

TRANSFORMING AUSTRALIA'S ELECTRICITY MIX AND REDUCING GREENHOUSE GAS EMISSIONS

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Abstract: *As a pressing priority for the global economy, the shift to clean energy profoundly influences individual national economic activities. However, a combination of technological, economic and political factors conditions the course of the decarbonization process. Australia represents an analytically significant case of energy transition, as the rapid growth of renewable energy sources occurs simultaneously with the persistent role of fossil fuels. The article aims to provide a descriptive evaluation of the transformation of electricity generation in Australia. The results of the article show an increase in the share of renewable energy sources, which was accompanied by a gradual decrease in the importance of coal in the energy sector. The fixed-base index of net greenhouse gas emissions decreased from 100 to 70.7 points between 2005 and 2024. The article identifies sectoral disproportions that persist in the Australian economy. The long-term decline was largely linked to changes in land use and the forestry sector and to lower emissions from electricity generation. Increases in emissions from transport and stationary combustion outside electricity generation offset this development.*

Keywords: *energy transition, legislative framework, renewable energy sources, climate act*

JEL Classification: Q42, Q58, O13

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1 Introduction

The energy transition represents one of the most significant economic and technological challenges of the 21st century. The growing negative consequences associated with climate change, the increasing volatility of energy commodity prices and the desire to ensure long-term energy security are leading countries to gradually transition from fossil fuel-based energy systems to low-carbon and sustainable development models (Saadi, Katekhaye & Magda, 2026; Khan et al., 2022; Zhang & Kong, 2022). In this context, the energy transition has become a key tool for achieving the goals of the Paris Agreement and the carbon-neutrality commitments adopted by several countries worldwide. As Hopkinson et al. (2025) argue, the Australian economy's dependence on fossil fuel exports and its relatively limited influence in shaping global climate rules allow us to approach Australia as a “recipient” of international policy signals rather than an active maker of rules and strategies

The energy transition in fossil fuel-exporting economies is not a direct replacement of one technology with another. It is a structural change in which climate commitments, network infrastructure, technology development, and commercial interests associated with the export of raw materials intersect. Australia is a particularly interesting case of energy transition. On the one hand, fossil fuels have long played a significant role in the Australian economy. On the other hand, it has one of the highest technical potentials for the development of renewable energy sources, especially solar and wind energy (Hopkinson et al., 2025; Johnsson, Kjärstad & Rootzén, 2017). Australia is one of the biggest net exporters of energy, including coal and natural gas. Around 88% of black coal energy production was exported in 2023 – 2024, as was around 74% of domestic natural gas production. LNG exports have increased by an average of 13% per year over the past decade (Australian Government, Department of Climate Change, Energy, the Environment and Water, n.d.). This concept reflects the asymmetric nature of global climate governance, in which technological and economic leaders set the regulatory frameworks that other states, including middle powers, must adapt.

The article aims to descriptively evaluate the transformation of electricity generation in Australia and assess the extent to which the growth in the share of renewable energy sources has been associated with changes in net greenhouse gas emissions.

The research answers two questions: *How did the structure of electricity generation change between 2005 and 2025, particularly the shares of coal and renewables, and to what extent was the growth of RES reflected in the development of net emissions, and which sectoral trends limited the continuation of their decline?*

2 Theoretical Overview and Literature Review

2.1 Energy Transition and Theoretical Background

Energy transition is perceived in the current scientific literature as a key process that significantly influences the formation of new global economic and geopolitical structures. This process cannot be reduced to technological innovation, as it represents a complex systemic change that affects the functioning of economic models, institutional frameworks, security policies, and regulatory mechanisms at both the national and international levels (Smil, 2017; Hopkinson et al., 2025; Kilinc-Pala, 2021). Energy transformations are context-specific, and their dynamics and resulting form are conditioned by the country's level of economic development, available technological capacity, natural and geographical conditions, and the setting of political and regulatory priorities (Smil, 2017; Liutak et al., 2023). Saadi, Katekhaye & Magda (2026) analysed the role of artificial intelligence as a technological tool for production prediction and operational optimisation, as well as the subsequent integration of renewable sources into the electricity system.

