Technical supplement - Analysis Methodology

Why State Land Use Reform Should Be a Priority Climate Lever for America

The analysis presented in this paper takes a closer look at the ability of state-by-state land use reform to reduce VMT and related GHG emissions. This work builds on prior analysis from RMI on the impacts of housing reform on emissions using a similar methodology.

Housing Production

This analysis considers transportation emissions associated with new housing a decade from now, using (1) population growth forecasts and housing underproduction data to project new housing constructed, and (2) a census block level data assimilation product of residential vehicle miles traveled (VMT) to determine transportation emissions in each state under different housing development scenarios. VMT data was not available for Alaska, therefore Alaska estimates are omitted in this study. The estimate of housing units produced assumes that states eliminate their existing housing shortages and accommodate projected population growth. Under this assumption, more than 13 million new units will be added nationally by 2033, with some states growing their housing stock by up to 25%, presenting an opportunity to build housing in more climate-aligned locations.

Housing production estimates in this methodology are estimated based on projected population growth as well as existing housing underproduction:

- 2022 state-level population data from the US Census is combined with annual population growth rate sourced from Berrill et al., 2021 to determine a state-level population projection in 2033. Berrill et al incorporated local housing market conditions in their state population growth forecast and assumed that market disequilibria could be addressed by policy. This likely returns a more accurate projection of future growth than assuming a uniform state growth rate or relying on historical trends.
- Housing shortage data, as a percentage of existing homes in each state, comes from Up For Growth's Housing Underproduction Report. While this dataset (published in 2023) accounts for year 2019 conditions, we use the percentage underproduction for 2023-based estimates, although this is likely conservative due to continued housing underproduction since 2019. This housing underproduction may be a conservative

estimate of how much housing would be needed to achieve broad affordability in the highest cost metro areas as it is likely that filling the housing shortage would induce more population inflow from other states. Under this assumption, the results from the analysis would likely be much larger in states such as California, Washington, and New York, which could see substantial migration.

Combining these data creates a housing stock growth per state that would result if each state solved its housing shortage by 2033 while accommodating new population over the next decade. We note that these estimates isolate the addition of homes to the total housing stock, and assume constant proportion of population and occupied, primary homes to total homes.

The use of housing shortage data to determine new housing production is optimistic, as it assumes the political and economic challenges associated with housing production in some states can be overcome. For states with high growth or more severe underproduction, the rate at which housing is built would need to grow significantly compared to the growth rate average in the last decade (nearly by a factor of 2 in CO and DC), for the shortage to be solved by 2033. However, this value also does not consider housing stock age and turnover, a factor that may increase the true housing need within states. A more complex study may also look at trends in household size and demographic factors that influence housing production, which are out of the scope of this paper. For example, in: Rosen et al., 2021 [Housing is Critical Infrastructure: Social and Economic Benefits of Building More Housing, NAR, 2021, https://www.nar.realtor/advocacy/housing-is-critical-infrastructure], estimates a range of up to 20 million homes constructed nationally in the next decade, compared to 13 million homes nationally from this study.

VMT Estimate

To estimate the impact of building housing in dense, walkable, and transit-oriented communities with low VMT, the analysis included two scenarios: a business as usual (BAU) case, and a low VMT, compact development case. The analysis uses census block level VMT data from 2022 to retrieve the distribution of average VMT per capita for each state and the 90th percentile lowest VMT per capita. The BAU case assumes that the new housing added by 2033 corresponds to the same average VMT per capita as 2033. By contrast, the low VMT case assumes that 90 percent of the new housing is associated with the 90th percentile lowest VMT per capita, while the other 10 percent of new housing corresponds to the current state average VMT per capita. The 90th percentile lowest VMT value was chosen to base the low VMT case on a value that is already achievable in each respective state, rather than a theoretically determined VMT estimate. In each case, the VMT per capita associated with existing housing remains unchanged.

Vehicle miles traveled (VMT) data is sourced from Replica (accessed February 2024), which has residential total VMT estimates at the census block level for the District of Columbia and all states in the US except Alaska. Replica provides two datasets for a Fall 2022 weekday and weekend day, which we combined to arrive at an average daily VMT estimate for each census block. To avoid skewing the distribution, census blocks that were not tagged to a state, had less than 1 person per square mile, and those with a population of less than ten were all removed from this dataset.

