Technical supplement for "Good Climate Policy Is Good Housing Policy," essay in Up for Growth's Housing Underproduction in the U.S. report

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Understanding the full greenhouse gas emissions impact of car-oriented communities and why vehicle electrification must be complemented by reducing car-dependence

- The U.S. produces about one third of global light-duty vehicle emissions, far above its population share (4%) or even its emissions share in other sectors (11%). Calculations based on year 2018 data. Sources:
    - IEA, Net Zero by 2050, 2021, https://www.iea.org/reports/net-zero-by-2050. Figure 3.21 shows about 3300 million [metric] tons CO2e of global light-duty vehicle greenhouse gas (GHG) emissions in 2018.
    - EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks, 2021, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2019. Table 2-13 shows 1100 million tons of U.S. light-duty vehicle emissions in 2018. Total U.S. emissions were 5900 million tons, including net land use CO2 (6700 million tons gross).
    - UNEP, Emissions Gap Report 2019, 2019, https://www.unep.org/resources/emissions-gap-report-2019. This shows global emissions as 55 billion tons in 2018, including net land use CO2.
    - The U.S. population was 330 million in 2018 versus 7.7 billion globally.
- In addition to direct tailpipe emissions, car-oriented communities exacerbate other emissions sources across all sectors.
    - Petroleum extraction and refining adds about 52% onto the direct emissions for typical gasoline used in California. See CARB LCFS rule based on ANL GREET analysis https://ww2.arb.ca.gov/resources/documents/lcfs-life-cycle-analysis-models-and-documentation, 2018; compare with direct emission intensities from EPA, "Emission Factors for Greenhouse Gas Inventories," 2020, https://www.epa.gov/sites/default/files/2020-04/documents/ghg-emission-factors-hub.pdf. The 2018 estimates may undercount fugitive methane emissions, e.g. EDF, "New Data: Permian Oil & Gas Producers Releasing Methane at Three Times National Rate," 2020, https://www.edf.org/energy/were-analyzing-methane-emissions-worlds-largest-oil-patch.

- Vehicle manufacturing comprises about 15% of the total lifecycle emissions for passenger internal combustion cars and 40% for EV cars in the U.S. in 2021. Bieker, "A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars," ICCT, 2021, https://theicct.org/a-global-comparison-of-life-cycle-ghg-emissions-from-passenger-cars/.
- Building energy use: Goldstein et al., "The carbon footprint of household energy use in the United States," PNAS, 2020, https://www.pnas.org/content/117/32/19122; Berrill et al. found that selected U.S. federal policies incentivizing single family over multifamily homes significantly increased total building energy use and emissions, on the order of tens of millions of [metric] tons CO_2/yr. Berrill, P., Gillingham, K. T., and Hertwich, E. G., "Linking Housing Policy, Housing Typology, and Residential Energy Demand in the United States," *Environmental Science and Technology*, 2021, https://pubs.acs.org/doi/10.1021/acs.est.0c05696.
- Materials, manufacturing, and construction emissions "embodied" in buildings and infrastructure: Berrill and Hertwich quantified opportunities to limit future emissions from housing construction in the U.S. and found that compact and multifamily housing could reduce total emissions from a business-as-usual case by as much as 1.5 billion tons CO_2 over the next 40 years. Berrill P. and Hertwich, E. G., "Material flows and GHG emissions from housing stock evolution in U.S. counties, 2020–60," *Buildings and Cities*, 2021, https://journal-buildingscities.org/articles/10.5334/bc.126/.
- The destruction of natural land carbon sinks by sprawling urban land use: According to the EPA U.S. GHG inventory, development for "settlements" has already degraded the U.S. natural and working land carbon sink by 78 million tons CO_2 per year. This could be an underestimate as urban land conversion that displaces cropland can indirectly displace forest land elsewhere in the world: van Vliet, "Direct and indirect loss of natural area from urban expansion," *Nature Sustainability*, 2019, https://www.nature.com/articles/s41893-019-0340-0.
- In summary, indirect emissions sources almost double the total GHG impact from car-oriented communities, as compared with direct tailpipe emissions of 1100 million tons CO_2e/yr: at least 70% from vehicle fuel and manufacturing; at least 4% and as much as ~10% from building energy (roughly scaling up Berrill et al.'s estimates of up to 44% greater emissions per home for large single family homes encouraged by federal policy, to the whole housing stock); 3% from housing embodied carbon; and at least 7% from the loss of land sink. This does not include impacts on GHG emissions from commercial buildings and public and transportation infrastructure, which would add to this estimate.

