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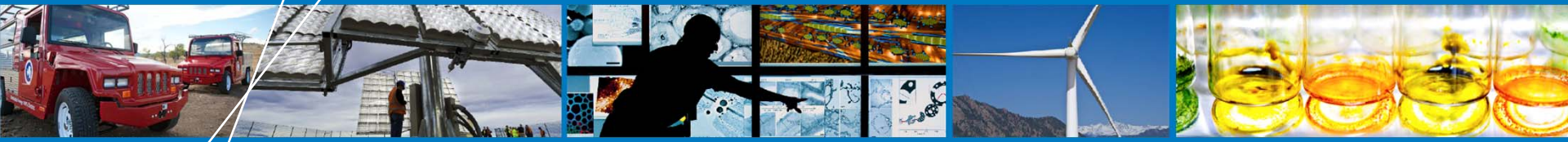
NATIONAL RENEWABLE ENERGY LABORATORY

Built Environment Energy Analysis Tool Overview



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Overview

- Developed for National Renewable Energy Laboratory (NREL) in support of U.S. Department of Energy (DOE) Transportation Energy Futures Study
- Designed for scenario analysis at a national level
- Objective – Assess impacts of future land use/built environment patterns on transportation energy and greenhouse gas (GHG) emissions
- Tool can be used to evaluate scenarios of different population distributions by density and urban design characteristics in 2030 and 2050

Models of Person-Miles of Travel

- Four models of daily PMT/capita developed from 2009 NHTS
  - » HBW & Other trip type; for Top 50 & Other MSA population
  - » Estimated at Census Tract level

Independent Variable	Categories
Household Income	<$30K, $30-60K, >$60K
Sex	M, F
Age (worker)	36-50, other
Home type	Single-family, multi-family
Population density	<750, 750-7000, >7000 persons per sq. mi.
Employment density	<100, 100-1000, >1000 jobs per sq. mi.
Region of U.S.	Northeast, Midwest, South, West
Area type	Urban, rural
MSA population size	<3M, >3M (Top 50); <200K, 200-500K, >500K (Other)
Infrastructure (top 50)	Congestion Index; Ratio of freeway to arterial miles

