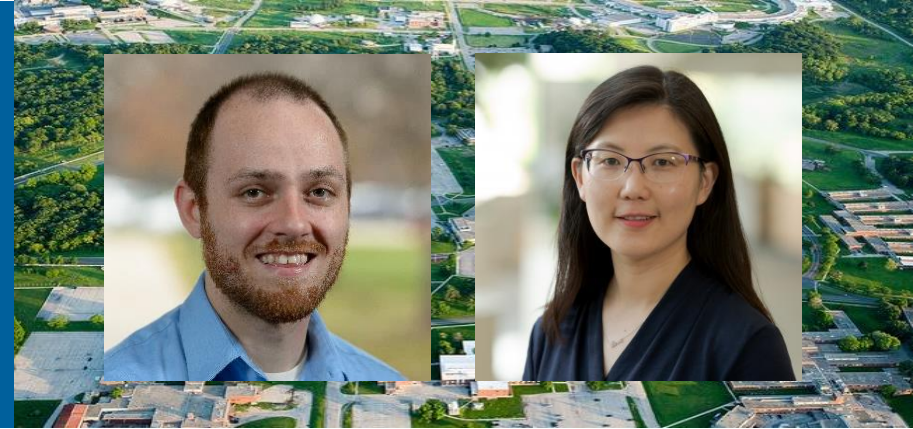


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AFFORDABILITY OF HOUSEHOLD TRANSPORTATION FUEL COSTS BY REGION & SOCIOECONOMIC FACTORS



JOANN ZHOU, DAVID GOHLKE, SPENCER AESCHLIMAN

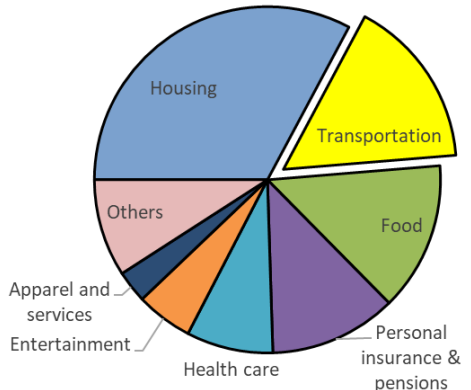
Argonne National Laboratory

HOUSEHOLD TRANSPORTATION ENERGY BURDEN DEPENDS ON THE ANNUAL VEHICLE MILES, FUEL PRICE, AND VEHICLE EFFICIENCY

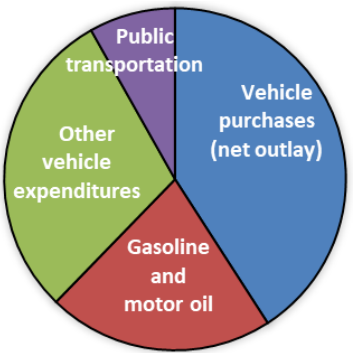
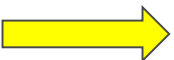
Transportation energy is an important component of household budgets

Household Transportation Energy Burden = $\frac{\text{Cost}}{\text{Income}} = \frac{\frac{\text{Vehicle Efficiency by zipcode}}{\text{mile}} \times \frac{\text{Fuel Price by zipcode}}{\text{gallon}} \times \frac{\text{Annual Vehicle Miles by zipcode}}{\text{mile}}}{\frac{\$}{\text{year} \cdot \text{household}}}$

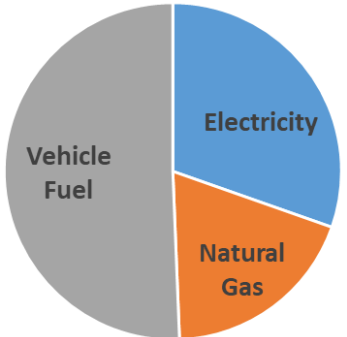
Key research question



Household expenditure categories



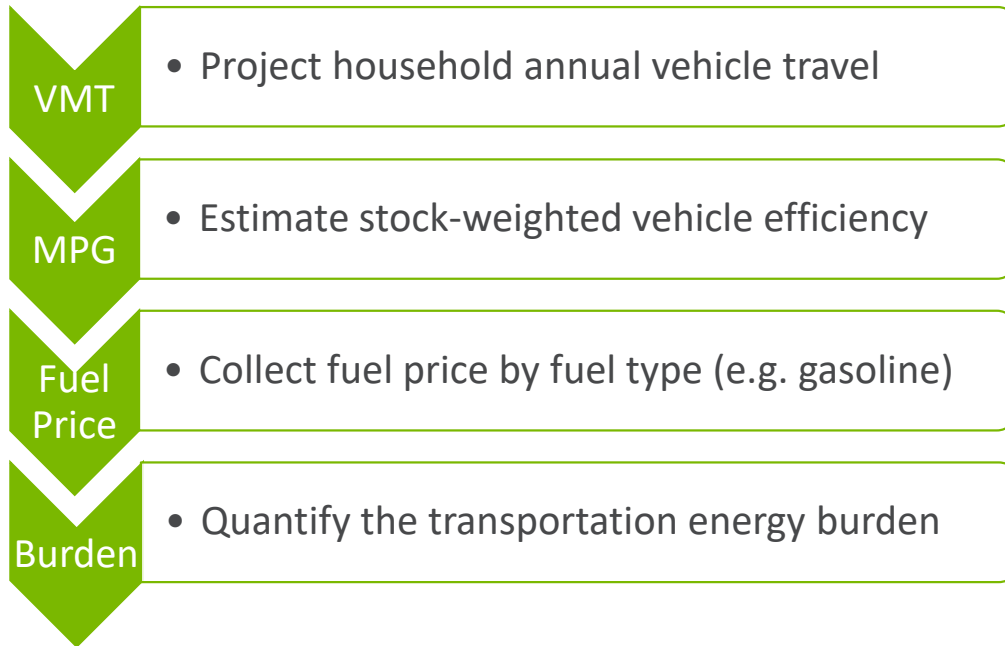
Household Income by Census tract



Household energy costs

WE USE HIGH RESOLUTION DEMOGRAPHIC CHARACTERISTICS OF EACH TRACT TO PROJECT HOUSEHOLD ANNUAL TRAVEL

Research framework



% of household by # vehicles, # workers and income group for a representative census tract (Tract ID: 17031770602)

