

COP30 TAFF Roadmap Submission – GRA

From an energy–systems perspective, the fastest and most applicable pathway to transition away from fossil fuels is to build abundant renewable supply, expand grids and storage, and electrify end–use demand; the “electrotech” transition. Electrotech brings together rapidly scaling technologies across generation, flexibility and end use, including solar, wind, pumped storage hydropower, short and long storage, demand–side management, electric vehicles (EVs) and heat pumps and green hydrogen (including its derivatives) for selected hard–to–abate applications ([GRA and Ember, 2025](#)). This is not only a climate strategy, but also an energy security strategy. Such technologies cuts exposure to fossil fuel price shocks, reduces import dependence, and strengthen resilience by shifting economies toward domestically available and increasingly low–cost electricity ([GRA, 2026](#)).

Question (a): What are the most critical barriers – whether physical, economic, financial, institutional, technological or social – preventing a transition away from fossil fuels?

The main barriers to transitioning away from fossil fuels do not lie in the absence of alternatives. They lie in the weakness of the systems needed to deploy those alternatives at speed and scale.

Financial and economic barriers: The largest financial barrier is the gap between where renewable energy investment is needed and where it is going. Tripling global renewable power capacity by 2030 is essential to peak energy–sector emissions this decade and keep the Paris Agreement targets. In 2025, global clean energy investment reached \$2.3 trillion, with renewables attracting \$690 billion and about 793 GW of new renewable capacity ([BloombergNEF, 2026](#); [Ember, 2025](#)). However, deployment remains below the pace required to meet the tripling goal. The solution is to scale and redirect financial flows to renewable power, particularly in emerging markets and developing economies (who only received 17% of global renewable investment in 2024, even though account for much of future demand growth and include many of the countries most exposed to fossil import dependence) ([IEA, 2024](#)).

At the same time, high sovereign risk, currency volatility and expensive capital continue to raise the cost of wind, solar, hydropower, storage and grid projects in many developing economies, even where this technology is now the cheapest source of new electricity, with 91% of renewables projects commissioned in 2024 being more cost–effective than their fossil fuel equivalents ([IRENA, 2025](#)).

International public finance remains far below what is needed: roughly 7% or around

USD 32 billion per year in these markets, which is not sufficient to shift the risk profile or crowd in investment at the required scale (IEA, 2025a). In Africa, debt servicing costs are now so high that they are equivalent to more than 85% of total energy investment in 2025, further constraining fiscal space for clean energy transitions (IEA, 2025a).

High capital costs and macroeconomic risk therefore keep countries locked into fossil dependence. Countries that cannot finance renewable power, storage and grid infrastructure remain more exposed to imported fossil fuels, volatile prices and balance-of-payments pressure.

Infrastructure barriers: The shift away from fossil fuels depends on electricity systems that can connect, balance and deliver much larger volumes of renewable power. Yet grid build out is lagging. Global investment in grids remains stuck at around USD 400 billion per year versus needed to reach over USD 600 billion–\$750 billion annually by 2030 to meet GST goals (IEA, 2023). The consequences are increasingly visible in project backlogs and congestion. In advanced development stages alone, around 1,650 GW of wind, solar and hydropower projects were waiting for grid connections by mid-2024 (IEA, 2024b). Transformer shortages, cable bottlenecks and slow network approvals are compounding these problems.

Storage and flexibility are also falling behind. High-renewable systems need short-duration batteries, pumped storage hydropower and flexibility, long-duration storage, demand response and digital system management to replace the balancing role that fossil generation has historically provided. Battery additions alone are rising quickly, annual additions exceeding 75 GW in 2024, but current deployment of energy storage across all technologies still does not match the scale of grid and flexibility needs, especially for long duration storage. (IEA, 2025). Battery technology will need to diversify so use of abundant materials like sodium, zinc, vanadium can enable fast commercialisation across regions. This is necessary for flexibility and resilience at scale, ensuring long term reserves and capacity adequacy to absorb renewables and deliver them when needed. Where storage and flexibility assets lag, curtailment rises, connection queues lengthen, and countries remain reliant on fossil generation for reliability.