Bhattarai, Maraseni & Apan (2022), based on a review of 248 studies, concluded that technological innovations are only one of the prerequisites for the energy transition. According to the authors, their real-world application is contingent on the availability of financing, institutional capacity, infrastructure quality, and regulatory stability. A similar conclusion can be observed in the empirical study by Li et al. (2020). Based on a systematic review of 118 documents, the authors pointed to the growing role of RES, the decommissioning of ageing coal-fired power plants, and the importance of support mechanisms. They also identified the need for infrastructure investments and better alignment of support instruments with the stability of the electricity system. Blakers, Lu & Stocks (2017) modelled a scenario of 100% renewable generation in the National Electricity Market and concluded that a technically feasible system could be based mainly on wind and photovoltaic generation, but would

require additional energy storage and stronger inter-regional interconnections. They thus confirm the possibility of future development and technological feasibility.

2.2 Political and Legislative Aspects

The energy transition legislative framework is a key legal instrument through which the Australian Government coordinates the strategic objectives of decarbonization and economic modernisation (Hopkinson et al., 2025). The federal framework for supporting renewable electricity began to take shape systematically with the Renewable Energy (Electricity) Act of 2000, which created a certification mechanism and a mandatory target for renewable generation. However, the development of the framework was not linear (Australian Government, n.d.; Simpoli, n.d.).

Following a change in political representation in 2013, the carbon pricing system was repealed through the Clean Energy Legislation (Carbon Tax Repeal) Act 2014. The Tony Abbott government argued that the mechanism constituted ineffective regulation and undermined the competitiveness of the Australian economy. The Centre for Public Impact (2017) reports that the tax was estimated to have increased the average household's electricity price by 10%. The Treasury estimated that introducing a carbon tax of AUD 23 per tonne increased the cost of living for a household by an average of AUD 9.90 per week and raised the consumer price index by 0.7%. Hopkinson et al. (2025) noted that Tranter (2013) found high polarisation between left- and right-wing voters in Australia at the time regarding their beliefs about the dangers of climate change and their support for the development of renewable energy sources or carbon pricing policies (Parliament of Australia). (n.d.).

The Labour Party's victory in the 2022 election removed a federal government that had previously actively weakened climate policy. The energy transition was no longer presented as an environmental cost but rather as a driver of industrial development and job opportunities. The new government used a two-tiered approach, supporting the development of renewable energy and critical minerals. This approach allowed the adoption of a new legislative framework without directly confronting existing fossil fuel interests. A significant legislative shift occurred after 2022 with the adoption of the Climate Change Act 2022, which set targets to reduce emissions by 43% by

2030 and achieve climate neutrality by 2050 (Australian Government, 2025; The Office of Parliamentary Counsel, 2022; Warry, 2022).

3 Data and Methodology

The article aims to descriptively evaluate the transformation of electricity generation in Australia and assess the extent to which the growth in the share of renewable energy sources has been associated with changes in net greenhouse gas emissions.

The research is designed as a single-case descriptive study of Australia based on secondary data. In line with the article's aim, neither econometric identification nor counterfactual scenarios are used. Therefore, the results reflect the extent, direction, and temporal concurrence of changes, not the causal effect of a specific policy.

The data used to create Chart 1 on the structure of electricity generation comes from Australian Energy Statistics. The analysis uses the relevant years 2005, 2010, 2015, 2020 and 2025. The categories include hard coal, lignite, natural gas, petroleum products and the aggregated category of renewables. The values represent shares of total electricity generation. The share of renewable energy sources (Chart 1) includes solar, wind, biomass, and hydropower, as reported by the Australian database.

Annual net greenhouse gas emissions data for the period 2005–2024 were taken from the Australian Bureau of Statistics (2025). To assess changes in net greenhouse gas emissions in 2005 – 2024 (Chart 2), the original absolute values, expressed in millions of tonnes of carbon dioxide equivalent (Mt CO₂-e), were converted into a fixed-base index with 2005 = 100. The fixed-base index for the Chart 2 was calculated according to the relation:

$$I_t = \frac{E_t}{E_{2005}} * 100 \quad (1)$$

Where:

E_t – represents CO₂ emission in the relevant year;

E_{2005} – 631,1 Mt CO₂-e;

I_t – represents the fixed-base index for the relevant year.