Number of Workers	Number of Vehicles	Annual Household Income (thousand \$)										
		0-5	5-10	10-15	15-20	20-25	25-35	35-50	50-75	75-100	100-150	150+
0	0	1.99%	0.15%	1.13%	0.45%	0.66%	1.13%	0.26%	0.51%	0.09%	0.00%	0.06%
0	1	1.04%	0.08%	0.25%	0.02%	0.45%	2.09%	0.84%	0.88%	0.40%	0.26%	0.07%
0	2	0.20%	0.00%	0.23%	0.07%	0.32%	1.32%	0.60%	1.31%	1.41%	0.67%	0.48%
0	3	0.00%	0.02%	0.00%	0.00%	0.04%	0.12%	0.03%	0.01%	0.01%	0.02%	0.01%
0	4+	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%	1.14%	0.00%	0.00%	0.00%
1	0	0.17%	0.20%	0.43%	0.45%	0.11%	0.07%	0.01%	0.11%	0.00%	0.05%	0.00%
1	1	2.71%	0.37%	1.87%	0.87%	2.03%	4.06%	2.11%	5.36%	2.06%	0.81%	0.31%
1	2	0.59%	0.08%	0.38%	0.30%	0.76%	1.43%	0.89%	3.55%	1.61%	1.15%	0.57%
1	3	0.07%	0.00%	0.00%	0.00%	0.44%	0.29%	0.36%	0.40%	1.16%	0.11%	0.05%
1	4+	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.12%	0.03%	1.18%	0.96%	0.55%
2	0	0.00%	0.00%	0.08%	0.00%	0.00%	0.01%	0.02%	0.36%	0.01%	0.15%	0.01%
2	1	0.00%	0.01%	0.05%	0.03%	0.13%	0.90%	0.48%	1.11%	1.50%	1.16%	0.57%
2	2	0.17%	0.00%	0.03%	0.03%	0.12%	0.28%	0.47%	3.01%	2.67%	4.14%	3.21%
2	3	0.00%	0.00%	0.00%	0.02%	0.03%	0.44%	0.19%	0.88%	0.86%	1.27%	1.06%
2	4+	0.00%	0.00%	0.00%	0.00%	0.23%	0.08%	0.00%	0.00%	0.03%	0.03%	0.01%
3+	0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
3+	1	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%	0.86%	0.33%	0.36%	0.14%
3+	2	0.00%	0.00%	0.00%	0.00%	0.00%	0.13%	0.10%	0.61%	0.33%	0.52%	0.50%
3+	3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	1.21%	1.21%	1.64%	1.35%
3+	4+	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.02%	0.02%	0.70%	1.53%	1.40%

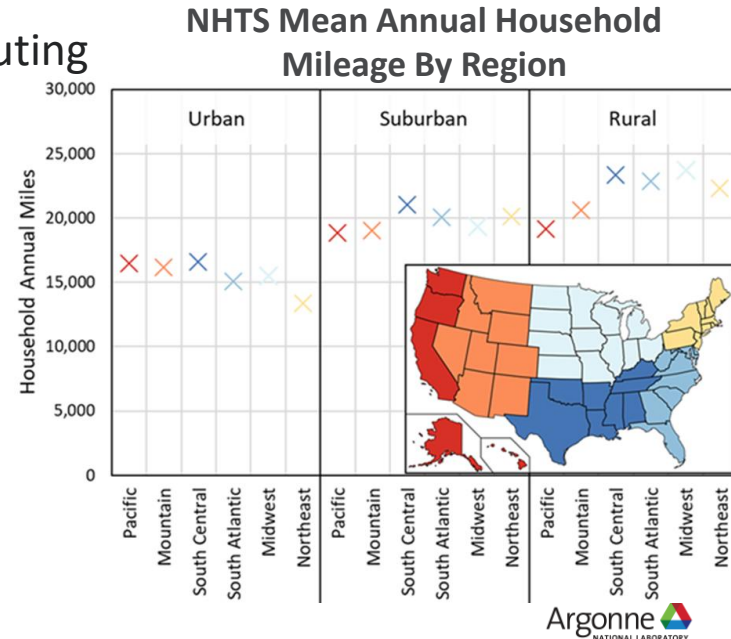
* Each census tract has 220 groups

HOUSEHOLD ANNUAL MILES VEHICLE TRAVEL (VMT) DEPENDS ON THEIR SOCIOECONOMIC FACTORS

Applied Machine Learning techniques to predict household annual vehicle miles traveled (VMT)

- Used National Household Travel Survey (NHTS) samples to develop models to project household annual VMT
- Identified **5** important socioeconomic factors contributing to household VMT (in order of feature importance)
 - # of vehicles
 - # of workers
 - household income
 - housing units density (Urban/Suburb/Rural)
 - Lifecycle factors (# of children or senior people)
- Developed **18** different VMT projection models considering the heterogeneity among census regions and urban/rural areas

