

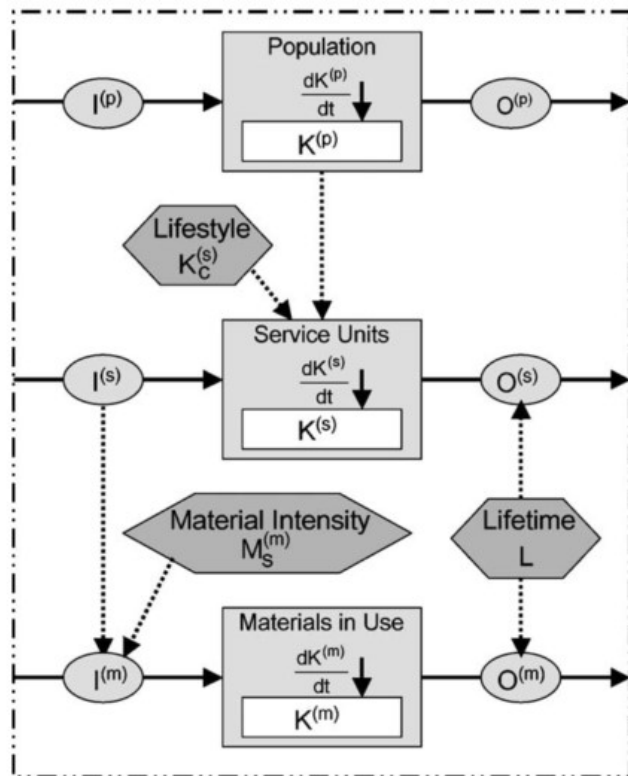
Estimation of demolition and new construction of housing in US counties until 2060

Implications for building material reuse potential

Peter Berrill
ICWMT 15, June 30, 2020

Dynamic Stock Models of Buildings

Dynamic Stock Model



Drivers (Inputs)

$K^{(p)}(t)$	Population
$K_c^{(s)}(t)$	Service stock per capita (lifestyle)
$L(t, t')$	Lifetime distribution
$M_s^{(m)}(t)$	Material intensity per service unit.

Results, over time

Inputs (construction)

Outputs (demolition)

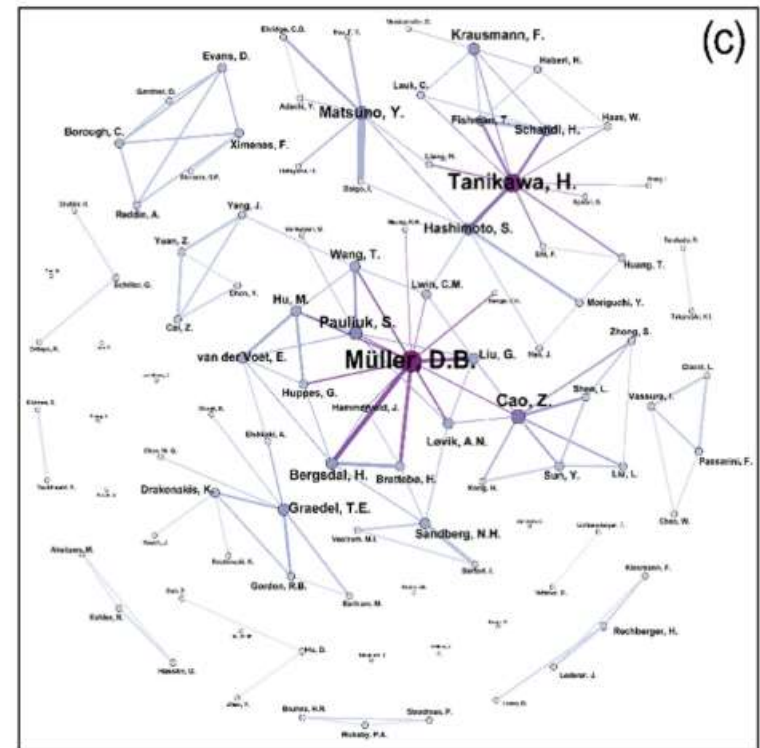
Total Stock

Müller, D.B (2006), *Ecol. Econ.*, 'Stock dynamics for forecasting material flows—Case study for housing in The Netherlands'

Dynamic Stock Models of Buildings



b) Tag cloud of the journal article authors



c) Network of coauthorship

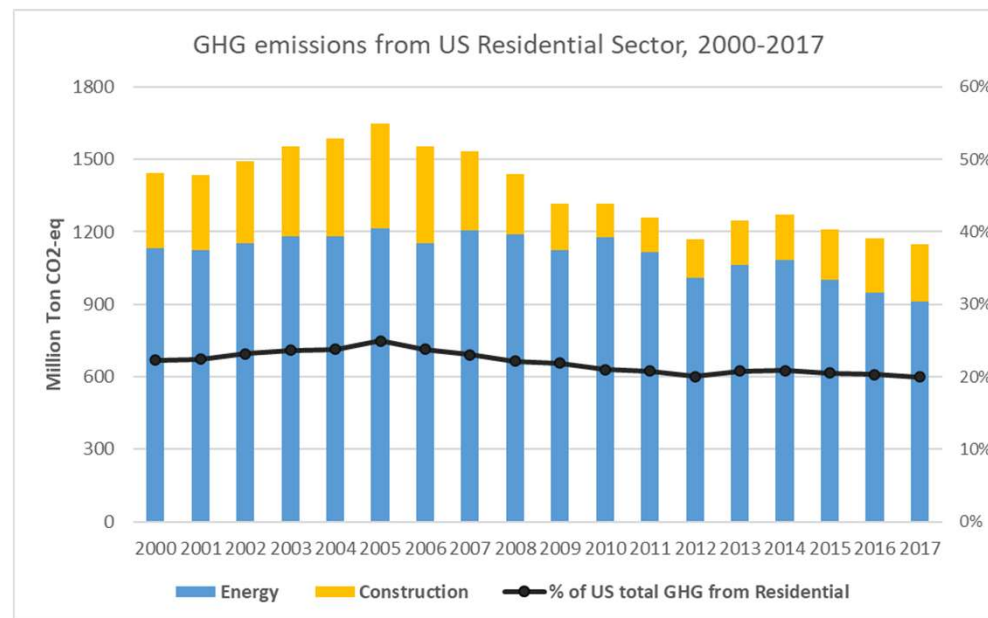
Lanau et al. (2019), *Env. Sci. Tech.*, 'Taking Stock of Built Environment Stock Studies: Progress and Prospects', Fig. 2

Current research goals

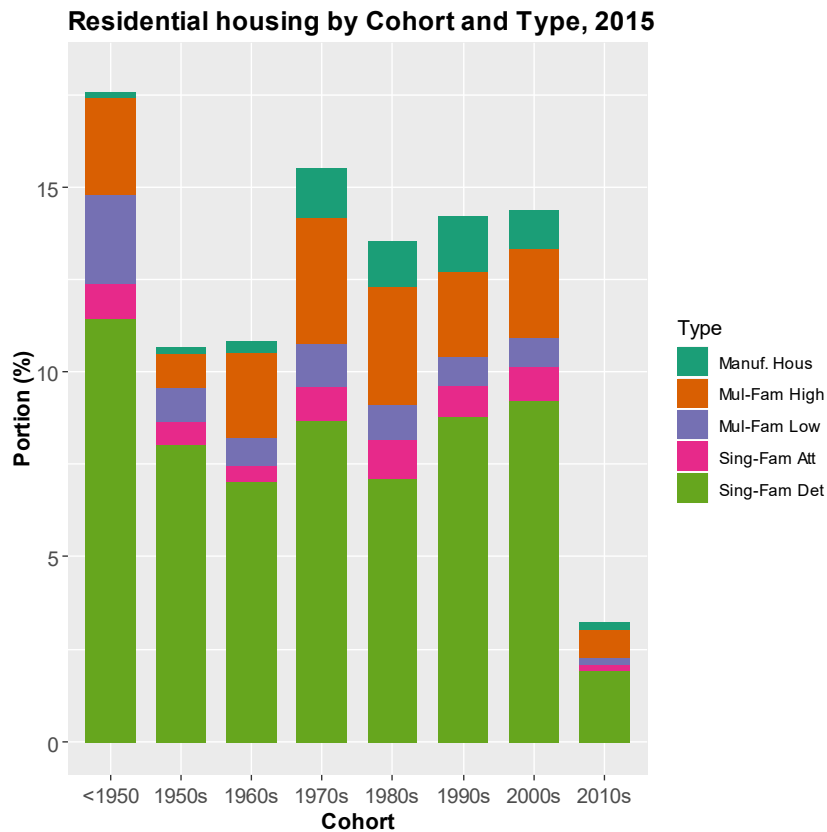
- Identify strategies for GHG reduction from US residential buildings, all life cycle stages
- Model and project results of
 - Energy demand
 - Construction material requirements and waste generation
 - Comprehensive GHG emissions from residential sector activities
- Data needs: housing stock by type, age, location

