Energy and the Built Environment
CRP 470.004 /570.004

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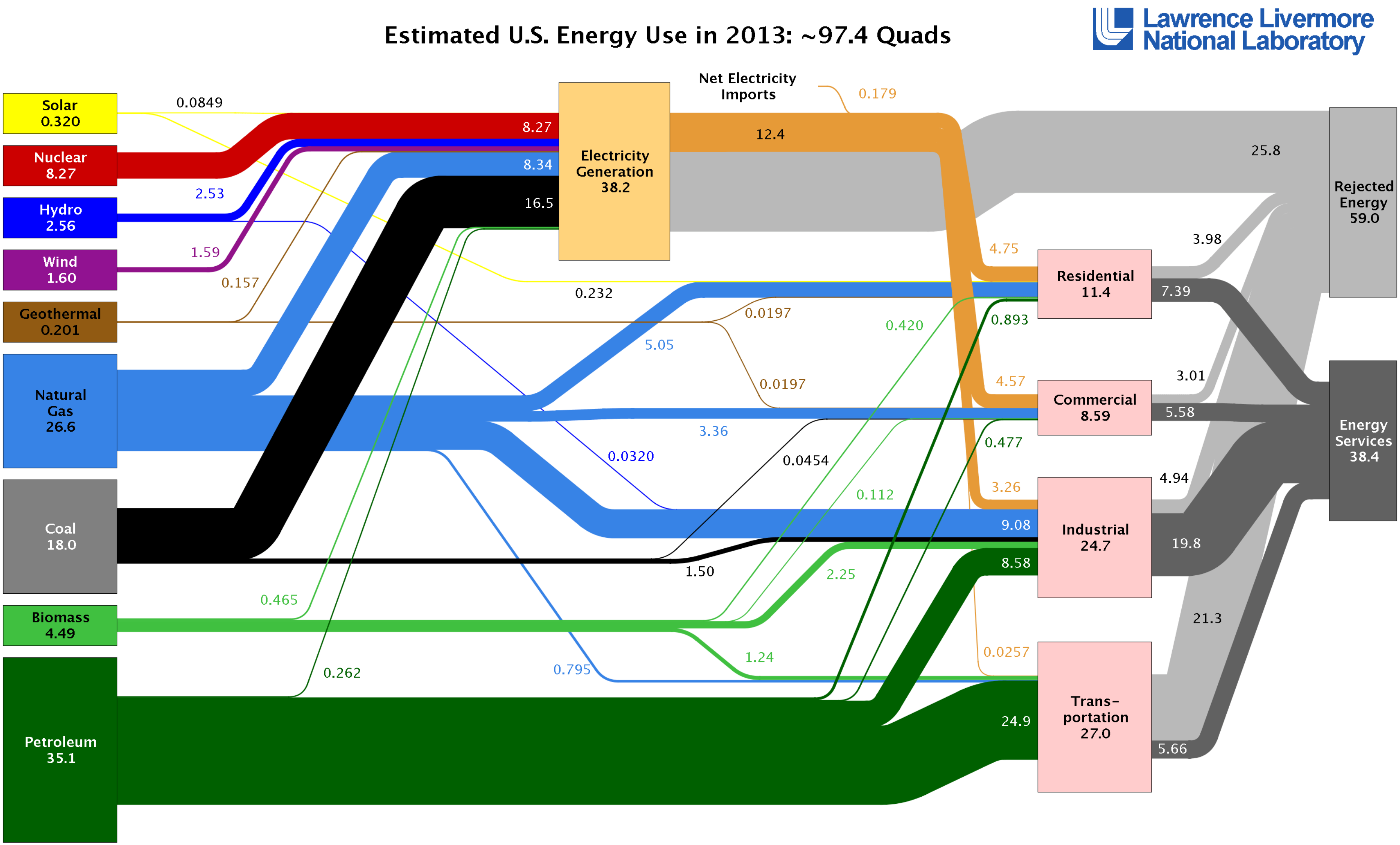
Lecture 9

