduce both primary material production and the amount of energy required to deliver industrial output[315].** Greater recycling and material recovery can substantially reduce the energy requirements associated with primary production. In steel, greater use of scrap through electric arc furnaces can significantly lower energy requirements relative to conventional primary production routes. In cement, clinker substitution with alternative cementitious materials can reduce both thermal energy requirements and the need for clinker production. Waste-heat recovery, high-efficiency equipment, digital energy-management systems and process optimization can further reduce energy use within existing facilities. Many of these solutions are already commercially mature and can contribute in the near term, although their relative impact varies considerably across industrial subsectors and production routes[316]. Deployment can be constrained by competition for corporate capital, the operational risks associated with modifying continuously operating facilities and slow equipment turnover, particularly where installation requires production downtime or affects process reliability[317].

Material efficiency and circularity face additional constraints related to the availability and quality of secondary materials and the systems required for their collection, sorting and processing[318]. In steel, greater scrap utilization depends on the availability and quality of suitable secondary steel, as variations in composition, impurities and material quality can constrain its use in applications with specific performance or product-quality requirements. Similar limitations apply across other industrial materials, where substitution may require additional treatment or process adaptation to meet final-product specifications.

3. **Electrification: innovative electrification technologies can directly substitute fossil fuels in selected high-temperature and process applications, although their potential remains more constrained than in light industry[319].** Existing electric technologies are already used in several industrial processes, while emerging solutions could extend electrification into applications that currently depend heavily on fossil fuels[320]. In the chemicals sector, electric steam cracking could reduce reliance on fuel combustion in one of the sector's most energy-intensive processes. Emerging electrified kiln technologies are also being tested for high-temperature cement production, while iron ore electrolysis could provide a longer-term pathway for producing iron directly using electricity rather than carbon-based reduction[321]. However, several of these technologies remain at relatively early stages of commercial development and require further demonstration and scale-up. Deployment can also require substantial redesign of process equipment and plant layouts, changes to operating practices, and significantly greater electricity supply and connection capacity at industrial sites, increasing capital intensity and implementation complexity[322].

Complementary emissions-reduction pathways can also play an important role in heavy industry, even where they do not directly reduce fossil fuel dependence. In selected applications, switching from coal to natural gas can reduce emissions intensity by displacing more carbon-intensive coal-based production routes[323]. Carbon capture, utilization and storage (CCUS) can also address process and residual emissions that are difficult to eliminate through changes in energy use alone, particularly in cement, chemicals and other emissions-intensive industrial processes[324]. However, because these pathways do not necessarily deliver structural fossil fuel substitution, they are treated separately from the demand-side solutions assessed through the relative impact and adoption-readiness framework.

Overall, heavy industry presents a more heterogeneous and technologically complex transition than light industry because fossil fuels are embedded in high-temperature heat, chemical feedstocks and long-lived production processes[325]. Sustainable and low-emissions fuels can provide structural fossil fuel substitution in selected applications, while energy efficiency, material efficiency and circularity can reduce both primary production requirements and energy use. Electrification provides an additional pathway for selected high-temperature and process applications as emerging technologies mature and scale**.** Innovation plays a particularly important role in heavy industry, where several of the technologies required for deeper fossil fuel substitution still need further demonstration, commercialization and integration into industrial production systems[326]. The transition depends on combining mature near-term efficiency and circularity measures with the continued scale-up of sustainable fuels and innovative electrification pathways required for deeper process transformation.

4. **Levers to accelerate implementation**

Based on the assessment so far, the tables below consolidate the specific demand-side solutions, their relative impact on fossil fuel demand reduction and adoption readiness, and the implementation levers required to accelerate deployment across the three macro solution areas: sustainable and low-emissions fuels [Table A.16]; energy efficiency and optimization [Table A.17] and electrification [Table A.18].

Table A.16: Heavy industry - Sustainable and Low-emissions Fuels: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Sustainable and low-emission fuels			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Hydrogen-based steelmaking and industrial feedstock substitution	**High** – can directly replace coal-based reduction in primary steelmaking and fossil-based hydrogen in selected chemical feedstock applications	**Long-term transformation** – key applications are technically demonstrated and early commercial deployment is emerging, but broad adoption requires substantial expansion of low-emissions hydrogen supply, infrastructure and industrial production capacity	**Develop low-emissions hydrogen supply, transport and storage infrastructure for major industrial demand centres** [Infrastructure & Supply Chains]
			Advance demonstration, commercialization and process integration of hydrogen-based industrial production technologies [Innovation & Technology]
			Coordinate hydrogen production, infrastructure and industrial demand across suitable industrial clusters [Institutional Planning & Coordination]
Sustainable bioenergy for high-temperature industrial heat	**Moderate** – can substitute fossil fuels in selected high-temperature heat applications, but its overall contribution is constrained by sustainable feedstock availability and competing uses	**Ready now** – commercially established bioenergy technologies can be deployed in compatible industrial boilers, kilns and thermal processes, although broader scale-up depends on sustainable feedstock supply and logistics	**Expand sustainable biomass supply chains, processing capacity and industrial fuel logistics** [Infrastructure & Supply Chains]
			Adapt and optimize industrial boilers, kilns and thermal processes for sustainable bioenergy use [Innovation & Technology]
			Strengthen sustainability and resource-allocation conditions for industrial bioenergy deployment [Institutional Planning & Coordination]

