NeurIPS 2025 Workshop
Tackling Climate Change with Machine Learning

Coupling Agent-based Modeling and Life Cycle Assessment to Analyze Trade-offs in Resilient Energy Transitions

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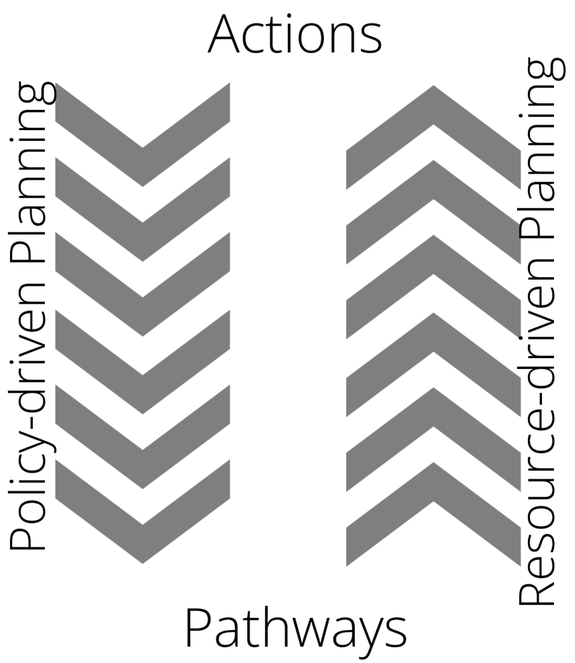
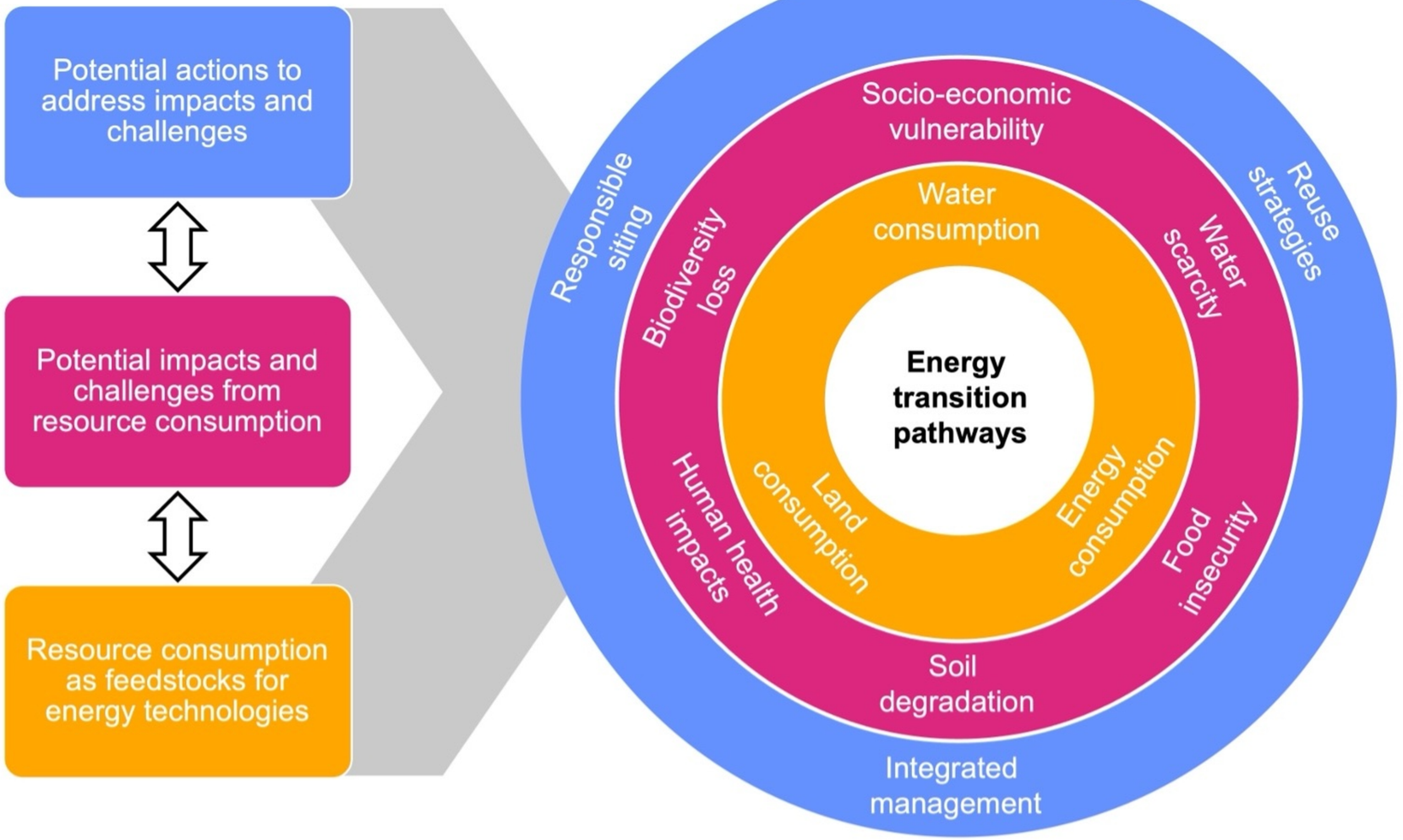
EARTH & ENVIRONMENTAL SCIENCES