Transportation

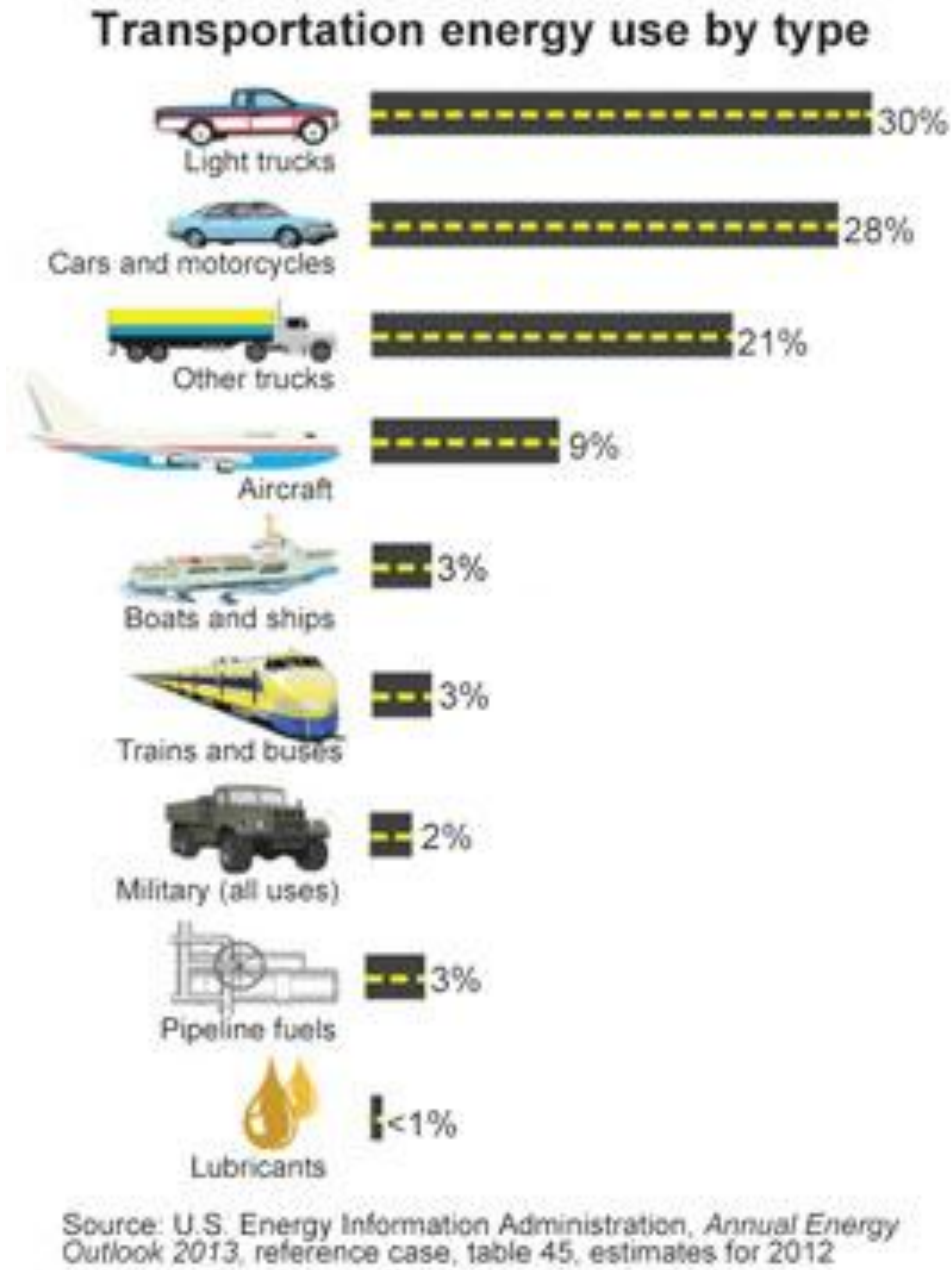
Introductory Activity

- Introduce 3 modifications (in the form of technology, policies, transformation of the built environment) that could reduce energy demand in the transportation sector in ABQ