US residential sector in context global GHG emission

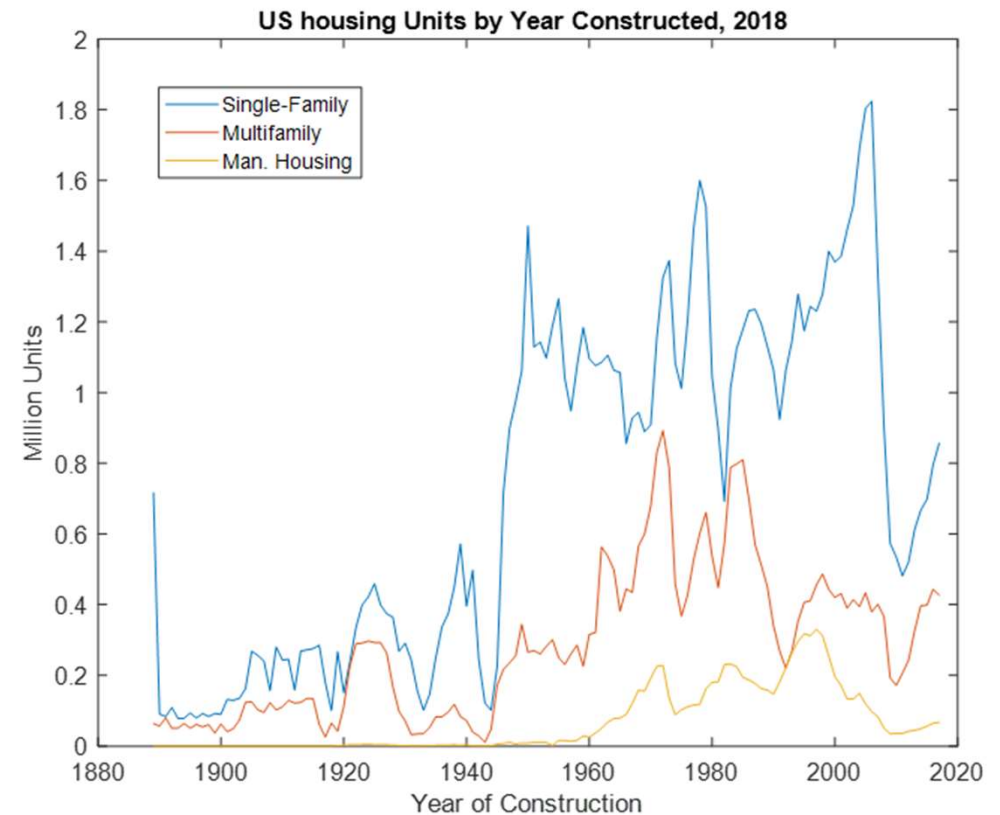
- In top 2 emitters of residential GHG emissions globally:
~1Gt CO₂ from energy, 0.2Gt CO₂ from construction.
Reducing by ~1.5% annually, due to low-C electricity



US housing mostly older & single-family



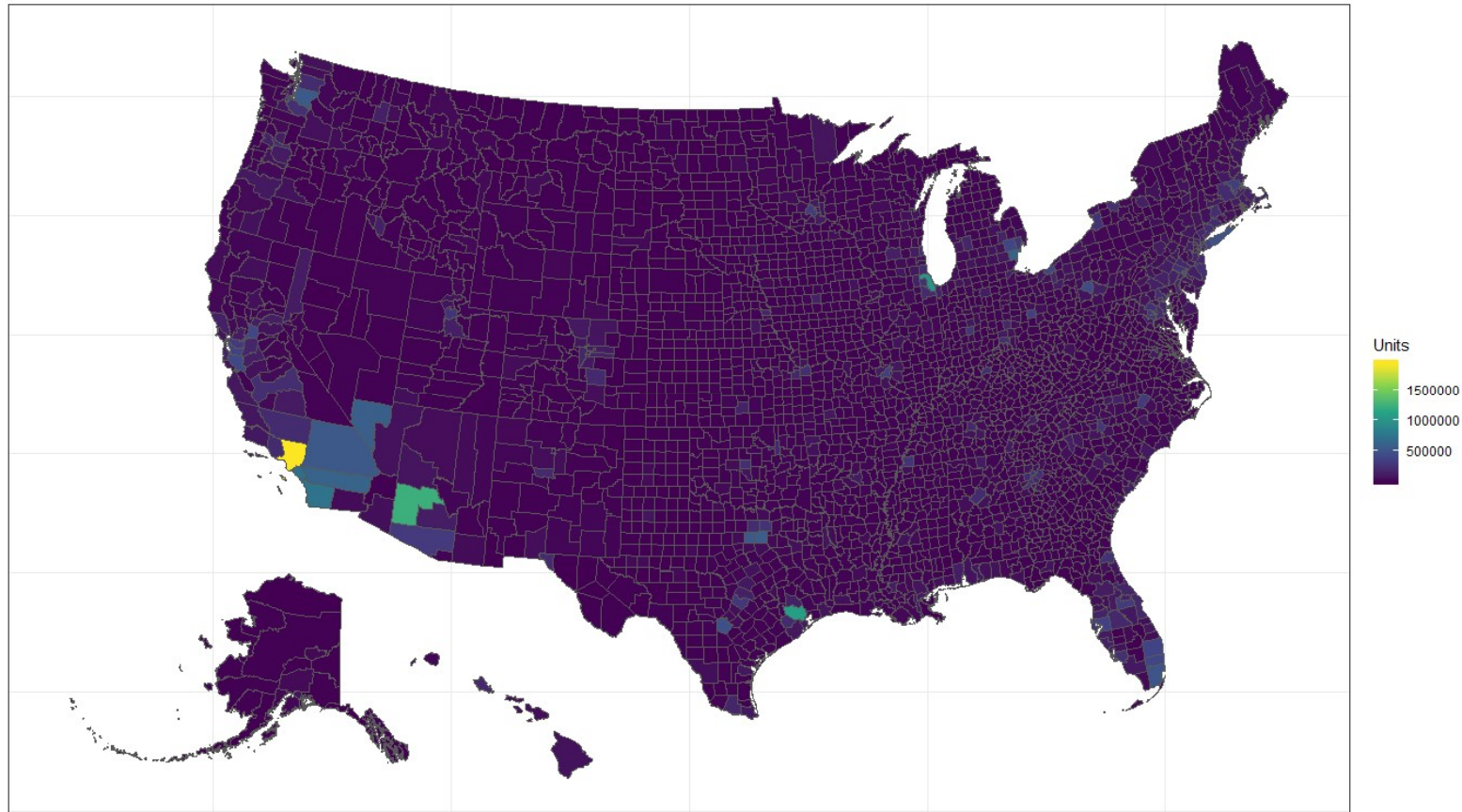
EIA, 2018



Own calculations, based on several sources

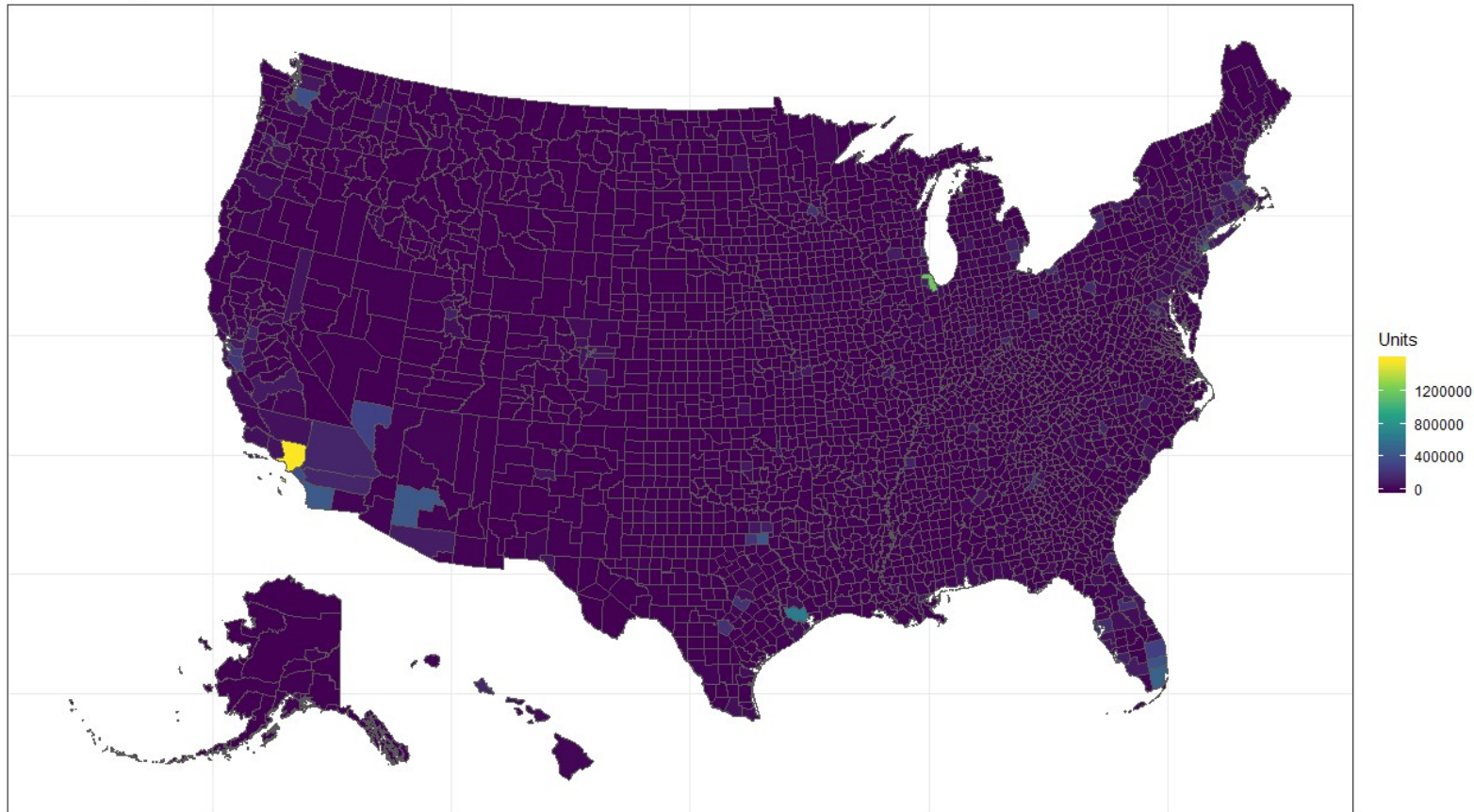
Spatially disaggregated housing stock – Single-family