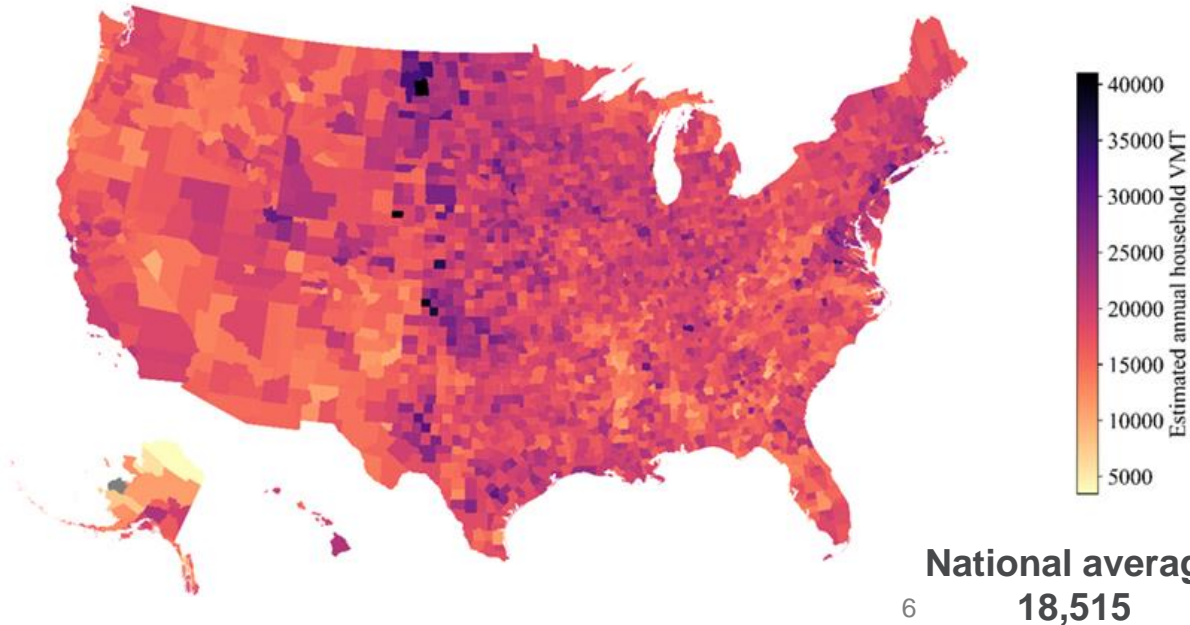
*6 Census Regions * 3 Urbanity (Urban/Suburb/Rural)*



WIDE VARIATION IN AVERAGE HOUSEHOLD VMT ACROSS THE U.S.

The national average annual household VMT is 18,515

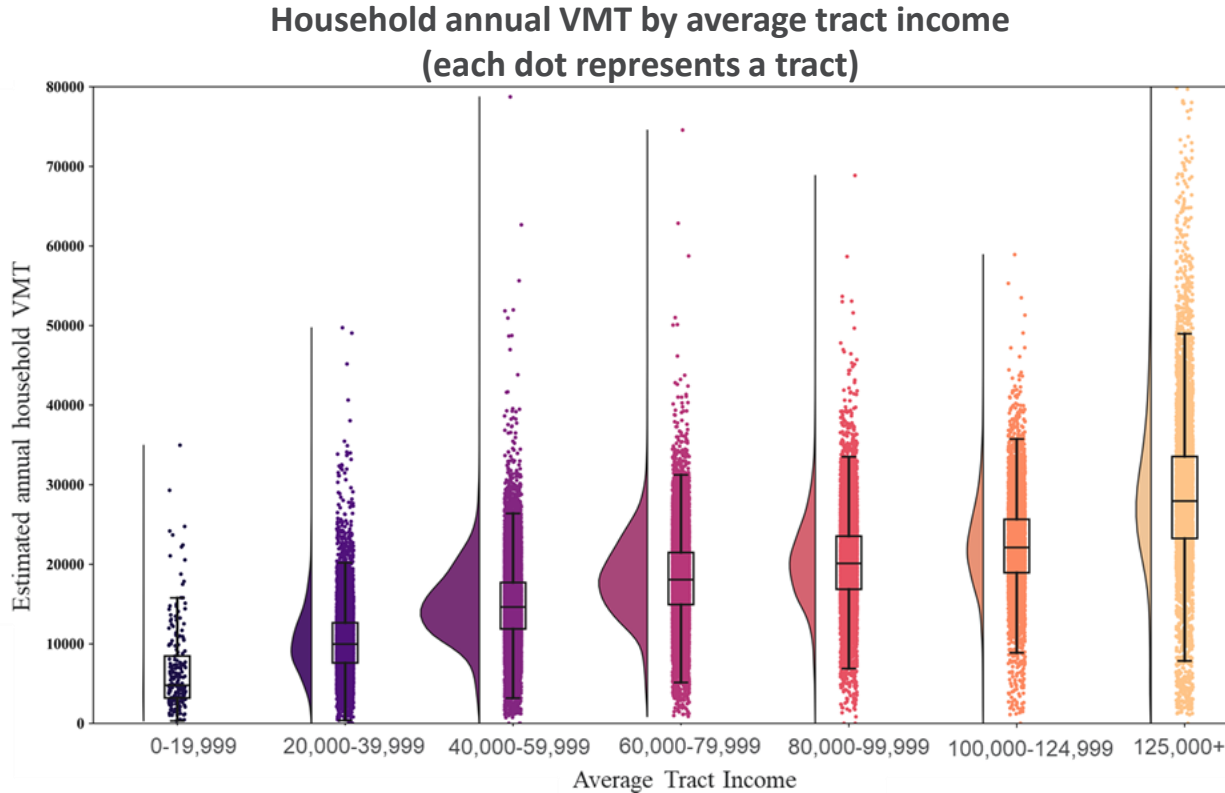
$$\text{Household Transportation Energy Burden} = \frac{\text{Cost}}{\text{Income}} = \frac{\frac{\text{gallon}}{\text{mile}} \times \frac{\$}{\text{gallon}} \times \frac{\text{VMT}}{\text{household}}}{\frac{\$}{\text{year} \cdot \text{household}}}$$