Sankey Diagram of US energy use

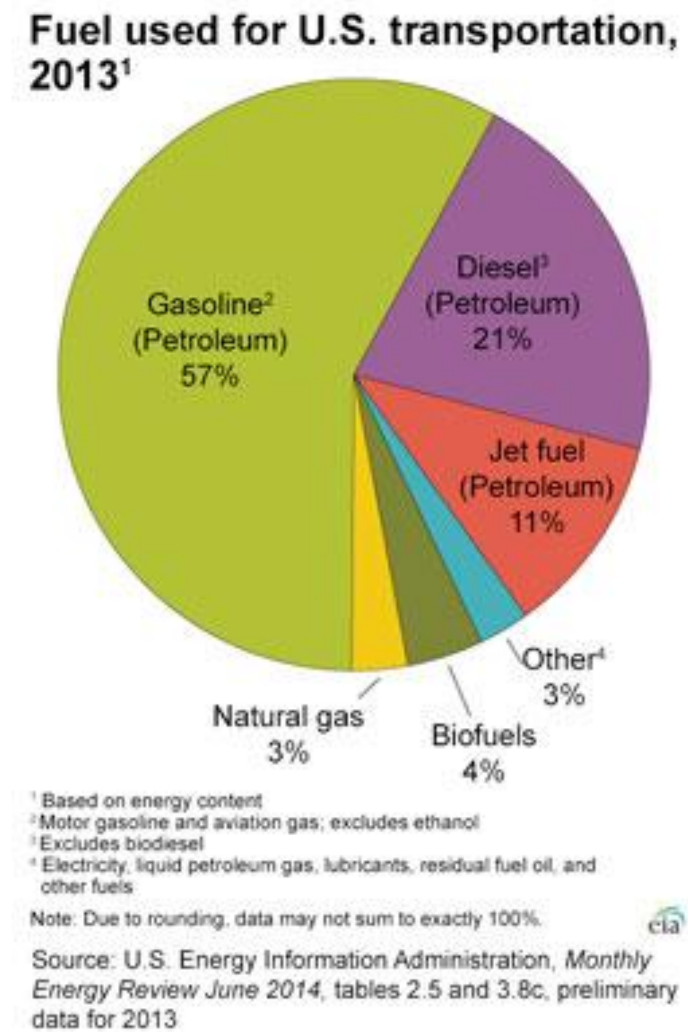


Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

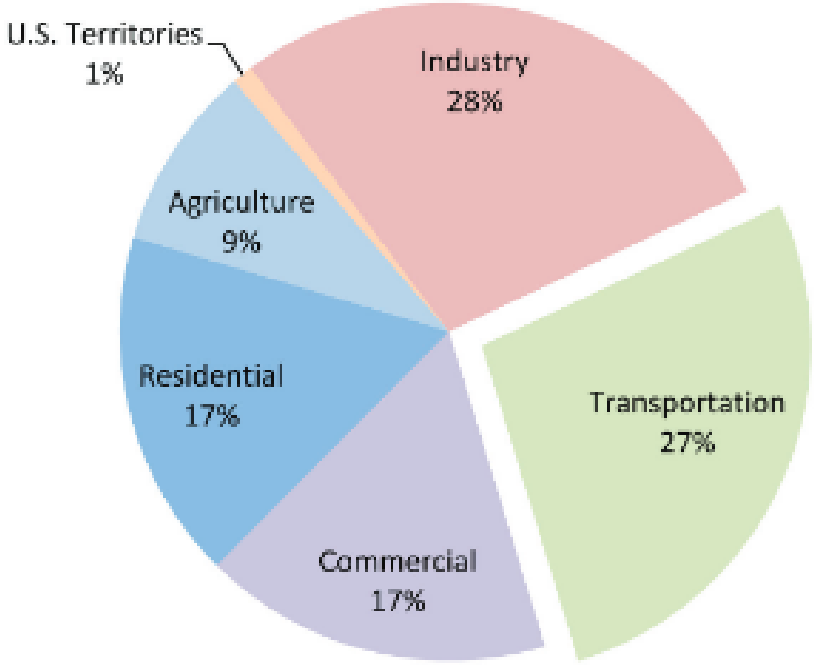


LDV – light duty vehicles

- U.S. transportation energy use accounts for 28% of total U.S. energy use.
- Cars and light trucks account for 59% of U.S. transportation energy use.

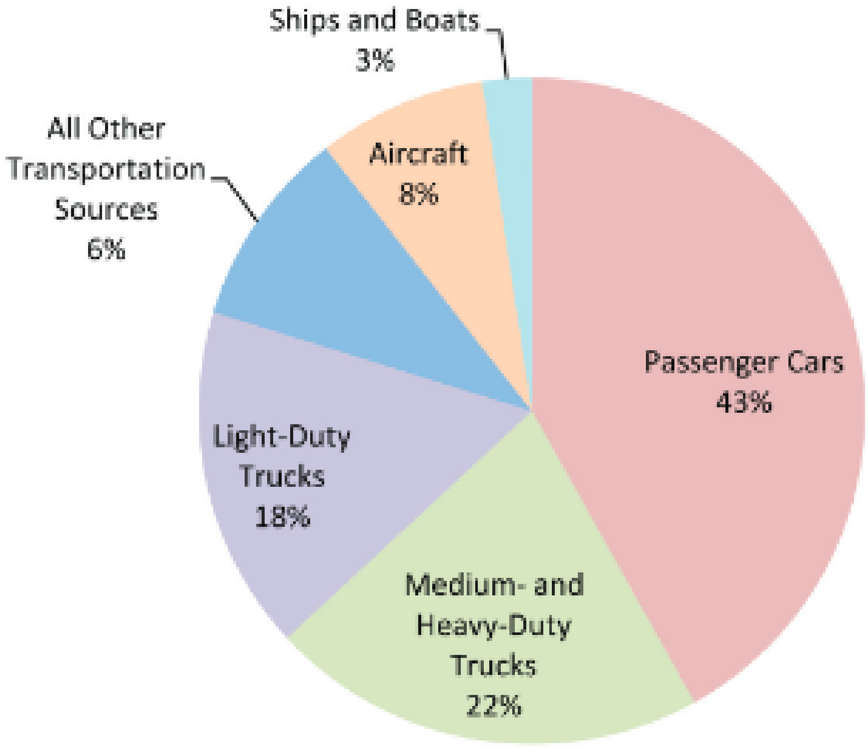


US Emissions (2011)



Share of U.S. GHG Emissions by End-Use Sector*

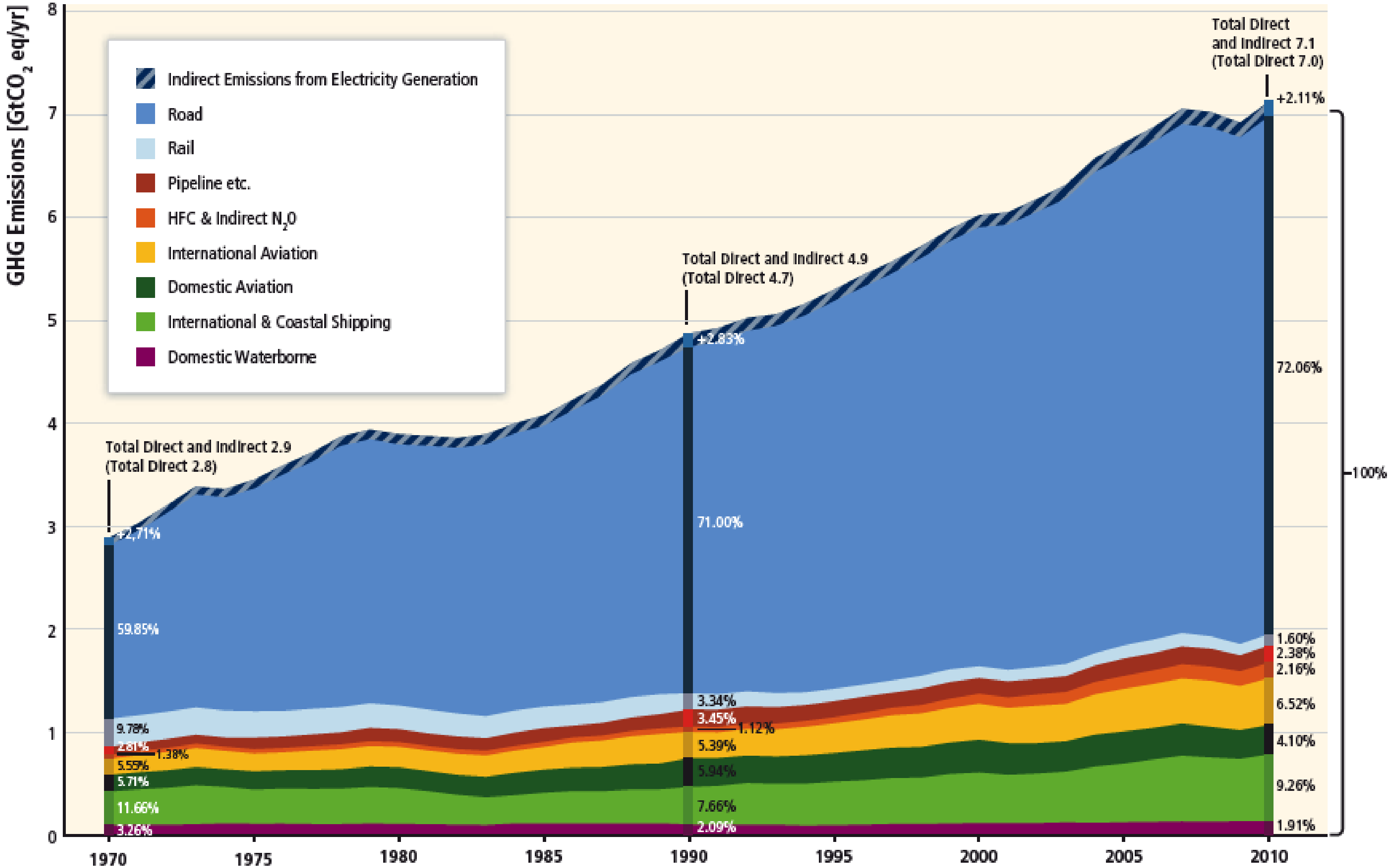
* Note: Totals may not add to 100% due to rounding.