Demand-side/electrification: Transitioning away from fossil fuels is structurally impossible unless fossil fuel demand falls in end-use sectors. Global electrification currently accounts for only around 21% of global final energy consumption, which means that most energy services are still being delivered through the direct combustion of fossil fuels (IEA, 2025b). IRENA's 1.5°C-aligned scenarios indicate this share would need to rise to around 35% by 2035, alongside the tripling of new

renewable generation and doubling of energy–efficiency (IRENA, 2024). Based on existing policies, the world is instead on track to reach only 25% electrification by 2035 (IEA, 2025b). Yet, the technologies already exist. Around 75% of global final energy demand could be electrified with existing technologies, and electric technologies are on average around three times more efficient than combustion-based systems (GRA and Ember, 2025). On that basis, one unit of electricity can replace approximately three (or more) units of fossil fuel energy (Eurelectric, 2024). The real barrier is therefore not technology readiness but weak deployment frameworks, poor price signals, inadequate infrastructure and insufficient political prioritisation of end-use electrification. Without faster switching to electrification, we will not realise the full potential available to us today for renewables to deliver efficiency improvements, emissions reductions, cost savings and energy security gains.

Market and regulations: Many markets remain organised around the operating logic of fossil fuel systems, rather than the needs of a renewables-dominated system. Market design still fails to reward flexibility, storage, demand response and efficient electrification. Legacy pricing structures, weak locational signals, and incomplete access to balancing and ancillary markets raise the cost of capital for flexibility assets and undermine system optimisation (IRENA, 2024). Electrification also often faces distorted relative price signals, particularly where electricity is taxed heavily while fossil fuels continue to benefit from subsidies or preferential treatment. Fossil fuel consumption subsidies remained around USD 620 billion in 2023, continuing to tilt the playing field against clean electricity (IEA, 2025a).

This matters because the transition away from fossil fuels depends not only on building renewable supply, but on making clean electricity the rational and affordable choice across transport, buildings and industry.

Permitting: Permitting remains a major bottleneck across renewable energy, storage and grid infrastructure. Fragmented authorities, unclear timelines, duplicative studies and weak administrative capacity routinely delay projects and increase financing costs. These delays raise financing costs, weaken investor confidence, and slow the build-out of precisely the assets needed to reduce fossil fuel demand.

This is now widely recognised as a structural barrier. When permitting is slow, even cost-competitive renewable technologies cannot deploy fast enough to displace fossil systems. This is especially important for capital-intensive infrastructure, many of which require long development lead times, such as hydropower, if institutions do not actively reduce policy friction.

Supply chain: Implementing the energy transition towards renewables requires well-functioning, cost-efficient, resilient and diversified supply chains. Today, critical mineral processing and renewable energy manufacturing remain highly concentrated. Nearly 50% of refining market value for key energy transition minerals is expected to be concentrated in China by 2030, while around 70–75% of refined supply growth for lithium, nickel, cobalt and rare earth elements is expected to come from the current top three producing countries (IEA, 2024e). Robust, diverse and fair global supply chains are integral to deliver the electrification and renewable energy shift at scale, as they are the backbone of infrastructure capacity to deliver energy security, affordability, and reliability. Diversification, circularity, recycling and better transparency, will help limit supply-chain disruptions that could slow the deployment of solar PV, wind turbines, short and long storage, grid equipment and electrolyser supply chains for green hydrogen.

Social and workforce barriers: Renewable energy employment reached 16.6 million globally in 2024 (IRENA, 2025), but geopolitical turmoil, automation and labour shortages across engineering, electrical installation, grid construction, equipment manufacturing and project delivery are leading to slight slowdown (IRENA, 2026). This is not a secondary issue; but an increasingly binding constraint on deployment speed. At the same time, many countries are at risk of missing out on the employment and industrial benefits of the transition unless workforce planning, local value creation and skills systems are deliberately strengthened when implementing projects.