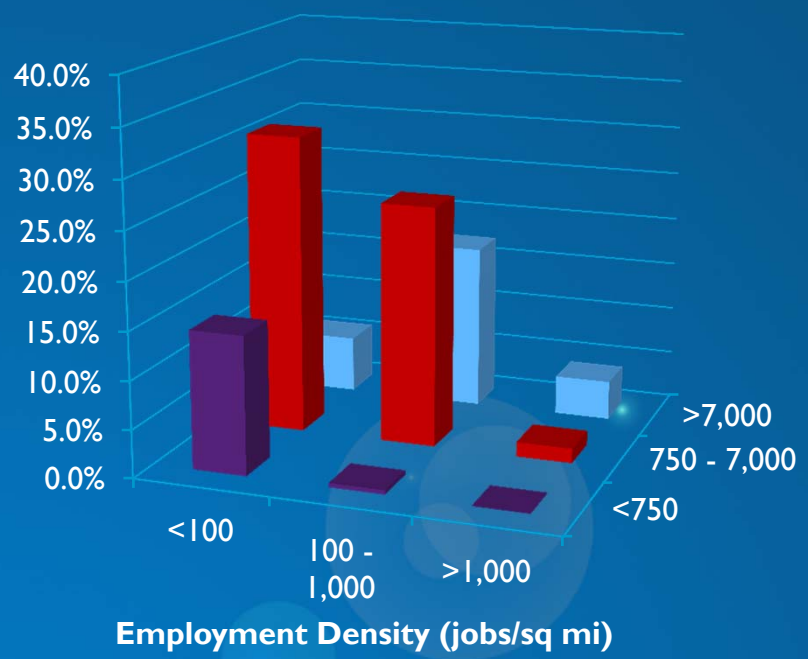
Fixed/User-Modifiable Inputs

- **Population, Demographics, and Travel**
  - » Total population
  - » Labor force participation rate
  - » Percent of population in MSA
  - » Distributions of HH income, workers by age
  - » Trips per day
  - » Average vehicle occupancy
  - » Mode shares by population density
- **Energy and GHG**
  - » Energy and CO2 content of fuels
  - » Fuel-cycle and CO2e scale factors
  - » % energy by fuel type & mode
  - » GHG intensity of electricity generation
  - » Future vehicle efficiency
  - » Transit – average load factor and percent of VMT by mode
- **Infrastructure**
  - » Congestion level
  - » Freeway versus arterial dominance

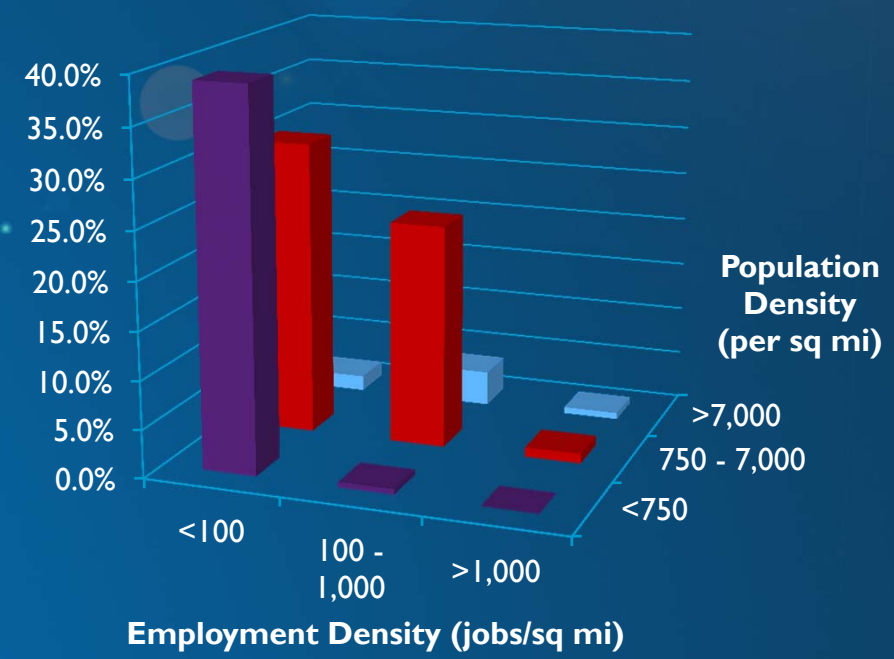
Population Density Distributions

- Percent of population by density, 2030 (baseline)

Top 50 MSAs



Other MSAs



Sample Scenario Inputs (2030, Top 50 MSAs)

Baseline – Percent of Population

Urban and Rural

Population Density	Employment Density			
	Low	Med	High	Total
Low	14.4%	0.5%	0.0%	14.9%
Medium	31.2%	25.1%	1.5%	57.8%
High	5.9%	17.3%	4.1%	27.3%
Total	51.5%	42.8%	5.6%	100.0%

Urban

Population Density	Employment Density			
	Low	Med	High	Total
Low	2.9%	0.3%	0.0%	3.3%
Medium	29.3%	24.9%	1.5%	55.8%
High	5.9%	17.3%	4.1%	27.3%
Total	38.2%	42.6%	5.6%	86.4%

Rural

Population Density	Employment Density			
	Low	Med	High	Total
Low	11.5%	0.1%	0.0%	11.6%
Medium	1.9%	0.2%	0.0%	2.0%
High	0.0%	0.0%	0.0%	0.0%
Total	13.4%	0.3%	0.0%	13.6%

Change – Percent of Population

Urban and Rural

Population Density	Employment Density			
	Low	Med	High	Total
Low	**-5.0%**	**0.0%**	**0.0%**	-5.0%
Medium	**-5.0%**	**0.0%**	**2.5%**	-2.5%
High	**0.0%**	**0.0%**	**7.5%**	7.5%
Total	-10.0%	0.0%	10.0%	0.0%

