KEY TAKEAWAYS: FIRST COHORT OF ACTION PLANS FOR RAPID POWER SECTOR DECARBONIZATION

Report for the 14th Clean Energy Ministerial (CEM14)

Goa, India
July 2023

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Background on Action Plans

A collaborative report from the Clean Energy Ministerial (CEM) on *Lessons Learned for Rapid Decarbonization of Power Sectors* was delivered to energy ministers and presented at the 13th CEM (CEM13) in the United States in September 2022. In light of these lessons learned and discussed at CEM13, several jurisdictions signaled intent to develop Action Plans for power sector decarbonization, to be released at CEM14 in India in July 2023.

These Action Plans complement, but are differentiated from, other international power sector initiatives such as the Breakthrough Agenda (whose broad purpose is to raise collective ambition) and the Global Power System Transformation (G-PST) Consortium (whose goals are to convene power system operators to accelerate research innovations and foster peer learning). The Action Plans, supported by the 21st Century Power Partnership and other CEM workstreams via direct technical assistance and capacity building, are intended to focus on select implementation actions given each country's existing power sector goals and activities, and are an opportunity for countries to display leadership in power sector decarbonization.

The first set of Action Plans has been developed by India, Australia, Chile, the European Union, and the United Kingdom.

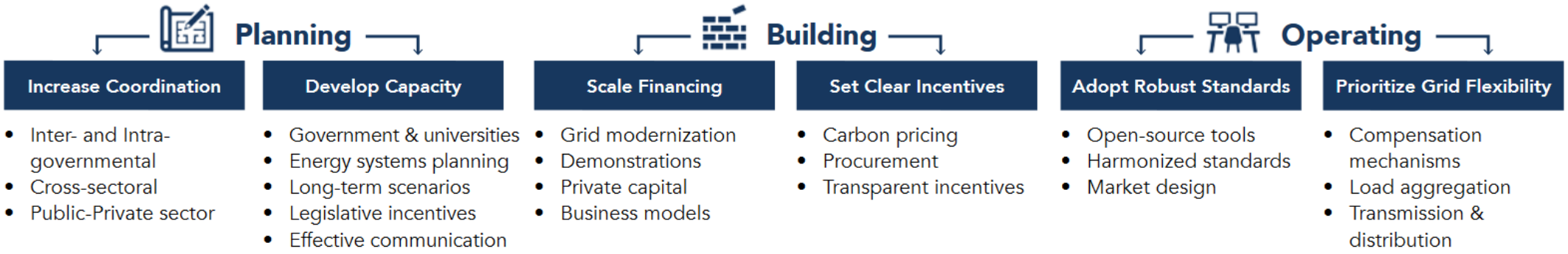
These Action Plans are voluntary, developed by each country individually, not comprehensive of all activities within the jurisdiction, and are living documents that are subject to change.

Purpose of Report

The purpose of this synthesis report is to extract key takeaways from the first cohort of CEM Action Plans for rapid power sector decarbonization, developed by India, Australia, Chile, the European Union, and the United Kingdom.

These Action Plans differ in their approach to power sector decarbonization based on the current conditions of the grid, domestic resources available, governance structure, and regional context, among other factors. However, they also share common themes that were emphasized in the collaborative report released at CEM13 and reiterated below.

Figure 1. Overarching Themes for Power Sector Decarbonization



This report is not intended to be inclusive of all components in each Action Plan. Rather, this report highlights how select best practices for planning, building, and operating power systems are being implemented differently in these Action Plans, with equal focus given to each jurisdiction. Ministers and stakeholders from other governments with similar decarbonization goals can consider these examples within their own unique context.

Note: Figures in this report are sourced from the individual country Action Plans.

Select key messages for energy ministers

Some of the messages may be more relevant to some ministers than others depending on the country context.

I. PLANNING

Increase Coordination

- Cross-sectoral: Drive integrated planning of generation and networks (transmission and distribution), transportation and grid, as well as industry and grid, including distributed energy resources

Develop Capacity

- Promote transparent and robust long-term scenarios based on rigorous studies

Cross-Sectoral Coordination (1/2)

India has various initiatives that connect the power sector to other sectors such as transport and industry. For instance, the country's Green Hydrogen Mission incentivizes the production of green hydrogen that can be used not only for clean electricity generation, but also for fertilizer production and high-temperature industrial heat applications. Further cross-sector linkages include green ammonia, biomass and ethanol for energy and industrial feedstocks, as well as substantial smart energy efficiency measures.

Australia's power sector goals (reaching 82% renewable energy for electricity by 2030) are linked to its broader economy-wide goals (achieving net zero greenhouse gas emissions by 2050). The Integrated System Plan for the power sector assumes that annual electricity demand will nearly double from 180 TWh in 2022 to 320 TWh in 2050 due to increasing electrification of transport and industry. The Powering Australia Plan is a coordinated approach to deliver Australia's climate and energy transformation, focusing on decarbonization, boosting renewables, enabling infrastructure, and energy affordability.

The power sector in **Chile** contributes 32% of the country's greenhouse gas emissions, compared to 24% for transport, 14% for industry, 11% for agriculture, and 7% for buildings. Thus, Chile's pathway to carbon neutrality by 2050 contains mitigation actions in the power sector, such as a coal phase out that is anticipated to contribute 13% of the reductions needed, as well as mitigation actions linking the power sector to industry (green hydrogen and sustainable industry) and transportation (electromobility via fuel cells and lithium-ion batteries).