- Household annual VMT varies by housing unit density and by region: **2,507 to 40,985**, by county
- Suburban and rural households have higher annual VMT than the urban households
- Households in the Pacific and Mountain regions tend to have lower annual VMT

ANNUAL VMT INCREASES AS THE HOUSEHOLD AVERAGE INCOME INCREASES: FROM 11,000 TO 30,000 MILES

Higher-income groups have the widest distributions of annual VMT



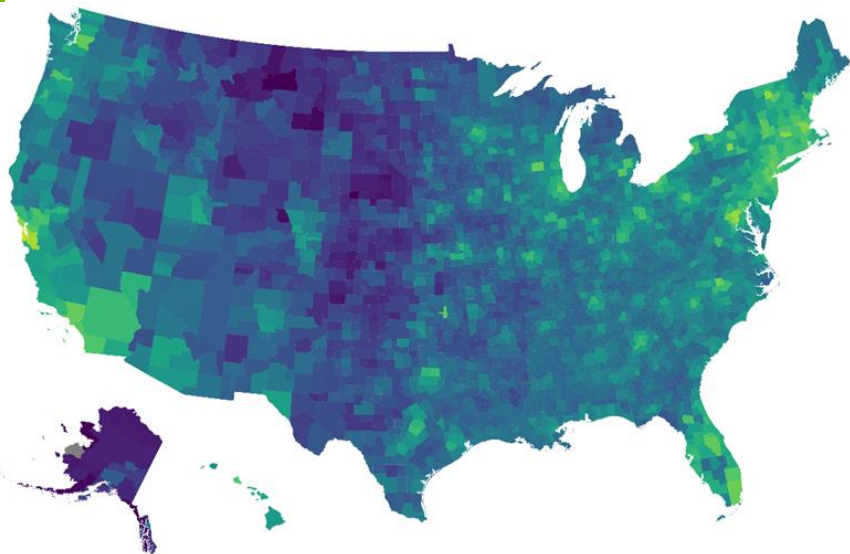
ON-ROAD VEHICLE MPG VARIES FROM 15.6 TO 23.3 BY COUNTY ACROSS THE U.S.

Adoption of newer vehicles or energy efficient vehicles increases the on-road vehicle efficiency

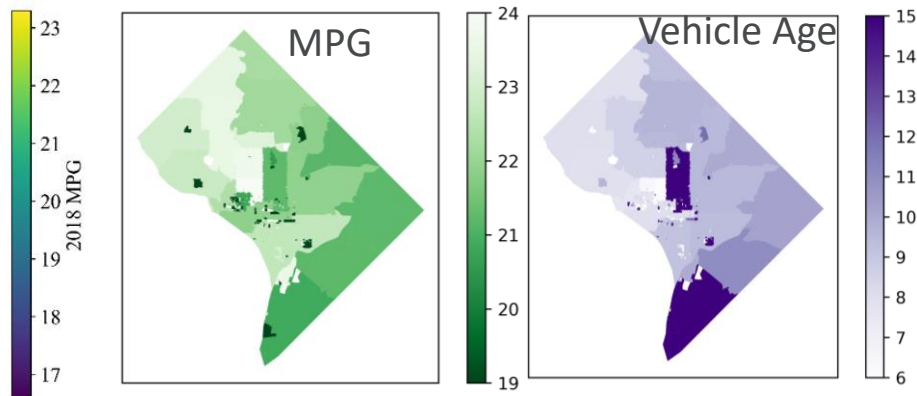
$$\text{Household Transportation Energy Burden} = \frac{\text{Cost}}{\text{Income}} = \frac{\frac{\text{gallon}}{\text{mile}} \times \frac{\$}{\text{gallon}} \times \frac{\text{VMT}}{\text{household}}}{\frac{\$}{\text{year} \cdot \text{household}}}$$

Efficiency of On-road Vehicles

(Stock-weighted MPG by County, 2018 Registration)



On-road Vehicle MPG vs. Average Vehicle Age (Washington D.C.)



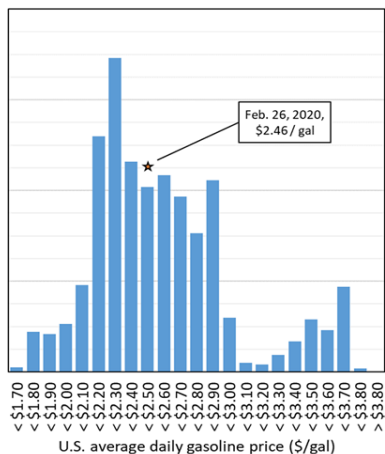
Results are available for each census tract

