Unraveling the Threads of Environmental Justice in Critical Mineral Extraction: A Framework for Regionalized Life Cycle Data

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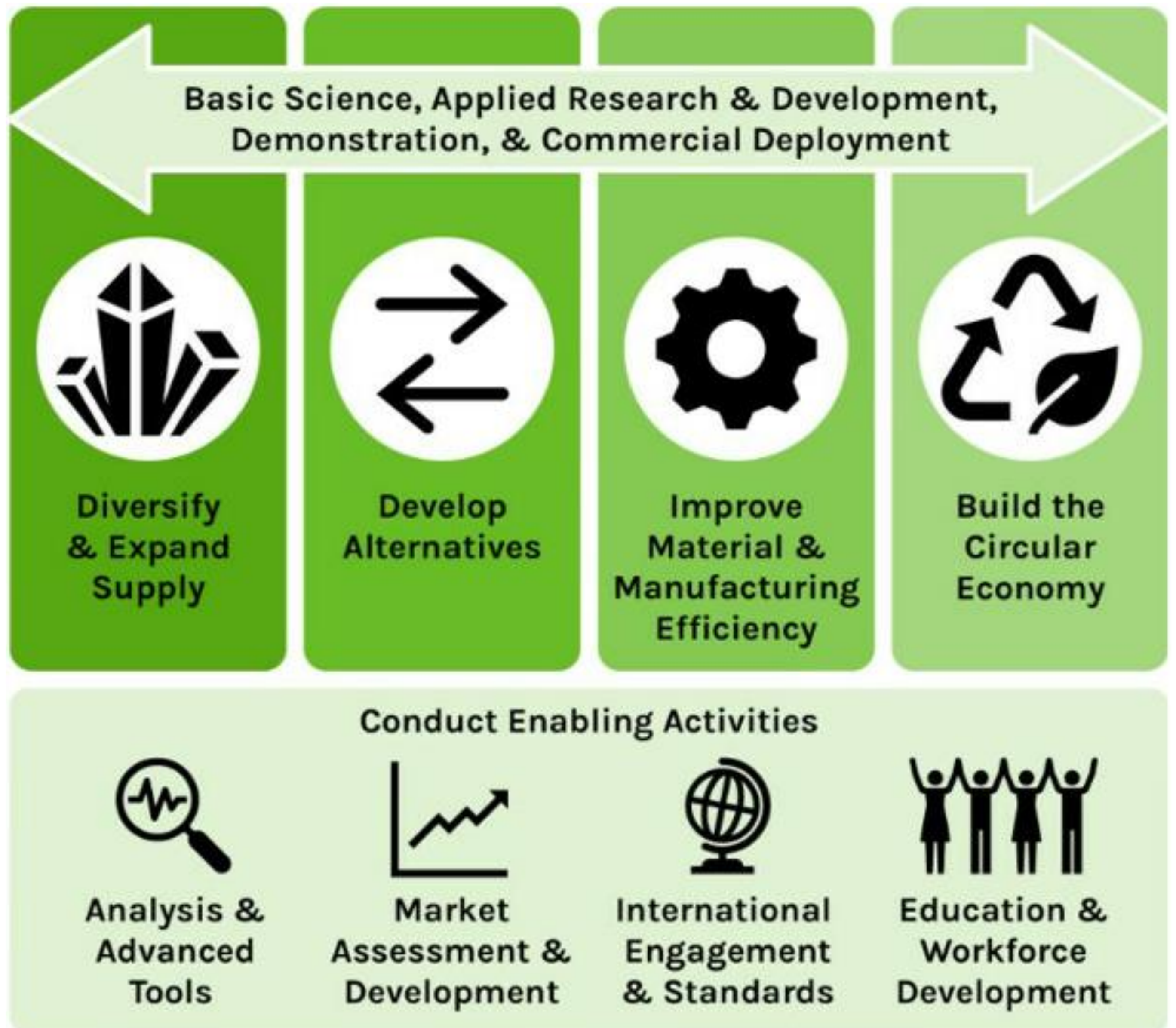


Figure 1. DOE critical minerals and material program strategy pillars [2].