Urban

Population Density	Employment Density			
	Low	Med	High	Total
Low	-1.0%	0.0%	0.0%	-1.0%
Medium	-4.7%	0.0%	2.5%	-2.2%
High	0.0%	0.0%	7.5%	7.5%
Total	-5.7%	0.0%	10.0%	4.3%

Rural

Population Density	Employment Density			
	Low	Med	High	Total
Low	-4.0%	0.0%	0.0%	-4.0%
Medium	-0.3%	0.0%	0.0%	-0.3%
High	0.0%	0.0%	0.0%	0.0%
Total	-4.3%	0.0%	0.0%	-4.3%

Sample Scenario Inputs (2030, Other MSAs)

Baseline – Percent of Population

Urban and Rural

Population Density	Employment Density: Low	Med	High	Total
Low	39.0%	0.6%	0.0%	**39.6%**
Medium	30.5%	23.1%	1.0%	**54.6%**
High	1.6%	3.6%	0.7%	**5.8%**
Total	**71.1%**	**27.3%**	**1.7%**	100.0%

Urban

Population Density	Employment Density: Low	Med	High	Total
Low	6.3%	0.4%	0.0%	6.7%
Medium	27.4%	22.7%	1.0%	51.1%
High	1.6%	3.6%	0.7%	5.8%
Total	35.2%	26.7%	1.7%	**63.6%**

Rural

Population Density	Employment Density: Low	Med	High	Total
Low	32.8%	0.1%	0.0%	32.9%
Medium	3.1%	0.4%	0.0%	3.5%
High	0.0%	0.0%	0.0%	0.0%
Total	35.8%	0.6%	0.0%	**36.4%**

Change – Percent of Population

Urban and Rural

Population Density	Employment Density: Low	Med	High	Total
Low	**-5.0%**	**0.0%**	**0.0%**	**-5.0%**
Medium	**-5.0%**	**2.5%**	**2.5%**	**0.0%**
High	**2.5%**	**2.5%**	**0.0%**	**5.0%**
Total	**-7.5%**	**5.0%**	**2.5%**	0.0%

Urban

Population Density	Employment Density: Low	Med	High	Total
Low	-0.8%	0.0%	0.0%	-0.8%
Medium	-4.5%	2.5%	2.5%	0.5%
High	2.5%	2.5%	0.0%	5.0%
Total	-2.8%	5.0%	2.5%	**4.7%**

Rural

Population Density	Employment Density: Low	Med	High	Total
Low	-4.2%	0.0%	0.0%	-4.2%
Medium	-0.5%	0.0%	0.0%	-0.5%
High	0.0%	0.0%	0.0%	0.0%
Total	-4.7%	0.0%	0.0%	**-4.7%**

Sample Scenario (continued)

- Outputs represent scenario in which 10% (2030) or 20% (2050) of future population is redirected from lower-density into higher-density/more mixed-use neighborhoods
- Pedestrian design index is increased in medium and high-density neighborhoods

Population Density (persons per sq mi)	Change in Ped Design Index (Scenario)	Elasticity of transit trips w/r/t sidewalk coverage	Elasticity of walk trips w/r/t ped environment factor
<750	0%	0.00	0.00
750 – 7,000	10%	0.20	0.15
>7,000	20%	0.20	0.15

