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GCAMUSAJobs: An R package for employment projections based on GCAM-USA power sector outcomes

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Software

- Review
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Summary

The GCAMUSAJobs R package was developed to post-process electric power projections from GCAM-USA (JGCRI, 2025), enabling the estimation of future power sector jobs at the state-level by generation technology and job type. GCAMUSAJobs extends GCAM-USA functionality by (1) estimating the capacity levels of different activities – operational capacity, capacity addition, and retirement; and (2) calculating jobs associated with production activities, including those in operation and maintenance (O&M), construction, and decommissioning. Additionally, this package is designed to be easily adaptable to the output of other energy system models besides GCAM-USA.

Statement of need

The development of GCAMUSAJobs was driven by the need to assess the distributional labor impacts of energy system evolution (Hanson, 2023; Mayfield et al., 2023; Raimi, 2021; Xie et al., 2023). While gross employment (Mayfield et al., 2023) and power sector employment (Xie et al., 2023) are expected to grow into the future, under both business as usual (BAU) and alternative scenarios, Xie et al. (2023) find insignificant differences in the U.S. national power sector jobs between BAU and decarbonization scenarios. However, distributional differences across U.S. states are much more significant, e.g., fossil fuel-intensive states may experience slower job growth or job losses, which was also found in other studies (Hanson, 2023; Mayfield et al., 2023).

The Global Change Analysis Model (GCAM) and its ancillary model GCAM-USA (JGCRI, 2025) are powerful tools for studying energy systems dynamics and evolution. Many previous studies have applied or integrated the tool to analyze potential impacts on the energy system and associated outcomes due to environmental and socioeconomic changes (e.g., Feijoo et al., 2020; Ganji et al., 2024; Ou et al., 2018; Pan & Shittu, 2025; Zhang et al., 2025). Currently, GCAM-USA does not calculate power sector jobs. GCAMUSAJobs addresses this gap by providing projected direct power sector jobs based on GCAM-USA output, enhancing the functionality of GCAM-USA for labor impact analysis.

Software design

The direct purpose of GCAMUSAJobs is to calculate different types of jobs in the power sector across U.S. states, built upon the existing open-source model GCAM-USA. As GCAM-USA is a complex multi-sector model with technological details, our design involves in-depth understanding and testing of how various components work together in GCAM-USA, especially

in the power sector, so that we can properly design the jobs calculation in our package and source available matching data (e.g., employment factors). This requires irreplaceable human efforts to comprehend the existing software and extend its capability through collaboration with GCAM-USA modelers and domain experts in socioeconomics.

`GCAMUSAJobs` is also designed to be easily adaptable to the output of broader energy system models to enable extended employment analysis. `GCAMUSAJobs` provides detailed employment factors extracted from simulations of the Jobs & Economic Development Impacts (JEDI) model (NLR, 2025), which calculates employment factors under a range of assumptions about power sector technologies. This means users can supply capacity activity output from an energy system model in the required format and conduct employment analysis using those readily applicable employment factors. For GCAM-USA users, the workflow is further simplified by directly ingesting GCAM-USA output databases in their original format and automatically performing capacity activity and employment analysis.

The package structure also allows users to access intermediate outputs and develop custom functions to examine or adapt analytical components. Besides, `GCAMUSAJobs` includes user-configurable options for key model assumptions and built-in visualization tools for rapid diagnostics.

Research impact statement

`GCAMUSAJobs` enables a new workflow to analyze various potential impacts on power sector jobs across U.S. states. Sources of impact can include, but are not limited to, socioeconomic development, environmental change, policy targets, and technological advancement. `GCAMUSAJobs` can perform ex-ante quantitative analysis of the associated distributional impacts on state-level power sector jobs. It can support analytical work in academic research and inform policymaking by providing useful information for preparedness and targeted responses to the anticipated impacts. To our knowledge, no such tool exists that extends the capability of an integrated multi-sector model (e.g., GCAM-USA) to analyze the impact on employment. `GCAMUSAJobs` has been used by researchers at the University of Maryland (external adopter) for a published report on the renewable energy transition in Maryland and its implications (Kennedy et al., 2024). Specifically, the report provides direct job estimates at Maryland's thermal power plants based on facility characteristics (e.g., nameplate capacity, capacity factor, and fuel type) and the employment factors produced by this package. Meanwhile, the package is expected to be developed by external researchers to expand its capabilities and grow its user base.

Workflow

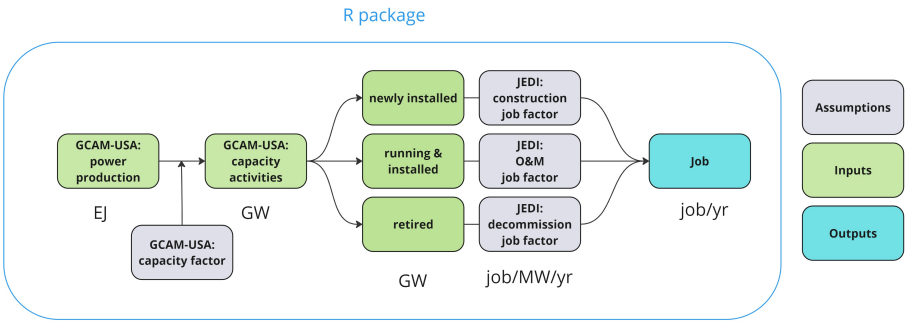

Figure 1: Figure. 1. Package workflow.