Figure 2. Secondary and unconventional critical mineral and material sources [4].

I. Background and Motivation

- The U.S. Environmental Justice40 Initiative ensures that 40% of federal investments, such as those in clean energy, benefit disadvantaged communities (DACs) identified by the Climate and Economic Justice Screening Tool [1].
- Critical minerals are essential for renewable energy technologies; however, their extraction often carries significant environmental and social burdens (see Fig. 1).
- Life cycle assessment (LCA) helps address these challenges by quantifying impacts such as GHG, PM2.5, and water use.
- Recovering rare earth oxides (REOs) from unconventional and secondary sources like acid mine drainage, coal mine tailings, and copper mine tailings, may provide benefits to DACs.
- A Justice40 Toolset is being developed to support domestic critical mineral production and environmental justice, with initial stages focused on a life cycle framework and data regionalization

II. Life Cycle Framework

Goal: Develop a flow chart for REO recovery from unconventional and secondary sources (Fig. 2), including their environmental impacts, using data from the NETL Unit Processes Library [3] and identifying any data gaps in these processes.

Case studies: coal mine tailings and acid mine drainage in Appalachia and copper mine tailings and produced water in Arizona.

Life Cycle Processes:

1. Pre-Processing (e.g., crushing, roasting)
2. Chemical Leaching (e.g., leaching with sulfuric or nitric acid)
3. Final Steps (e.g., filtration, solvent extraction, precipitation)

The flow chart below forms a framework, enabling flexible combinations tailored to specific feedstocks and processes.