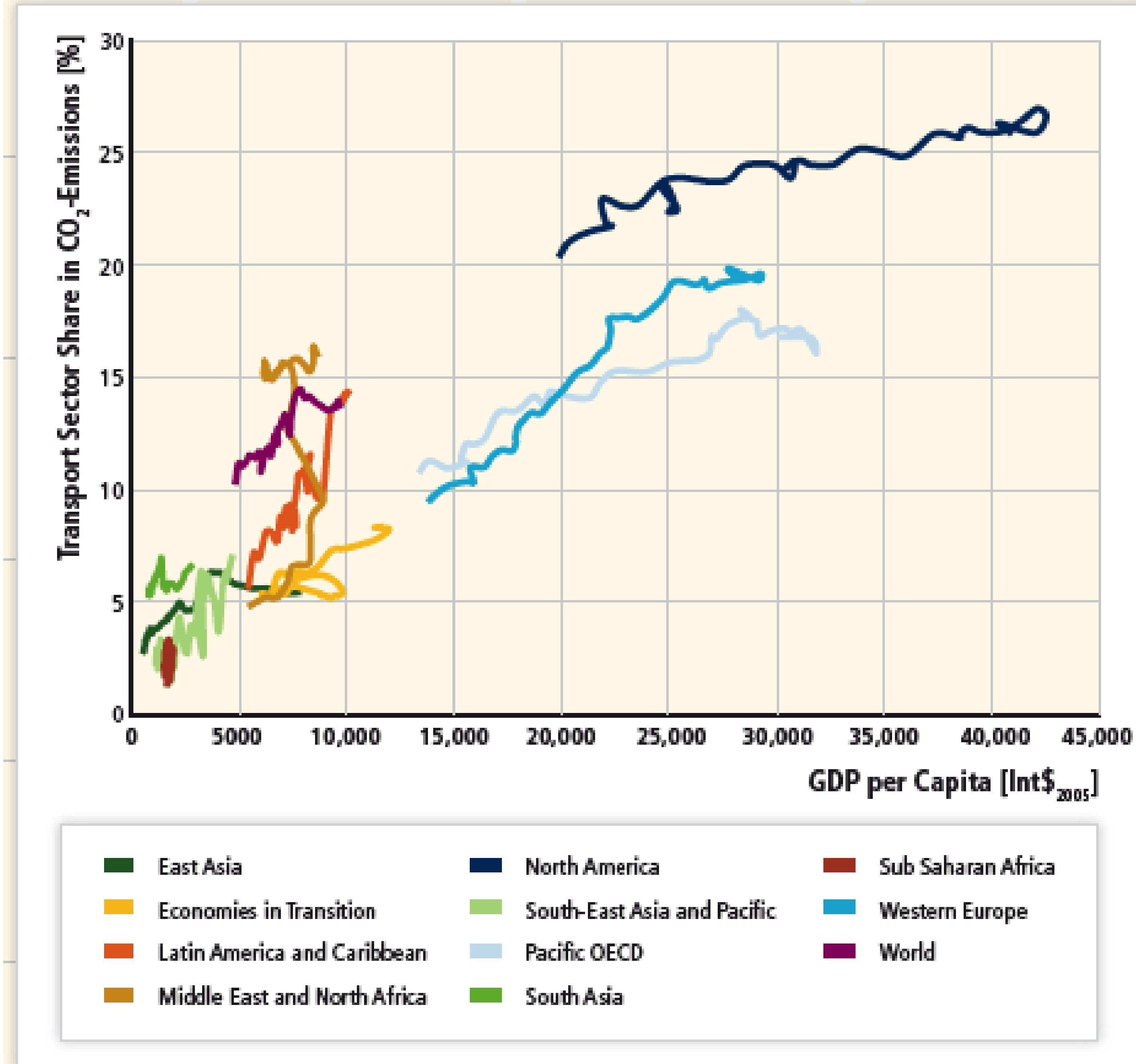
Share of U.S. Transportation End-Use Sector GHG Emissions by Source*

* Note: Totals may not add to 100% due to rounding.