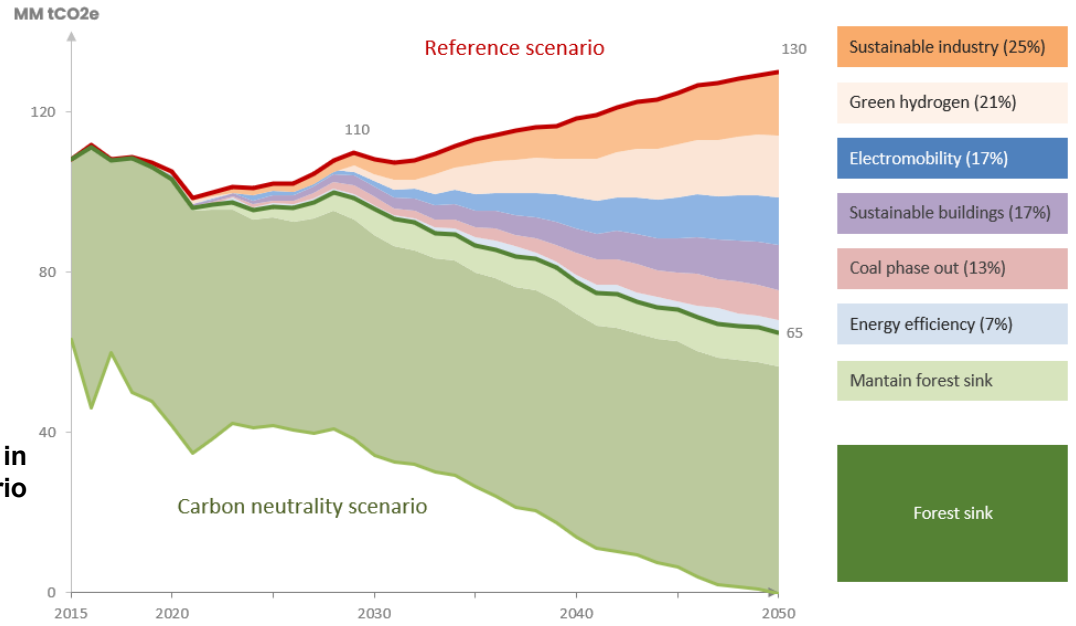


Figure 2. Chile Greenhouse Gas Emissions in Reference Scenario versus Carbon Neutrality Scenario

CROSS-SECTORAL COORDINATION (2/2)

The European Green Deal is the **European Union's** economy-wide plan to achieve carbon neutrality by 2050. The interim climate targets for 2030 include a Renewable Energy Directive for the power sector, as well as regulations on alternative fuels for industry, maritime transport, and aviation, all of which would benefit greatly from a decarbonized grid. The REPower EU plan also links renewables (increasing the target to 42.5% of the energy mix by 2030) to energy security (ending EU dependence on Russian oil and gas imports).

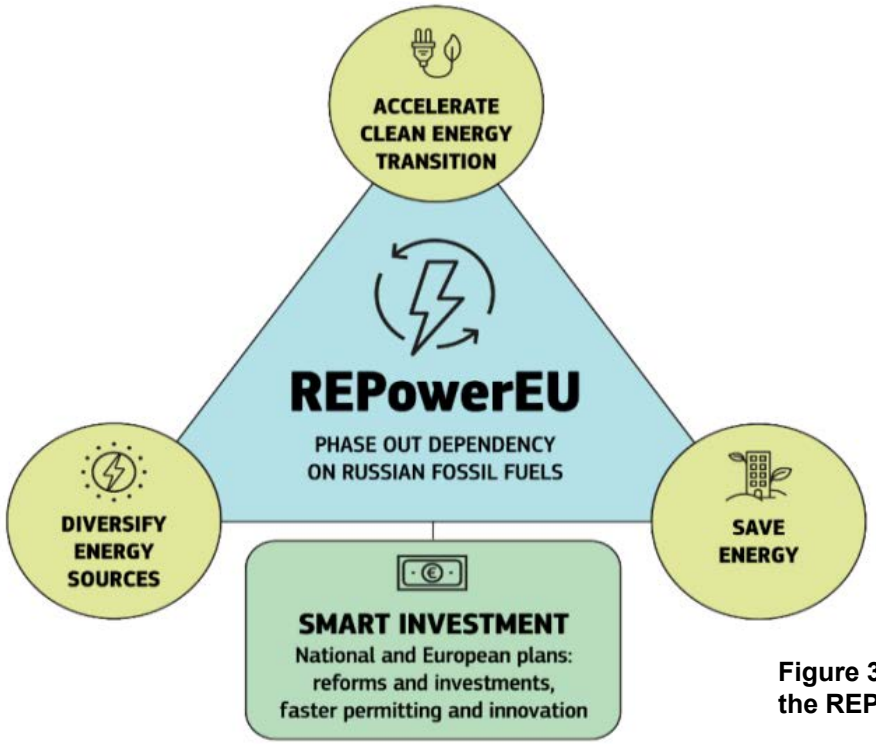


Figure 3. Components of the REPowerEU Plan

The **United Kingdom's** decarbonization ambitions include targets related to hydrogen production and carbon capture, utilization, and storage (CCUS). Hydrogen, if produced through a fully decarbonized power sector (which the Electricity System Operator is targeting for 2035), can support decarbonization of other sectors such as transport and industry. Furthermore, CCUS technology can facilitate emissions reductions in heavy industry (e.g., cement and steel production, etc.). Finally, the Powering Up Britain plans include a whole-of-economy approach to both energy security and net zero greenhouse gas emissions.

Long-Term Scenario Development (1/2)

India has conducted several long-term studies focused on the evolution and operation of its power sector, beginning with the Greening-the-Grid project on pathways to integrate 175 GW of renewable energy into the grid, the Transmission Plan for Integration of 500 GW of Renewable Energy, and a recent 2022-2032 National Electricity Plan, which is developed every 5 years by the Central Electricity Authority. India utilizes a suite of models to inform planning and operational changes, such as coal plant flexibility, monitoring and forecasting of wind and solar generation, enhanced grid codes, and faster scheduling and dispatch of resources.

Australian Energy Market Operator's 2022 Integrated System Plan envisions a significant build-out of utility-scale wind and solar PV (9-fold increase by 2050), distributed solar PV (5-fold increase by 2050), and storage (30-fold increase by 2050). Storage includes batteries, virtual power plants (e.g., distributed storage coordinated by aggregators), and pumped hydropower. The long-term plan also includes a complete retirement of coal capacity by 2043. In 2050, the plan also accounts for some peaking gas and other liquid fuels, along with hydropower.