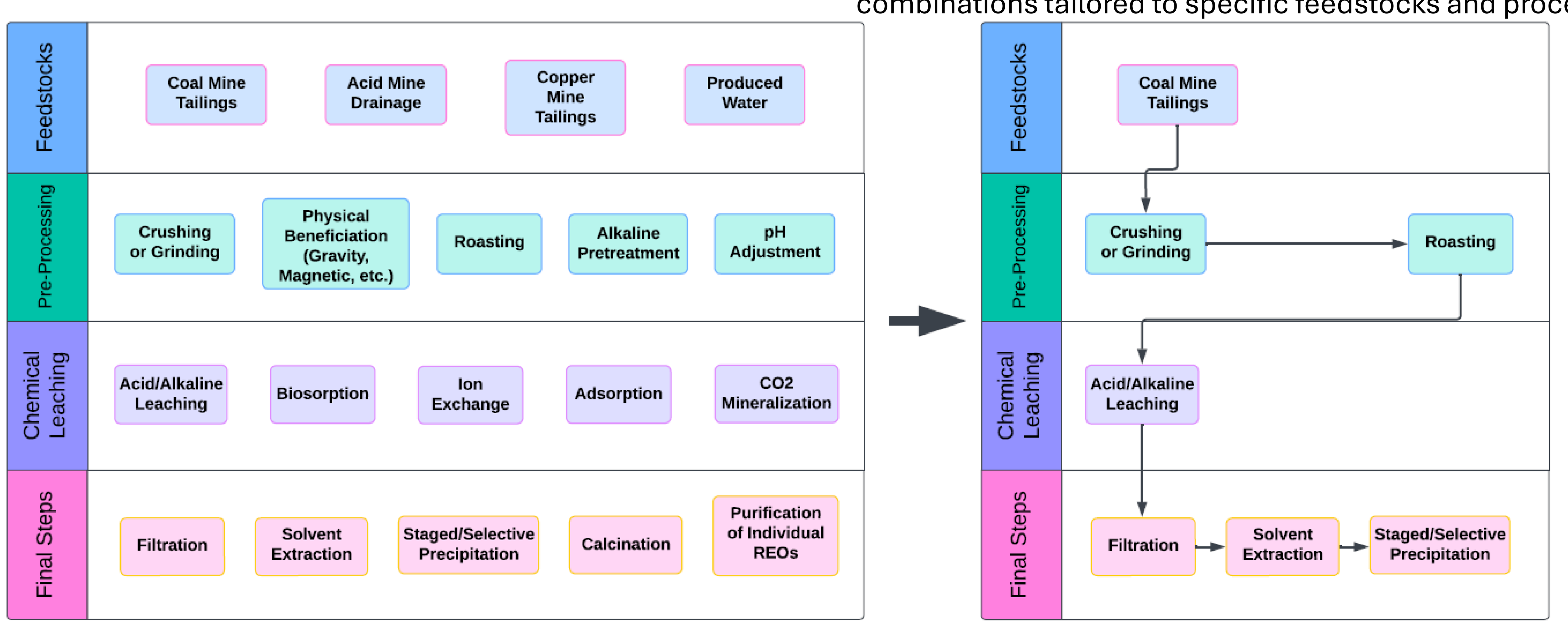


Figure 3. Life cycle unit process framework for secondary/unconventional critical mineral production.