Framework for Assessing Interdependencies in Emerging Energy Transition Pathways

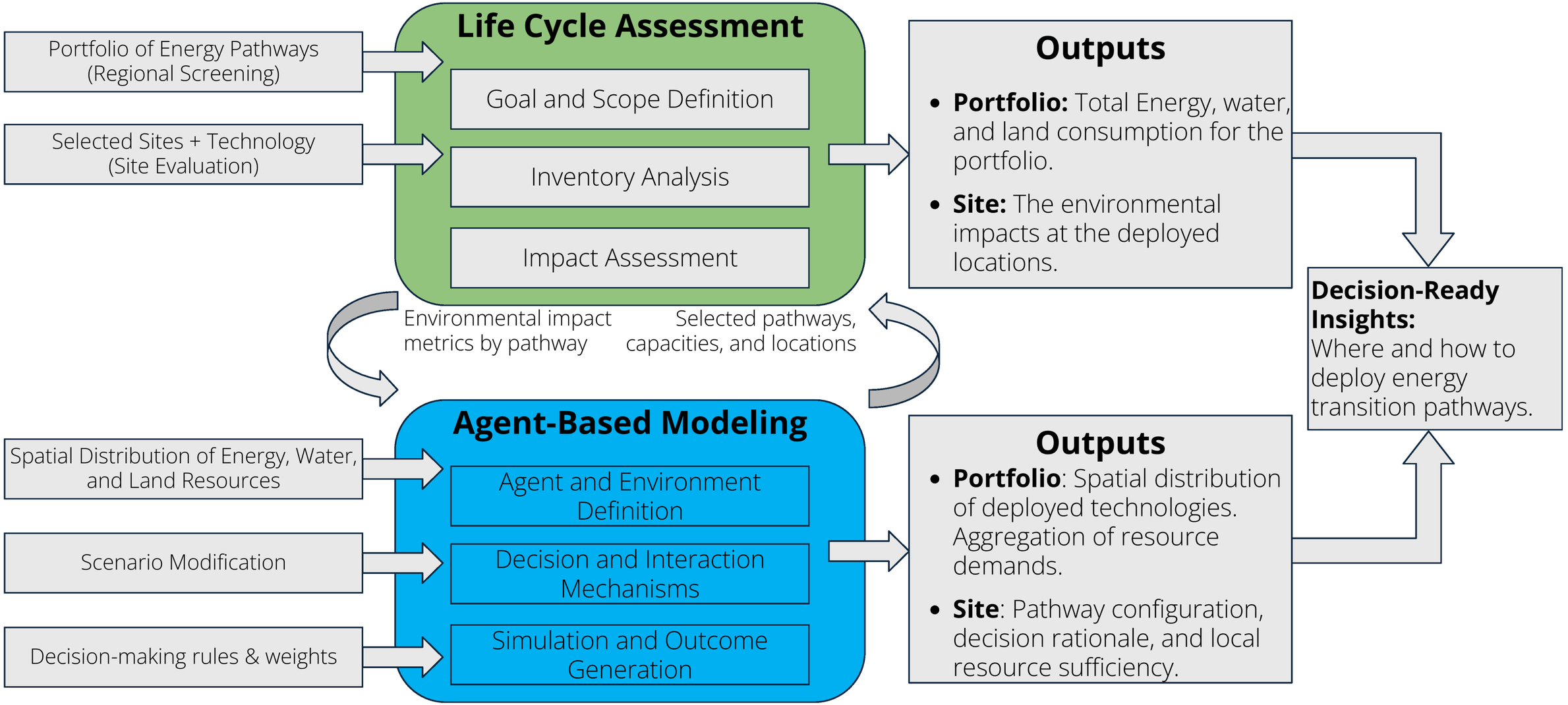