Total Single-family homes, 2018



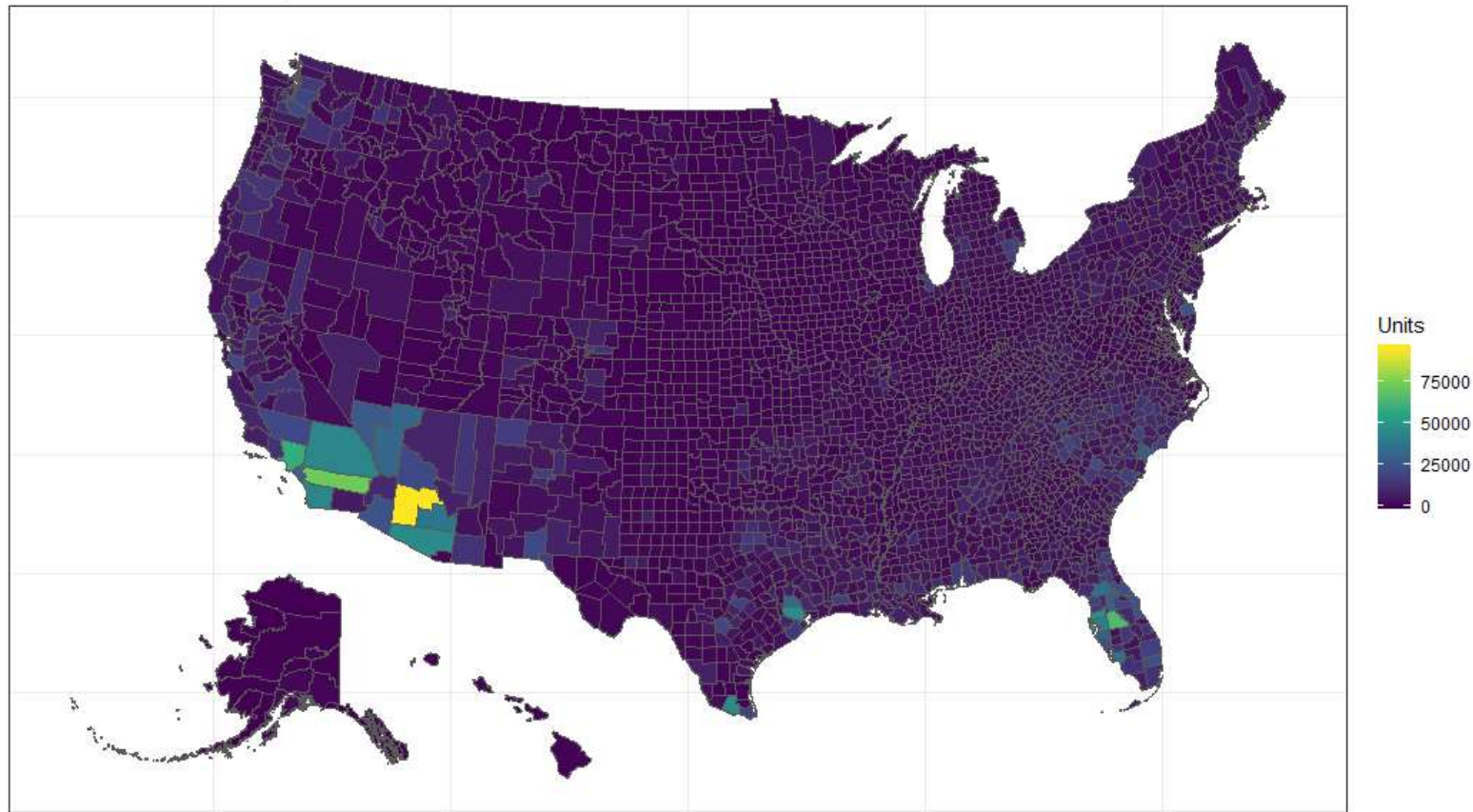
Spatially disaggregated housing stock – Multifamily

Total Multifamily homes, 2018



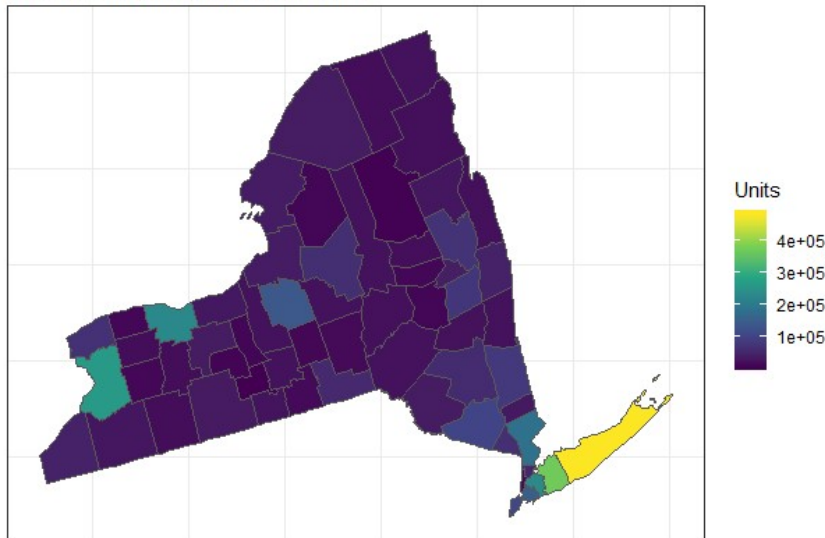
Spatially disaggregated housing stock – Manuf. Homes