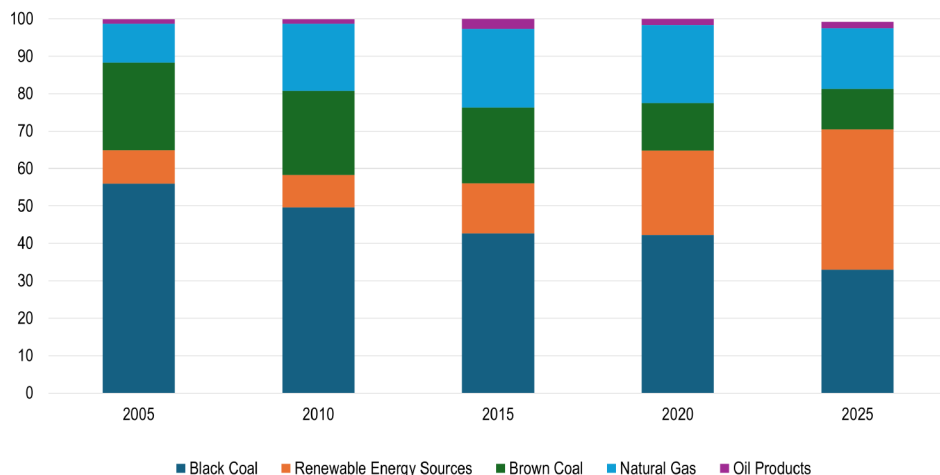
The article identifies several limitations. First, electricity generation shares are shown in five-year intervals and may not capture short-term volatility. Second, descriptive time series do not establish causality between the law's adoption and changes in CO₂ emissions. They serve only to demonstrate and describe the dynamics of change in the Australian energy sector as a supporting argument. Third, the descriptive design does not separate the effects of federal laws from those of state policies, technology costs, fuel prices, demand, and investment cycles. Therefore, the results cannot be generalised to all fossil fuel-exporting economies or interpreted as a causal estimate of the effectiveness of legislation.

4 Results

4.1 Changing the Electricity Mix

“Australia is one of the world's best places for renewable energy. The strength and consistency of our sunlight are perfect for solar. Many areas in Australia also experience consistent, strong winds. Our sunshine, wind and vast land can be used to generate abundant energy.” (EBSCO, 2024). Solar and wind energy have been the main drivers of the more-than-doubling of renewable energy generation over the past decade. Small-scale solar power generation grew by 15% in 2024 and has grown by an average of 21% per year since 2015 (Australian Government Department of Climate Change, Energy, the Environment and Water, n.d.). In the monitored period, there was a significant change in the structure of electricity production.

Figure 1: Australian electricity generation by fuel mix, in %



Source: Australian Government. Department of Climate Change, Energy, the Environment and Water, 2026.

Figure 1 shows the evolution of the share of electricity generation from coal and renewable energy sources in Australia in the period 2005 – 2025. The results point to a significant transformation of the Australian electricity sector, which was reflected in a gradual decrease in the share of black coal from approximately 56% in 2005 to approximately 33% in 2025. Coal's share of electricity generation contributed to its long-term decline, while gas-fired generation's share was lower due to increased renewables output. Fossil fuels contributed 60.5% of total electricity generation in 2025. At the same time, there was a significant increase in the share of renewable energy sources, from 8.9% to more than 37%. The observed trend indicates a gradual substitution of traditional fossil sources with low-carbon technologies, primarily solar and wind energy.

The development does not represent a smooth substitution. Between 2005 and 2010, the share of RES decreased slightly, while the share of natural gas increased. Only the following period brought a more sustained expansion of renewable production. The first formulated question can therefore be explained as empirically demonstrable, especially after 2015, with its core being the growth of RES and the retreat of both coal types. However, it is not about the end of fossil fuel dominance, which in 2025 still accounted for approximately three-fifths of production.