While markets that are experiencing rapid expansion are facing shortages in the availability of appropriately trained workers to deliver projects safely, competently, and to a consistent level of quality. Lack of adoption of globally recognised training standards can lead to uneven skills, poor installation practices, safety risks, underperformance, and reduced investor and consumer confidence.

Question (b): What potential levers – economic, financial, institutional, social or technological – exist for accelerating the implementation of the transitioning away commitment?

The strongest levers those that work across the whole system at once. Countries need to build more renewable power, expand grids and storage, electrify demand, and align finance and market rules around that shift.

Financial and economic levers: A key priority is to cut the cost of capital and shift investment toward the countries and sectors where it is most needed. Public finance should focus on concessional capital, guarantees, political risk insurance, foreign exchange risk mitigation and blended finance structures that crowd in private

investment. This is essential in a context where around USD 4.3 trillion per year needs to be invested in clean energy through 2030 to stay on track for net zero by 2050 (IEA, 2025). Achieving this requires coordinated action by governments, financial institutions and industry to mobilize capital, lower financing costs and improve project viability through stable policy frameworks, investment pipelines and de-risking instruments. Increasing annual renewable investment would accelerate deployment where it is most needed, help deliver the global 3xRenewables goal and reduce fossil fuel demand. Governments and public finance institutions should also improve investment visibility through clear renewable build targets, auction calendars, bankable pipelines and stable long-term revenue frameworks

Long-term instruments such as power purchase agreements, contracts for difference, cap-and-floor mechanisms and regulated investment frameworks are particularly important for grid infrastructure and storage. Redirecting subsidies support away from fossil fuel consumption and toward clean electricity, flexibility and end-use electrification would also accelerate the shift in capital allocation and improve affordability over time.

Infrastructure levers: grids, storage and system flexibility: Grid expansion and modernisation is one of the most powerful delivery levers available. Transmission and distribution plans need to be aligned with renewable energy targets and electrification pathways, and they need to be based on forward-looking, anticipatory investment rather than reactive upgrades.

Storage and flexibility must be scaled alongside grids. Short-duration batteries, long-duration storage technologies such as pumped storage hydropower and flexibility, demand response, digital system management and flexible electric loads all reduce curtailment, improve reliability and enable renewable electricity to displace fossil generation more consistently across the day and across seasons. In practice, this means reforming power systems so that storage and demand-side flexibility can participate fully in wholesale, balancing and ancillary services markets, while also supporting early deployment of commercially proven but not yet fully bankable technologies. The objective should be to build systems that are flexible by design, rather than continuing to rely on fossil assets to provide balancing services.

Demand-side levers: electrification and the electrotech transition: The most direct way to cut fossil fuel demand is to make clean electricity the default energy carrier across transport, buildings and industry. This requires aligning policy, pricing and infrastructure so that electrification becomes the cheapest and most secure option. Governments should make electrification a priority in national energy plans, supported by dedicated policy programmes to drive EV deployment, charging

infrastructure, heat pump uptake, industrial electrification roadmaps, appliance standards and public procurement. A shared, global direction of travel toward 35% electrification of final energy by 2035 would create a strong signal for investors, manufacturers and grid planners (GRA and Ember, 2025).

Scaling electrification also requires correcting distorted price signals. In many markets, electricity is over-taxed while fossil fuels remain subsidised. Shifting the tax burden away from electricity, phasing out inefficient fossil fuel subsidies, and protecting vulnerable consumers would accelerate fuel switching and improve affordability (GRA and Ember, 2025). Electrification must also be integrated with system flexibility. Time-of-use pricing, demand response, storage and digital system management can ensure that EVs, heat pumps and industrial loads support grid stability and reduce system costs.