GCAMUSAJobs utilizes GCAM-USA annual electricity generation outputs to estimate underlying capacity levels based on assumptions about capacity factors and calculate associated power sector jobs based on employment factors (Fig. 1). The employment factor represents the average number of jobs created per unit of power production activity (e.g., jobs per gigawatt). This method is widely used in the relevant literature (Mayfield et al., 2023; Rutovitz et al., 2015). GCAMUSAJobs adopts employment factors from the JEDI model, which has been broadly used in the literature (Jacobson et al., 2017; Rutovitz et al., 2015; Xie et al., 2023).

Key functions

GCAMUSAJobs::GCAM_EJ queries power generation data (in exajoules, EJ) from the GCAM-USA output database for a single scenario, disaggregating generation from existing plants, newly added plants, and the generation lost from recently retired plants. The output is provided annually, broken down by state and fuel technology. Building on this, GCAMUSAJobs::GCAM_GW, taking the output from GCAMUSAJobs::GCAM_EJ, calculates the average annual capacity levels (in gigawatts, GW) by state and fuel technology for different activities, including operation, addition, and retirement. It supports both the "Total" and "Net" methods. In the "Total" method, all capacity additions and retirements are counted separately. In the "Net" method, premature retirement is offset with capacity addition. The "Total" method is better suited for large states with many facilities, where it is plausible that while one plant is retiring, a facility at a different location in the state is beginning construction. In small states with few facilities, simultaneous retirement and addition may not reflect reality. For example, if only one coal plant exists in a small state and it retires, any new capacity is likely a direct replacement, not a separate project. In this case, the replacement would imply a lower number of jobs needed than if the retirement and addition occurred as separate projects. The two options of user-defined methods ensure that job estimates for capacity expansion and decommissioning remain realistic and regionally appropriate. GCAMUSAJobs::GCAM_JOB then utilizes the output from GCAMUSAJobs::GCAM_GW to estimate the average annual job estimates, broken down by fuel type and job type, including construction (both on-site and construction-related), operations & maintenance, and decommissioning. Users can select between the "Total" or "Net" method, with "Total" used as the default. GCAMUSAJobs also provides a list of functions to visualize the employment factor assumptions, capacity, and job outcomes.

GCAMUSAJobs::GCAM_EJ is compatible with both the GCAM-USA output database as well as a project data file queried using the R package rgcam. Please refer to the package vignette for

additional examples and visualizations.

Implementation

For demonstration purposes, we use `GCAMUSAJobs` to post-process the outcome from GCAM v7.1 for a standard reference scenario, estimating the direct job, aggregated over states, associated with U.S. power generation (Fig. 2).

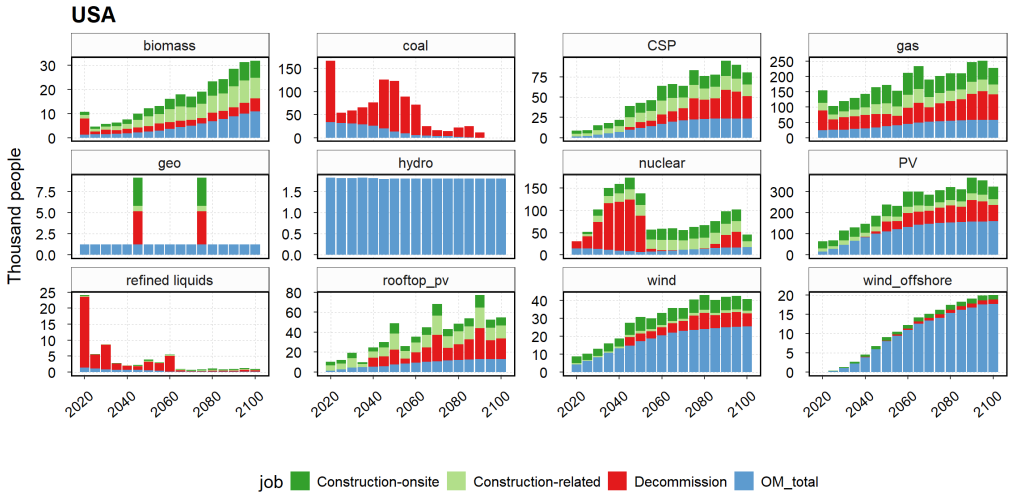

Figure 2: Figure. 2. Annual average power sector jobs by fuel and job types over a 5-year model period. Note that y-axes have different scales.

AI usage disclosure

No generative AI tools were used in the development of this software, the writing of this manuscript, or the preparation of supporting materials.

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