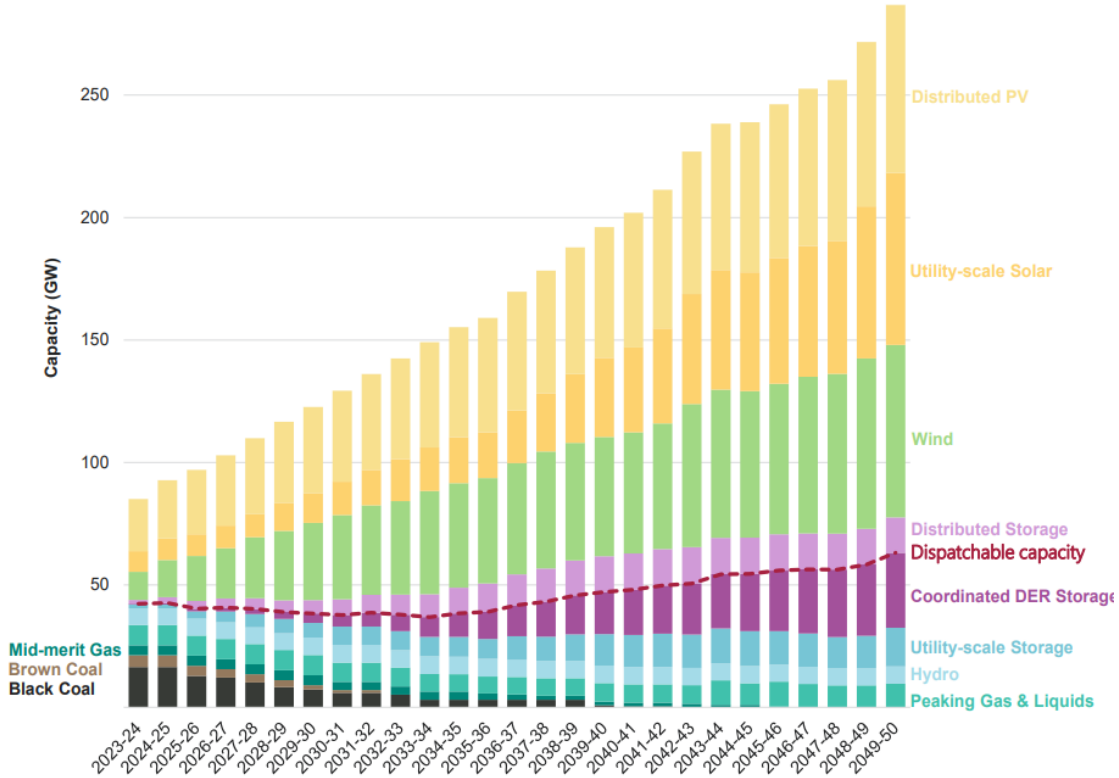


Figure 4. Long-term Plan for Power Sector Resources in Australia

Long-Term Scenario Development (2/2)

Chile conducts economy-wide analysis to inform sector goals for rapid decarbonization, including power for mobility, hydrogen, and industry. They are targeting a coal phaseout by 2040, and the projected power generation mix by 2050 includes a significant amount of solar PV and wind. Unique among the cohort, Chile is also anticipating a strong build-out of concentrating solar power (CSP) in the 2040s due to the favorable solar resources in the northern Atacama Desert.

The **European Union's** Joint Research Centre, through its Global Energy and Climate Outlook publication, provides long-term global and EU energy and emissions projections under different scenarios. In the 1.5 °C scenario, the EU power generation mix is dominated by wind and solar, followed by nuclear. The long-term scenario does not include a significant role for power plants with carbon capture and sequestration, which only account for 1.9% of generation in 2050.

By 2025, the **United Kingdom** Electricity System Operator is targeting carbon-free transmission network operation for short periods of time. By 2035, the UK electricity network aims to operate carbon free year-round, in-line with the country's ambitions for net zero greenhouse gas emissions by 2050. To assist with long-term scenario development and to ensure that the 2050 target is achievable, the UK government is required to set five-year carbon budgets (i.e., emissions caps) twelve years in advance, along with a corresponding detailed plan to meet those budgets.

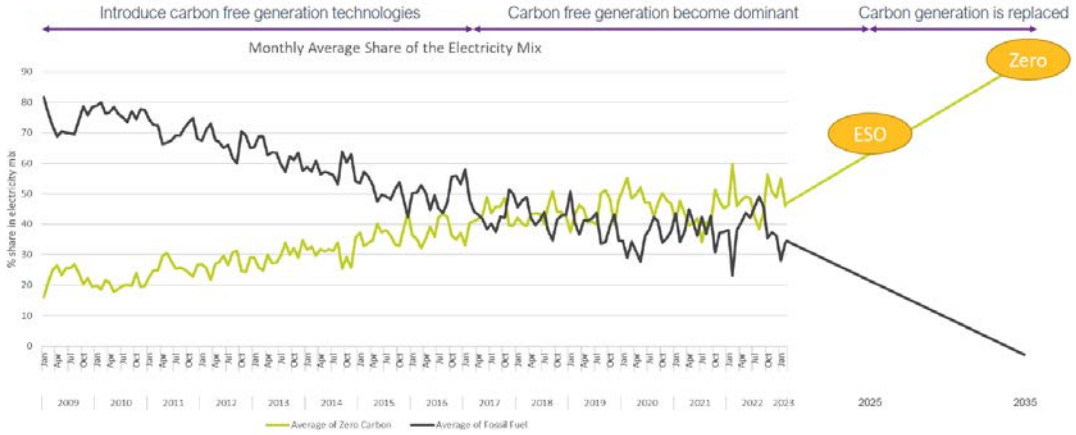


Figure 5. Trajectory of Zero Carbon and Fossil Fuel Electricity Generation in the UK with Energy Targets Achieved

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II. BUILDING

Grid Modernization Actions

- Prioritize actions for electricity grid modernization, digitalization, and resilience

Clear Procurement Approaches

- Develop clear procurement mechanisms (e.g., auctions)

Grid Modernization Actions (1/2)

India is supporting the development of transmission to interconnect 500 GW of renewables and non-fossil capacity by 2030, and this build-out is focused on renewable energy zones (REZ) for solar and wind. Furthermore, India has been developing guidelines to ensure resource adequacy with high levels of renewables, assigning different roles to different agencies (e.g., the Central Electricity Authority has developed guidelines on resource adequacy for distribution utilities to implement).