The impact is already visible. Electric cars alone displaced more than 1.3 million barrels per day of oil in 2024, and under current policy settings are on track to displace more than 5 million barrels per day by 2030 (IEA, 2025c).

Market design and regulatory levers: Governments should reform markets, so they reward the capabilities a renewable system needs: flexibility, storage, demand response, efficient location signals, and faster interconnection. They should also remove policy distortions that keep electricity expensive relative to fossil fuels.

Permitting and governance: Administrative reform can accelerate deployment immediately. Streamlined permitting and consenting processes for renewables, storage and grid infrastructure can cut project timelines, reduce uncertainty and lower financing costs. Governments can achieve this by introducing one-stop-shop systems, digitising procedures, setting clear legal timelines, fast-tracking repowering, and strengthening administrative capacity at national and subnational level.

Institutional coordination across ministries, regulators, grid operators, industrial policy, labour policy and local planning also needs to improve. Countries that integrate these functions into coherent national transition strategies are better able to align solar and wind build-out, hydropower and pumped storage development, renewable hydrogen strategies, electrification, infrastructure planning, workforce needs and industrial development.

Industrial, supply-chain and corporate levers: Accelerating the transition also requires stronger industrial ecosystems around renewable energy, grids, storage and electrotech. This includes diversifying supply chains, expanding manufacturing capacity, supporting circularity and recycling, and embedding environmental and labour standards in clean energy trade and procurement. Critical minerals concentration remains high, so resilience and diversification need to be treated as a

strategic part of transition planning rather than a separate industrial policy issue (IEA, 2024e).

Corporate clean electricity procurement is another important lever. Where regulation allows direct procurement and time-based matching, corporate demand can drive investment in new renewable generation, storage and firm clean capacity. The growth of 24/7 carbon-free electricity models and the move toward more granular Scope 2 accounting are helping shift markets away from annual certificate-based claims and toward procurement models that are more relevant to real system decarbonisation (GHG Protocol, 2025).

Social and workforce levers: Finally, workforce and social policy should be treated as part of the delivery strategy. Training programmes for electricians, engineers, technicians, construction workers and system planners are essential to scaling renewables, grids, storage and electrification. Skills strategies, just transition planning, local benefit-sharing and consumer awareness programmes can all strengthen public support and improve implementation outcomes (IEA, 2024d).

Question (c): What country, regional or sector roadmap experiences, best practices, and lessons learned can be shared?

The most useful experiences are those where a clear policy, regulatory or market change led to faster deployment of renewables, electrification, storage or grid infrastructure, and therefore to lower fossil fuel use. Across these cases, the lesson is consistent: when governments reduce administrative friction, improve market signals, create demand visibility and strengthen infrastructure planning, deployment accelerates. The strongest results come from integrated approaches that scale wind, solar, hydropower, storage, grids, electrification and renewable hydrogen within one electrotech strategy, rather than treating them as separate agendas (GRA and Ember, 2025).

Key lessons and transferable best practice:

- **Use global goals to unlock implementation momentum.** The GST's tripling renewables / doubling efficiency goals have helped align national actions, investment and markets around clear signals.
- **Integrate supply, networks and demand in one delivery plan:** Roadmaps that align renewable deployment, transmission and distribution, storage, flexibility and electrification avoid stranded assets, reduce system costs and enable faster fossil fuel displacement than fragmented approaches (IEA, 2025).

- **Make “time to build” a policy outcome:** Time-bound permitting, one-stop-shop systems, acceleration areas and simplified procedures for co-located assets can materially shorten delivery timelines without abandoning environmental safeguards.
- **Anchor the transition in affordability and energy security:** The rapid expansion of renewables storage has been strongest where policymakers have combined deployment support with measures that lower exposure to imported fossil fuels and reduce long-term system costs ([IRENA, 2025](#); [GRA and Ember, 2025](#)).
- **Demand-side action is a major accelerator:** Corporate procurement, especially where it shifts toward time-based and location-aware clean electricity sourcing, can help drive investment in new wind, solar, storage and other firm clean power options, rather than relying solely on annual accounting-based claims ([GHG Protocol, 2025](#)).
- **Treat supply chains and critical minerals resilience as part of orderly transition planning:** As deployment scales, countries will need stronger strategies for manufacturing, refining, recycling, and value-chain diversification across solar PV, wind turbines, batteries, grid equipment and electrolyser supply chains for green hydrogen ([IEA, 2024](#)).

