DEEP DECARBONIZATION OF THE ELECTRIC POWER SECTOR: INSIGHTS FROM RECENT LITERATURE

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Overview

The electric power sector is widely expected to be the linchpin of efforts to reduce greenhouse gas (GHG) emissions. Most studies exploring climate stabilization pathways envision a decline in global anthropogenic GHGs of 50-90% below current levels by 2050 (IPCC 2014; Loftus et al. 2015). To reach these goals, the power sector would need to cut emissions nearly to zero, while expanding to electrify (and consequently decarbonize) portions of the transportation, heating, and industrial sectors (GEA 2012; IPCC 2014; Krey et al. 2014; McCollum et al. 2014).

This paper reviews recent literature on the deep decarbonization of the electric power sector, defined here as 80-100% reduction in carbon dioxide (CO_2) emissions. To capture insights from recent research, this review encompasses 30 deep decarbonization studies published since 2014. These studies employ a variety of methods, including detailed power system optimization models, higher-level energy-economic and integrated assessment models, and scenario-driven exercises. They also span different scopes, from the regional to national to global, and they entail different research objectives. Despite this diversity of parameters, the recent literature presents a set of clear and consistent insights. This review seeks to synthesize these key insights and present these findings in a policy-relevant manner.

Methods

Literature review and comparative analysis of methods.

Results

There is a strong consensus in the literature that reaching near-zero emissions is much more challenging — and may require a very different mix of resources — than comparatively modest emissions reductions (50-70% or less). Planning and policy measures should therefore focus on long-term objectives (near-zero emissions) in order to avoid costly lock-in of suboptimal resources.

In addition, there is strong agreement in the literature that a diversified mix of low-CO_2 generation resources offers the best chance of affordably achieving deep decarbonization. While it is theoretically possible to rely primarily (or even entirely) on variable renewable energy resources such as wind and solar, it would be significantly more challenging and costly than pathways that employ a diverse portfolio of resources. In particular, including dispatchable low-carbon resources in the portfolio, such as nuclear energy or fossil energy with carbon capture and storage (CCS), would significantly reduce the cost and technical challenges of deep decarbonization.

Conclusions

The recent literature sheds significant light on the challenge of decarbonizing electric power systems. Despite a wide variety of analytical methods, goals, and scopes, there is strong agreement in the recent literature that deep decarbonization—reaching zero or near-zero CO_2 emissions—is best achieved by harnessing a diverse portfolio of low-carbon resources.

In particular, low-carbon dispatchable baseload resources such as nuclear, biomass, hydropower, or CCS, are an indispensible part of any least-cost pathway to deep decarbonization. Recent literature indicates that removing this dispatchable base from the generation portfolio, relying instead entirely or predominately on variable renewable energy resources such as wind and solar, would significantly increase the cost and technical challenge of decarbonizing power systems.

In addition, reaching zero emissions requires a significantly different capacity mix than achieving comparatively more modest goals. This finding implies that policymakers and planning should be wary of lock-in of suboptimal capacity investments, and should consider policy and market mechanisms that incentivize action toward longterm goals.

References

GEA. 2012. Global Energy Assessment: Toward a Sustainable Future. Edited by Thomas B. Johansson, Anand Patwardhan, Nebojsa Nakicenovic, and Luis Gomez-Echeverri. Cambridge, UK, New York, NY, USA and Laxenburg, Austria: Cambridge University Press and the International Institute for Applied Systems Analysis. doi:10.1017/CBO9780511793677.

IPCC. 2014. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by O. Edenhofer, R. PichsMadruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, et al. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. doi:10.1017/CBO9781107415416.

Krey, Volker, Gunnar Luderer, Leon Clarke, and Elmar Kriegler. 2014. “Getting from Here to There – Energy Technology Transformation Pathways in the EMF27 Scenarios.” Climatic Change 123 (3–4): 369–82. doi:10.1007/s10584-013-0947-5.

Loftus, Peter J., Armond M. Cohen, Jane C. S. Long, and Jesse D. Jenkins. 2015. “A Critical Review of Global Decarbonization Scenarios: What Do They Tell Us about Feasibility?” Wiley Interdisciplinary Reviews: Climate Change 6 (1): 93–112. doi:10.1002/wcc.324.

McCollum, David, Volker Krey, Peter Kolp, Yu Nagai, and Keywan Riahi. 2014. “Transport Electrification: A Key Element for Energy System Transformation and Climate Stabilization.” Climatic Change 123 (3–4): 651–64. doi:10.1007/s10584-013-0969-z.