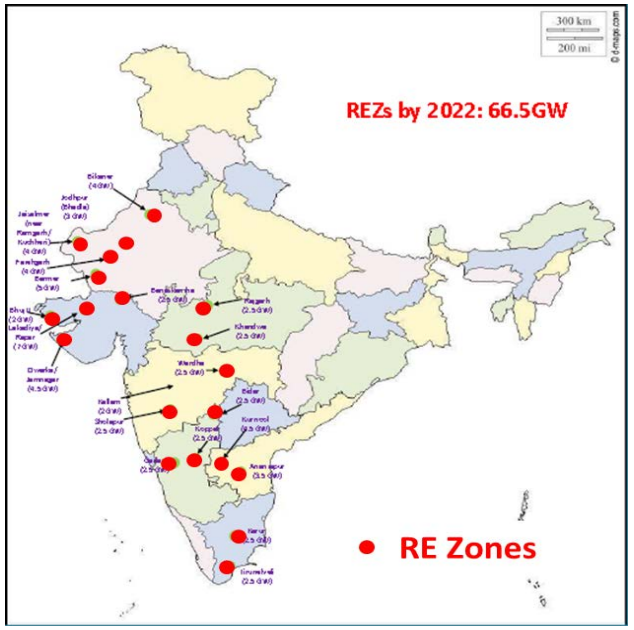


Figure 6. Select Renewable Energy Zones (REZs) Identified in India

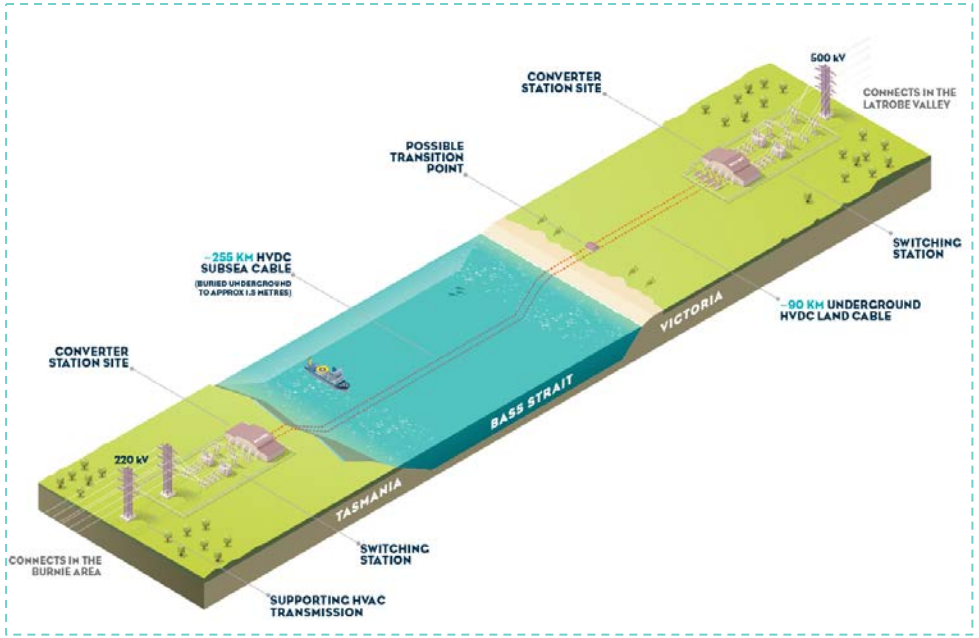


Figure 7. Schematic of Undersea Transmission Project in Australia to Further Connect Tasmania and Victoria

Australia is also investing heavily in transmission expansion via a Renewable Energy Zone (REZ) planning approach. Under the Rewiring the Nation (RtN) program, the government aims to invest up to $20 billion Australian dollars (AUD) in low-cost finance to expand and modernize the grid, including for interstate transmission lines and REZs. For example, the Government is supporting the development of additional undersea high-voltage DC (HVDC) transmission cables to cross the Bass Straight and further connect Tasmania to the National Electricity Market (NEM) via Victoria. This will provide the NEM increased access to hydropower resources in Tasmania, supporting grid decarbonization targets.

Grid Modernization Actions (2/2)

Chile has a law to promote efficient development of transmission and other enabling infrastructure for the energy transition. The transmission expansion plan is paired with the build-out of utility-scale battery storage and distributed energy resources (DERs). For instance, Chile has embarked on technical studies to determine the capacity of some DERs to prevent congestion on transmission lines. These efforts are aimed at tackling the country's transmission expansion challenges, exacerbated by its unique geography among cohort members (e.g., a long north-south span with significantly shorter east-west spans).

The **European Union** has unique considerations when planning large scale infrastructure, given its supranational governance structure that encompasses 27 sovereign member states. Every two years, the European Network of Transmission System Operators for Electricity publishes a non-binding ten-year network development plan, which builds on national and regional investment plans developed by the individual Transmission System Operators.

Like the European Union, the **United Kingdom** relies significantly on cross-border grid interconnections to meet its electricity needs and targets. The UK cross-border connections are both across jurisdictional boundaries (e.g., UK to EU member states) and within jurisdictional boundaries (e.g., Northern Ireland to Scotland). In addition to its operational transmission lines to Ireland, France, Belgium, the Netherlands, and Norway, the UK is constructing additional lines to France and Denmark and considering lines to France and Germany.

