

Challenges of a low-carbon transition in regional fossil fuel-dependent economies: the case of Santa Catarina and Rio Grande do Sul in Brazil

The transition toward a cleaner and more sustainable future requires far more than incremental technological adjustments; it demands a profound rethinking of economic activities and the reorganization of societies upon new, sustainable foundations. In this context, the formulation of coherent public policies and territorially sensitive development strategies becomes central to achieving regional sustainability. Transforming local and regional economies is not limited to the diffusion of greener products or the expansion of clean energy sources. Rather, it entails confronting conflicting intersectoral interests, cognitive misalignments among stakeholders, insufficient or misdirected investments, institutional fragmentation, and entrenched power disputes that shape regional development trajectories.

These challenges are particularly acute in regional economies historically linked to fossil fuels, such as coal-mining regions. Such territories face deep structural constraints when adapting to low-carbon economic scenarios. Moving beyond technological substitution toward a sustainable transition, it requires productive reconversion, comprehensive social protection mechanisms, economic diversification strategies, workforce retraining, and, ultimately, the construction of new long-term development pathways capable of replacing carbon-intensive specializations.

Nevertheless, territorial restructuring processes inevitably generate tensions that heighten the complexity of innovation policies. Innovation, while frequently associated with economic growth per se, does not automatically produce socially desirable or environmentally sustainable outcomes. Its transformative potential depends on governance arrangements, regulatory frameworks, and the directionality of public investment. Effective innovation policies must therefore steer technological and productive change toward addressing broad societal challenges, articulating the economic, social, and environmental dimensions of development in a coherent manner.

The experience of Norway provides a particularly relevant example of how regions heavily dependent on fossil fuels can strategically manage the energy transition. Although it remains one of Europe's largest exporters of oil and gas, the country has allocated revenues from the sector into the Government Pension Fund Global, building substantial financial reserves that support long-term public policy and investments in economic diversification and green innovation. At the same time, regions such as Stavanger, traditionally linked to the petroleum industry, have promoted workforce reskilling and the development of clusters in renewable energy and clean technologies, illustrating how fossil fuel dependence can be progressively transformed into a strategy for a just and resilient transition.

From this perspective, the success of regional sustainability strategies depends less on isolated technological capabilities and more on the capacity of key actors—public authorities, firms, labor unions, civil society organizations, and financial institutions—to build public legitimacy, institutional coordination, and sustained social support. Regional sustainability thus emerges as a politically mediated and socially negotiated process, integrating economic

development, social inclusion, and environmental protection within specific territorial configurations.

Against this backdrop, this paper analyzes the Brazilian Climate Plan 2024–2035 as a strategic framework for advancing a low-carbon economy, while acknowledging the significant implementation challenges it faces. Particular attention is given to the socio-economic implications for regional economies that remain heavily dependent on coal extraction and thermoelectric power generation, especially in the states of Santa Catarina and Rio Grande do Sul.

The Brazilian Climate Plan 2024–2035 was revised and presented at COP 30, held in Belém, Pará, in November 2025. Its overarching objective is to guide, promote, implement, and monitor coordinated actions aimed at achieving net-zero greenhouse gas (GHG) emissions by 2050, while simultaneously strengthening the adaptation of human and natural systems to climate change. The Plan adopts short-, medium-, and long-term strategies grounded in the principles of sustainable development and climate justice. Structurally, it is organized around three interrelated pillars: mitigation strategies, adaptation strategies, and transversal strategies designed to guide implementation and governance processes.

Mitigation strategies are directly linked to reducing GHG emissions and expanding carbon sinks, in alignment with the Paris Agreement and Brazil's Nationally Determined Contribution (NDC). They seek to promote decarbonization across energy, industry, agriculture, and land-use sectors, fostering technological innovation and structural transformation. Adaptation strategies, in turn, focus on reducing the vulnerabilities of populations, ecosystems, and economic sectors, while enhancing resilience to climate-related risks. This involves strengthening adaptive capacity across multiple levels of governance and reinforcing socioeconomic, institutional, and environmental resilience.

