



Strategic pathways for decarbonization: a data-driven typology to strengthen climate policy

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ABSTRACT

As global temperatures approach critical thresholds and emissions continue to rise, the urgency for strategic, accelerated decarbonization grows. The climate mitigation literature is vast, but evidence on how mitigation options cluster into overarching decarbonization pathways remains fragmented. Here, we use artificial intelligence-enabled text and citation analysis on an initial corpus of over one million scientific papers (2011–2021) to derive a data-driven typology of six recurrent decarbonization pathways: Technology Breakthrough, Electrification of Uses, Integrated Policy, Decarbonization of Electricity, Demand Reduction & Co-Benefits, and Land Use & Circularity. Rather than proposing new mitigation options, this typology organizes existing work into a small set of archetypal strategies and maps their prevalence across regions, disciplines, and policy orientations. For example, Electrification of Uses is most prominent in the EU27, while Technology Breakthrough dominates in China, the United States, and Japan. The analysis highlights synergies and complementarities between pathways, the scientific competencies that typically underpin them, and persistent gaps – particularly in Land Use & Circularity. We illustrate the policy relevance of the typology by comparing pathway profiles with stated climate policy directions, identifying areas where research and policy emphases are misaligned. This framework can support policymakers and researchers by benchmarking policy portfolios against the typology and highlighting research needs associated with national decarbonization goals.

Key policy insights

- The typology provides a diagnostic to benchmark national pathway portfolios in research and policy and identify underweighted pathways.
- Regional variation in pathway emphasis and scientific capacities calls for tailored strategies aligned with national profiles.
- Combining complementary pathways can strengthen system-wide impacts (including emissions and efficiency), e.g. by pairing Electrification of Uses with Decarbonization of Electricity.
- Land Use & Circularity is comparatively underrepresented relative to other pathways, despite offering mitigation, ecosystem, resilience and resource-efficiency co-benefits.
- The typology can diagnose research–policy gaps and guide timing (sequence or fast-track), recognizing that policy and research co-evolve.

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1. Introduction

Despite the Paris Agreement's goal to limit global warming to well below 2°C – and ideally to 1.5°C – global emissions have continued to rise. With global mean temperatures having temporarily reached 1.5°C above

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