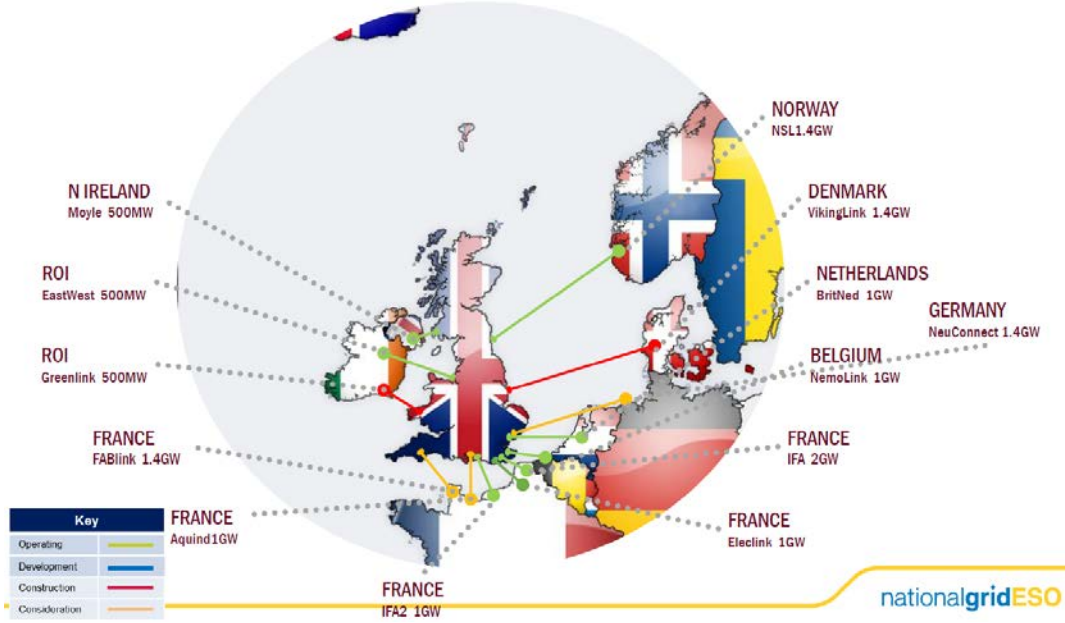
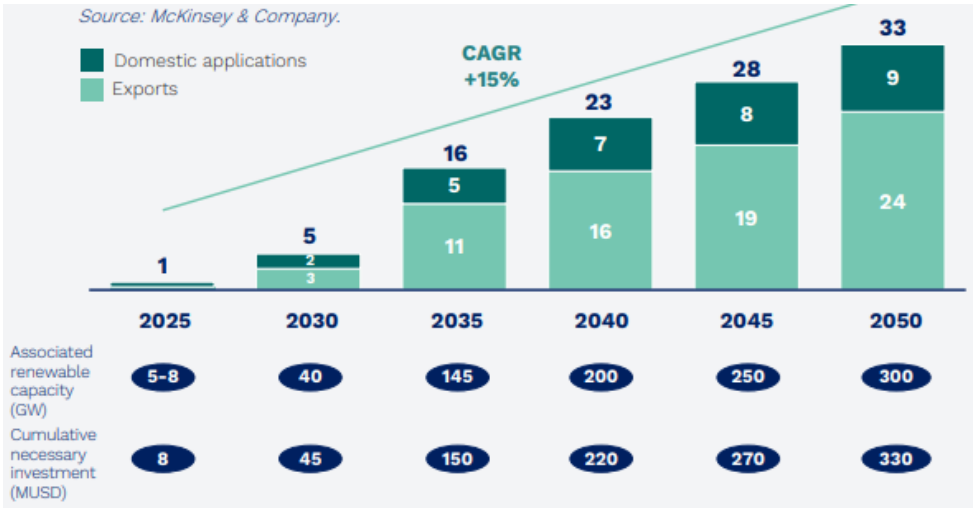


Figure 8. Existing, Under-Construction, and Under-Consideration Transmission Lines Between the UK and EU

Clear Procurement Approaches (1/2)

India has a variety of processes for procurement and grid interconnection of renewables. The government is also setting up a carbon credit trading scheme, which seeks to increase private sector participation in emissions reductions. Furthermore, through the Green Energy Open Access program, India has reduced the limit of open access to transmission from 1 MW to 100 kW, which increases access to renewables for smaller customers. This program also involves a streamlined approval process for interconnection, which reduces the transaction costs and waiting time.

Australia's Action Plan includes a section on supply chains for the clean energy transition, which is an important component of power sector decarbonization. The National Reconstruction Fund (NRF) commits $AUD 15 billion to support Australia's manufacturing and industrial capabilities for technologies such as wind turbines, battery cells, solar PV panels, green metals, and critical minerals. The Australian Renewable Energy Agency (ARENA) also provides grant funding to support research and commercialization of new technologies. The newly announced $AUD 400 million Industrial Transformation Stream provides grants to support regional industrial decarbonization, including the mining, manufacturing, agriculture, and food processing sectors.



Chile's law to promote energy storage includes payments in both the energy (kWh) and capacity (kW) markets, which incentivizes both stand-alone storage development and storage paired with renewables. Additionally, Chile recently announced plans to invest $USD 2 billion in large scale energy storage in the northern Atacama desert. Chile also seeks to support procurement of green hydrogen through its National Green Hydrogen Strategy, which aims to make Chile one of the largest producers and exporters of green hydrogen in the world. Finally, Chile seeks to sustainably mine lithium from its domestic reserves through its National Lithium Strategy.

Figure 9. Projection of Chilean Markets for Green Hydrogen and its Derivatives

CLEAR PROCUREMENT APPROACHES (2/2)

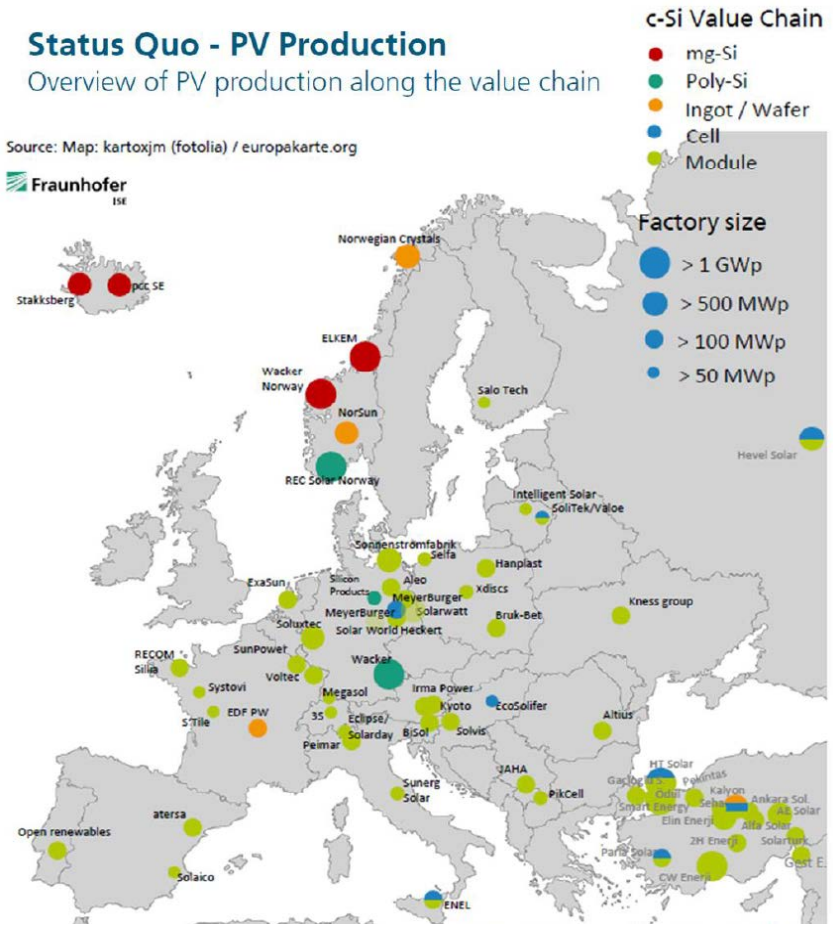


Figure 10. Solar PV Production Along the Value Chain in the EU

The **European Union's** Renewable Energy Directive (RED) has been revised several times over the past decade, increasing the targets for renewable energy generation each time and providing a strong signal to support industry growth. The RED targets are supported by the EU Offshore Renewable Energy Strategy and the EU Solar Energy Strategy. In addition to generation and capacity targets, the EU policies support manufacturing to strengthen the European supply chain and clean energy job market. This focus on supply chains is shared in Australia's Action Plan.