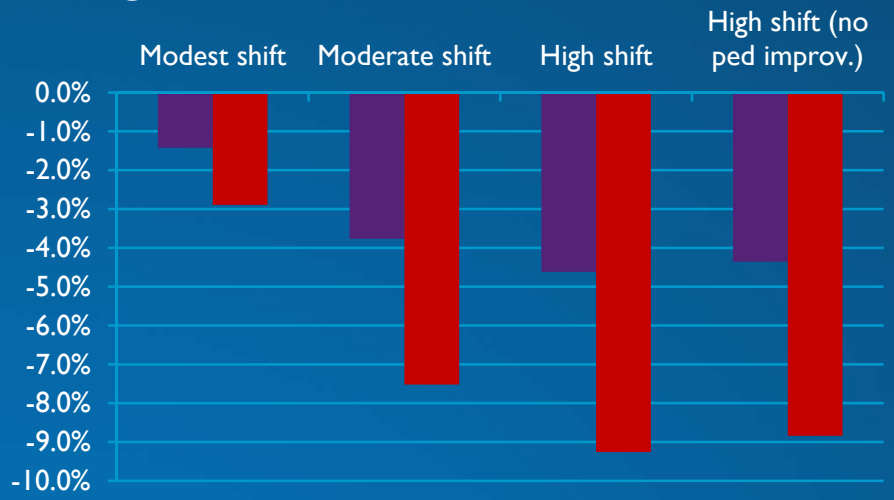
Four Test Scenarios

Scenario	Description	% Total Pop Shift – 2030	% Total Pop Shift – 2050	% of Pop Growth Shifted	Ped Design Improvement[a]
A	Modest shift	5%	10%	33%	5-20%
B	Moderate shift	10%	20%	66%	10-30%
C	High shift	15%	30%	100%	15-30%
D	High shift (no ped improvement)	15%	30%	100%	0%

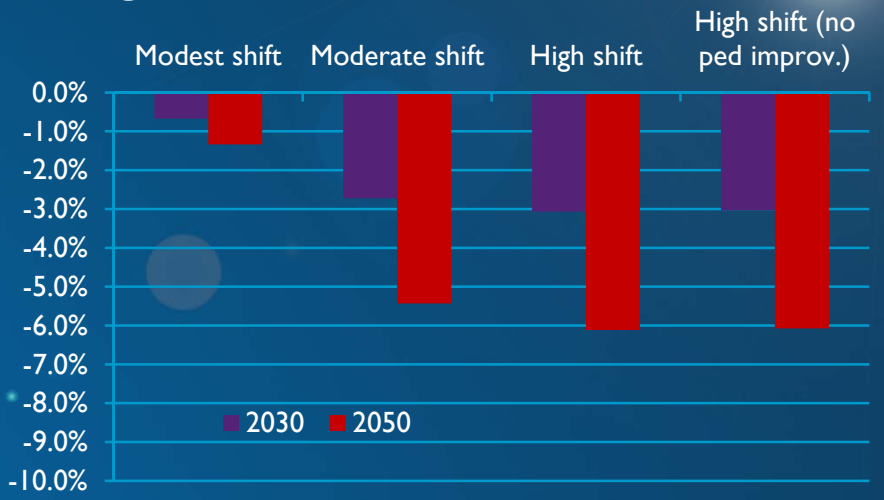
[a]Ped improvements in medium and high density areas only

