Harmonizing Ecosystem Services into Life Cycle Impacts of Modern Electricity Generation Options

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Abstract

To limit global warming and avoid the worst potential impacts of climate change, the IPCC has called for net-zero global greenhouse gas (GHG) emissions by around mid-century. Achieving this requires a transition of our energy system. In the U.S., solar, wind, and natural gas are the predicted dominant sources of electricity generation in the decades to come. In this study, we combine life cycle assessment (LCA) and biodiversity and ecosystem (BES) models to compare the environmental impacts of combined cycle gas turbine (CCGT), solar, and wind facilities, all at utility-scale.

The area of interest (AOI) for this study includes 33 counties centered on the Midland Basin, spanning over 10.5 million hectares of the Chihauhuan Desert, High Plains, Southwestern Tablelands, Edwards Plateau, and Central Great Plains ecoregions. We use OpenLCA and ReCiPe 2016 to quantify life cycle impacts from cradle-to-grave. For BES, we use the InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) modeling suite to evaluate impacts to five dominant services. A new workflow includes placing potential facilities throughout the AOI using a statistical approach weighted according to proximity to high voltage transmission and protected lands, identifying the land footprint of each facility, and assessing impacts to BES impacts at each location. To compare across technologies and methodologies, we develop the Marginal Cost Index (MCI), a normalization scheme to account for the comprehensive impacts expected.

Results indicate lower GHG emission-related impacts (97% reduction) and particulate matter formation (67% reduction) for wind and solar generation when compared to CCGT, as well as lower water use (90-99% reduction), but land occupation impacts are higher for renewables than CCGT. BES model results highlight the importance of considering ecoregion, with impacts to BES varying significantly based on facility location. This research offers a more comprehensive evaluation of the environmental impacts of electricity generation options. The developed workflow can be incorporated into siting decisions at various scales, allowing for a more holistic consideration of tradeoffs and minimizing the potential for unintended consequences.

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