The **United Kingdom** has set clear goals with significant investments to procure offshore wind, solar PV (rooftop and ground-mount), and hydrogen (produced via electrolysis or paired with CCUS). Unlike its other cohort members, the UK's Action Plan has a strong focus on CCUS, with up to £20 billion in funding for eight initial projects and more to be identified in the future, and nuclear, with up to £120 million for the Nuclear Enabling Fund and other measures. The UK's focus on nuclear as a power sector solution is notable; the government launched the Great British Nuclear (GBN) organization and is interested in small modular reactor (SMR) technology.

Some of the messages may be more relevant to some ministers than others depending on the country context.

III. OPERATING

Innovative Market Designs

- Promote operational efficiency through innovative market designs

Prioritize All-Asset Flexibility

- Commission efforts to enable aggregation of flexible and efficient end-use loads

INNOVATIVE MARKET DESIGNS (1/2)

India has incorporated flexibility into grid operations in order to integrate more renewables. For instance, the government has issued regulations and implemented programs targeted at increasing the ramp rate of coal-fired power plants and reducing their minimum operational level. The grid operator, Grid Controller of India Limited, is also piloting projects for faster scheduling and dispatch of resources. Furthermore, India has launched a Green Term-Ahead and Green Day-Ahead market, in order to increase the market participation of clean energy generators.

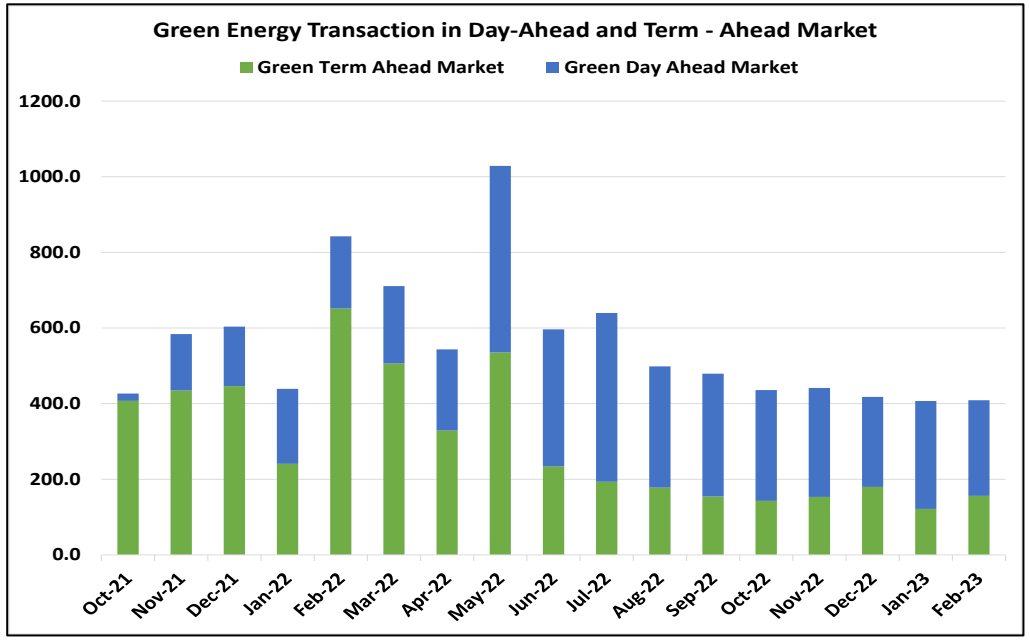


Figure 11. Participation in India's Green Day-Ahead and Term-Ahead Markets

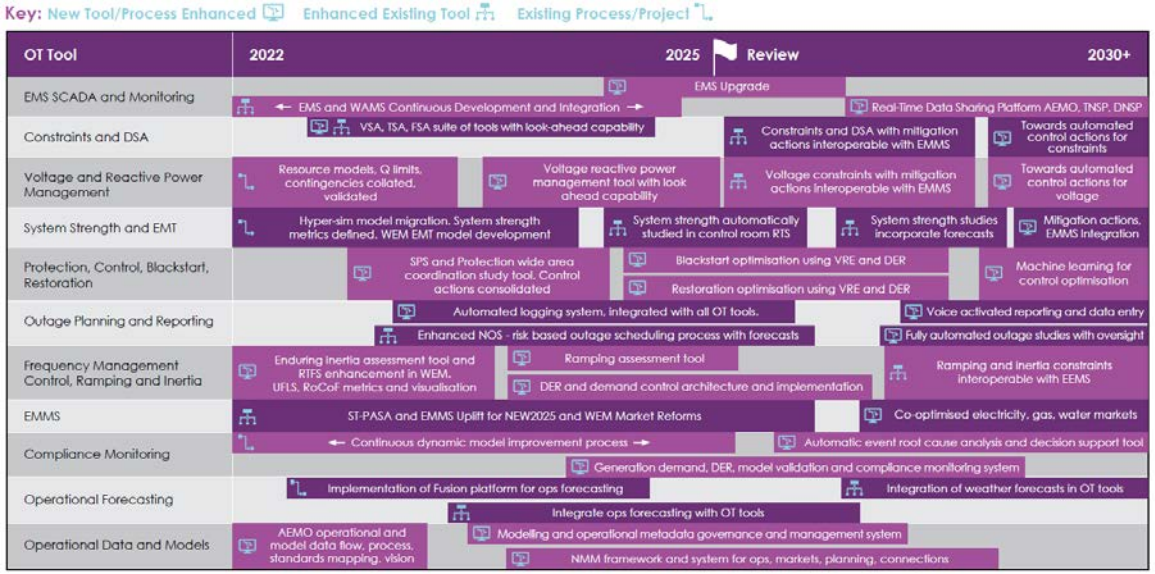


Figure 12. AEMO's Operating Tool Roadmap

Australia's National Electricity Market (NEM) accounts for over 80% of electricity generation and installed capacity. The Australian Energy Market Operator (AEMO), which manages these markets, has developed a detailed and comprehensive Operations Technology Roadmap that identifies the system and market operations capabilities needed to accelerate the energy transition.