Two-way Interpretation



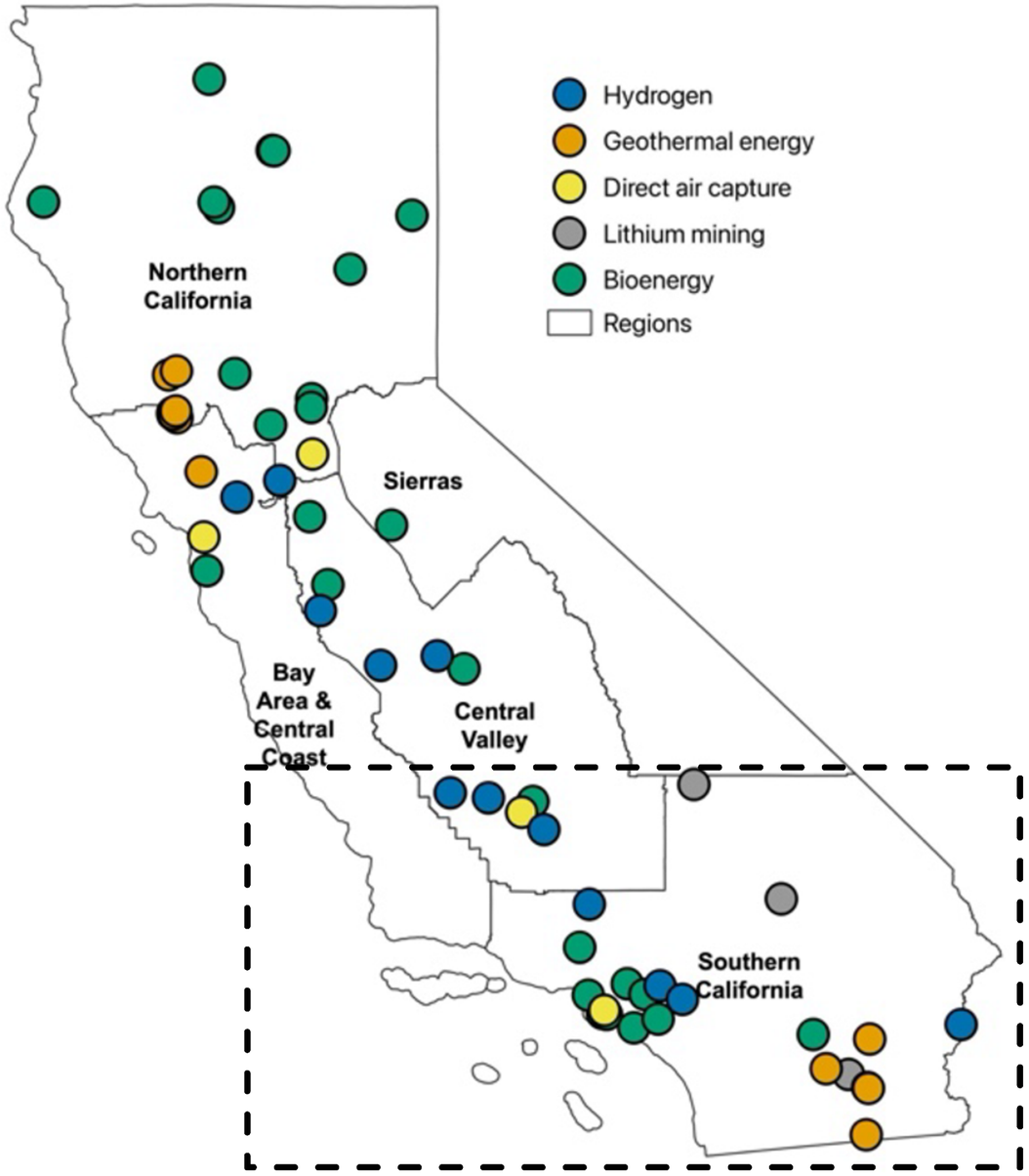


(Zaki et al., submitted)