• A strategy focused solely on changing what cars we drive is incomplete. We must also reduce how much we drive by building compact cities and shifting from single occupancy vehicles to public transport, active transportation, and shared vehicles.

  - Milovanoff et al., "Electrification of light-duty vehicle fleet alone will not meet mitigation targets," *Nature Climate Change*, 2020, https://www.nature.com/articles/s41558-020-00921-7.
  - Alarfaj et al., Decarbonizing U.S. passenger vehicle transport under electrification and automation uncertainty has a travel budget, *Environmental Research Letters*, 2020, https://iopscience.iop.org/article/10.1088/1748-9326/ab7c89.
  - IPCC, *Climate Change 2022: Mitigation of Climate Change*, 2022, https://www.ipcc.ch/report/ar6/wg3/. See Chapters 8 and 10 (or Technical Summary).
  - Teske et al., *TUMI Transport Outlook 1.5°C – A global scenario to decarbonise transport*, TUMI, 2021, https://outlook.transformative-mobility.org/.
  - ITDP, *The Compact City Scenario – Electrified*, 2021, https://www.itdp.org/publication/the-compact-city-scenario-electrified/.
- Compact cities are complementary to vehicle electrification, reducing the number, size, and range of electric vehicles needed and leaving room for carbon-intensive industrial sectors to decarbonize over time.
  - IEA, *Net Zero by 2050*, 2021, https://www.iea.org/reports/net-zero-by-2050.
  - Grubler et al., "A low energy demand scenario for meeting the 1.5°C target and sustainable development goals without negative emission technologies," *Nature Energy*, 2018, https://www.nature.com/articles/s41560-018-0172-6.
  - Pauliuk et al., "Global scenarios of resource and emission savings from material efficiency in residential buildings and cars," *Nature Communications,* 2021, https://www.nature.com/articles/s41467-021-25300-4.
  - They may also perhaps reduce the stress on existing supply chains: Shepard and Pratson, "The myth of US energy independence," *Nature Energy*, 2022, https://www.nature.com/articles/s41560-022-01053-2.
- In its recent report on climate mitigation, the Intergovernmental Panel on Climate Change (IPCC) highlighted the opportunity for compact cities to contribute to emission reductions, finding that better urban planning could reduce emissions by 23 to 26%.
  - IPCC, 2022 (see above), Chapter 8: "Integrated spatial planning to achieve compact and resource-efficient urban growth through co-location of residences and jobs, mixed land use, and transit-oriented development could reduce [urban sources of] GHG emissions between 23-26% by 2050 compared to the business-as-usual scenario *(robust evidence, high agreement, very high confidence).* Compact cities with shortened distances between housing and jobs, and interventions that support a modal shift away from private motor vehicles towards walking, cycling, and low-emissions shared and public transportation, passive energy comfort in buildings, and urban green infrastructure can deliver significant public health benefits and have lower GHG emissions." Note that the IPCC here uses "urban" to encompass both urban and "suburban" as commonly referred to in the U.S.

Methodological details for estimating national technical potential for greenhouse gas benefits from climate-aligned housing