Total Manufactured homes, 2018

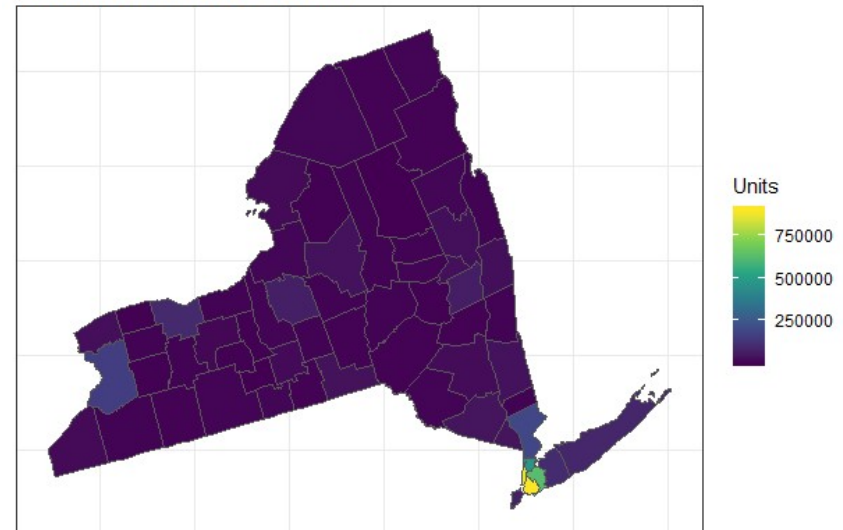


Single-family and Multifamily homes, NY State

NY State Single-family homes, 2018



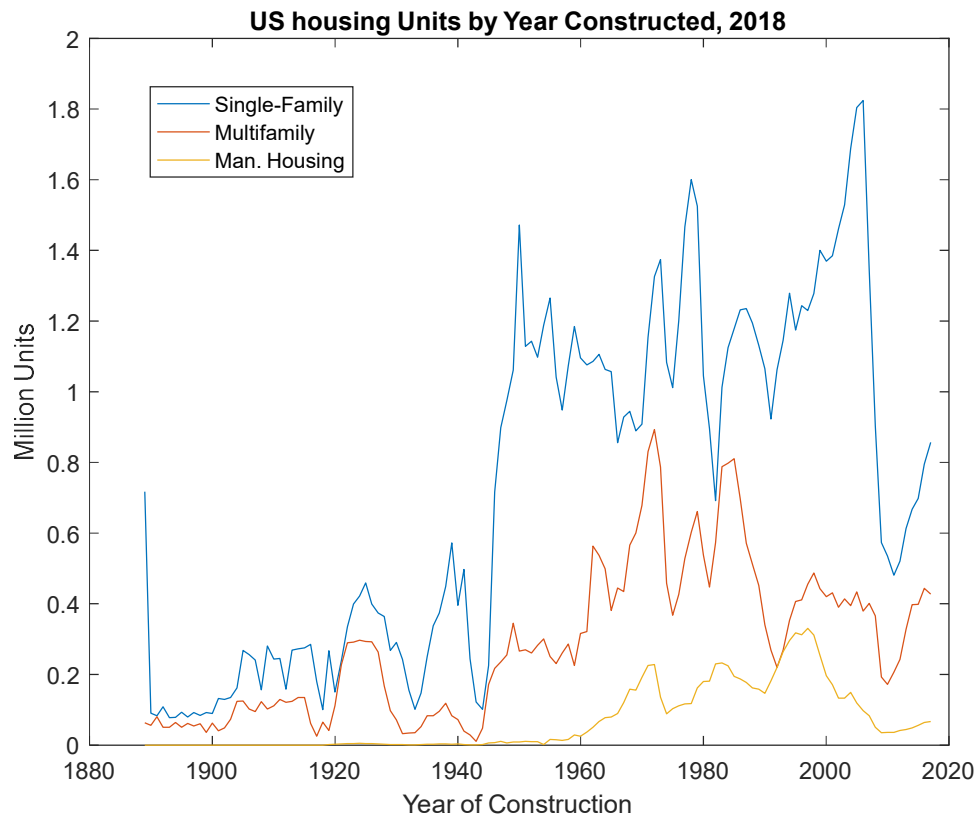
NY State Multifamily homes, 2018



Basic stock model equations

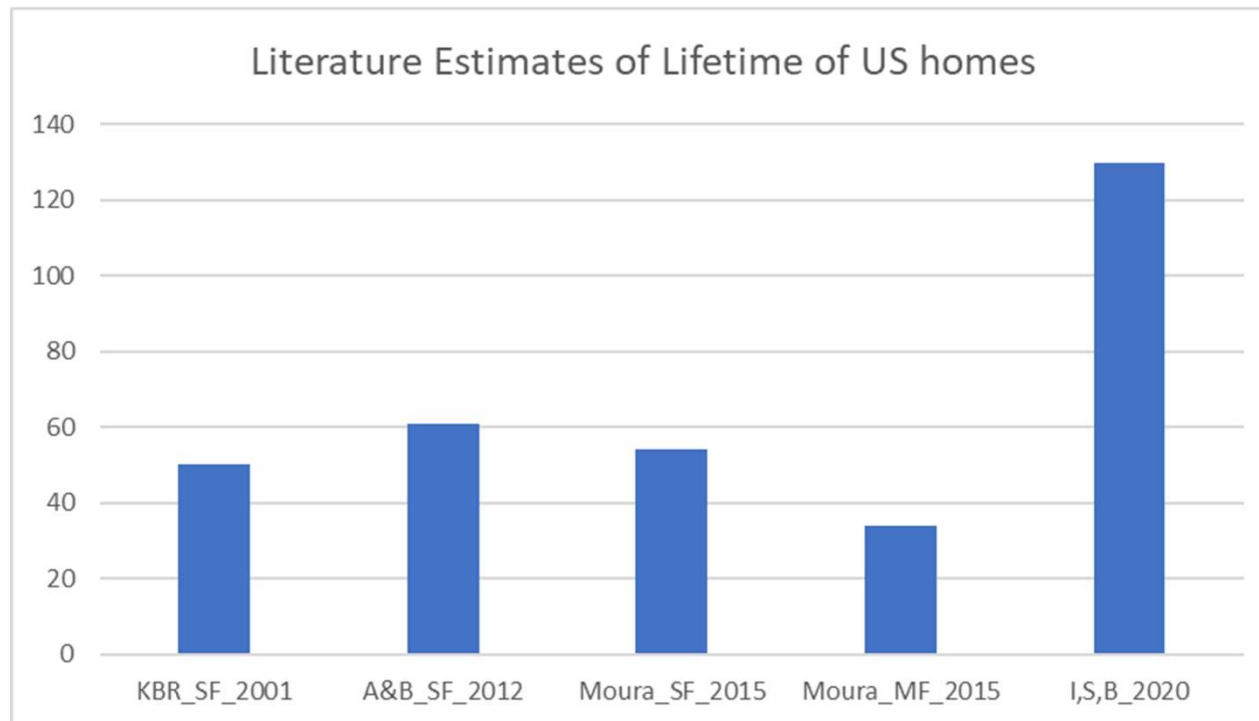
- $C_{t+1} = (S_{t+1} - S_t) + D_{t+1}$
- C = new construction, D = demolition, S = stock = $V \cdot O$
- V = vacancy ratio = total units/occupied units; O = occupied units
- New construction can result from $S_{t+1} > S_t$, from $D_{t+1} > 0$, or from $V_{t+1} > V_t$

Projections of demolition, based on lifetime distribution



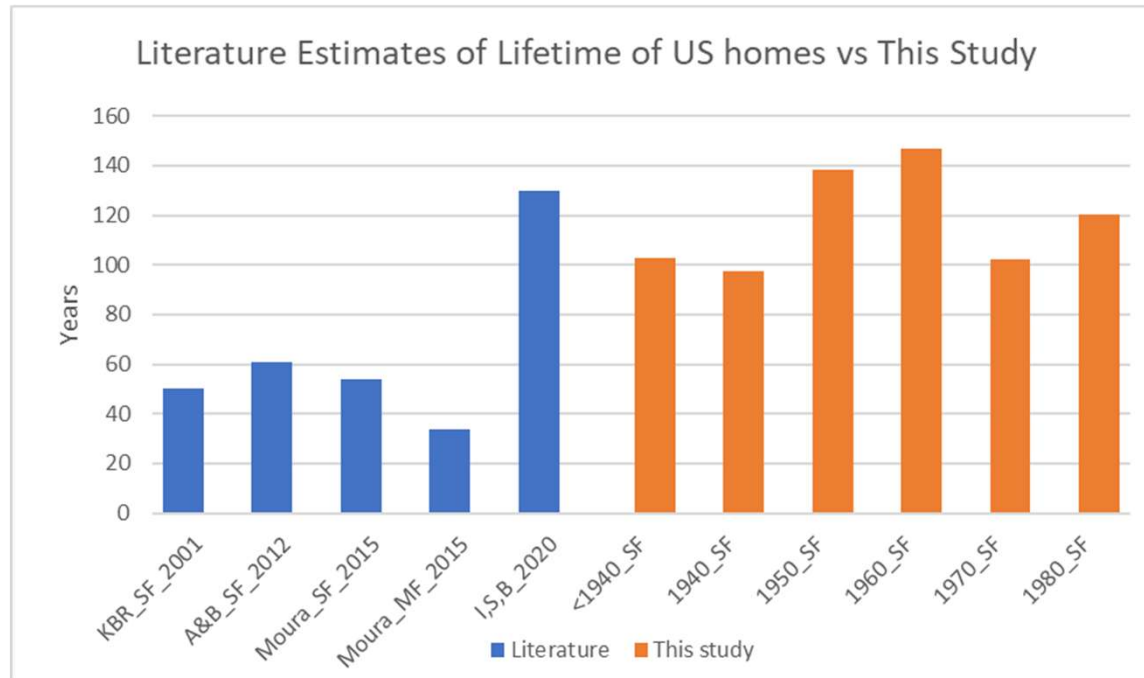
- Year of construction (<1890 to 2017) based on decadal Censes, various survey data, and estimates by Moura et al (2015)
- Lifetime distribution functions estimated per each decadal cohort (1940s, 1950s, etc.)

What is the lifetime of a house in the US?



Sources: Keolian et al (2001); Aktas & Bilec (2012); Moura et al (2015); Ianchenko et al (2020)

What is the lifetime of a house in the US?