Innovative Market Designs (2/2)

Chile has one main electrical system, with two smaller and isolated systems in the south. The National Electric Coordinator, which has a roadmap for achieving a 100% renewable energy grid, is the main grid operator and is responsible for guaranteeing open access to transmission. Chile has a wholesale market for energy, capacity, and ancillary services. Chile also recently introduced updated competition conditions in its market. Instead of generators bidding for the entire 24 hours of a day, generators can now bid for specific time blocks (in either 1- or 6-hour increments). This change supports wind and solar generators, who can bid for different quantities at different prices throughout the day based on the variability of those renewable resources.

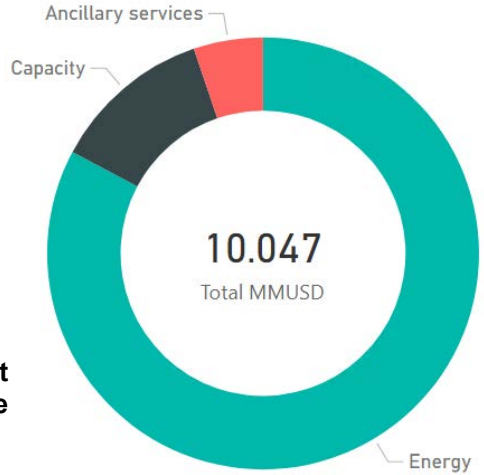


Figure 13. Breakdown of Electricity Market Value in Chile

The **European Union** has proposed several revisions to its electricity market design in order to reach its renewable energy goals. The market consists of individual bidding areas that mostly align with the borders of EU member states. Within a bidding zone, unlimited exchange of electricity is permitted. The bidding zones are physically connected via transmission lines and the markets are coupled, and one proposal is to allow cross-border intraday trading of electricity closer to real time (i.e., 30 minutes in advance). This reform will create more opportunities for bidding zones to trade renewables and other flexibility assets. The EU, though it has a different market structure compared to the other cohort members, is showcasing the importance of cross-border trade for power decarbonization.

In 2022, the **United Kingdom** government held a public consultation to review electricity market arrangements in order to identify potential reforms needed to reach its decarbonization, cost, and energy security objectives. The Action Plan identifies its capacity market (designed to ensure secure electricity supplies at least cost to customers) and contracts for difference (designed to provide stable revenue for low carbon technologies) as key enablers of the energy transition over the last decade.

PRIORITIZE ALL-ASSET FLEXIBILITY (1/2)

In addition to coal plant flexibility requirements, **India's** pilot projects have provided important insights for itself and other countries on the beneficial ancillary services that can be provided by emerging demand-side resources such as distributed battery storage, electric vehicles, and demand response. India has also prioritized automated meter reading and data processing, and this emphasis on smart meters for end-use loads is shared by other Action Plans. Furthermore, India has co-located 13 Renewable Energy Management Centers with Load Dispatch Centers, in order to enhance its real-time monitoring capabilities for renewable generation and coordinate this effort with more accurate load forecasting at a regional level.

Australia's Distributed Energy Resources Program seeks to incorporate high levels of DERs into the grid through workstreams on demonstrations, modeling, and standards development. A subset of this program is the Customer Energy Resources (CER) Implementation Plan, which includes end-use loads such as smart appliances and electric vehicles in addition to distributed solar PV and storage. This plan seeks to reward consumers and support innovative business models for asset flexibility. Some of the actions in AEMO's Operations Technology roadmap that will also enhance flexibility include the ramping assessment tool, integration of weather forecasts into tools, and the DER and demand control architecture item.

In its Action Plan, **Chile** has identified future challenges in its grid digitalization effort related to the use of smart meters (managing large amounts of data) and net demand (controllable loads that are responsive to grid conditions). In its projections for electricity system operation, Chile anticipates demand for hydrogen production to peak in the middle of the day (coinciding with solar production) and demand for electromobility to peak at night (due to flexibility).

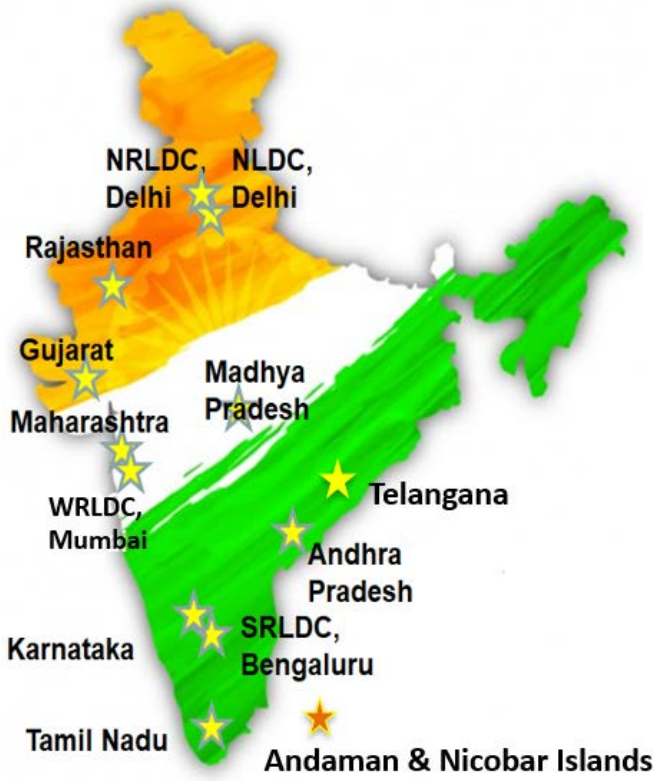


Figure 14. Renewable Energy Management and Load Dispatch Center Locations in India

PRIORITIZE ALL-ASSET FLEXIBILITY (2/2)

In its proposed electricity market revisions, the **European Union** has called on member states to define national objectives for demand response, distributed storage, and other sources of flexibility. The EU also indicates in its Action Plan that Transmission System Operators can procure a peak shaving product (i.e., demand response) to reduce demand during peak hours. Furthermore, Distribution System Operators are prioritizing the roll-out of smart meters, which are projected to cover 77% of EU customers by 2024.