The estimate for target VMT for new housing in our ‘low VMT’ scenario is based on the distribution of VMT per capita at the census block level. We established the 90th percentile lowest VMT per capita, respectively in each state, as the target VMT for new housing, to account for VMT patterns reflecting differences in conditions between states. There is variability in the difference between the 90th percentile lowest VMT and average VMT in each state, with some states having a wider or longer tailed distribution of VMT per capita per census block than others. Further state specific analysis that accounts for sub-state development patterns could consider a more nuanced threshold than this fixed percentile and provide insights into policy opportunities.

In each case modeled, the VMT per capita associated with existing housing remains unchanged between 2023 and 2033, which does not account for more recent development patterns within each state that could affect the BAU average VMT per capita. However, RMI was unable to identify robust data to go beyond this assumption. (For instance, the U.S. Building Permit Survey relies on reporting at the municipal level, too coarse a scale to capture neighborhood VMT differences—and city reporting is incomplete.) Furthermore, this analysis assumes no transportation synergies with existing housing, such as improved transit and access to retail for people currently living in areas where new housing is added, suggesting that these VMT and emissions reduction estimates are a conservative estimate based on existing research.

GHG Emissions

The analysis considers three elements of GHG emissions reductions from land use reform: (1) direct GHG savings from vehicle operation, (2) vehicle lifecycle GHG savings, and (3) rough GHG savings including other non-transportation sectors.

Direct emissions per VMT are based on national average fuel use per mile for LDVs, national average emissions factors for gasoline combustion, and state-level emissions factors for electricity consumption for electric LDVs (sourced from NREL Cambium Mid-Case Scenario Consumption Based CO2/kWh). EV average fuel economy used in this model is the median listed fuel economy of 2022 battery electric LDV models on the market. Both fuel economies are assumed to be constant on average for vehicle fleets between 2023 and 2033. Electric LDV fleet penetration in 2023 and 2033 is estimated using Energy Innovation's Energy Policy Simulator (EPS) (accessed February 2024). For the 2033 estimates, the EV fleet penetration nationally is estimated to be 15%, which is used as the fleet penetration for most states in this model that are not committed to Advanced Clean Cars II (ACCII), which is an electric vehicle sales trajectory to 100% by 2035. For states that have committed to ACCII (CA, VT, NY, WA, OR, RI, NJ, MD), EV stock percentage is projected to be 33% in 2033. For more details on this projection, see EPS documentation for its handling of a Zero-Emission Vehicle Sales Standard policy.

In addition to direct tailpipe emissions, the vehicle lifecycle emissions include emissions from upstream petroleum extraction and processing, and from vehicle manufacture. Using CARB's LCFS rule based on ANL GREET, and comparing the emissions intensity to EPA's gasoline emissions factor, petroleum extraction and refining adds about 52% onto the direct emissions for typical gasoline used in California. These estimates are approximate and depend on state specific fuel import sources and uncertainties around upstream fugitive methane emissions from oil and gas. Vehicle manufacturing comprises about 7% of the total lifecycle emissions for passenger internal combustion cars and 41% for EV cars in the U.S. in 2021, and 48% for EV cars in 2030.

The broader emissions savings estimate including non-transportation sectors, includes the following factors:

- Building energy use: Berrill et al. and Goldstein 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 CO2/yr.
- 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 CO2 over the next 40 years.
- 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 CO2 per year. This could be

an underestimate as urban land conversion that displaces cropland can indirectly displace forest land elsewhere in the world.

Comparing these values with direct tailpipe emissions estimates of 1100 million tons CO2e/year nationally, this adds up to 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. Including these values on top of vehicle manufacture and upstream fuel extraction, indirect emissions sources almost double the total GHG impact from car-oriented communities compared to direct emissions alone. This does not include impacts on GHG emissions from commercial buildings and public and transportation infrastructure, which would add to this estimate.

While these emissions projections are for 2033 alone, the cumulative emissions impact of energy and transportation efficiency due to improved housing policy would continue to grow over time as housing stock continues to turn over beyond 2033.

The analysis estimates the technical potential of emissions reductions and does not consider political or economic barriers of building more housing in each state. The analysis adopts an optimistic viewpoint that policy is the sole constraint on housing production in low-VMT areas and that development patterns could immediately shift pending policy reform. This reform may also need to include policies to limit sprawl in suburban areas to prevent greenfield and wildland urban interface development. At the same time, the analysis is conservative because it excludes likely synergies from added housing in reducing residential VMT for existing residents in the low VMT scenario due to improved transit and accessibility to local destinations. The analysis also does not quantify additional indirect GHG savings.