Table A.17: Heavy industry - Energy Efficiency and Optimization: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Energy efficiency and optimization			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Recycling, material efficiency and circularity	**High** – can reduce fossil fuel and energy requirements by avoiding part of energy-intensive primary material production and increasing the use of secondary materials	**Ready now** – recycling, material recovery and resource-efficiency practices are commercially established, although deployment depends on secondary-material availability, quality and integrated recovery systems	**Expand collection, sorting, recycling and secondary-material infrastructure** [Infrastructure & Supply Chains]
			Advance material recovery, processing and product-design solutions that increase the use and quality of secondary materials [Innovation & Technology]
			Strengthen coordination across circular supply chains and industrial material flows [Institutional Planning & Coordination]
Industrial process efficiency and waste-heat recovery	Moderate – can materially reduce energy and fossil fuel requirements across existing heavy-industry facilities, although it does not generally provide direct fossil fuel substitution	**Ready now** – high-efficiency equipment, waste-heat recovery and process-optimization technologies are commercially mature, although adoption can be constrained by asset turnover, investment priorities and production-disruption risks	**Expand integration and utilization of recoverable industrial waste heat** [Infrastructure & Supply Chains]
			Deploy high-efficiency equipment, advanced process controls and digital energy-management systems [Innovation & Technology]
			Optimize industrial operations and maintenance to reduce process energy losses [Behavioural & Demand Optimization]

Table A.18: Heavy industry - Electrification: specific demand-side solutions, impact, readiness and levers

Macro demand-side solution: Electrification			
Specific demand-side solution	**Relative impact**	**Adoption readiness**	**End-use implementation levers**
Electrification of high-temperature industrial processes	**Moderate** – can directly displace fossil fuels in selected high-temperature industrial processes, but its overall contribution is constrained by process-specific technical requirements and limited applicability across heavy-industry activities	**Long-term transformation** – several high-temperature electrification technologies remain at demonstration or early commercial stages and require further process development, infrastructure expansion and industrial integration	**Expand industrial electricity connections and site-level power infrastructure for large electrified process loads** [Infrastructure & Supply Chains]
			Accelerate development and deployment of electric furnaces, electric steam crackers, electrified kilns and iron ore electrolysis technologies [Innovation & Technology]
			Strengthen process integration and industrial planning for large-scale electrification of heavy-industry facilities [Institutional Planning & Coordination]

APPENDIX B. COAL SENSITIVITY ANALYSIS

The Belém Readiness Approach is designed to support implementation of the transition away from all fossil fuels (coal, oil and natural gas). Across the demand-side, supply-side and economic pillars, its framework provides a common structure through the Readiness Indexes, archetypes, foundational levers and archetype-specific implementation levers. Countries and other stakeholders can use these elements to assess their structural conditions and identify implementation priorities in line with national circumstances.

Coal-dependent energy systems present structural characteristics that can affect how some of the indicators should be interpreted. To account for these differences while preserving the common structure of the framework, the COP30 Presidency suggests a coal sensitivity analysis of the existing Readiness Indexes. The sensitivity analysis does not establish a separate coal-specific index or modify the underlying exposure-and-capacity logic. Instead, it identifies the indicators for which coal-specific conditions may require additional attention, disaggregation or interpretation across the three pillars.

In practical terms, the coal sensitivity analysis should be applied after the relevant Demand-side, Supply-side and Economic Readiness Indexes have been considered. It provides an additional interpretative lens for countries with significant coal dependence, allowing them to identify where aggregate indicators may mask coal-specific exposures or capabilities. These insights can then be used to refine the interpretation of a country's archetype and, within the corresponding implementation pathway, determine which foundational and archetype-specific levers require greater emphasis, adaptation or earlier action. Therefore, the sensitivity analysis does not change the structure of the framework or automatically reassign countries across archetypes; it sharpens how the framework is interpreted and applied in coal-dependent contexts.