Coupled ABM-LCA Modeling Framework

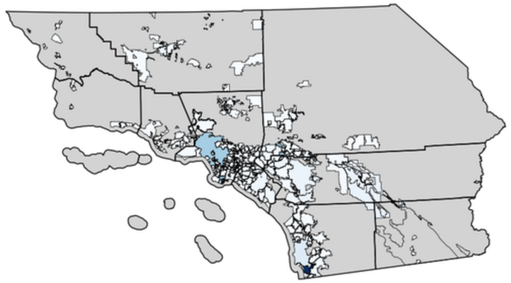


Case study in Southern California

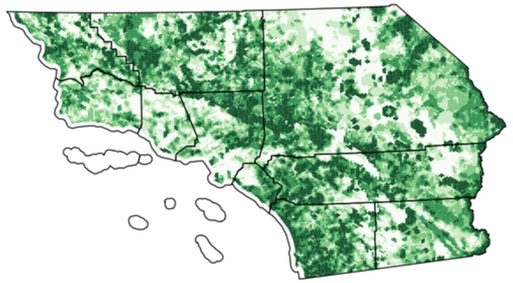


Energy resource

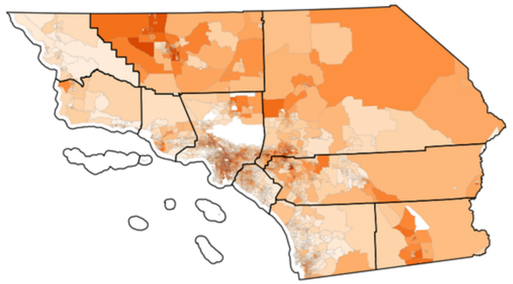
Water resource



Land resource



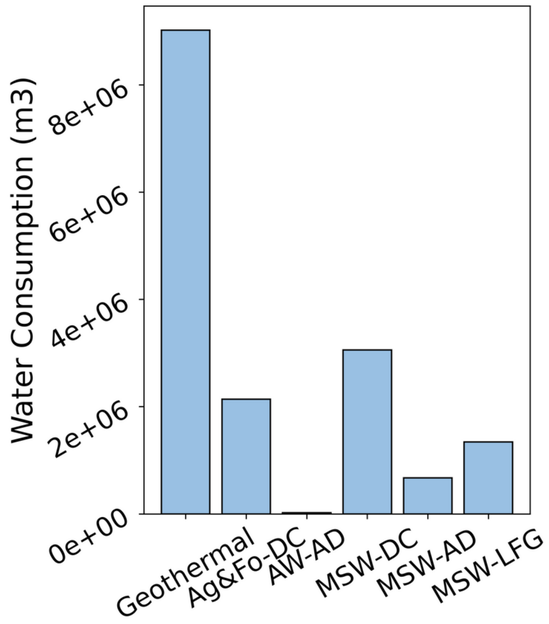
Community burden

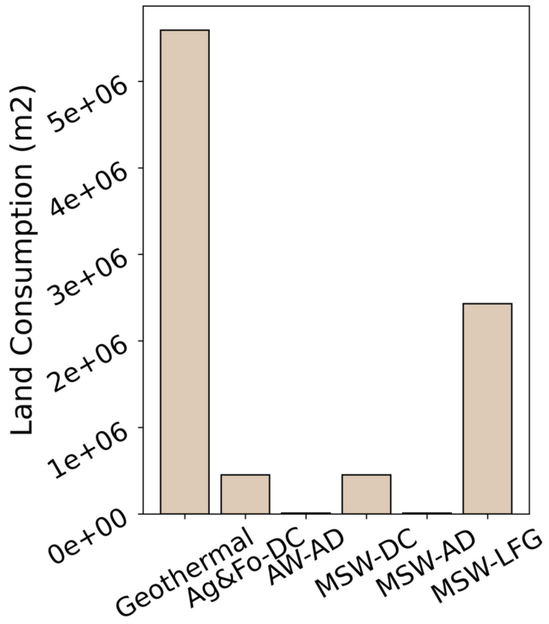


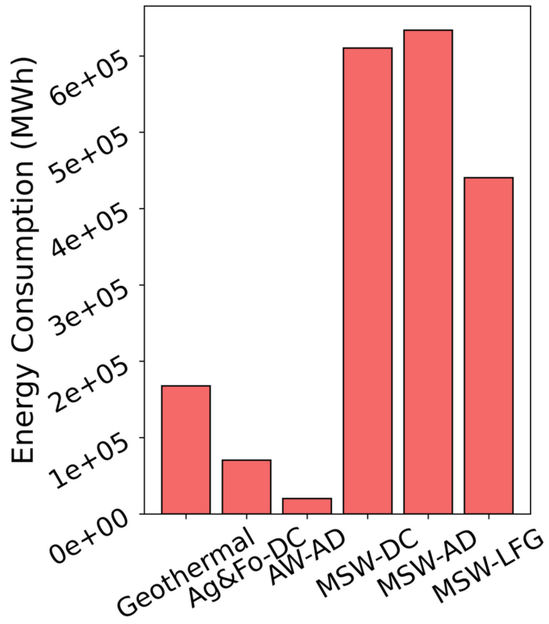
Portfolio of Energy Transition Pathways in the Case Study