GRA has compiled case studies from leading companies demonstrating how the right policy frameworks unlock private sector action in the energy transition. In Brazil, the 1,700 km Alto Paranaíba transmission project was made possible by a predictable regulatory framework from ANEEL, enabling significant private investment in grid infrastructure. In the maritime sector, the Green Pioneer, the world’s first ammonia-powered vessel, shows how cross-border collaboration between industry, regulators and research institutions can drive innovation while shaping enabling policies. [See all case studies here.](#)

Country / initiative	Policy or market change	Observable impact	Relevance for the COP30 roadmap
Germany	Legal and policy reforms gave renewables stronger legal priority and accelerated permitting for wind and solar.	Germany added around 20 GW of new wind and solar capacity in 2024, including roughly 16–17 GW of solar. Solar capacity reached around 100 GW by end-2024, while renewables supplied roughly 60% of power generation (S&P Global, 2025).	Shows that clear legal priority and faster permitting can unlock large-scale deployment quickly.
European Union (RED III / acceleration areas)	The EU introduced permitting deadlines, renewables acceleration areas, simpler procedures for repowering and co-located storage.	The reform created a stronger delivery framework for continued expansion of wind, solar and storage across member states (European Union, 2023).	Shows that institutional reform can scale across multiple jurisdictions while maintaining safeguards.
Pakistan	Falling solar costs, high retail electricity prices and enabling conditions drove a rapid distributed solar surge.	Pakistan imported roughly 19 GW of solar modules in 2024 alone, making it one of the fastest solar deployment surges in the world (IEA, 2025a).	Shows how distributed solar can cut fossil dependence quickly where economics favour self-generation and energy security is a driver.
North Sea Countries	Regional cooperation framework among North Sea countries to coordinate offshore wind development, cross-border grid infrastructure, and hybrid projects.	Accelerated deployment targets for offshore wind highlighted in Hamburg Declaration (over 120 GW by 2050 across participating countries), alongside the development of hybrid interconnectors and energy islands to integrate large-scale renewable generation more efficiently across borders.	Demonstrates how regional coordination and system-level planning can unlock scale in offshore wind, optimise grid utilisation, and reduce system costs - offering a model for other regions to move beyond national approaches toward integrated energy systems.
China	Wind-powered green methanol (Xing'an League, Inner Mongolia) shows integration of large-scale	Deployment of wind-powered green methanol production facilities, extending the value chain of wind energy beyond	Highlights the importance of sector coupling and demand creation - showing how renewables can drive

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	wind power with industrial policy to support green fuels, enabling renewable energy to directly supply hard-to-abate sectors through power-to-X pathways.	electricity into chemicals and fuels, while supporting industrial decarbonisation and regional/ local level economic development.	decarbonisation beyond the power sector and support industrial upgrading in emerging clean energy value chains.
Global renewable targets	Policy support, lower technology costs and energy security concerns accelerated renewable deployment.	Renewable capacity additions reached around 700 GW in 2024, led by solar at around 550 GW and wind at around 120 GW, while hydropower additions also increased (IEA, 2025d).	Confirms that when policy, economics and security align, renewables become the dominant source of new generation growth.
Corporate 24/7 clean electricity procurement	Corporate buyers and standards processes are shifting toward hourly matching and more location-specific procurement.	These approaches increasingly support investment in new renewable generation, storage and flexibility resources rather than relying solely on annual certificate claims (GHG Protocol, 2025).	Shows that private demand can accelerate the build-out of cleaner, more reliable power systems.