- Median lifetimes estimated based on Weibull lifetime distribution functions for different vintages

Sources: Keolian et al (2001); Aktas & Bilec (2012); Moura et al (2015); Ianchenko et al (2020). See also Miatto et al (2017)

Method to project future demand for housing

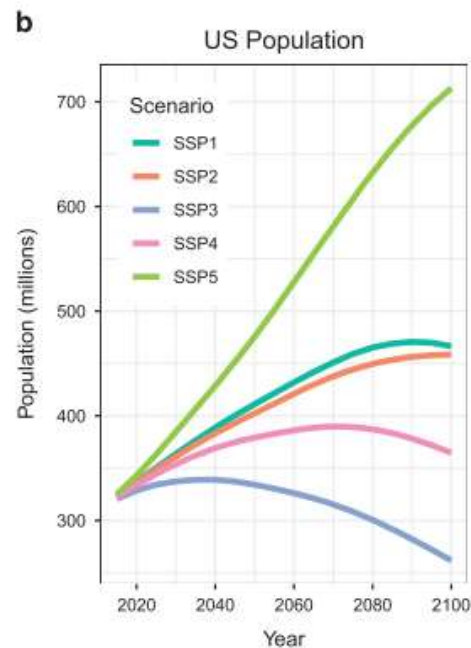
- $C_{t+1} = (S_{t+1} - S_t) + D_{t+1}$
- Estimate future stock of total housing per county based on three factors:
 1. Population by house type
 2. Household size by house type
 3. Vacancy rate by house type

1. Q: Who would estimate future population at local scale?

- A: Hauer (2019) scaled SSP population projections to 2100 to US county level

Data Descriptor: Population projections for U.S. counties by age, sex, and race controlled to shared socioeconomic pathway

Mathew E. Hauer^{1,2}

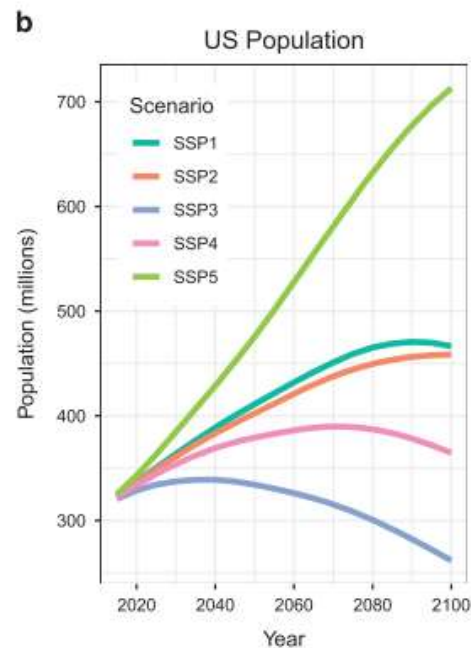


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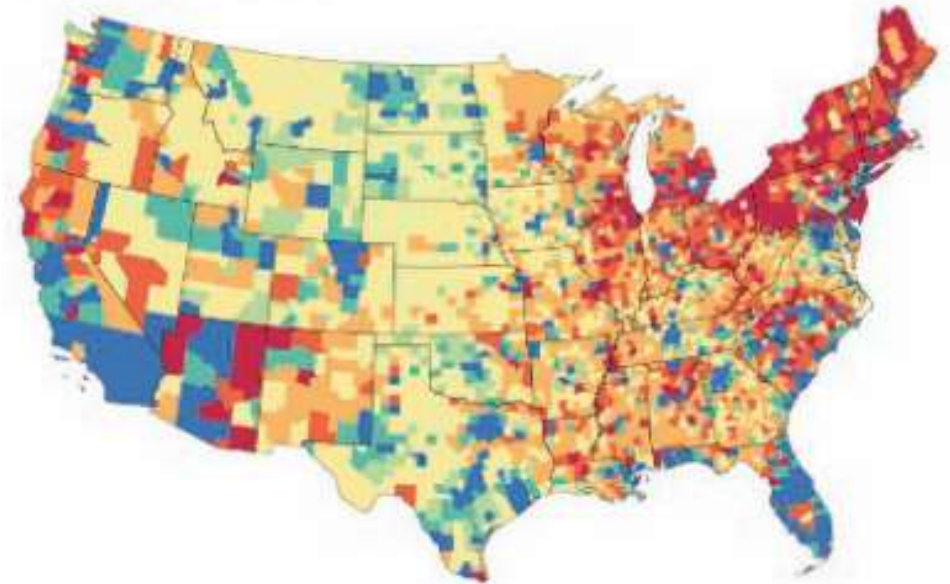
Mathew E. Hauer^{1,2}



SSP2: Middle of the road

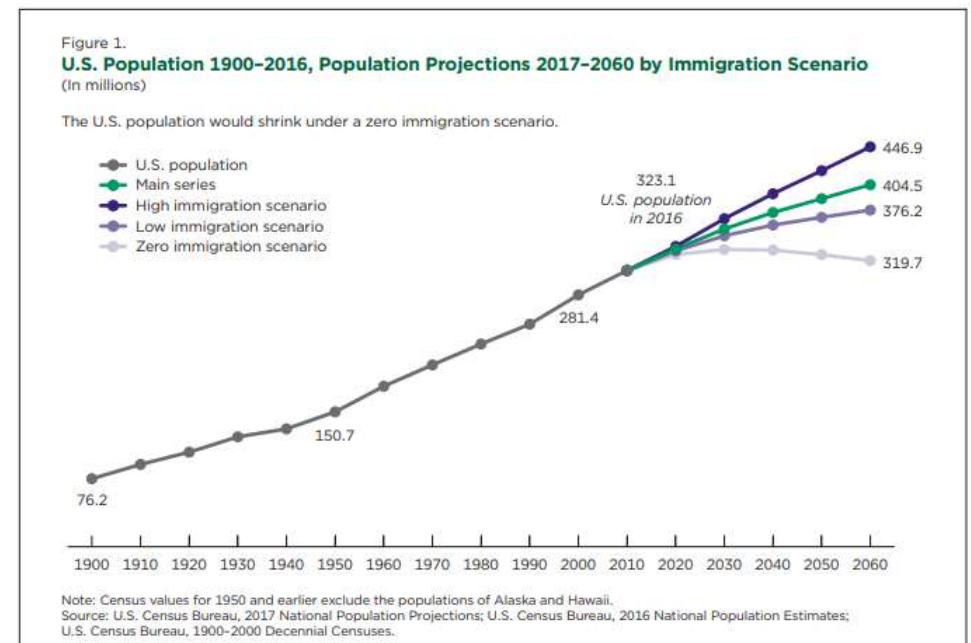
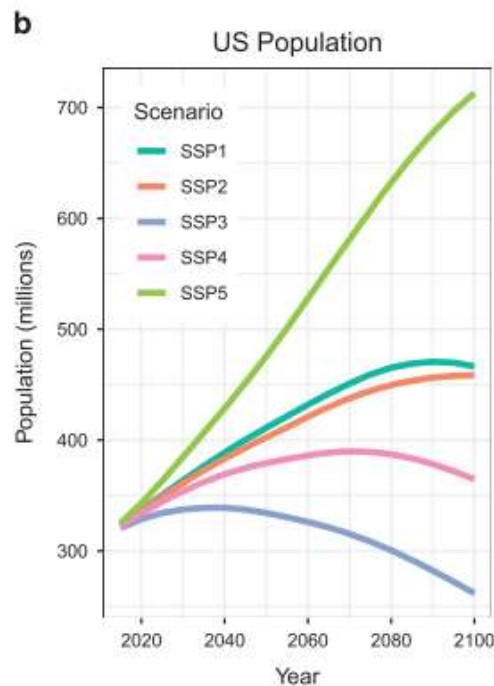
Numeric Change

- Less than -30,000
- 30,000 to -15,000
- 15,000 to -5,000
- 5,000 to 0
- 0 to 5,000
- 5,000 to 15,000
- 15,000 to 90,000
- 90,000 or more