Some characteristics are particularly relevant to justify this differentiated reading:

Demand-side: direct coal use is concentrated in selected energy-intensive industrial activities, while coal-fired power can indirectly shape end-use transition pathways through the electricity consumed across sectors. This concentration means that coal-dependent economies may face particularly significant transition challenges in heavy industry and in the electrification of end uses where power generation remains coal-intensive[327]. Rapid growth in energy and electricity demand can further reinforce this exposure where additional demand is met through new coal-dependent assets with long operating lifetimes[328] [Table B.1].

Table B.1: Demand-side coal sensitivity analysis

Dimension	Indicator	Coal-specific consideration
Demand-side Exposure	Fossil fuel share in final energy consumption	**High relevance.** Disaggregate coal from oil and gas. Coal demand is concentrated in heavy industry and electricity-related uses, so a high fossil fuel share driven by coal implies a different transformation pathway than one driven primarily by oil and gas
	Energy intensity and efficiency of final energy use	**Limited relevance.** Coal-intensive industrial economies tend to be energy-intensive, but the indicator operates at aggregate level without requiring coal disaggregation
	Growth in final energy and electricity demand	**High relevance.** In coal-dependent systems, coal often remains the marginal fuel meeting electricity and industrial demand growth. Rapid growth can lock in new coal assets with long operating lifetimes
	End-use sector composition (hard-to-abate sectors)	**High relevance.** Coal demand is concentrated in hard-to-abate industrial activities. Attention should be given to the share of industrial demand linked to coking coal and other coal-intensive processes
Demand-side Transition Capacity	Electrification and adoption of low-emissions end-use technologies	**Moderate relevance.** Electrification and low-emissions end-use technologies can reduce direct fossil fuel use, but their effect on coal demand depends on the power-generation mix. In coal-intensive power systems, rising electrification can sustain or increase coal demand
	Access, affordability and quality of modern energy services	**Limited relevance.** This indicator captures service outcomes rather than fuel source, so coal-specific treatment generally adds limited analytical value
	Digitalization and demand-side management capabilities	**Limited relevance.** Fuel-neutral by design, this indicator is relevant across demand systems regardless of fuel mix
	Institutional planning and governance capacity	**High relevance.** Coal transition requires specific governance instruments, including just transition plans, managed plant retirement frameworks, and regional workforce and economic-diversification strategies

Supply-side: coal dependence can create distinct challenges for power-system transformation, domestic resource dependence and the transition of existing assets and infrastructure. In many coal-dependent systems, continued coal production and use do not respond primarily to international cost competitiveness, but reflect domestic resource availability, energy-security considerations and the integration of coal-fired generation within existing power systems. Coal trade exposure can also be less significant than for oil and natural gas where domestic production primarily serves domestic consumption. Transitioning away from coal requires the parallel expansion of reliable, secure and affordable low-emissions supply, together with adequate networks, storage, interconnections and other sources of system flexibility[329]. Coal production, generation assets and associated infrastructure can also be concentrated in regions, increasing the importance of coordinated asset-retirement and repurposing strategies, power-system planning and regional transition frameworks[330] [Table B.2].

Table B.2: Supply-side Coal Sensitivity Analysis

Dimension	Indicator	Rationale
Supply-side Exposure	Fossil fuel share in primary energy supply	**High relevance**. Disaggregate coal from oil and gas where possible. Coal supply is concentrated particularly in power generation, so a high fossil fuel share implies different supply-transition requirements from one driven primarily by oil or natural gas
	Fossil fuel import and export dependence	**Moderate relevance.** Coal trade exposure varies substantially across countries. In many coal-producing economies, domestic production primarily serves domestic consumption, reducing the importance of external trade dependence relative to oil and natural gas. For countries with significant coal imports or exports,, trade exposure can remain relevant to energy security and supply-transition planning
	Fossil fuel reserves	**High relevance.** Large coal reserves and long reserve-to-production horizons can reinforce production persistence and long-term fossil fuel lock-in. Coal assets may also face different displacement dynamics from oil and natural gas
	Production competitiveness	**Limited to moderate relevance.** Coal production and use do not always respond primarily to international cost competitiveness. In many coal-dependent systems, continued production reflects domestic resource availability, energy-security considerations and integration with existing power and industrial infrastructure
Supply-side Transition Capacity	Competitiveness of low-emissions alternative	**Moderate relevance.** Low-emissions alternatives are increasingly cost-competitive in power generation, but relative cost alone may not determine the pace of coal displacement. Domestic resource availability, energy-security considerations, system reliability and the availability of enabling infrastructure are important factors of coal use
	Infrastructure readiness and system flexibility	**High relevance.** Coal-fired generation can provide firm and dispatchable electricity in many power systems. Reducing coal dependence therefore requires adequate networks, storage, interconnections, demand-side flexibility and other sources of system flexibility alongside the expansion of low-emissions supply
	Project development and supply chain capacity	**Moderate relevance.** Coal-dependent regions may already possess industrial, engineering and infrastructure capabilities that can support the development of new energy projects. Repurposing existing assets and capabilities, however, may require targeted project development, workforce adaptation and supply-chain transformation
	Institutional planning and governance capacity	**High relevance.** Coal transition requires specific planning and governance arrangements, including coordinated asset-retirement and repurposing strategies, power-system planning, regional transition frameworks and coordination across national and subnational institutions