The following summary table highlights several of the key drivers of differences and results among the states in the analysis. As outlined in the main body, the state housing underproduction and projected annual population growth significantly impact the potential VMT savings and GHG savings that could result from state-by-state land use reform.

State	Housing Underproduction (% of Existing Homes)	Projected Annual Population Growth Rate (%/year)	Existing Weekday VMT Per Capita	Target Weekday VMT Per Capita	Statewide VMT Savings (% of average VMT)	Gross Rough Lifecycle GHG Savings (MMT CO_2e/Year)
AL	1.44%	0.2%	27.0	15.6	1%	0.4
AR	0.72%	0.4%	24.5	13.9	1%	0.3

AZ	0.16%	1.1%	22.9	13.1	5%	2.4
CA	3.83%	0.7%	18.9	11.4	5%	8.3
CO	6.07%	1.4%	22.5	13.0	6%	2.3
CT	3.98%	-0.1%	21.3	11.4	1%	0.2
DC	2.85%	1.8%	6.8	2.6	11%	0.2
DE	3.21%	0.7%	23.2	13.8	3%	0.2
FL	1.83%	1.2%	21.6	12.9	5%	7.0
GA	2.43%	0.9%	25.3	15.0	4%	3.3
HI	3.08%	0.7%	15.5	6.0	5%	0.3
IA	1.80%	0.5%	28.8	17.4	2%	0.4
ID	0.60%	1.0%	23.1	13.9	5%	0.6
IL	5.40%	-0.2%	19.2	8.4	1%	0.6
IN	2.08%	0.3%	22.4	12.8	2%	0.6
KS	0.96%	0.3%	25.5	15.3	1%	0.3
KY	0.68%	0.3%	26.3	15.3	1%	0.4
LA	1.24%	0.5%	21.6	10.5	2%	0.6
MA	0.18%	0.5%	17.7	6.1	5%	1.5
MD	3.53%	0.6%	22.9	11.0	4%	1.6
ME	3.79%	-0.2%	25.0	14.0	1%	0.1
MI	2.00%	0.0%	25.5	14.6	1%	0.6
MN	2.59%	0.6%	25.0	13.1	4%	1.5
MO	4.19%	0.2%	26.6	15.2	1%	0.5
MS	1.13%	0.1%	27.8	16.5	0%	0.1
MT	0.39%	0.8%	26.6	12.0	4%	0.3
NC	0.74%	0.9%	29.2	17.9	3%	2.7
ND	1.25%	2.2%	30.0	14.7	9%	0.6
NE	0.20%	0.7%	25.1	14.7	3%	0.4
NH	1.78%	0.0%	25.0	16.7	1%	0.1
NJ	4.77%	0.2%	16.7	6.9	3%	1.2
NM	3.80%	0.0%	25.4	13.7	1%	0.2
NV	3.06%	1.2%	18.1	10.1	6%	0.9
NY	3.20%	0.2%	13.3	1.0	4%	2.5
OH	2.82%	0.0%	23.2	13.3	1%	0.5
OK	1.52%	0.8%	27.3	15.9	3%	0.9
OR	0.33%	0.9%	20.5	10.7	5%	1.1
PA	4.75%	0.0%	19.8	7.6	1%	0.6
RI	1.69%	0.0%	19.0	10.0	1%	0.0
SC	1.23%	1.0%	25.4	16.1	3%	1.2
SD	0.31%	1.0%	28.2	15.0	4%	0.3
TN	1.26%	0.7%	25.0	15.3	3%	1.3
TX	1.80%	1.5%	23.1	13.6	6%	12.4

UT	2.58%	1.4%	19.9	12.7	6%	1.1
VA	5.13%	0.7%	25.6	14.0	4%	2.3
VT	3.01%	-0.3%	25.8	13.0	1%	0.0
WA	2.33%	1.1%	20.0	11.0	6%	2.3
WI	4.51%	0.2%	24.8	12.4	2%	0.6
WV	2.07%	-0.3%	32.7	18.2	0%	0.0
WY	0.58%	0.7%	27.7	17.1	3%	0.1