Sectoral plans operationalize these objectives. Among them, the Energy and the Industry and Mining Sectoral Plans are particularly relevant to this study. The Energy Plan emphasizes ensuring fuel supply security—especially biofuels and other low-carbon fuels—in the face of climate threats. The Industry and Mining Plan promotes preventive and resilient actions to strengthen the adaptive capacity of industrial infrastructure and surrounding communities, while encouraging the progressive replacement of high-emission inputs and processes with low-carbon alternatives, including green hydrogen and carbon capture technologies.

Despite the formal advancement represented by the Plan, public debate surrounding COP 30 revealed tensions. Media outlets and civil society organizations criticized the targets as insufficiently ambitious. Notably, a formal roadmap for the phase-out of fossil fuels was excluded from the final documents. Given that decisions at the Conference of the Parties require unanimity, the proposed roadmap—although supported by 80 to 85 countries—did not reach consensus. Nevertheless, the so-called Belém Package included a commitment to triple adaptation finance by 2035, reinforcing a shift toward implementation-oriented governance. This commitment underscores the importance of ensuring that climate targets do not remain declaratory statements but are supported by measurable indicators, monitoring systems, and enforceable governance mechanisms.

In comparative terms, Brazil's energy transition appears less dramatic than in many industrialized countries, largely because its electricity matrix is already relatively clean, with significant participation of hydropower, wind, and solar sources. However, national emission profiles reveal a more complex reality. In 2024, agribusiness accounted for approximately 42% of emissions, while land-use change and forestry represented 29%, followed by the energy sector at 20%, primarily from fossil fuel combustion. These figures indicate that the energy transition, while important, is only one component of Brazil's decarbonization challenge.

Less emphasized in policy discourse, however, are the social inequalities that have emerged as unintended consequences of the renewable energy expansion. Strategic mitigation objectives focus primarily on technological substitution and emission reduction in energy, agriculture, and industry. While environmentally necessary, such objectives often overlook distributive effects. A sustainable transition must also be socially inclusive, guided by principles of efficiency, justice, and equity.

The Brazilian experience reveals a significant social bias. Although the country has achieved notable success in expanding renewable generation capacity and attracting private investment, these achievements have not translated into equitable access to benefits, resulting in private and privileged access to these gains.

Studies have demonstrated that electricity costs weigh disproportionately on low-income household budgets. This distortion is partly linked to financial mechanisms supporting carbon-intensive thermoelectric generation, whose costs are socialized across consumers through electricity tariffs. Vulnerable populations, lacking access to credit and capital, are often unable to adopt decentralized solar solutions, resulting in a dual structure: private access to renewable benefits for higher-income groups and generalized cost burdens for the broader population.

The social dimension of transition becomes even more evident in coal-dependent regions. According to data from DIEESE (2022¹), in 2019 there were 3,175 workers employed in coal extraction and processing in Rio Grande do Sul and Santa Catarina. Of these, approximately 775 were directly linked to subsidized thermoelectric power plants. While the absolute number may seem modest at the national scale, its territorial concentration amplifies its socioeconomic impact.

In 2022, Federal Law 14.229/22 established the Just Energy Transition Program (TEJ), including provisions for socioeconomic support. The legislation aims to prepare the coal-mining region of Santa Catarina for the anticipated termination, by 2040. The law explicitly recognizes the socioeconomic collateral effects of decarbonization and seeks to promote a timely, responsible, and sustainable transition.