LOCAL VARIABILITY IN FUEL PRICES UNDERSCORES THE NEED FOR HIGH GEOGRAPHIC FIDELITY

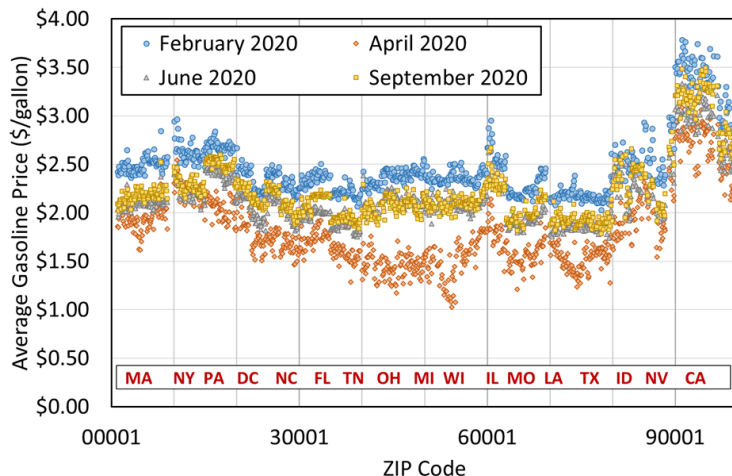
Estimate typical household fuel costs at the tract level

$$\text{Household Transportation Energy Burden} = \frac{\text{Cost}}{\text{Income}} = \frac{\frac{\text{gallon}}{\text{mile}} \times \frac{\$}{\text{gallon}} \times \frac{\text{VMT}}{\text{household}}}{\frac{\$}{\text{year} \cdot \text{household}}}$$

Gasoline Price Distribution



Local (ZIP3) Gasoline Prices



- Gasoline prices vary over time and by place

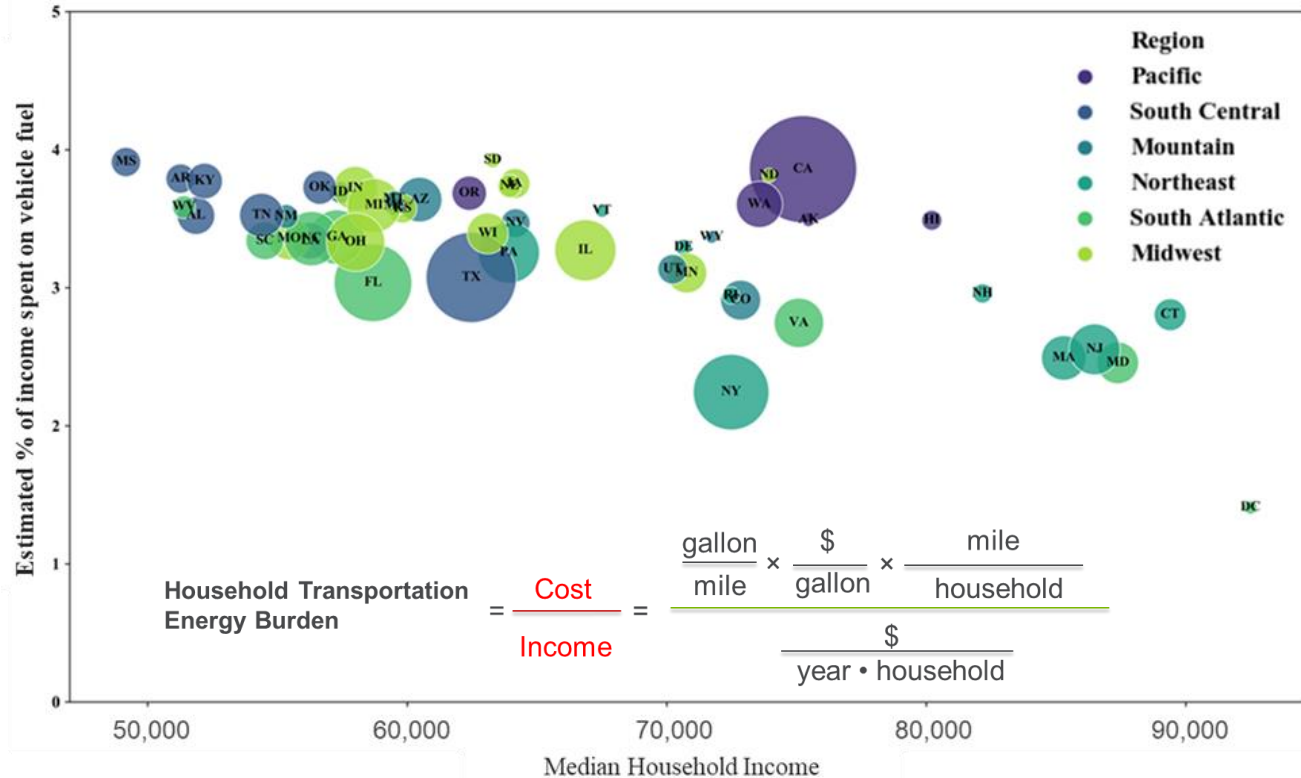
- Multiplied the on-road MPG by the cost of fuel (in \$/GGE) for each fuel type to find the cost per mile of operating each vehicle

$$\text{Cost} \left(\frac{\$}{\text{mile}} \right) = \text{MPGGE} * \$/\text{GGE}$$