Economic: coal dependence can generate concentrated fiscal, employment and regional adjustment challenges. The economic structure of coal dependence can differ from that associated with oil and natural gas[331]. In many economies, coal may represent a more limited share of national fiscal revenues and export earnings, while employment, local economic activity and associated infrastructure remain highly concentrated in specific producing regions. Coal-dependent economies may consequently face significant subnational adjustment needs even when aggregate national economic exposure appears more limited[332]. Coal mines, power plants, transport infrastructure and associated industrial assets can also create significant stranded-asset exposure as coal use declines. This makes employment dependence, regional diversification, stranded-asset exposure and institutional capacity particularly important considerations in assessing economic transition readiness[333] [Table B.3].

Table B.3: Economic Transition Coal Sensitivity Analysis

Dimension	Indicator	Rationale
Economic Exposure	Dependence on fossil fuel revenues	**Moderate relevance.** Coal-related revenues can be important in specific producing regions, but national fiscal dependence is often more limited than in oil- and gas-dependent economies. Coal-specific disaggregation may be particularly relevant where royalties, production taxes or public revenues are concentrated in coal-producing regions
	Dependence on fossil fuel trade	**Moderate relevance.** Coal trade exposure varies significantly across countries. In many coal-producing economies, domestic production primarily serves domestic consumption, limiting the macroeconomic relevance of external trade relative to oil and natural gas
	Employment dependence	**High relevance.** Coal-related employment is often geographically concentrated in mining regions and associated industrial clusters, making employment dependence and regional adjustment particularly important even where national-level economic exposure is limited
	Exposure to stranded assets	**High relevance.** Coal mining assets, power plants, transport infrastructure and associated industrial facilities can face significant stranded-asset risks as coal use declines, particularly where assets are relatively young, long-lived or regionally concentrated
Economic Transition Capacity	Access to affordable finance	Moderate relevance. Coal-dependent economies may face higher perceived transition risks and financing constraints, while access to concessional finance, risk-sharing instruments and transition finance can support asset repurposing, economic diversification and new investment
	Macroeconomic and fiscal stability	**Moderate relevance.** Where coal-related revenues, employment or trade are economically significant, declining coal activity can create fiscal and macroeconomic pressures. The relevance of this indicator depends on the scale and concentration of coal-related economic exposure
	Innovation and productive capabilities	**Moderate relevance.** Coal-dependent regions may require stronger innovation, industrial diversification and workforce capabilities to develop alternative sources of economic activity and redeploy existing productive capabilities beyond coal-related value chains
	Institutional planning and governance capacity	**High relevance.** Coal transition often requires coordination across national and subnational institutions, including regional transition planning, workforce strategies, asset repurposing and economic-diversification policies. Strong institutional capacity is particularly important where coal-related economic activity is geographically concentrated

The coal sensitivity analysis is intended to support countries with significant coal dependence in interpreting individual indicators within their own energy and economic context. By identifying where coal-specific conditions warrant greater attention, disaggregation or interpretation, countries can refine their understanding of demand-side, supply-side and economic exposure and transition capacity. This can, in turn, sharpen the interpretation of their archetype and inform how the corresponding implementation pathway is applied, including which foundational and archetype-specific levers may require greater emphasis, adaptation or earlier action. The analysis can also identify existing capabilities that may facilitate implementation and areas in which earlier progress may be feasible.

Importantly, the coal sensitivity analysis complements and does not duplicate the framework. While coal presents structural characteristics that differ in important respects from oil and natural gas, these differences can be captured through the same overarching logic of exposure, transition capacity and implementation readiness. The sensitivity analysis adds specificity to this common structure by indicating where coal dependence may affect the interpretation of an indicator, the characterization of an archetype or the relative priority and sequencing of implementation levers. Maintaining a common framework also enables countries with different fossil fuel profiles, including economies dependent on more than one fossil fuel, to assess their transition through a consistent analytical structure.