Global transportation GHG emissions



Source: IPCC, AR5 – Transport, 2014



Transport Sector Share in CO_2-Emissions [%]
30
25
20
15
10
5
0
0
5000
10,000
15,000
20,000
25,000
30,000
35,000
40,000
45,000
GDP per Capita [Int$$_{2005}$]
East Asia
Economies in Transition
Latin America and Caribbean
Middle East and North Africa
North America
South-East Asia and Pacific
Pacific OECD
South Asia
Sub Saharan Africa
Western Europe
World

US Cars and light trucks

- There are 232,137 total light vehicles (cars and light trucks) in the US.
- The average age of a U.S. car is 11.4 years;
- Ave share of house expenditures on transport - 17.5%
- The average fuel economy for the U.S. car fleet is 24.5 mpg (18.4 for light trucks)
- Cars comprise 50% of new light vehicle sales.
- Ave person/vehicle 1.6 (car), 1.8 (trucks)
- U.S. car registrations account for 16% of total world car registrations.
- U.S. truck and bus registrations account for 38% of total world truck and bus registrations.
- The average U.S. household vehicle travels 11,300 miles per year (2009 NHTS).

Source: Transportation Energy Data Book, Edition 33, 2014

Useful measures

- VMT – vehicle miles travelled
- MPG – tells us vehicle efficiency
  - 1 MPG = 0.4 km/l
- BTU per passenger mile tells us efficiency in moving **people** (what we want!)
  - 1 kWh per p-km = 5459.68 BTU per p-mi
  - kWh per 100 p-km = 54.59 BTU per 100 p-mi

Emissions Example

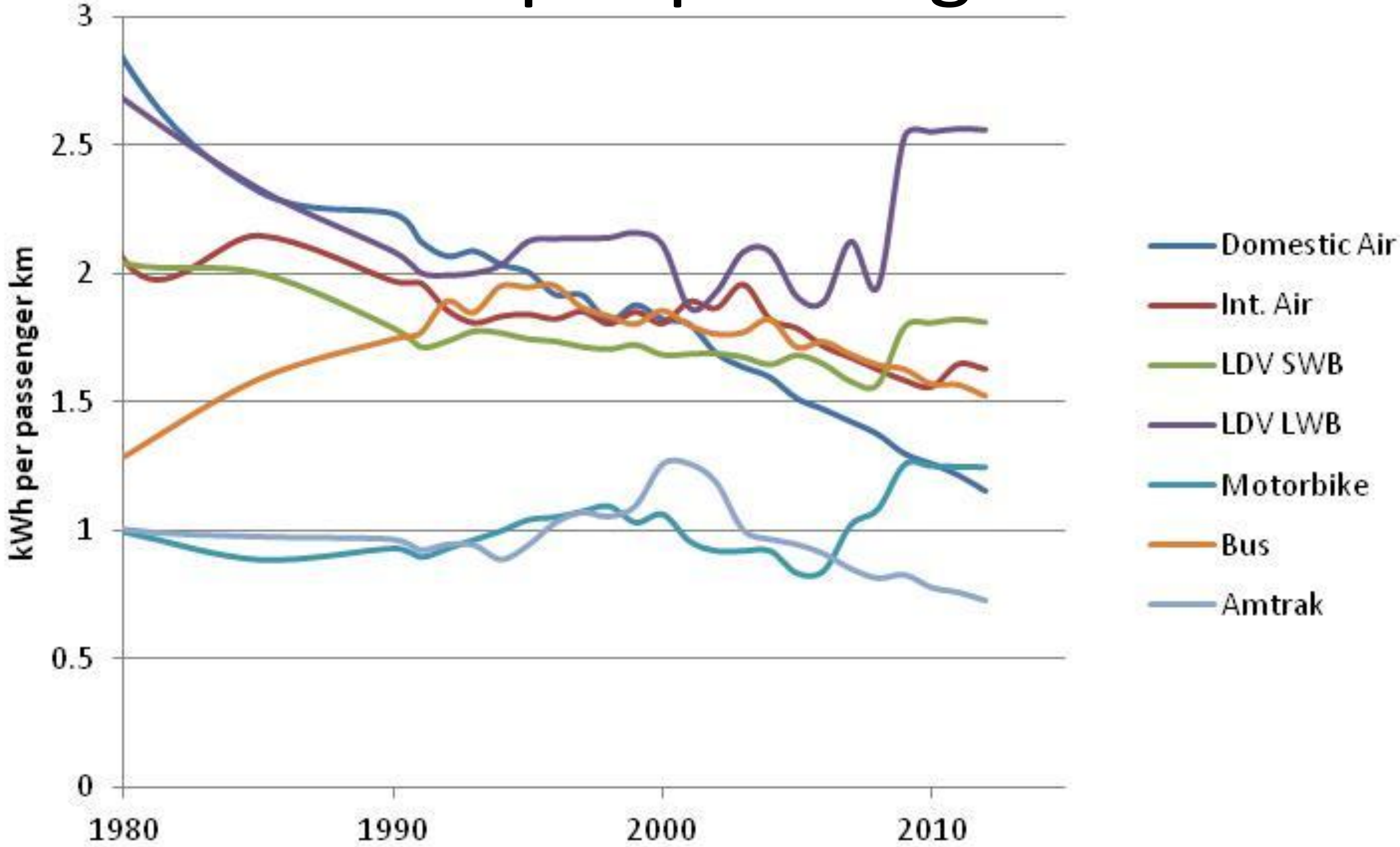
CO_2 Emissions from a gallon of gasoline:	8,887	grams CO^2/ gallon[1]
CO_2 Emissions from a gallon of diesel:	10,180	grams CO^2/ gallon[2]