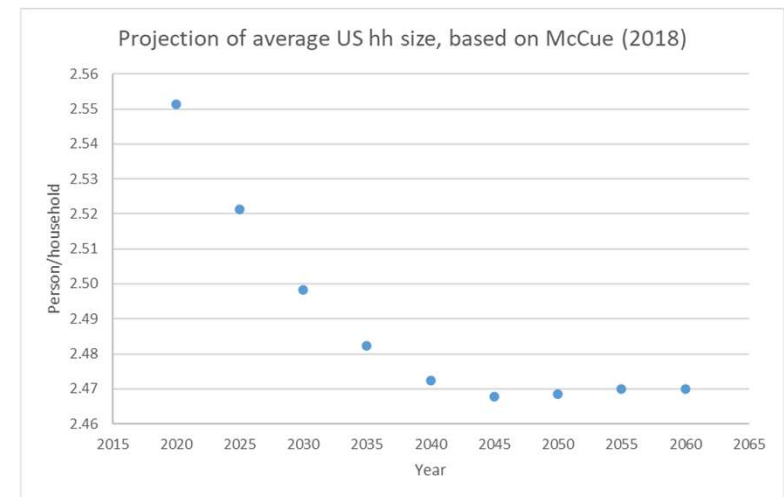
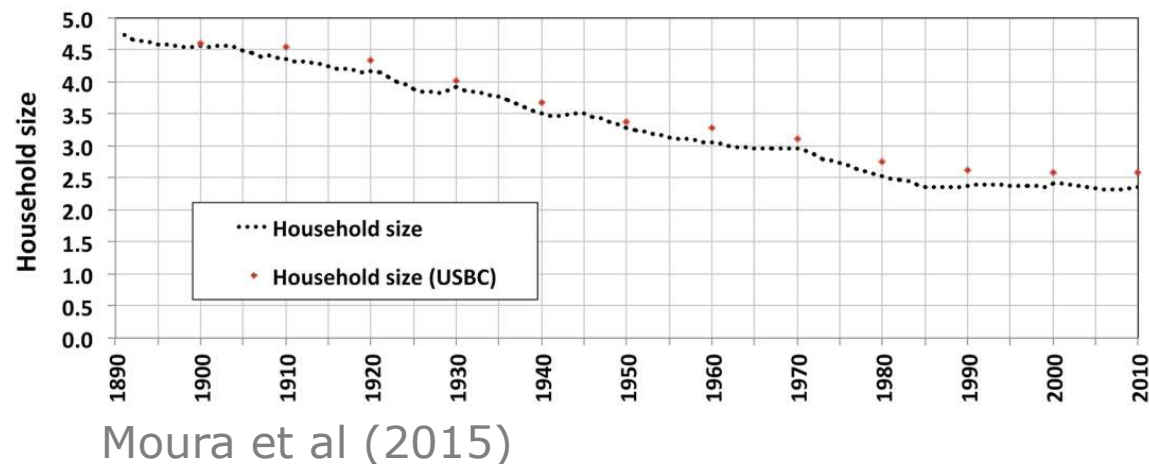
1. Implementation of Hauer Population Data

- Scaled SSP2 to match the main series from the USCB population projection
- Assumed no change in house type split of population per county, for now



2. Projections of household size

- Like most countries, US has seen notable decline in household size

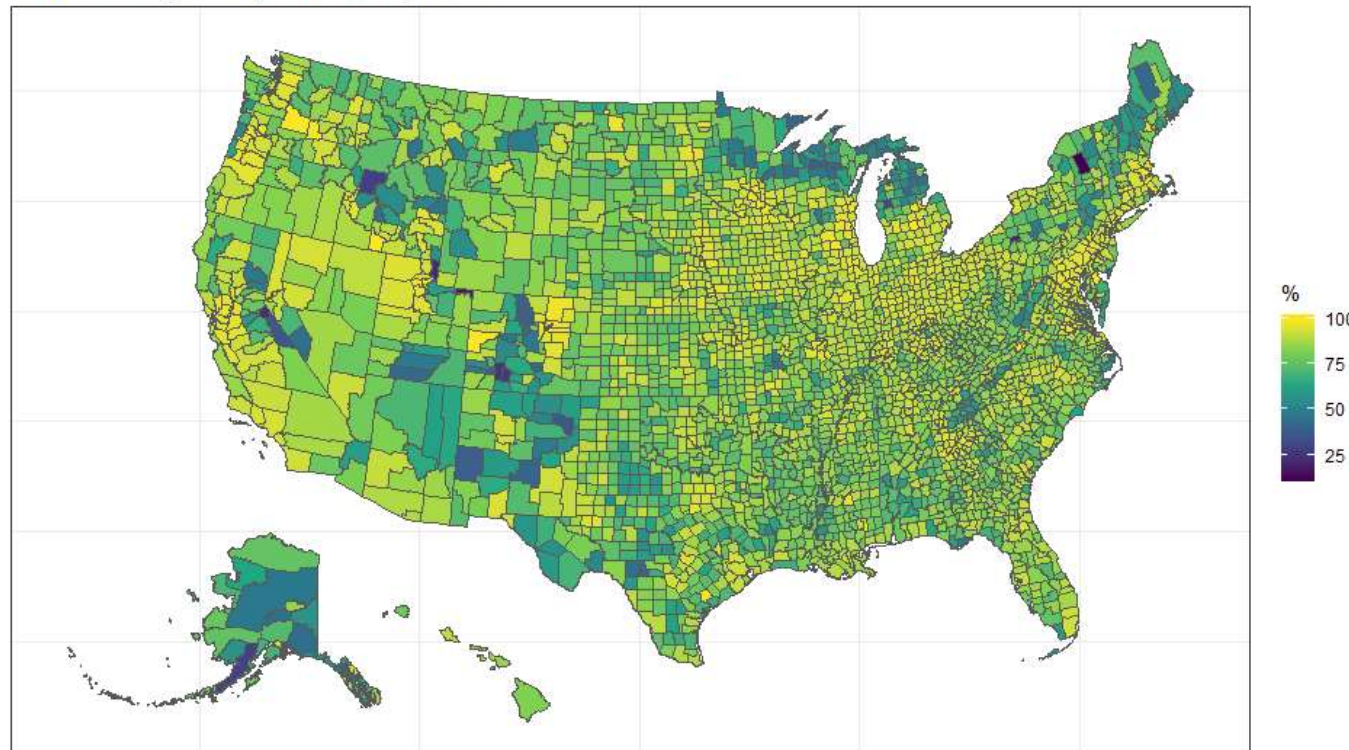


- I use data from McCue (2018) to project further modest reductions from 2020-2060, with the same average reduction applying evenly to different house types and counties

3. Occupancy/vacancy rates by county

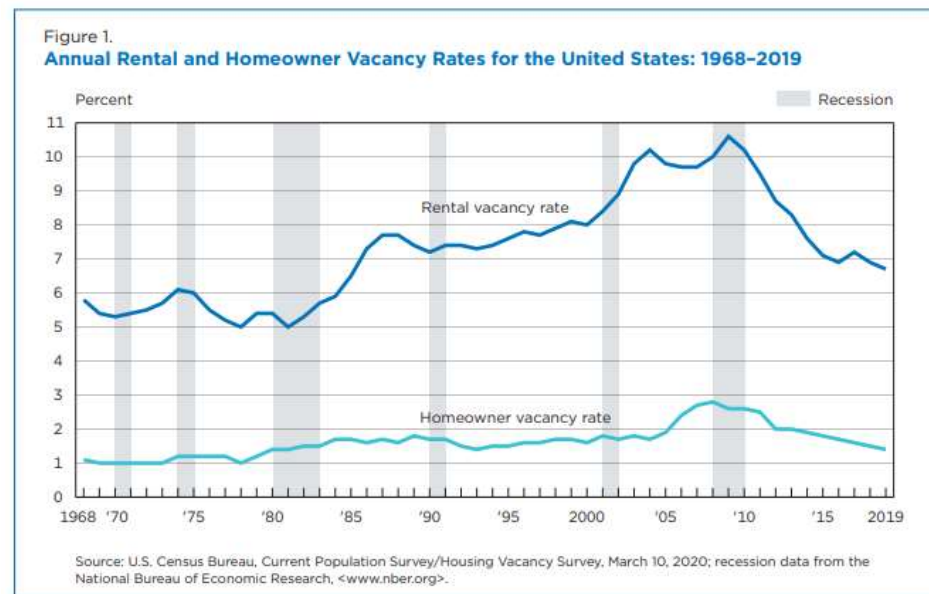
- 10% of SF homes are vacant. 15% for MF, 22% for MH. Lowest rates since mid-1980s

Percent of Single-family homes occupied, 2018



3. How will vacancy rates develop?

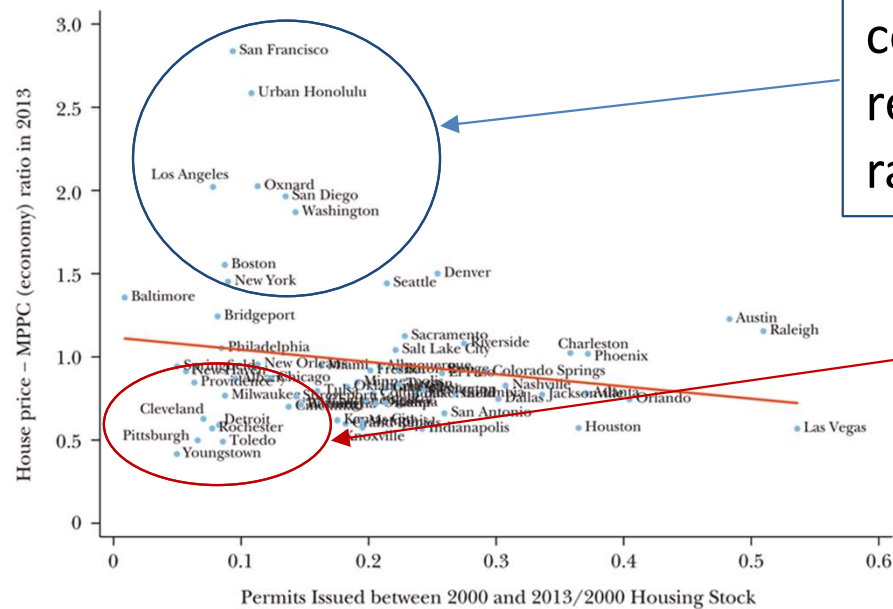
- On downward trend, construction is currently not keeping up with population growth, & large increase in demand for rental housing



How will vacancy rates develop?