The sensitivity analysis does not prescribe a uniform sequencing of coal, oil and natural gas transition. The appropriate pace and sequencing will depend on country-specific structural conditions, including energy-security requirements, the availability and competitiveness of low-emissions alternatives, infrastructure readiness, emissions intensity, economic dependence, asset characteristics and institutional capacity. These conditions are reflected across the demand-side, supply-side and economic Readiness Indexes and can inform differentiated implementation pathways consistent with a just, orderly and equitable transition.

Summary: How to use the coal sensitivity analysis

1. **Assess:** apply the relevant demand-side, supply-side and economic Readiness Indexes, following the Belém Readiness Approach.

2. **Interpret:** use the coal sensitivity analysis to identify indicators for which coal-specific conditions require additional attention or disaggregation.

3. **Refine:** consider whether these conditions affect the interpretation of exposure, transition capacity and the resulting archetype.

4. **Prioritize:** use these insights to determine which foundational and archetype-specific levers require greater emphasis, adaptation or earlier action.

5. **Sequence:** consider coal-specific energy-system, asset, regional and socioeconomic conditions when determining the timing and sequencing of implementation.

APPENDIX C. FIRST STEPS BY ARCHETYPE: SEQUENCING PRIORITIES OF SPECIFIC IMPLEMENTATION LEVERS IN THE THREE PILLARS

Demand-side perspective

Archetype: Demand transition constrained (High demand exposure · Low transition capacity)

Sequencing priorities to foster implementation

1. **Avoid new fossil fuel lock-in while meeting rapidly growing energy demand**
   Meet expanding demand by directing it towards electrified and other low-emissions energy solutions wherever technically and economically viable

2. **Build enabling conditions for demand-side transformation**
   Improve electricity services, strengthen planning capabilities and develop the digital and institutional foundations of modern energy systems

3. **Promote efficient and sustainable energy use**
   Accelerate energy-efficient technologies, encourage behavioral change and align urban development and industrial expansion with long-term transition objectives

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Demand transition reformers (High demand exposure · High transition capacity)

Sequencing priorities to foster implementation

1. **Accelerate the replacement of fossil fuel use across mature demand systems**
   Expand commercially competitive electrification, low-emissions energy solutions and integrated transition pathways for hard-to-abate sectors

2. **Optimize increasingly electrified demand systems**
   Deploy advanced digital energy management, strengthen demand-side flexibility and enable active consumer participation

3. **Remove remaining barriers to widespread adoption**
   Replace long-lived fossil fuel technologies and practices, improve the affordability of low-emissions solutions and enable consumers and businesses to participate actively in demand-side transformation

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Demand vulnerable (Low demand exposure · Low transition capacity)

Sequencing priorities to foster implementation

1

Build modern energy demand systems as access expands

Accelerate the transition from basic electricity access to modern energy services and direct growing demand towards electrified and low-emissions end-use applications

2

Avoid future fossil fuel lock-in

Replace traditional biomass with modern energy solutions and integrate long-term transition objectives into energy access planning

3

Strengthen the quality and efficiency of emerging demand systems

Promote decentralized digital solutions and improve energy efficiency among households and businesses

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Demand-side front-runners (Low demand exposure · High transition capacity)

Sequencing priorities to foster implementation

1

Complete the remaining demand-side transition

Accelerate integrated pathways for hard-to-abate sectors and address residual barriers to the widespread adoption of low-emissions technologies

2

Optimize mature demand systems

Deploy advanced digital energy management, strengthen demand-side flexibility and enable active consumer participation while maintaining reliable, affordable and high-quality energy services

3

Strengthen international leadership

Create lead markets for next-generation low-emissions energy solutions and promote international cooperation

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Supply-side perspective

Archetype: Supply transition constrained (High supply exposure - Low transition capacity)

Sequencing priorities to foster implementation

1. **Transform the energy supply mix**
   Reduce dependence on fossil fuels while expanding competitive low-emissions energy systems
2. **Build the enabling environment for supply-side transformation**
   Strengthen infrastructure, institutional capacity and implementation capabilities to accelerate investment and project delivery
3. **Enhance the competitiveness and sustainability of the energy sector**
   Develop domestic industrial capabilities, strengthen low-emissions supply chains and reduce emissions from remaining fossil fuel production

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Supply Exposed but capable (High supply exposure · High transition capacity)

Sequencing priorities to foster implementation

1. **Diversify the energy supply mix**
   Manage the orderly transition of fossil fuel production while accelerating the expansion of competitive and diversified low-emissions energy systems
2. **Redirect infrastructure and industrial capabilities**
   Reorient existing infrastructure and industrial capabilities towards emerging energy industries and strategic value chains
3. **Reinforce the competitiveness of low-emissions energy supply**
   Strengthen supportive market conditions, while reducing operational emissions from remaining fossil fuel production

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Supply Structurally vulnerable (Low supply exposure · Low transition capacity)