What would be the annual emissions (tons CO2) for an American driver with a car that gets 21.6 mpg, with annual VMT of 11,400?

$$CO_2 \textit{ emissions per mile} = \frac{CO_2 \textit{ per gallon}}{MPG} = \frac{8{,}887}{21.6} = 411 \textbf{ grams}$$

$$\textit{Annual } CO_2 \textit{ emissions} = \frac{CO_2 \textit{ per gallon}}{MPG} \times \textit{miles} = \frac{8{,}887}{21.6} \times 11{,}400 = 4.7 \textbf{ metric tons}$$

US kWh per passenger km

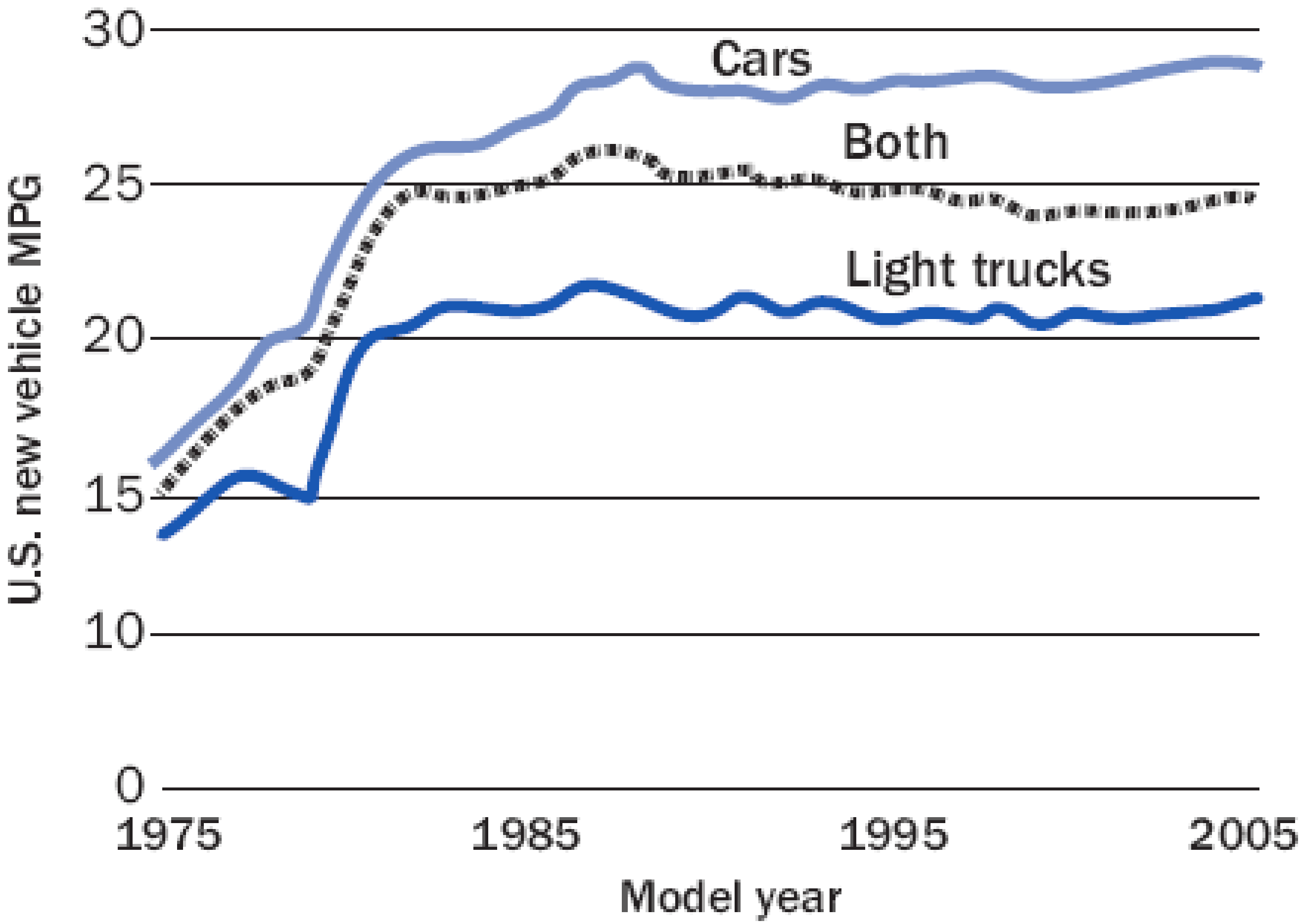


Source: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html

Figure 5

U.S. miles per gallon

Fuel economy of U.S. cars and light trucks, 1975-2005.

