Smart Decarbonization of the Built Environment in the Nexus of Climate Change, Population Growth and Technology Adoption

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30% of US greenhouse gas emissions stem from buildings mostly for heating and cooling.
“Cities are at the center of climate action”

IEA, Empowering Cities for a Net Zero Future, 2021

Paper
https://arxiv.org/abs/2202.07458

Dashboard
https://tinyurl.com/yeyk9229
“Cities are at the center of climate action”

IEA, Empowering Cities for a Net Zero Future, 2021

Yet very few tools exist to project expected emissions for combinations of decarbonization scenarios

→ IMPACT Pathways

IMPACT: INTEGRATED MULTI-DOMAIN EMISSION PATHWAYS FOR CITIES UNDER LAND-USE POLICY, TECHNOLOGY ADOPTION, CLIMATE CHANGE AND GRID DECARBONIZATION
Decarbonization of the built environment

✓ Electrification of end use (heating/cooling)
✓ High-efficiency HVAC (& lighting)
✓ Local PV generation
✓ Grid decarbonization

(Leibowicz et al, 2018)
Decarbonization of the built environment

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How to incentivize?

How fast?

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How to incentivize?

How fast?

How does climate change impact demand?

Goal:
‣ create model to capture interactions
‣ investigate trade-offs & synergies
‣ ex: tech adoption vs urban development

How does city growth impact demand?
Model implementation in Austin, TX

- 3 neighborhoods (Brentwood, South Manchaca and Montopolis)
- Emission pathways until 2100 in decades

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Model implementation in Austin, TX

- 3 neighborhoods (Brentwood, South Manchaca, and Montopolis)
- Emission pathways until 2100 in decades
- Low and high density scenarios created using Envision Tomorrow
- Improvement-to-land value ratio (ILR) drives redevelopment of parcels

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Model implementation in Austin, TX

Agent based model in each residence decides whether or not to adopt:
- high efficiency HVAC
- PV & storage
- smart thermostat

Based on two incentive/mandate scenarios and socio economics

Model developed and validated with survey in Austin, TX

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Model implementation in Austin, TX

- Each building is modeled and simulated to determine annual energy demand under climate change
- Energy demand is reduced accordingly for buildings that adopted technologies
- Parcels are redeveloped according to scenarios

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Model implementation in Austin, TX

Emissions estimated assuming:
- energy demand is met fully electrically (strong assumption)
- based on grid decarbonization scenarios
Summary

• 2 urban development scenarios
• 2 incentive/mandates scenarios
• 3 climate change scenarios
• 3 grid decarbonization scenarios
• 3 neighborhoods

loads of data to explore
IMPACT Pathways

for A1B climate scenario
(+1.5C by 2050, +2.5C by 2100)

Annual emissions, per unit for all three neighborhoods (t CO₂ eq/unit)

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A. Rapid grid decarbonization results in the fastest emission reductions.

B. Emission reductions are amplified by densification.
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B. Emission reductions are amplified by densification.

C. For moderate grid decarbonization, low-density development shows rebound of emissions after 2060, while

D. The high-density development does not show rebound.
Climate Change & Premium for Sprawl

Climate Change amplifies difference between low and high density developments

→ Premium for Sprawl

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Climate Change & Premium for Sprawl

Premium for Sprawl = Emissions (High Density) - Emissions (Low density) (assuming the same number of residences)

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Preprint & Online Dashboard

**IMPACT:** INTEGRATED MULTI-DOMAIN EMISSION PATHWAYS FOR CITIES UNDER LAND-USE POLICY, TECHNOLOGY ADOPTION, CLIMATE CHANGE AND GRID DECARBONIZATION

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Conclusion

- IMPACT Pathways demonstrate substantial impact of zoning policy and housing on emission reductions: *Premium for Sprawl*. Technology adoption is negligible.
- **Rebound**: Short term emission reductions can be overturned in the longer term
- Demand variation due to climate change must be considered in emission scenarios
- IMPACT Pathways can be further integrated with other domains, e.g., transportation emissions, embodied carbon, EV adoption, or demand response.