- Currently no modeled change in vacancy rates. Adapt -> reduce vacancy in growing/highly regulated counties. Increase vacancy in declining counties

Price-to-Cost Ratios and Permitting Intensity, 2000–2013



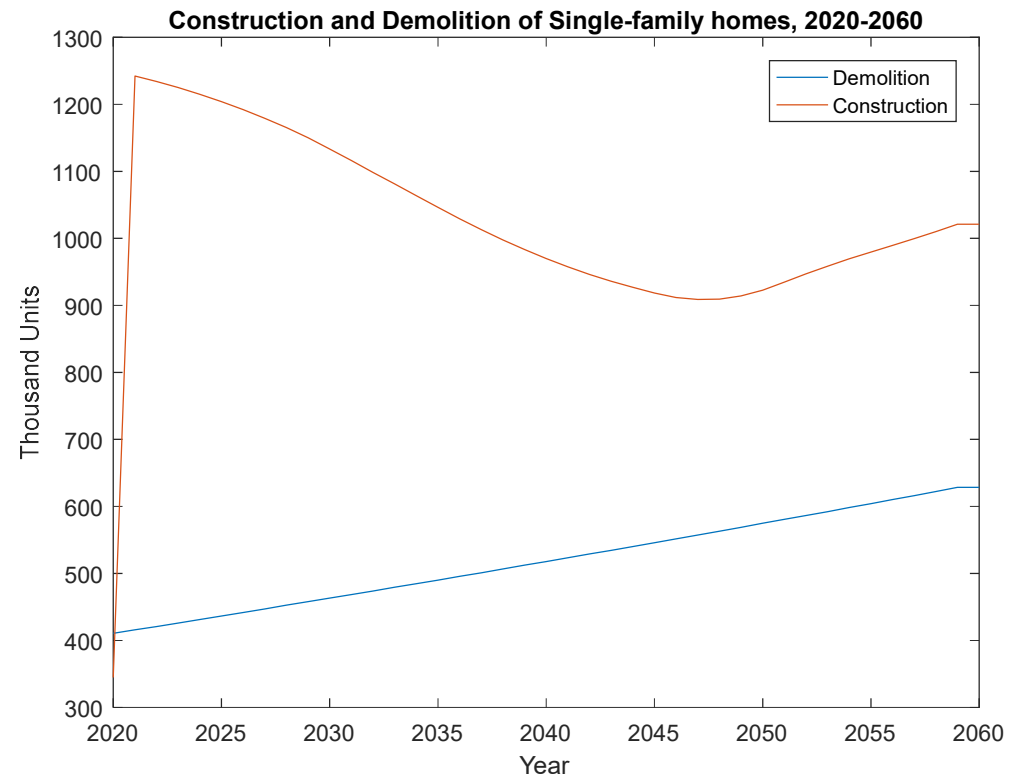
Housing construction highly restricted, vacancy rates may decline

Population decreasing, low demand for new housing, vacancy rates may increase

Glaeser & Gyourko (2018), *Jour. Econ. Per.*, 'The economic implications of housing supply'

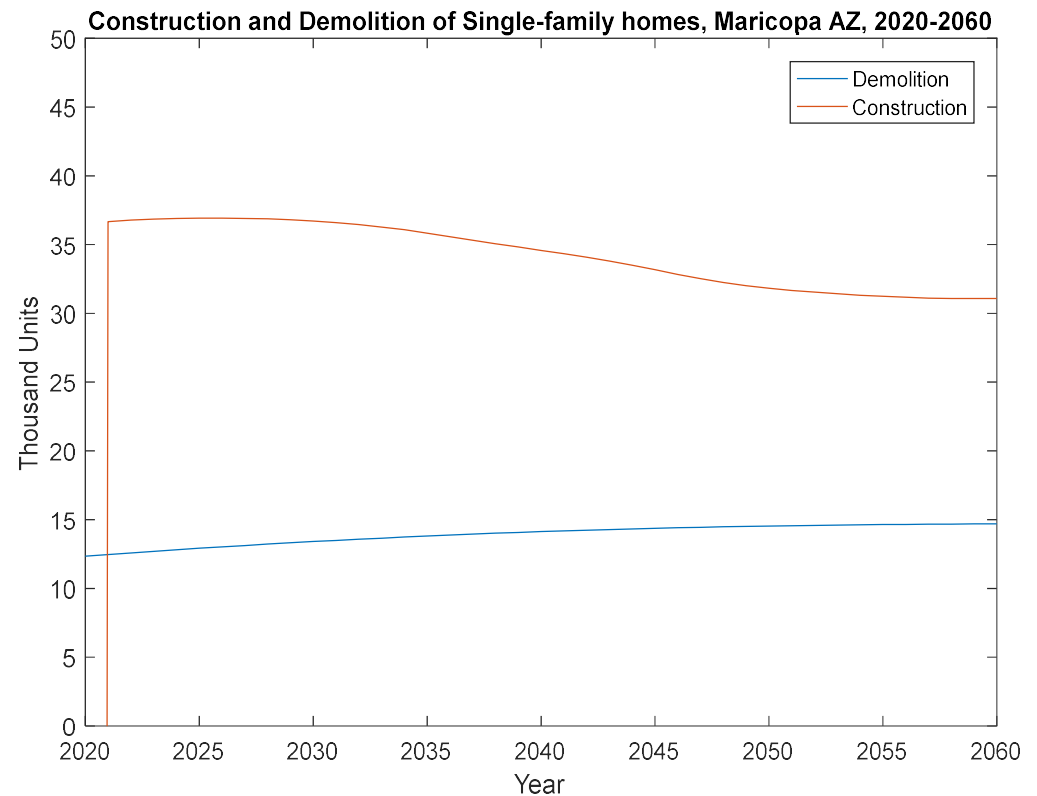
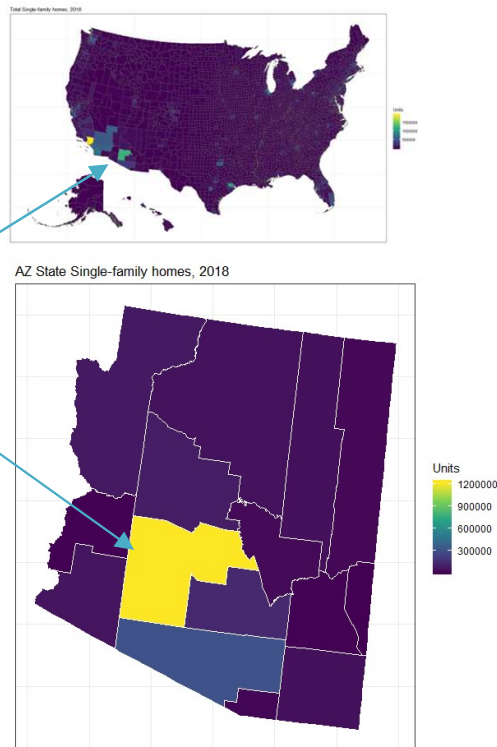
Results: National annual construction and demolition