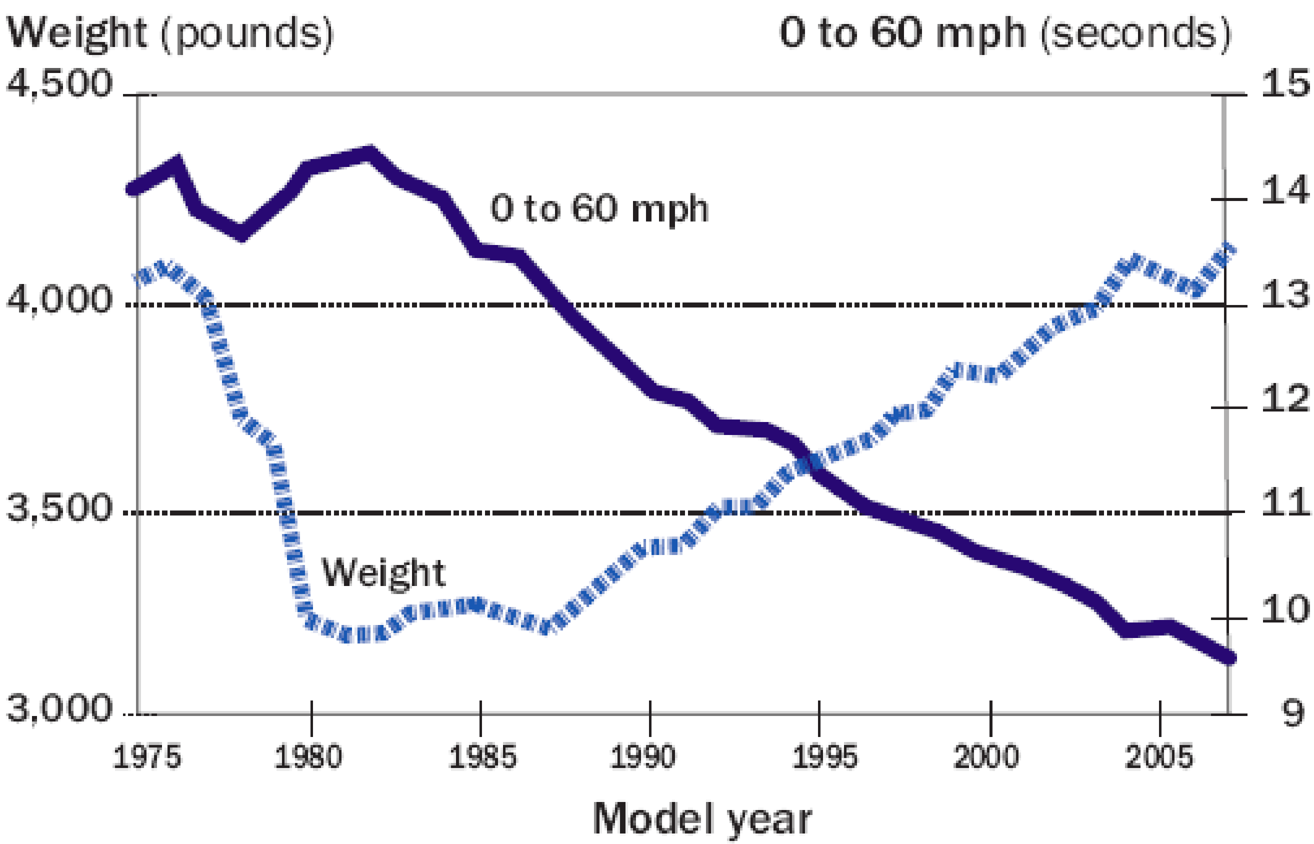


Sources: U.S. Environmental Protection Agency, National Highway Traffic Safety Administration

Figure 7

Vehicle weight and acceleration, 1975-2007

Vehicle weight initially decreased to help meet the new standards, but has increased ever since.