The dynamics of the transition are determined by the shift from fuel-intensive to investment-intensive technologies. One of the main factors is the changing cost structure of electricity generation. To compare the economic efficiency of individual technologies, the Levelized Cost of Electricity (LCOE) indicator is often used in the literature, which represents the average lifetime cost of producing one megawatt-hour of electricity. The indicator includes capital costs (CAPEX), operating and maintenance costs (O&M), fuel costs, and, for fossil sources, costs associated with carbon emissions. At the same time, it should be noted that the LCOE indicator does not provide a complete picture of the energy system's costs. It does not take into account the costs of developing transmission systems, energy storage or ensuring the stability of the electricity system with a high share of intermittent renewable sources. When interpreting the results, it is therefore necessary to perceive the LCOE as a tool for comparing production technologies at the power plant level, not the entire energy system (International Energy Agency, 2020; Chandra Asri, 2026).

Table 1: Comparison of the levelized cost of electricity (LCOE) for selected electricity generation technologies

Category	Technology	LCOE (USD/MWh)
Renewable energy sources	Solar PV + Storage	46 – 102
	Wind – onshore	24 – 75
	Wind + Storage	42 – 114
	Wind – offshore	72 – 140
Non-renewable energy sources	Combined cycle gas (CCGT)	39 – 101
	Coal	68 – 166
	Nuclear	115 – 221
	Gas peaking	141 – 221

Source: Author's own processing based on Clean Energy Council, 2024.

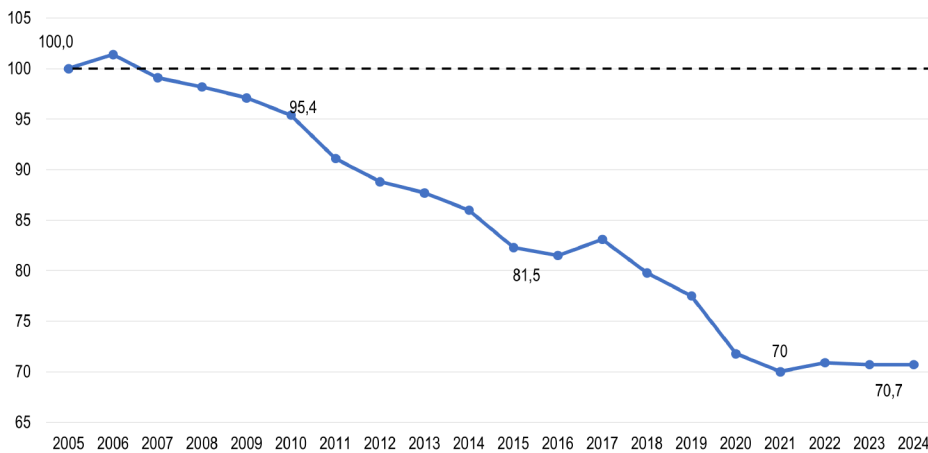
Comparisons of the levelized cost of electricity (LCOE) indicate that renewables are no longer just an environmental alternative, but also economically competitive technologies. Utility-scale solar PV and onshore wind have the

lowest LCOE ranges (US\$24-96/MWh and US\$24-75/MWh, respectively), and in many cases these values are lower than those of conventional fossil technologies. In contrast, gas-fired peaking and nuclear power stations have significantly higher electricity generation costs. The results therefore suggest that one of the main economic drivers of Australia's energy transition is the increasing cost competitiveness of renewables, which is supporting a shift in investment towards low-carbon technologies.

The CSIRO Annual Reports (2024) indicated that the capital costs of large-scale solar PV have fallen by 8%. However, onshore wind generation costs increased by 2% (a lower rate than the 8% increase last year), reflecting ongoing but moderate increases in equipment and installation costs (CSIRO, 2024). Non-renewable energy sources are often subject to price volatility driven by market fluctuations, geopolitical tensions, and supply-and-demand dynamics. For example, military activities in 2022 led to a global increase in gas prices, which resulted in higher energy bills in Australia. In contrast, renewable energy provides a route away from dependence on fossil fuel imports, allowing Australia to diversify its economy and protect communities from the unpredictable price fluctuations associated with fossil fuels. In addition, regional communities are already demonstrating how renewable energy can provide more secure energy through microgrids and other local energy sources, reducing the need to transport energy from distant locations. The extensive geographical spread of wind and solar power mitigates the risk of large-scale outages caused by weather events, and they do not rely on water for electricity generation, making them less vulnerable during droughts and heat waves (WWF Australia, 2025).

