Decarbonization in Europe: a long-term view on the role of electrification

Topic:
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Introduction
Electricity is considered key for decarbonization and meeting the European Green Deal goals for 2050. One strategy to achieve these goals is by assuring 100% (or close) renewables in the EU power sector. A second strategy is to promote the electrification of final end-uses still dominated by fossil fuels, such as transport or industrial heat. Finally, electricity-based digital technologies can aid decarbonization by promoting energy and material efficiency in all economic sectors.
Deep electrification is a common goal shared by many EU member states for the future. Still, the process of electrification in Europe is not new, having occurred for more than one century. However, the impacts of renewable electricity and direct electrification were different across countries due to different levels of economic development, natural resources, and energy policies.
While the long-run impact of electrification on economic development has been studied from various angles, the long-period historical impact of electricity on energy efficiency or emission intensity has been less studied. This is somewhat surprising given that many European countries have witnessed a long-run decoupling of energy and emissions with economic development from the Second Industrial Revolution and a decline/stabilization in emissions from the 1970s, which coincides with the uptake of the Third Industrial Revolution.
This paper analyzes the long-term contribution of electrification on the efficiency and decarbonization of European energy systems, by comparing the long-term electrification path of four countries, Portugal, the UK, Denmark and Sweden with distinct resource endowments and climate, degrees of electrification and patterns of development.
To investigate the role of electricity in each country's energy efficiency and decarbonization, we use a combined EEIOA modeling and decomposition approach.
First, we build multi-factor physical input-output models of two indicators for each country: economy-wide energy efficiency (considering primary energy resources to useful energy services conversion) and total energy-related CO2 emission. Following Guevara and Domingos (2017), these models disaggregate these indicators into structural factors that describe in detail the conversion processes and value chain of the energy flows production and consumption within these economies. Second, we evaluate the structural changes that the energy systems of these economies have experienced. Third, by applying a temporal structural decomposition analysis, we seek to understand how electricity contributed in each country to the energy efficiency and decarbonization of the overall energy system and what is the relative role of electricity services supply with respect to the supply of services by other energy carrier. Fourth, by applying a spatial structural decomposition analysis, we attempt to assess the reasons for differences in electricity efficiency and emission intensity trends across the four countries, as well as discuss different historical electrification rates across end uses. Finally, we perform an integrated analysis of results.
To do so, we use a newly constructed long-term primary to useful exergy flow database, developed by FelÃ-cio et al (2019, 2023) for Portugal and extended by the authors to other European countries. This database details for each final energy carrier, their primary energy flows and associated carbon emissions, the mix of end-uses and the efficiency of conversion from final to useful exergy.
Our work identifies the main processes along the value chain of these countriesâ€™ energy systems that influenced their trend of electrification and the trend of economy-wide energy efficiency. Also, we unveiled the structural factors behind differences in energy and electrification performance between these countries. The results contribute to the decoupling-degrowth debate and help develop systemic understanding of potential decarbonization paths of European energy

systems.