Scenario Results

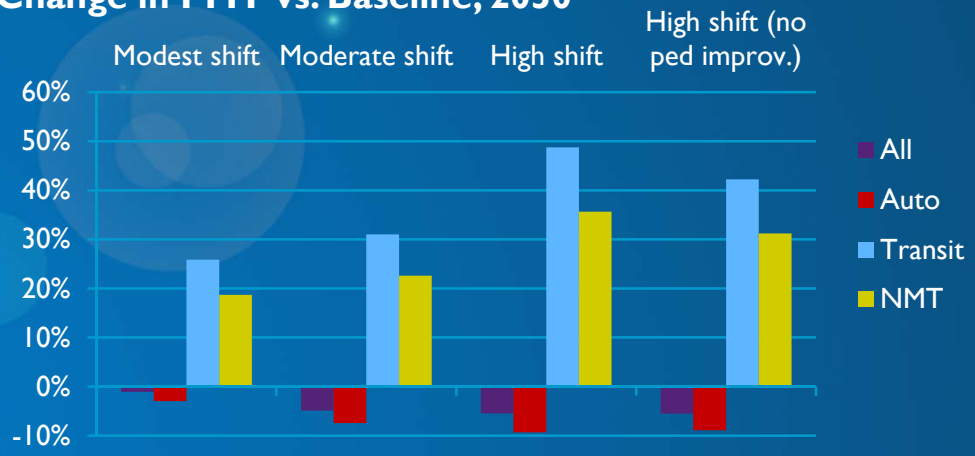
Change in VMT vs. Baseline



Change in GHG vs. Baseline



Change in PMT vs. Baseline, 2050



Conclusions

- Empirically estimated model based on disaggregate data
- Model allows for analysis of joint population/employment density scenarios as well as pedestrian environment factor
- Results were validated against VMT/capita, total energy use and GHG emissions from other sources
  - » Total and auto validation performed well, but transit overestimated
- Model also allows for tweaking of energy and GHG factors and provides full fuel-cycle outputs

Conclusions (continued)

- Shifting 10-15% of 2030 population from lower-density, single-use areas into higher-density, mixed-use areas could reduce VMT by 4-5% and GHG by around 3% vs. baseline
- Extrapolating trend to 2050 could reduce VMT by 7-9% and GHG by 5-6% vs. baseline
- Energy and GHG savings are less than VMT savings because of significant increase in transit use (30-50%)
- Impacts of land use change are of similar magnitude to those found in other recent studies (e.g., Moving Cooler, Growing Cooler, TRB Special Report 298)

Limitations and Potential Enhancements

- Land use variables still limited
  - » With NHTS-based model can only use NHTS appended variables and aggregate indicators for top 50 MSAs
- Mode choice model could be estimated including land use variables

EXTRAS

Sample Scenario Results

	2010	2030 Baseline	2030 Scenario	2050 Baseline	2050 Scenario
MSA Population and Workers (1,000s)					
Population	262,000	309,423		374,334	
Workers	169,514	182,341		218,688	
Vehicle-Miles of Travel					
Total Auto VMT (MM)	1,989,012	2,284,460	2,198,408	2,750,907	2,544,079
% Change vs. 2010		14.9%	10.5%	38.3%	27.9%
% Change vs. Baseline			**-3.8%**		**-7.5%**
Auto VMT per Capita	7,592	7,242	6,969	7,420	6,862

Sample Scenario Results (Continued)

	2010	2030 Baseline	2030 Scenario	2050 Baseline	2050 Scenario
PMT per Capita	12,566	12,026	11,578	12,322	11,405
% Change vs. 2010					
All Modes		15.2%	12.4%	38.9%	32.1%
Auto		15.2%	10.9%	38.8%	28.4%
Transit		15.1%	33.6%	40.8%	84.5%
Nonmotorized		16.7%	30.3%	42.4%	74.6%
% Change vs. Baseline					
All Modes			-2.4%		-4.9%
Auto			**-3.7%**		**-7.4%**
Transit			**16.1%**		**31.0%**
Nonmotorized			**11.7%**		**22.6%**

Sample Scenario Results (Continued)

	2010	2030 Baseline	2030 Scenario	2050 Baseline	2050 Scenario
Energy - quadrillion Btu					
Auto	15.22	13.12	12.62	15.25	14.10
Transit	0.72	0.71	0.82	0.85	1.12
Total	15.94	13.83	13.45	16.10	15.22
% Change vs. 2010		-13.2%	-15.6%	1.0%	-4.5%
% Change vs. Baseline			**-2.7%**		**-5.5%**
GHG - mmt CO2e					
Auto	1,162.6	993.5	956.1	1,153.6	1,066.9
Transit	56.8	55.1	64.0	66.0	86.5
Total	1,219.4	1,048.6	1,020.0	1,219.6	1,153.4
% Change vs. 2010		-14.0%	-16.4%	0.0%	-5.4%
% Change vs. Baseline			**-2.7%**		**-5.4%**