MPGGE: miles per gallon of gasoline-equivalent

AVERAGE HOUSEHOLD TRANSPORTATION ENERGY BURDEN RANGES FROM 1.4% TO 4.0% BY STATE

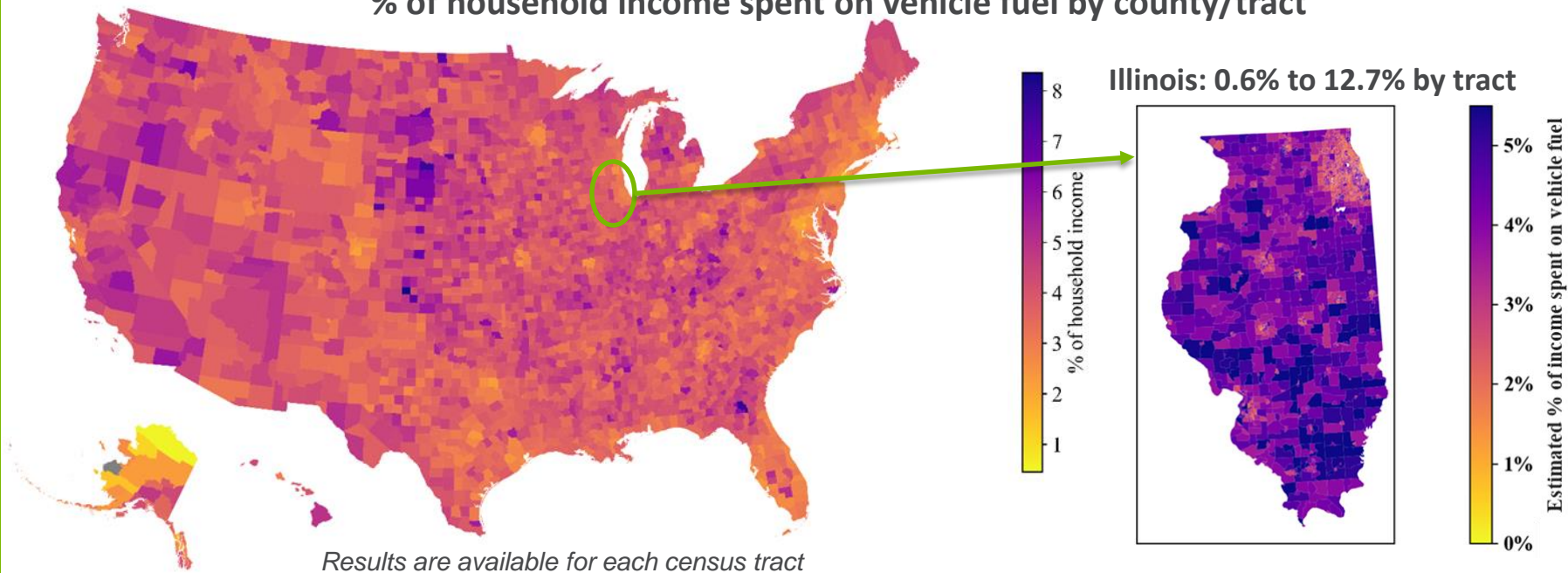
Household transportation energy burden depends on household VMT, MPG, and fuel price



HOWEVER, THE BURDEN BY CENSUS TRACT VARIES BETWEEN 0.09% AND 23.3%

Rural households have higher transportation energy burden than suburban and urban households for all regions (households with at least 1 vehicle)

% of household income spent on vehicle fuel by county/tract



THIS VARIATION IN TRANSPORTATION ENERGY BURDEN CAN BE LARGELY EXPLAINED BY VEHICLE FUEL EFFICIENCY

Besides income, energy burden highly correlates with vehicle efficiency

$$\text{Household Transportation Energy Burden} = \frac{\text{Cost}}{\text{Income}} = \frac{\frac{\text{gallon}}{\text{mile}} \times \frac{\$}{\text{gallon}} \times \frac{\text{VMT}}{\text{household}}}{\frac{\$}{\text{year} \cdot \text{household}}}$$

- Adoption of more fuel-efficient vehicles, especially among low-income households, could have the biggest impact on improving household transportation energy burden

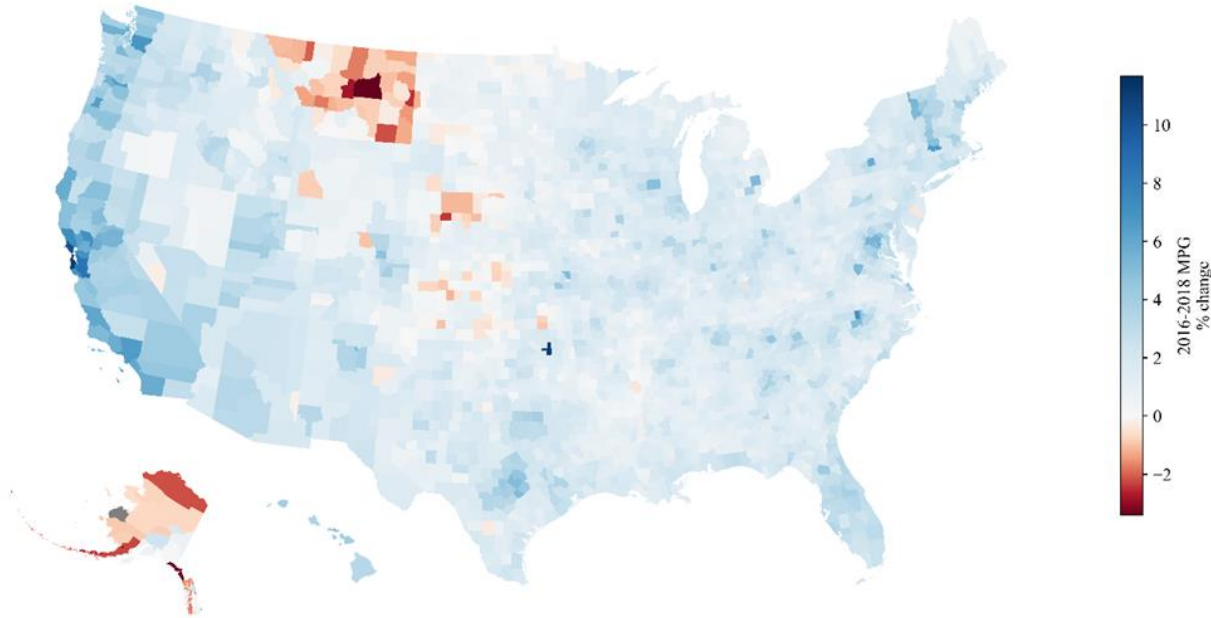
Factor Correlations	Burden	Fuel Consumption	Income	VMT	Fuel Price
Burden	+1.00	+0.78	-0.83	+0.46	+0.04
Fuel Consumption	+0.78	+1.00	-0.63	+0.41	-0.15
Income	-0.83	-0.63	+1.00	-0.18	+0.26
VMT	+0.46	+0.41	-0.18	+1.00	-0.32
Fuel Price	+0.04	-0.15	+0.26	-0.32	+1.00