4.2 Net Emissions Dynamics

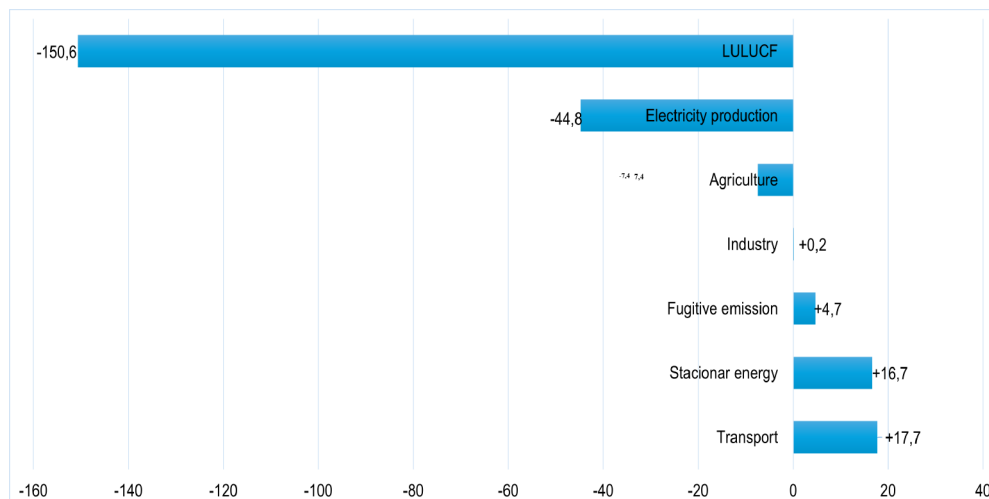
The stationary energy sector, which mainly includes energy use in buildings, industry, and mining, accounts for more than 22% of total CO₂ emissions. Transport accounts for around 21% and agriculture for 18%. This pattern of greenhouse gas emissions highlights the deep linkages between the energy sector and Australia's economic activities, as well as the environmental impacts of fossil fuels, which cut across several key sectors of the economy. As a result, Australia's energy system is under increasing international pressure to transition to renewable energy sources (Energy Supply Australia, 2025; UTS, 2023).

Figure 2: Australian electricity generation by fuel mix, in %

Source: Author's own processing based on data from the Australian Bureau of Statistics, 2025.

According to the sectoral decomposition provided by the Department of Climate Change, Energy, the Environment and Water (DCCEEW, 2025), the decline did not result from uniform decarbonization across the Australian economy. Instead, it reflected opposing trends among individual economic sectors. Reduced land clearing and native forest harvesting, together with the expansion of plantations and native vegetation and improvements in soil carbon on agricultural land, strengthened the sector's contribution to lowering net emissions. The second major driver was the transformation of the electricity generation mix. Emissions from electricity generation declined primarily because of the increasing deployment of renewable energy sources and the gradual displacement of coal and, to a lesser extent, natural gas from the generation mix. These reduction effects were partially offset by rising emissions from activities in different sectors of the Australian economy (Energy Supply Australia, 2025; UTS, 2023).

Figure 3: Sectoral contributions to emissions development from 2005 to 2024, in Mt CO₂-e



Source: Author's own proceeding based on data DCCEEW, 2025.