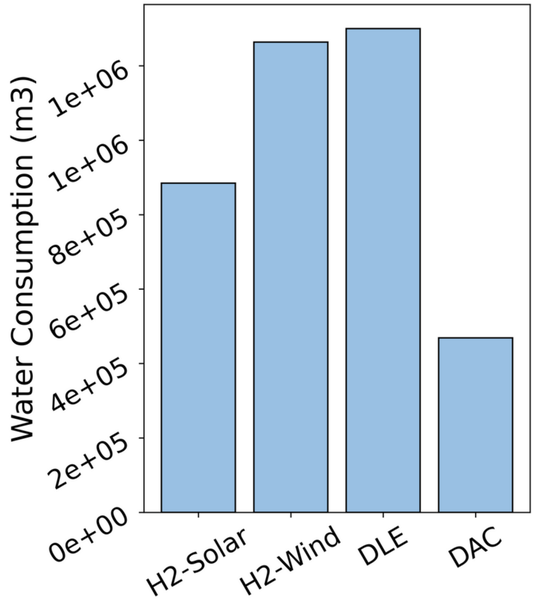
Pathway	**Capacity**	**Unit**
H_2 production by solar	350	MW
H_2 production by wind	300	MW
Ag. and Fo. residues – direct combustion	70	MW
Animal waste – anaerobic digestion	10	MW
Municipal solid waste – landfill gas	300	MW
Municipal solid waste – anaerobic digestion	150	MW
Municipal solid waste – direct combustion	100	MW
Geothermal	450	MW
Direct Lithium Extraction	125,000	Tonne
Direct Air Capture	10,000	Tonne