The **United Kingdom** has significantly phased down the percentage of coal generation in its electricity mix, going from 40% in 2012 to 1.8% in 2020. This has been enabled by flexibility in both demand and generation assets, such as natural gas, imports, and renewables. In May 2022, for example, 0% of generation came from coal, with 44% due to zero carbon sources such as wind, nuclear, solar, and biomass.

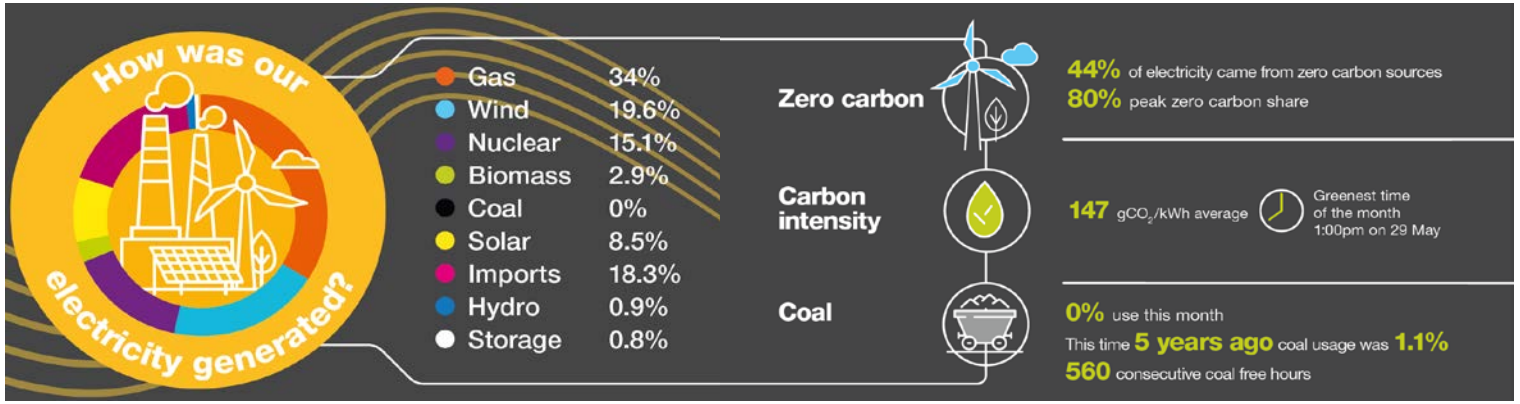


Figure 16. Electricity Generation in the UK in May 2022

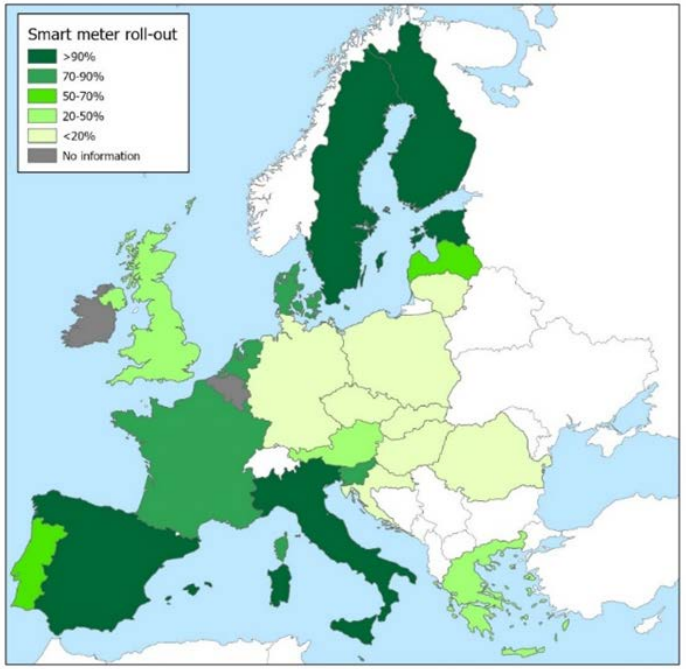


Figure 15. Smart Meter Deployment Levels in Europe

Stakeholder Engagement and Inclusion

India's Action Plan, primarily developed by the Grid Controller of India Limited, lists a variety of national and international partners that it collaborates and coordinates with. National stakeholders include the Ministry of Power, the Central Electricity Authority, and the Ministry of New and Renewable Energy. International partners include the International Energy Agency, International Renewable Energy Agency, the Global Power System Transformation Consortium, the Clean Energy Ministerial, and the National Renewable Energy Laboratory.

Australia has established the National Energy Transformation Partnership (NETP) in order to align and coordinate actions by federal, state, and territory governments. This framework is operated by the Energy Advisory Panel (EAP), which is represented by the Australian Energy Market Commission, the Australian Energy Regulator, the Australian Energy Market Operator, and the Australian Competition and Consumer Commission. Australia is also developing a First Nations Clean Energy Strategy, co-designed with Indigenous communities, to ensure First Nations people have input on energy policies.

Chile's Action Plan includes a dedicated section on the Just Energy Transition, including support for coal communities. At the highest level of governance, this involves collaboration among the energy, labor, economy, health, social development, education, women, and gender equality ministries. The operating structure also includes participation by civil society and is a strong example of how power sector decarbonization actions can be more equitable and inclusive.

The **European Union's** Action Plan includes a dedicated section on citizen engagement through energy communities and energy sharing. Energy communities are legally recognized entities within EU law, which enable citizen-driven action and also gives consumers the right to produce renewable energy. The EU also references a Rural Energy Community Advisory Hub, ensuring that rural areas are not left behind in the energy transition.

The **United Kingdom's** Department for Business, Energy and Industrial strategy split in 2023 to form the Department for Business and Trade and the Department for Energy Security and Net Zero. This department works closely with National Grid Electricity System Operator (ESO), which is the grid operator for Great Britain, and the Office of Gas and Electricity Markets, along with many other public and private organizations.

ACKNOWLEDGEMENTS

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Australia Action Plan: https://www.nrel.gov/docs/fy23osti/86637.pdf

Chile Action Plan: https://www.nrel.gov/docs/fy23osti/86636.pdf

European Union Action Plan: https://www.nrel.gov/docs/fy23osti/86635.pdf

United Kingdom Action Plan: https://www.nrel.gov/docs/fy23osti/86714.pdf

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