Question (d): How can a just, orderly and equitable transition best reflect the diverse realities of countries at different stages of development and with different degrees of dependence on fossil fuels?

Core principles and recommendations

- **Different starting points require differentiated pacing and support, but a common direction of travel:** The GST explicitly recognises national circumstances and pathways, while still calling for accelerated action this decade ([UNFCCC, 2023](#)).
- **Make energy access and affordability a priority objective:** 730 million people still lack electricity access and 2 billion lack clean cooking access; distributed renewables are highlighted as critical for remote populations ([IEA, 2025](#)). In many low-income and energy-access-first contexts, decentralised renewables, mini-grids and stand-alone systems will provide the fastest and most affordable route to expanding access, especially in remote areas.
- **Increase grant-equivalent and highly concessional finance for countries with limited fiscal space:** This is particularly important where high debt burdens and high costs of capital would otherwise delay the build-out of solar, wind, hydropower, storage, grids and end-use electrification ([UNFCCC, 2023](#)).
- **The transition should support domestic value creation and industrial participation:** Countries in the Global South should not only be consumers of imported clean technologies; they should also be able to capture jobs, skills and industrial development opportunities from the growth of renewable energy, batteries, grid equipment and green hydrogen value chains. This requires international cooperation on finance, trade, standards, due diligence, critical minerals governance and workforce development ([IEA, 2024](#)).
- **Shift fossil fuel subsidies to renewable investment with protection for vulnerable households and workers.** Fossil subsidies remain extremely large (USD 1tn in 2022; USD 620bn in 2023 per IEA) and distort markets; subsidy reform toward renewables, affordable clean electricity, efficient electric technologies with targeted protection is a key equity lever ([IEA, 2023](#); [GRA and Ember, 2025](#)).
- **Ensure workforce and regional development plans are integral to transition strategies:** Skill shortages are emerging across deployment, grids, storage and electrification. Countries that invest early in training, reskilling and local supply-chain development will be better placed to capture the employment benefits of the transition and reduce political resistance in fossil-dependent regions ([IEA, 2024](#)).

Differentiated recommendations by country grouping

High-income, fossil-dependent economies

These economies often have stronger capital markets and greater institutional capacity, but they may also face significant political economy risk because of fossil-linked jobs, revenues, industrial structures and incumbency power. In these contexts, the priority should be to set explicit signals for fossil demand reduction and phase-out, accelerate the build-out of wind, solar, hydropower, storage and electrification, and modernise market design so that flexibility and demand response are valued. Instruments should focus on long-term revenue certainty and lower-cost capital for grids, battery storage, pumped hydropower, long-duration storage and industrial electrification ([UNFCCC, 2023](#); [IEA, 2025](#); [IRENA, 2024](#)).

EMDEs with material fossil revenues or fossil export dependence

These countries face a dual challenge: exposure to future decline in fossil rents, and high financing costs that slow clean investment today. In these contexts, transition strategies should combine diversification of the economy with large-scale investment in renewables, grids, storage, electrification and, where justified, green hydrogen for export-competitive or hard-to-abate sectors. Public and concessional finance should be used to reduce sovereign and foreign-exchange risk, crowd in private capital, and support credible national investment pipelines with auctions, grid plans and permitting windows ([IEA, 2024](#); [UNFCCC, 2023](#)).

Low-income, energy-access-first countries

In low-income countries, the priority is often first access, then scale. The main constraints are the affordability of capital, weak grids and limited fiscal space. In these contexts, policy should prioritise distributed renewables, mini-grids, stand-alone systems and targeted grid extension, while also creating productive demand and improving service reliability. Access strategies should be paired with “electrotech readiness”: appliance standards, efficient electric equipment, workforce programmes, durable operations and maintenance systems, and planning for future integration of broader productive uses of electricity ([IEA, 2025](#)).