¹ DIEESE - Departamento Intersindical de Estatística e Estudos Socioeconômicos. (2022). *Os trabalhadores em extração e beneficiamento de carvão mineral em Santa Catarina e Rio Grande do Sul. Estudo e Pesquisas n. 101*. <https://www.dieese.org.br/estudosepesquisas/2022/estPesq101Carvao.pdf>

However, important limitations emerge. The regulatory framework displays a clear geographical bias by prioritizing Santa Catarina while comparatively neglecting Rio Grande do Sul. This is paradoxical. Although Santa Catarina holds only about 10% of Brazil's coal reserves, it concentrates roughly 70% of the sector's workforce. Conversely, Rio Grande do Sul accounts for approximately 88% of national coal reserves but represents only 17% of employment. Both states, however, maintain comparable shares in coal-fired thermoelectric generation.² Such asymmetries reveal inconsistencies between resource endowments, labor distribution, and policy design.

Coal mining, as part of the extractive industry, is characterized by high capital intensity, relatively low technological dynamism, and limited diversification potential. Importantly, wages in the coal sector are significantly higher than the average across other regional economic activities, particularly in Santa Catarina. This wage differential constitutes a structural barrier to labor mobility. Workers transitioning to emerging green sectors or service activities often face substantial income losses, which may generate social resistance to decarbonization policies.

The political dimension of this resistance is captured in the statement of the Mayor of Candiota, in Rio Grande do Sul, who questioned the legitimacy of decisions perceived as externally imposed. His remarks illustrate the friction between national climate commitments and local development concerns:

It is very easy and convenient for those sitting in an office, in a capital city, to say that we pollute, when, in fact, they have their air conditioning on and only travel by car... Who is the irresponsible, reckless person who would want to shut down a thermoelectric plant that generates jobs and development, keeps children in school, and provides a dignified wage for the people?", questions the mayor³

For communities dependent on thermoelectric plants, these facilities represent employment, municipal revenues, and social stability. Abrupt closures, without credible alternatives, risk deepening territorial inequalities.

The evidence presented highlights a broader challenge: insufficient coordination and articulation across federal, state, and municipal levels of government. Effective decarbonization requires multiscale governance arrangements capable of integrating climate objectives with regional development strategies. Without such coordination, climate policies risk becoming fragmented, generating uneven territorial impacts.

Decarbonization must therefore proceed without reproducing or amplifying existing social inequalities. Reducing structural distortions in electricity financing—particularly those

² <https://diamanteenergia.com/institucional-diamante/historia>; <https://www.cgteletrosul.com.br/nosso-negocio/geracao/candiota>; <https://www.pampasulenergia.com.br/#b10380>

³ <https://apublica.org/2023/08/capital-nacional-do-carvao-corre-contra-o-tempo-para-fazer-transicao-energetica/>

linked to coal subsidies—could alleviate the burden on household budgets. Simultaneously, productive restructuring policies must be territorially embedded, fostering new economic activities capable of generating quality employment. Maintaining carbon-intensive industries may temporarily preserve jobs, but at the cost of higher electricity tariffs and long-term environmental liabilities, special for more vulnerable consumers.

This paper examines the Brazilian Climate Plan as a strategic framework for energy transition, focusing on its impacts and implementation challenges in the coal-mining regions of Santa Catarina and Rio Grande do Sul. Through a comparative case study integrating documentary analysis, socioeconomic and environmental datasets, and territorial mapping, the research investigates institutional capacities, governance arrangements, and structural barriers to policy implementation.

The findings suggest that while the Climate Plan establishes relevant technical guidelines and emission targets, its effectiveness is constrained by limited multilevel coordination, insufficient targeted funding, and the absence of territorially differentiated productive reconversion strategies. Historical dependence on coal intensifies employment and income vulnerabilities, requiring comprehensive social protection, professional retraining, and incentives for economic diversification.

To address these gaps, the study proposes integrated measures, including regional transition funds, participatory governance committees, retraining programs explicitly linked to green job creation targets, and robust monitoring instruments capable of assessing distributive effects. Such mechanisms are essential to enabling a just and territorially sensitive transition.

Ultimately, the Brazilian case illustrates that climate policy is inseparable from questions of regional development and social justice. The articulation of innovation, inclusion, and environmental sustainability requires more than technological change; it demands institutional learning, political negotiation, and long-term commitment to equitable structural transformation.