Blue: Positive Correlation

Orange: Negative Correlation

3% IMPROVEMENT IN STOCK-WEIGHTED MPG SAVED AMERICAN HOUSEHOLD \$8.2 BILLION

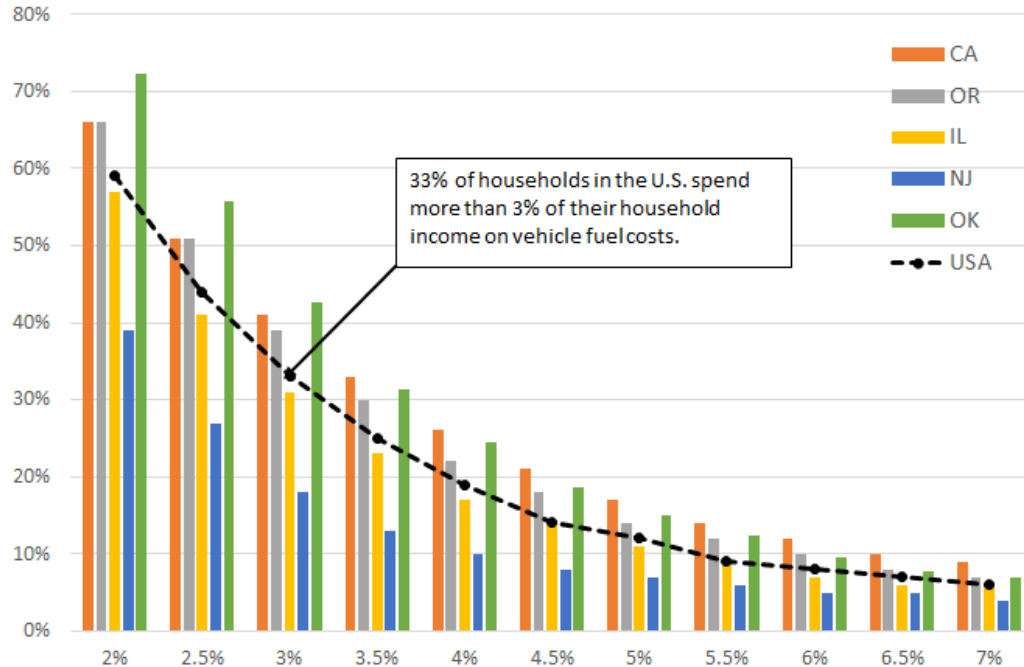
On-road Vehicle MPG Difference: 2018 vs. 2016



- Largely due to improvement of ICE fuel economy for new vehicles and increasing PEV adoption
- Other benefits such as GHG emission reductions could also be quantified

Calculations keep gasoline price and household VMT unchanged to focus on fuel economy improvements

THIS STUDY DEVELOPS A FRAMEWORK TO IDENTIFY THE REGIONAL AFFORDABILITY LEVEL AND QUANTIFY OVERBURDENED FRACTION OF HOUSEHOLDS

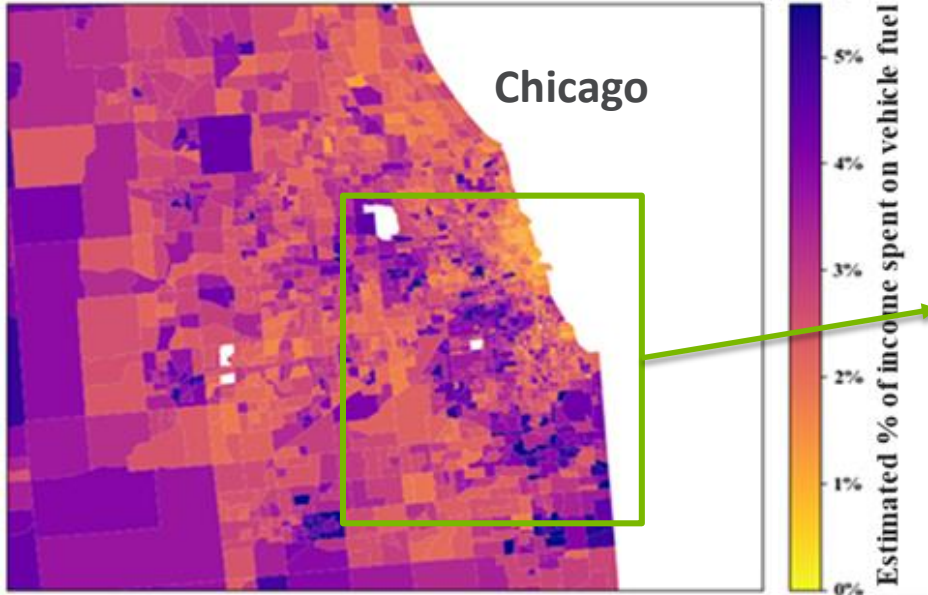


- A baseline to show % of households spending above a given affordability threshold on household vehicle fuel
- Help to identify underserved communities and rural populations for future investment
- Help to identify the communities that could benefit from energy efficient technologies