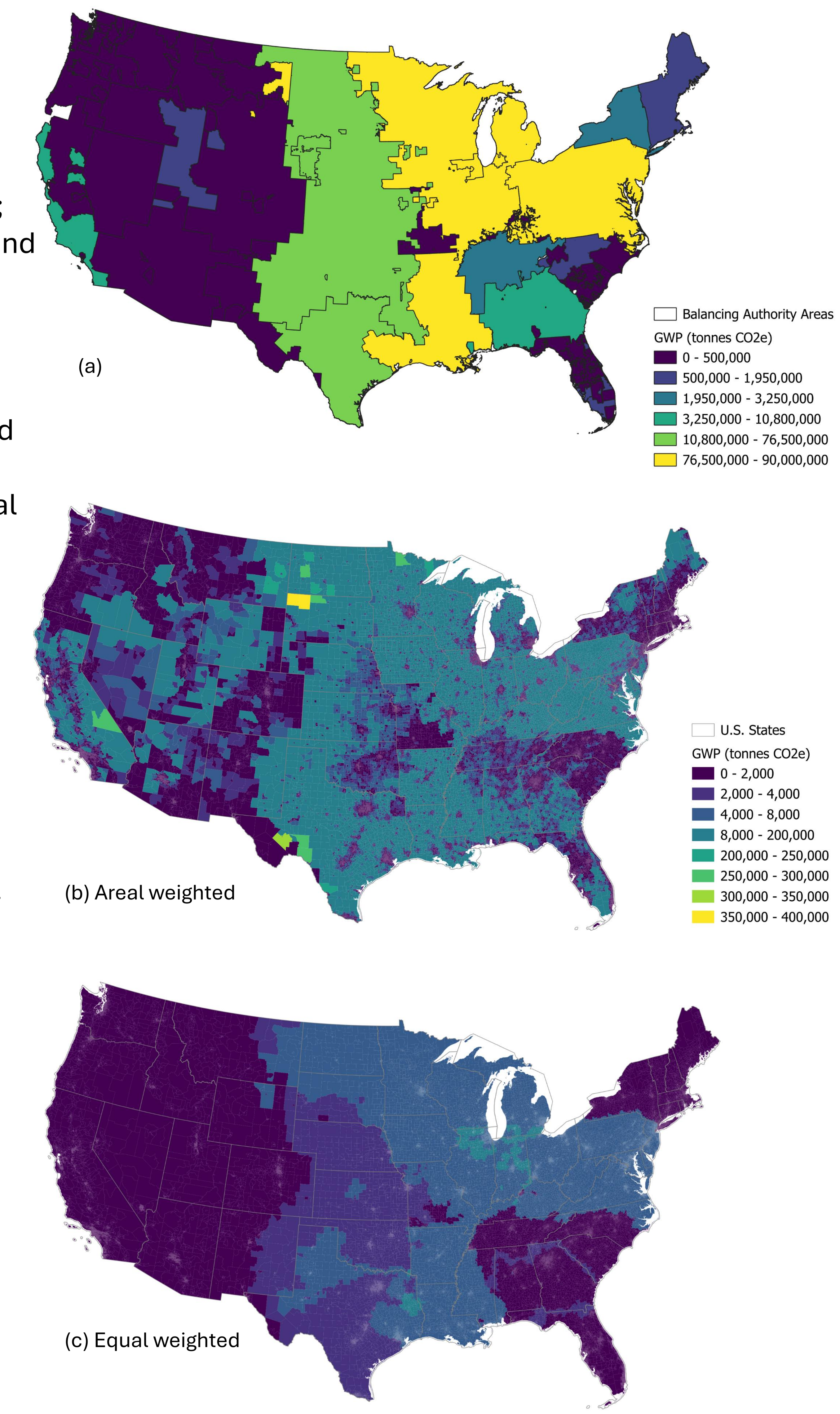


Figure 4. Regionalization demonstration of global warming potential (tonnes CO_2e) from balancing authority (a) to U.S. census tract using areal weighting (b) and equal weighting (c) methods. [5].

III. Regionalization

Challenge: Life cycle inventory data and impacts are often tied to large regions (e.g., states, electricity balancing authorities, coal basins) that are not relevant to DACs.

Solution: Regionalize spatially relevant LCA data to U.S. census tract.

- *Areal Weighting*: Distribute data based on overlapping areas (e.g., for air emissions and impacts).
- *Equal Weighting*: Equally distribute data to overlapping areas (e.g., for product flows).

Outcome: : Reduce ~6 hr computation of regionalizing census tracts down to a matter of seconds

Example: GWP (tonnes of CO_{2e}) regionalized from balancing authority (Fig. 4a) to census tract using both weighting methods (Figs. 4b and 4c).

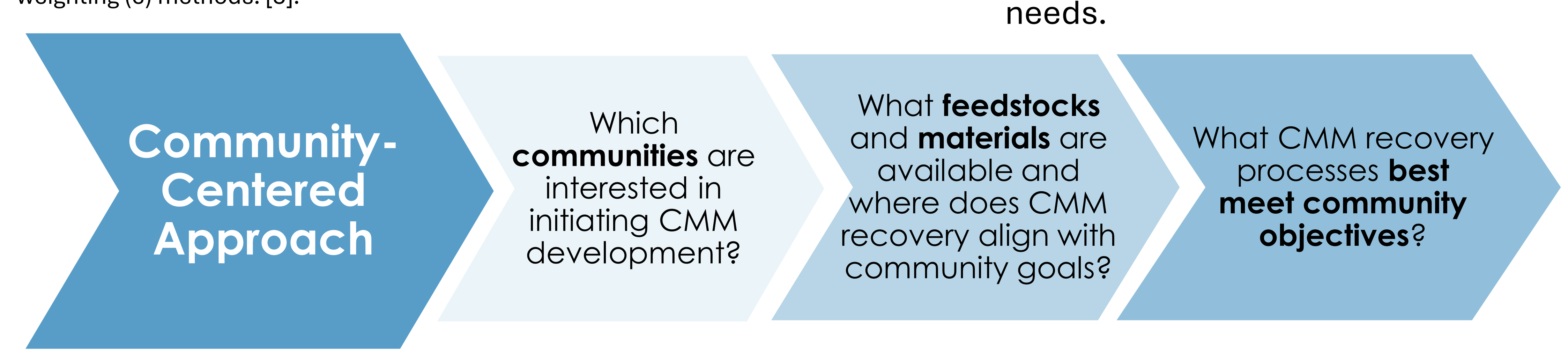
IV. Future Work

Advanced Regionalization:

- Incorporate additional weighting approaches (e.g., population density and finances) and regions.
- Link regionalization to life cycle inventories and impacts framework.

Long-Term Goals:

- Incorporate this framework and regionalization into a decision-support tool for REO production.
- Enable real-time policy and investment decisions.
- Ensure equitable energy transition and support diverse stakeholder needs.



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