- We illustrate the clear relationship between population density and VMT.
  - Based on 2017 National Household Travel Survey (NHTS) data, retrieved from https://nhts.ornl.gov/ in 2020. Tables used include "Annual VMT Per Driver" as a function of "Number of drivers in household" and "Category of housing units per square mile in the census tract of the household's home location;" "Number of Households" as a function of same; and "Number of Persons" as a function of "Category of housing units per square mile in the census tract of the household's home location." VMT per household as a function of housing density was calculated as a weighted average of VMT per driver, weighted by number of drivers and households, and then converted to VMT per capita using average persons per household by housing density.
- Including all emissions sources, our analysis of Jones and Kammen (2014) data shows that a family at a particular income level will emit ~5 to 15 fewer tons CO_2e/year when living in a denser urban neighborhood.
  - This represents ~10 to 30% fewer emissions compared to the mean. It would be greater magnitude reduction as compared with a worse-than-average low density neighborhood.
  - Jones and Kammen (2014) found that after controlling for income, population density was inversely related to household emissions. In the absence of this control, high income, moderate density, highly emitting suburbs partially obscure the relationship. Moreover, population density is inversely related with household size; controlling for income partially negates this potential statistical confounding factor, but more research is needed to disentangle these factors. Jones and Kammen, "Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density," *Environmental Science & Technology*, 2014, https://doi.org/10.1021/es4034364.
  - Data downloaded from https://coolclimate.berkeley.edu/maps.
- The ongoing demand for new housing will stack onto the cumulative 3.8 million home shortage estimated by this report, providing an important opportunity for building housing in the right places—perhaps upwards of 14 million homes over the next decade.
  - This report estimates the national shortage to be 3.8 million homes. Solving this shortage and meeting decadal population growth of 7% on a base of 140 million homes to recover a healthy housing market adds up to 15 million. Decadal growth is from U.S. Census, accessed 2022, https://www.census.gov/data/tables/2017/demo/popproj/2017-summary-tables.html. The number of housing units is from U.S. Census as of 2019, accessed 2022 https://www.census.gov/quickfacts/U.S.. A more sophisticated estimate would

consider trends in household size, age-cohort analysis (i.e., Millennials are a large generation entering peak age for forming households), and internal migration. Such estimates range up to 20 million homes: Rosen et al., *Housing is Critical Infrastructure: Social and Economic Benefits of Building More Housing*, NAR, 2021, https://www.nar.realtor/advocacy/housing-is-critical-infrastructure.

  - Note that these estimates focus on the net addition of new homes to the total housing stock, assuming constant proportion of occupied, primary homes to total homes. Retrofitting existing homes to support climate and equity goals is a complementary topic not covered in this chapter.

- Multiplying the per household emissions savings by this number of homes suggests a technical potential of roughly 100-200 million tons of CO_2e/year avoidable after 10 years if we build housing in the right places. The upper end of this range [for total emission reductions] is roughly equal to the [direct] emission reduction potential of phasing out all gas appliance sales by 2030, or of all U.S. states adopting California's target of 100% of vehicle sales being zero emission passenger vehicles by 2035.
  - See Energy Innovation's U.S. Energy Policy Simulator, https://us.energypolicy.solutions/, accessed 2022 (v. 3.3.1, "NDC Pathway" scenario). For more documentation including impacts of these measures in a national scenario consistent with policy goals, see Orvis and Mahajan, *A 1.5°C NDC For Climate Leadership By The United States*, Energy Innovation, 2021, https://energyinnovation.org/publication/a-1-5-celsius-pathway-to-climate-leadership-for-the-united-states/. Numbers quoted here may differ slightly from the published scenario due to ongoing model updates. The scenario assumed a linear ramp-up to 100% sales of electric appliances in both existing (at time of natural replacement) and new buildings by 2030, resulting in 170 million tons of CO_2e avoided in 2030. In other words, no new or replacement installations of gas or petroleum burning devices would be allowed after 2029, nationwide. The scenario also assumed a linear ramp-up to 100% sales of zero emission (modelled as electric) passenger vehicles in 2035, associated with 180 million tons of CO_2e avoided in 2030; for this calculation, we added the overlapping conventional fuel efficiency measure in estimating the marginal emissions savings from zero emission vehicles.
  - Note that the Energy Policy Simulator uses direct emissions accounting, including some interaction with domestic energy supply emissions, while our estimate for urban infill housing uses the consumption-based accounting of the Coolclimate dataset. Also note that all three policies – urban infill housing, building electrification, and vehicle electrification – will continue to grow in annual emissions reduction magnitude after 2030 as building, appliance, and vehicle stock-rollover have cumulative impacts. Eventually, more of the emission savings from infill will overlap with these other measures, yet still be critical for limiting cumulative emissions and avoiding residual emissions in other sectors. The "Avoid, Shift, Improve" (or "Avoid, Shift, Electrify") framework proposes that the emission reductions from efficiency measures like compact development should logically be counted first (IPCC, 2022).