Sequencing priorities to foster implementation

1. **Strengthen reliable, affordable and secure energy systems**
   Expand renewable energy, sustainable fuels and the infrastructure needed to improve energy system resilience
2. **Build the enabling environment for supply-side transformation**
   Strengthen institutional capacity, improve project delivery and reinforce public-private collaboration
3. **Enhance long-term energy resilience**
   Advance regional cooperation and cross-border infrastructure while supporting the orderly retirement and repurposing of ageing or uncompetitive fossil fuel assets

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Supply Transition ready (Low supply exposure · High transition capacity)

Sequencing priorities to foster implementation

1. **Expand low-carbon energy systems**
   Strengthen system flexibility, expand sustainable fuels and maximize the integration of renewable energy
2. **Optimize the enabling environment for low-carbon energy systems**
   Improve regulatory frameworks, market design and strategic value chains to support long-term system performance and resilience
3. **Provide international leadership for the supply-side transition**
   Advance regulatory cooperation, promote common market standards and share knowledge and implementation experience to accelerate low-emissions energy systems globally

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Economic perspective

Archetype: Economic transition constrained (High economic exposure · Low transition capacity)

Sequencing priorities to foster implementation

1. **Strengthen fiscal resilience**
   Improve the management of existing revenues, mobilize domestic resources and expand fiscal space
2. **Mobilize investment and productive diversification**
   Leverage concessional finance, private capital, technology adoption and innovation to support new economic activities
3. **Enable an inclusive structural transition**
   Promote workforce reskilling and regional economic diversification to reduce long-term dependence on fossil fuels

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Economically Exposed but resilient (High economic exposure · High transition capacity)

Sequencing priorities to foster implementation

1. **Reallocate existing financial resources**
   Redirect fossil fuel revenues, sovereign wealth and public investment towards future growth sectors
2. **Accelerate industrial transformation**
   Strengthen capital markets and innovation ecosystems while expanding participation in low-emissions and strategic value chains
3. **Manage an orderly transition**
   Support fossil-dependent workers and regions while maintaining long-term competitiveness

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Economically vulnerable (Low economic exposure · Low transition capacity)

Sequencing priorities to foster implementation

1. **Strengthen enabling conditions for investment**
   Improve macroeconomic resilience, expand fiscal capacity, strengthen domestic financial systems and enhance the investment climate
2. **Build domestic capabilities**
   Foster innovation ecosystems, productive capabilities, technology absorption and human capital
3. **Expand access to finance and knowledge**
   Mobilize concessional finance, facilitate technology transfer and strengthen international partnerships to support productive transformation

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

Archetype: Economically diversified (Low economic exposure · High transition capacity)

Sequencing priorities to foster implementation

1. **Maintain domestic leadership**
   Sustain macroeconomic resilience, advanced manufacturing and innovation capabilities
2. **Shape international markets**
   Advance certification, green public procurement partnerships, standards and industrial cooperation to expand demand for low-emissions products
3. **Support the global transition**
   Mobilize international finance, technology, innovation and partnerships for developing and emerging economies

Steps overlap in practice; the sequence indicates where attention is most needed first, not a fixed order

APPENDIX D. GLOSSARY

Adoption readiness: the extent to which an end-use solution can be deployed at scale, considering technological maturity, degree of commercialization, infrastructure, market development and other enabling conditions required for implementation. The Roadmap distinguishes three broad categories: Ready now, Scaling phase and Long-term transformation.

Archetypes: illustrative and dynamic analytical profiles derived from different combinations of exposure and transition capacity. They group countries facing broadly similar transition conditions to help identify common strengths, constraints, opportunities and differentiated implementation priorities. Archetypes are not rankings, fixed country classifications or prescriptive pathways.

Archetype-specific implementation levers: differentiated strategic priorities associated with the structural conditions, exposure and transition capacity of each archetype. They identify the transformations most relevant to strengthening readiness in each context and recognize the complementary roles of main and supporting actors.

Break-even cost: the oil or gas price required for a project to become commercially viable, reflecting capital and operating costs, fiscal terms and resource characteristics.

Capital lock-in: the stock of capital already committed to long-lived fossil fuel and carbon-intensive assets, which can increase the cost and complexity of shifting investment and economic activity toward alternative systems.

Carbon capture, utilization and storage (CCUS): a set of technologies that capture carbon dioxide from industrial or energy-related processes and either use it in products or processes or transport it for permanent storage. Within the Roadmap, CCUS is considered relevant for reducing process-related and residual emissions that are difficult to eliminate through changes in energy use alone.

Clean energy: renewable energy, electricity grids, storage, low-emissions fuels, energy efficiency and electrification.