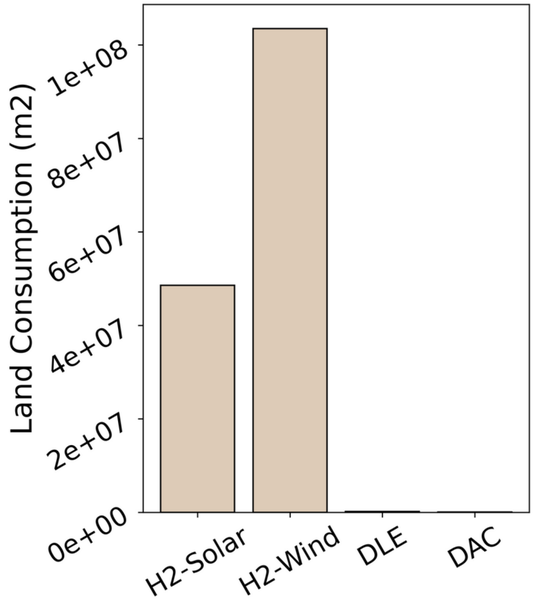
System-level Impact Assessment in Southern California

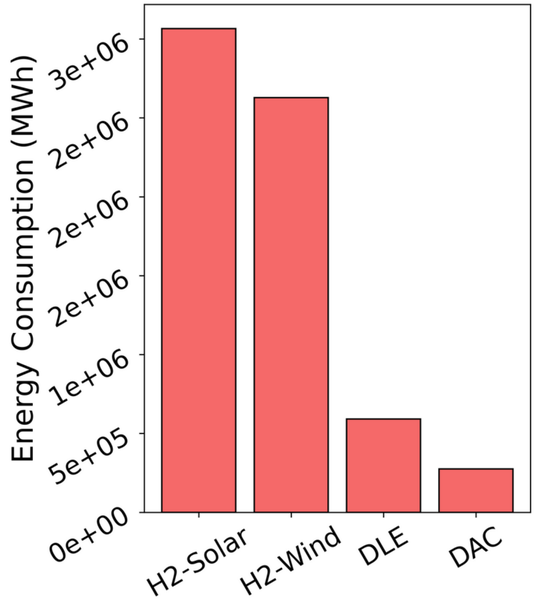




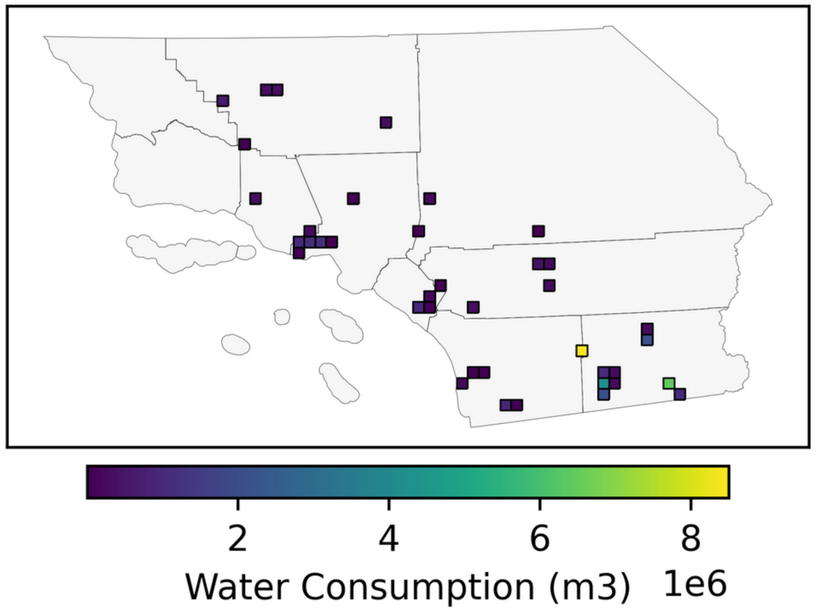


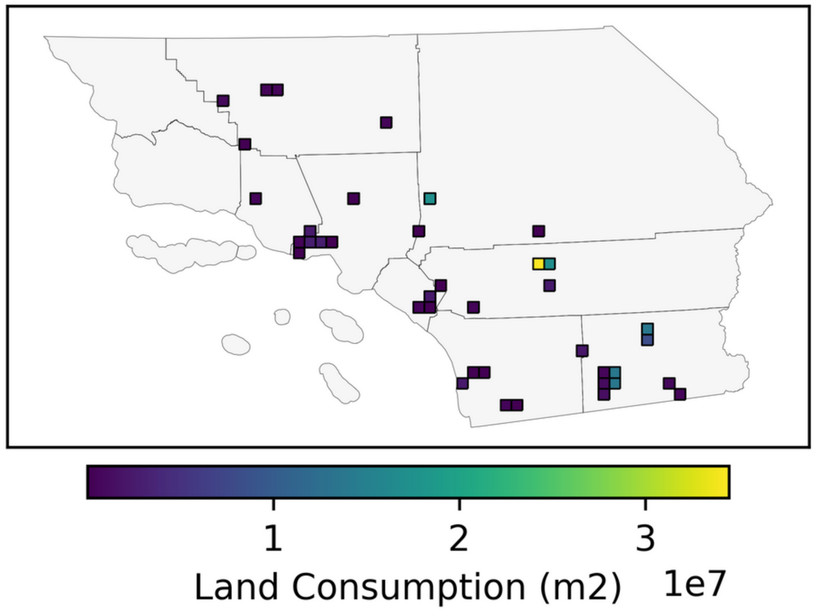


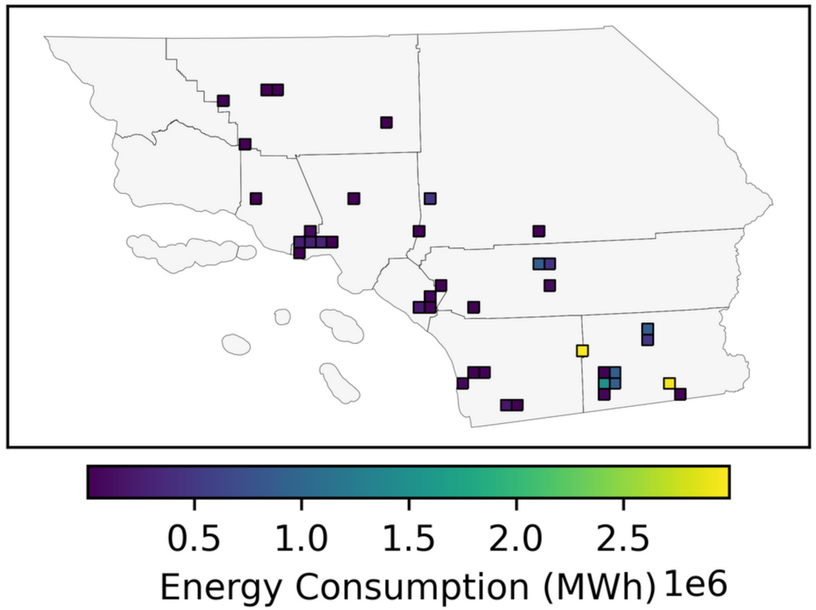




Site-level Impact Assessment in Southern California







Takeaways

🧩 Model development

- Novelty:
  First coupled ABM-LCA model for energy transition trade-offs and impacts.
- Complexity:
  Captures multi-pathway, multi-impact, multi-resource, and dynamic interactions.
- Scalability:
  Transferable to a different area, combined with diverse scenarios and model outputs.

💡 Key insights

- Some pathways are more resource-intensive than others in specific locations.
- Resource and policy constraints shift deployment patterns.
- Model supports direct pathway comparisons at the spatial scale.

Thank you!

Any questions?

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