- National total



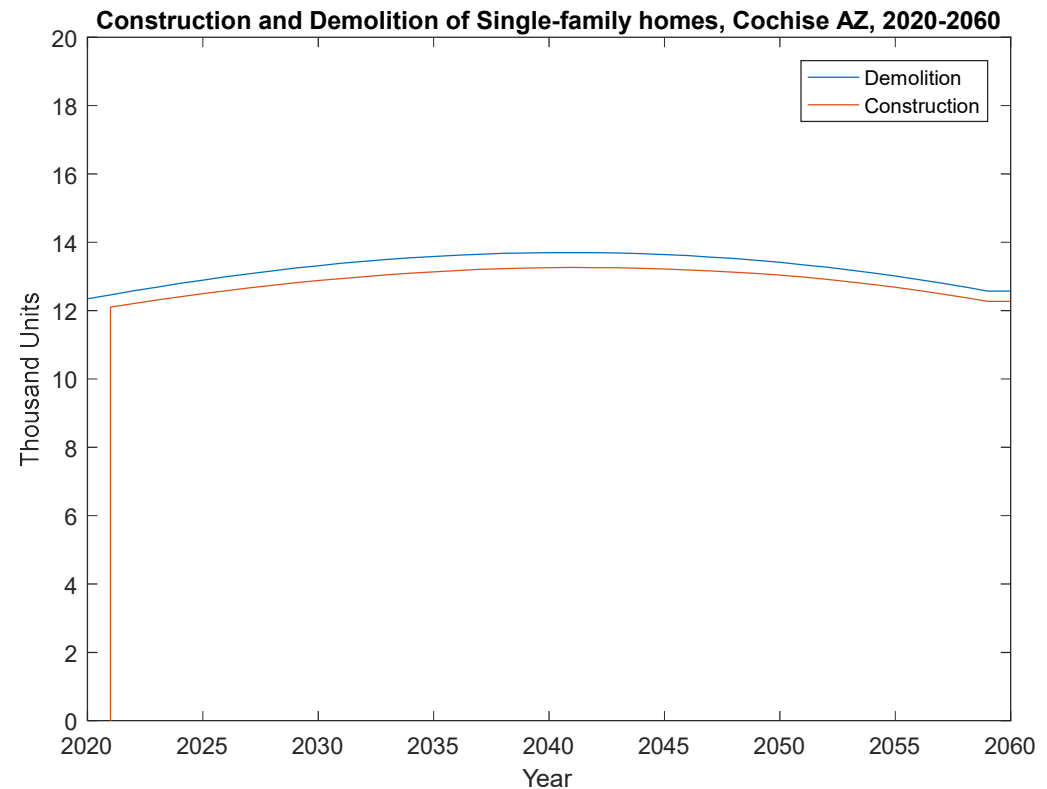
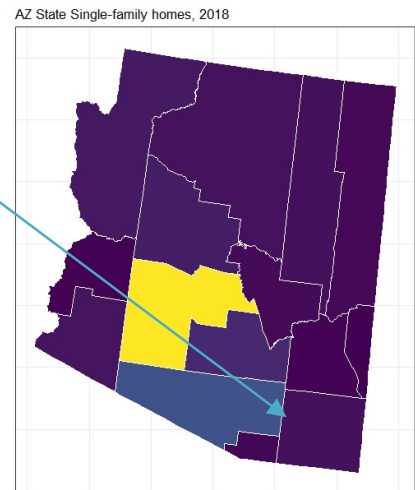
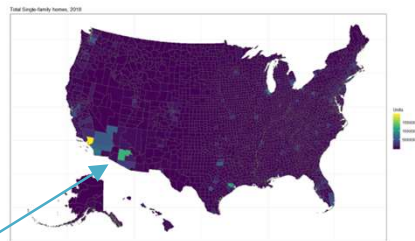
Results: National annual construction and demolition

- Maricopa Cty, AZ



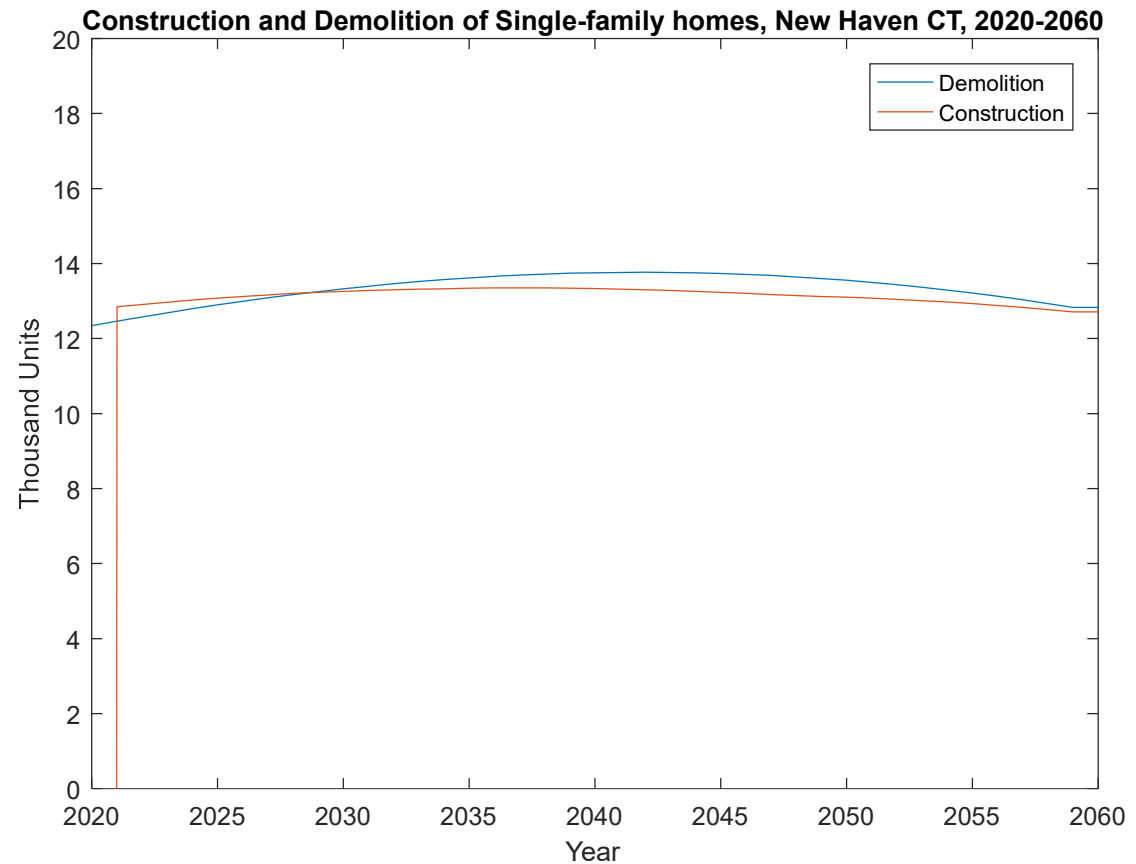
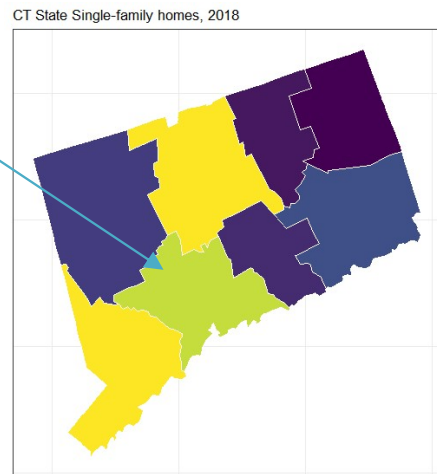
Results: National annual construction and demolition

- Cochise Cty, AZ



Results: National annual construction and demolition

- New Haven Cty, CT



Implications for material reuse

- Circular economy potential may exist for bulk construction material in some counties
- With further refining of our model and investigating of local effects, we can find out which locations have highest/lowest potential for material reuse
- Currently only considering one sector – residential buildings. Broadening scope to include non-residential buildings, roads, and other infrastructure can give more insights

Where does construction waste currently go?

- Most end-of-life concrete currently goes back into road bases, only a small part goes back into new concrete

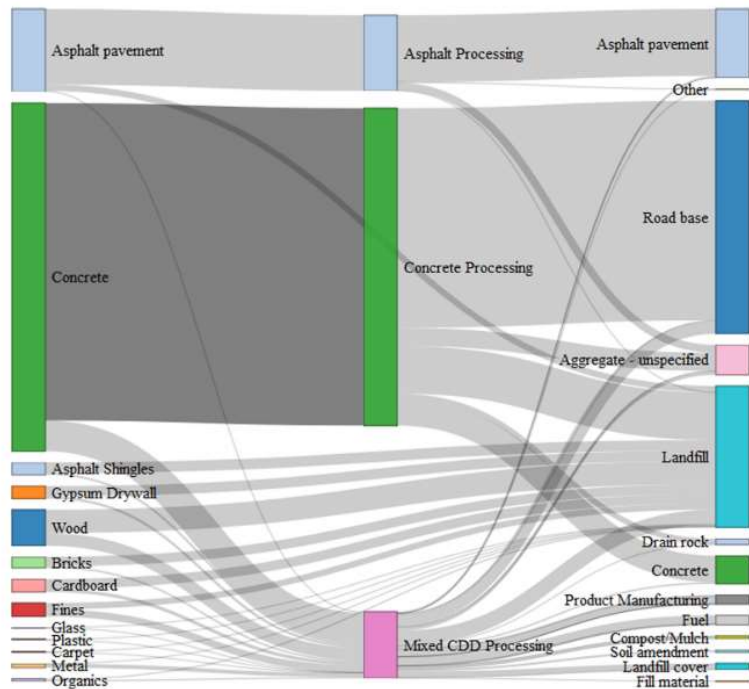


Fig. 2. CDD material flows and dispositions. Sankey diagram created using the d3Network package in the R software (Allaire et al., 2017).

Townsend et al (2018), Waste Mgmt., 'CDDPath: A method for quantifying the loss and recovery of construction and demolition debris in the US'

Next steps

- Assumptions regarding vacancy rates
- Calculation of material intensity of housing, to estimate material flows
- Investigate environmental benefit of circular material flows
- Energy scenarios based on lifetime distribution, household size, housing type mix

Thank you!



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https://www.researchgate.net/profile/Peter_Berrill