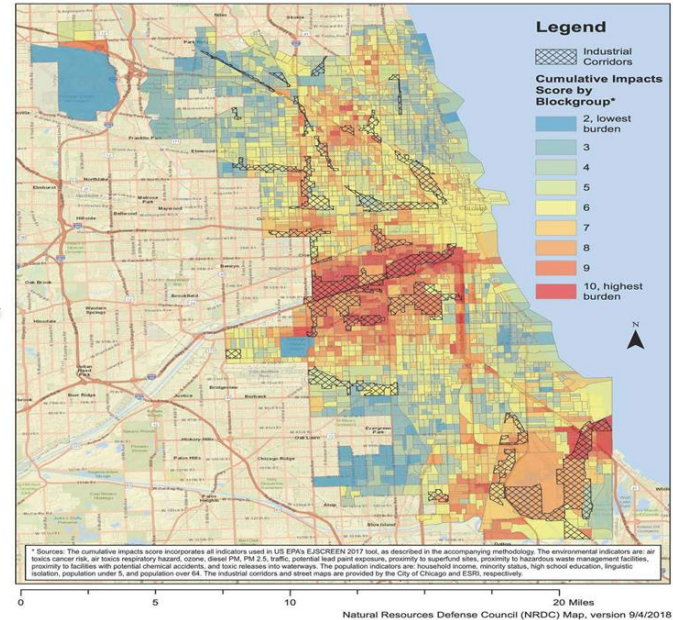
COMMUNITIES WITH HIGH TRANSPORTATION ENERGY BURDEN ALSO FACE HIGH ENVIRONMENTAL BURDEN

Identify the communities that could benefit from energy efficient technologies

% of HH income spent on vehicle fuel



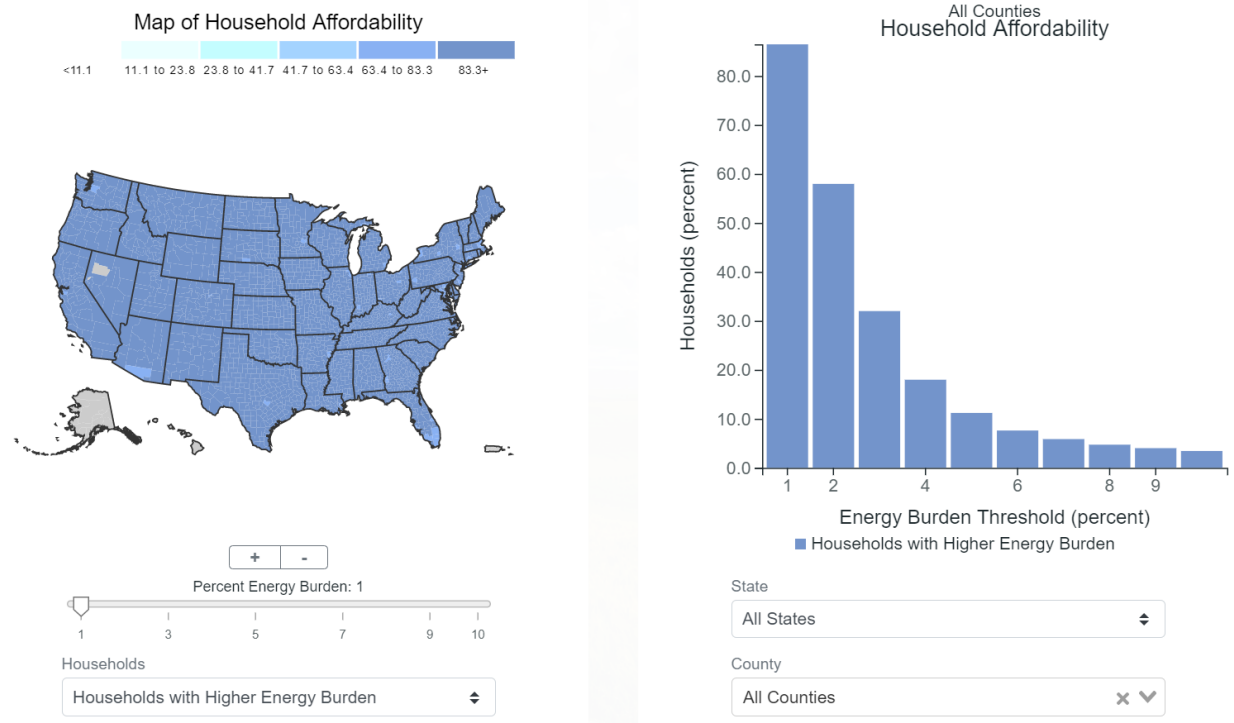
Burden of Environmental Exposures & Population Vulnerability



Source: NRDC

THE FULL DATASET IS AVAILABLE TO VISUALIZE, DOWNLOAD AND EXPLORE

https://openei.org/wiki/Transportation_Energy_Affordability



SUMMARY

Method

- Estimate household transportation energy burden, based on annual VMT, on-road vehicle efficiency and fuel price

Conclusions

- Variation in transportation energy burden can be largely explained by vehicle fuel efficiency

Equity

- Currently, wealthier census tracts have better fuel economy on average

Applications

- Identify the communities that could benefit from energy efficient technologies

Future work

- Include other vehicle ownership costs into the framework

THANK YOU!

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