Coal sensitivity analysis: a complementary interpretative lens applied to the existing demand-side, supply-side and economic Readiness Indexes in countries where coal plays a particularly important role. It identifies indicators for which coal-specific conditions may require additional attention, disaggregation or interpretation, without establishing a separate coal-specific framework or changing the underlying exposure-and-capacity methodology.

Demand response: changes in electricity consumption by consumers or businesses in response to system conditions, prices or other signals, helping improve demand-side flexibility and balance electricity supply and demand.

Demand-side management: measures, policies and technologies that influence when and how energy is consumed, including energy efficiency, demand response, pricing and other approaches that optimize consumption and flexibility.

Digitalization: the use of digital technologies: sensors, software, data analytics, artificial intelligence (AI) and automated control systems, to monitor, manage and optimize energy consumption. These technologies support greater energy efficiency and demand-side flexibility, enabling consumers to adjust energy use in response to energy-system conditions.

Economic Transition Readiness Index: an analytical tool designed to support countries in assessing their preparedness to manage the economic transformation associated with the transition away from fossil fuels and identify differentiated implementation priorities. It is structured around two complementary dimensions: Economic Exposure, which captures the extent to which countries remain structurally exposed to fossil fuel-related economic activities, and Economic Transition Capacity, which captures countries' ability to manage structural transformation and build new sources of sustainable growth.

E-fuels: synthetic fuels produced using low-emissions hydrogen and other inputs, providing a potential pathway for replacing conventional fossil fuels in applications where direct electrification is difficult. In the Roadmap, e-fuels are considered particularly in the context of longer-term aviation fuel substitution.

Electrification: the increasing use of electricity to meet energy needs across end-use sectors, including industry, transport and buildings, replacing the direct use of fossil fuels through electricity-powered technologies and processes. Electrification can reduce overall energy consumption through efficiency gains, while its decarbonization benefits depend on both these efficiency improvements and the emissions intensity of the electricity supplied, which can be generated from fossil fuel or low-emissions sources.

End-use implementation levers: strategic actions and enabling changes needed to support the adoption and scaling of specific solutions across end-use sectors. They describe what needs to change to enable deployment at scale and are grouped into five categories: Infrastructure & Supply Chains; Innovation & Technology; Market & Finance; Behavioral & Demand Optimization; and Institutional Planning & Coordination.

Energy efficiency: the ability to provide the same or a greater level of useful energy services or economic output while consuming less energy.

Energy intensity: the amount of energy required to generate a unit of economic output, providing a broad indication of the energy requirements of an economy.

Energy Demand Transition Readiness Index: an analytical tool designed to support countries in assessing their preparedness to undertake the demand-side transition and identify differentiated implementation priorities. It is structured around two complementary dimensions: Demand-side Exposure, which captures the scale and complexity of the transformation required to reduce fossil fuel dependence, and Demand-side Transition Capacity, which assesses countries' ability to implement that transformation through technological, service-access, digital, institutional and planning capabilities.

Energy Supply Transition Readiness Index: an analytical tool designed to support countries in assessing their preparedness to undertake the supply-side transition and identify differentiated implementation priorities. It is structured around two complementary dimensions: Supply-side Exposure, which captures the scale, persistence and characteristics of fossil fuel supply systems, and Supply-side Transition Capacity, which assesses countries' ability to develop and integrate reliable, secure and affordable low-emissions energy systems.

Exposure: the dimension of transition readiness that captures the scale, persistence and complexity of the transformation required to reduce dependence on fossil fuels. Its specific characteristics vary across the demand-side, supply-side and economic pillars.

Fossil fuel lock-in: the persistence of fossil fuel consumption resulting from long-lived end-use technologies, infrastructure and consumption patterns that constrain or slow the adoption of low-emissions alternatives.

Foundational levers: actions that are broadly relevant across readiness profiles within each pillar and establish or strengthen the institutional, regulatory, technological, financial and systemic enabling conditions required for transition implementation.

Green premium: the additional cost of a low-emissions product, technology or production process relative to its conventional fossil fuel-based alternative. The size of the premium can vary across technologies, sectors, countries and stages of market development.

Hard-to-abate sectors: activities within end-use sectors where reducing greenhouse gas emissions is particularly challenging due to technological, thermodynamic, economic or structural constraints. These activities are also often described as hard-to-decarbonize or hard-to-electrify.

Independent oil and gas producer: a non-state-owned oil and gas producer operating independently of the major integrated international oil companies, often with a stronger focus on exploration and production. Independent producers can be particularly relevant in short-cycle and market-responsive supply and may adjust investment more rapidly to changing market conditions.