The sectoral breakdown shows that the decline in net emissions was not the result of uniform decarbonization. The largest absolute change occurred in LULUCF, where emissions fell by 150.6 Mt CO₂-e due to less land clearing and logging of native forests, expansion of plantations and natural vegetation, and higher carbon sequestration in agricultural land. The second-largest contribution was a decline in emissions from electricity generation of 44.8 Mt CO₂-e, which the DCCEEW attributes to the accelerated deployment of renewables and the displacement of coal and, to a lesser extent, natural gas. These reductions were offset by growth in stationary energy outside electricity production of 16.7 Mt CO₂-e (+20.6%), transport of 17.7 Mt CO₂-e (+21.6%) and fugitive emissions of 4.7 Mt CO₂-e (+10.9%). The DCCEEW links the growth in stationary combustion and fugitive emissions mainly to the development of liquefied natural gas production and exports. The growth in transport reflects higher transport activity. The transport sector includes emissions from the direct combustion of fuels for road, rail, domestic aviation, and domestic shipping, as well as from the combustion of fuels for the transportation of gas by pipeline. In 2024, consumption of road diesel and domestic aviation fuel reached record levels. A halt in RES growth cannot, therefore, explain the stagnation after 2021. In 2024, renewable generation in the National Electricity Market increased by 5.6% year-on-year, but high demand and weaker hydropower generation simultaneously increased the use

of gas and coal. Emissions from electricity generation therefore increased by 1.5% in the year. At the same time, transport and fugitive emissions increased, while declines in industrial processes, agriculture and stationary energy almost completely offset these pressures. The second issue raised in the article is that the growth of renewables was associated with a long-term decline in electricity emissions. However, the economy-wide outcome was also determined by land-use changes and the conflicting developments in transport, mining, processing and export of fossil fuels.

5 Discussion

The results of the article point to a gradual transition of the Australian electricity system towards a low-carbon model, driven by the increasing use of renewable energy sources. The sectoral results also provide empirical support for the conclusion of Warren, Christoff & Green (2016) on the decoupled development of climate and energy policies and for the dual-track model of Hopkinson et al. (2025). On the one hand, electricity emissions fell, and renewable energy generation rose sharply. On the other hand, emissions in sectors related to transport and LNG production grew. This confluence explains why it is wrong to use the growth of the share of renewables as a proxy for the decarbonization of the entire economy.

The growth in the share of renewable energy sources is consistent with Li et al. (2020), who argue that the combination of technological potential, the declining importance of coal assets, and political incentives creates pressure to change the generation mix. The article shows that the technological restructuring of electricity was not accompanied by a further decrease in net greenhouse gas emissions after 2021.

The results are also compatible with the study by Blakers, Lu and Stocks (2017), which demonstrated the technical feasibility of a highly renewable system assuming more extensive storage and transmission interconnections. The actual growth in the share of RES shows that the technological trajectory is moving in this direction, but does not automatically confirm the realisation of the modelled scenario. The Climate Change Authority (2024) continues to warn that commercially mature projects face regulatory and permitting barriers and that achieving the 82% renewable electricity target by 2030 requires accelerating investment in generation, storage and networks.

6 Conclusion

The article aims to descriptively evaluate the transformation of electricity generation in Australia and assess the extent to which the growth in the share of renewable energy sources has been associated with changes in net greenhouse gas emissions.

The article showed that the core of Australia's energy transition was a change in the electricity mix over the period under review. Between 2005 and 2025, the share of renewables increased from 8.9% to 37.5%, while the share of coal fell. The transition accelerated especially after 2015, but fossil fuels retained the majority share of electricity generation. Net greenhouse gas emissions, according to the fixed-base index, decreased from 100 points in 2005 to 70.7 points in 2024. However, this result cannot be attributed solely to the growth of renewables; it is at best a partial argument for it. The largest decrease came from the land use and forestry sector, and the second-largest from electricity generation. Their impact has been partially offset by growth in emissions from transport, non-electricity stationary energy and fugitive emissions. The stagnation of national emissions since 2021 is therefore not in contradiction with continued growth in renewables but is a consequence of opposing sectoral trends.

The main conclusion is that decarbonising the electricity sector is a necessary but not sufficient condition for decarbonising the Australian economy. The Climate Change Act 2022 and subsequent investment instruments provide a more stable target framework. However, their effectiveness will depend on the development of transmission networks and storage, the reduction of emissions from transport and industrial combustion, and the limitation of fugitive emissions associated with the fossil sector. Australia has the potential to develop clean energy technologies and has so far achieved significant sectoral shifts.

Acknowledgement

This work is a part of the project: ESG A-25-105/3020-13. *Current relevance and prospects for the development of green cooperation between Australia and the European Union in the field of sustainable energy.*

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