Integrated TAFF Readiness Framework: the framework that combines the Energy Demand Transition Readiness Index, Energy Supply Transition Readiness Index and Economic Transition Readiness Index, providing countries with an integrated basis for self-assessing their preparedness to manage the transition away from fossil fuels in a just, orderly and equitable manner.

International oil company (IOC): a privately owned or publicly listed oil and gas company with operations across multiple countries. IOCs generally operate on a commercial basis and can play an important role through their technical capabilities, access to capital, experience in complex projects and research and development capacity.

Leapfrogging: the opportunity to move directly toward more efficient and low-emissions energy or productive systems while avoiding some forms of legacy fossil-fuel infrastructure and technological lock-in, where enabling conditions allow.

Low-emissions energy: energy sources and solutions that generate substantially lower greenhouse gas emissions than conventional fossil-fuel alternatives, including renewable energy, nuclear energy and sustainable low-emissions fuels, depending on the application.

Low-emissions fuels: liquid and gaseous fuels with substantially lower lifecycle greenhouse gas emissions than conventional fossil fuels, including sustainable biofuels, low-emissions hydrogen and hydrogen-based synthetic fuels.

National oil company (NOC): an oil and gas company wholly or substantially owned or controlled by a national government. NOCs can combine commercial activities with roles connected to national resource, energy and economic strategies and therefore can have significant influence over long-term production and investment decisions. The Roadmap highlights their particularly significant role in global production and reserves.

Operational emissions: greenhouse gas emissions associated with the operation of energy-production assets and related activities. In the oil and gas context, the Roadmap uses the term primarily to refer to Scope 1 and Scope 2 emissions and excludes emissions from the end use of sold fossil fuels.

Relative impact: a sector-specific assessment of the potential contribution of an end-use solution to reducing fossil fuel demand relative to other solutions within the same sector. It should not be interpreted as a comparison of absolute fossil fuel reductions across different end-use sectors.

Stranded assets: assets that may face early retirement, repurposing, refinancing or loss of economic value as market, technological or policy conditions change during the transition, creating potential financial losses.

Structural factors: relatively persistent characteristics embedded in the underlying configuration of economic, energy, institutional and productive systems. They differ from conjunctural, cyclical or temporary conditions, which are more closely associated with short-term fluctuations, shocks or changing market conditions.

Supporting ecosystem: the broader set of international organizations, financial institutions, development partners, research institutions, private-sector actors and other stakeholders that can support countries through finance, technology, data, capacity building, technical assistance and implementation support.

Sustainable aviation fuel (SAF): sustainable liquid fuels that can substitute conventional jet fuel while making use of established aviation fuel infrastructure and operational practices. The Roadmap considers pathways including bio-based fuels and alcohol-to-jet fuels.

System flexibility: the ability of an energy system to balance supply and demand and accommodate changing or variable generation and consumption patterns while maintaining reliability and security, supported by resources such as storage, demand response, interconnections and firm capacity.

TAFF Tripod: a graphical representation of transition readiness across the three pillars of the Integrated TAFF Readiness Framework. Each vertex represents one pillar: demand, supply or economic, and reflects the readiness level resulting from the interaction between exposure and transition capacity within the corresponding Readiness Index.

Transition capacity: the dimension of transition readiness that captures the capabilities and enabling conditions available to implement the required transformation, including technological, infrastructure, institutional, financial, productive and other relevant capabilities depending on the pillar. The Roadmap explicitly treats exposure and transition capacity as complementary dimensions.

Useful energy: energy effectively available to provide an energy service after accounting for conversion losses between final energy consumption and the service delivered.

APPENDIX E. ENDNOTES

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38. **Structural factors** are defined as relatively persistent characteristics embedded in the underlying configuration of economic, energy, institutional and productive systems. They differ from conjunctural, cyclical or temporary conditions, which are more closely associated with short-term fluctuations, shocks or changing market conditions.

39. **Digitalization**: refers to the use of digital technologies, including sensors, software, data analytics and automated control systems, to monitor, manage and optimize energy consumption. These technologies support greater energy efficiency and demand-side flexibility, enabling consumers to adjust energy use in response to energy system conditions

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77. **Hard-to-abate sectors:** activities within end-use sectors where reducing greenhouse gas (GHG) emissions is particularly challenging due to technological, thermodynamic, economic or structural constraints. These activities are also often described as hard-to-decarbonize and hard-to-electrify

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103. Throughout this section, the steps identified for each archetype overlap in practice, and their sequence indicates where attention is most needed first, not a fixed order.

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214. Differences in countries' development conditions are reflected across several indicators used to assess transition capacity, including access to finance, institutional capacity, infrastructure, technological capabilities, productive structure and innovation systems. Development stage is not treated as a separate analytical dimension but is reflected through the underlying conditions captured by the framework.

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