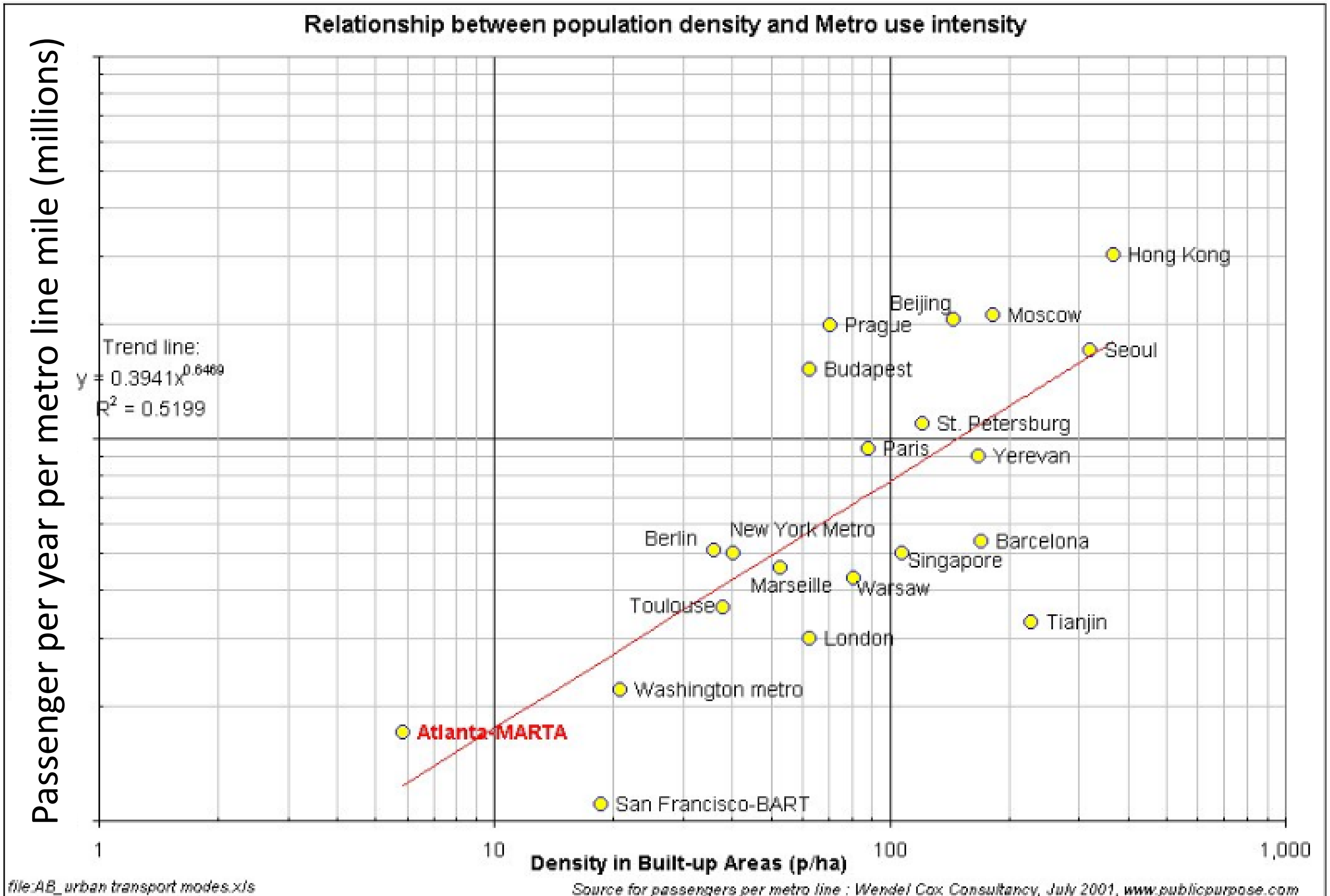


Source: Environmental Protection Agency, 2007

Figure 2.4. Energy Intensity of Commuter Rail Systems, 2012

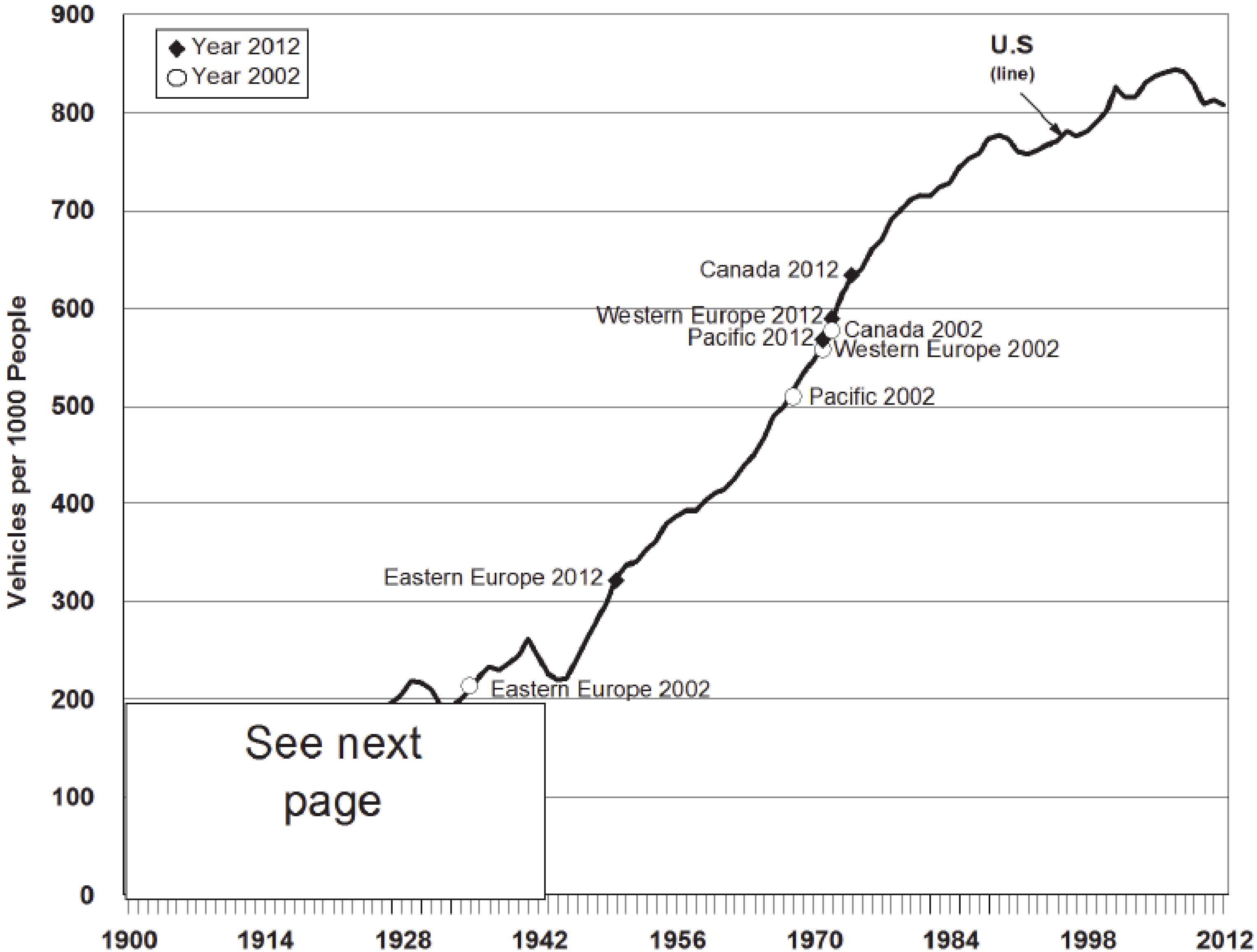
Source:
U.S. Department of Transportation, *National Transit Database*, May 2014. (Additional resources: www.ntdprogram.gov)

Urban densities vs public transport

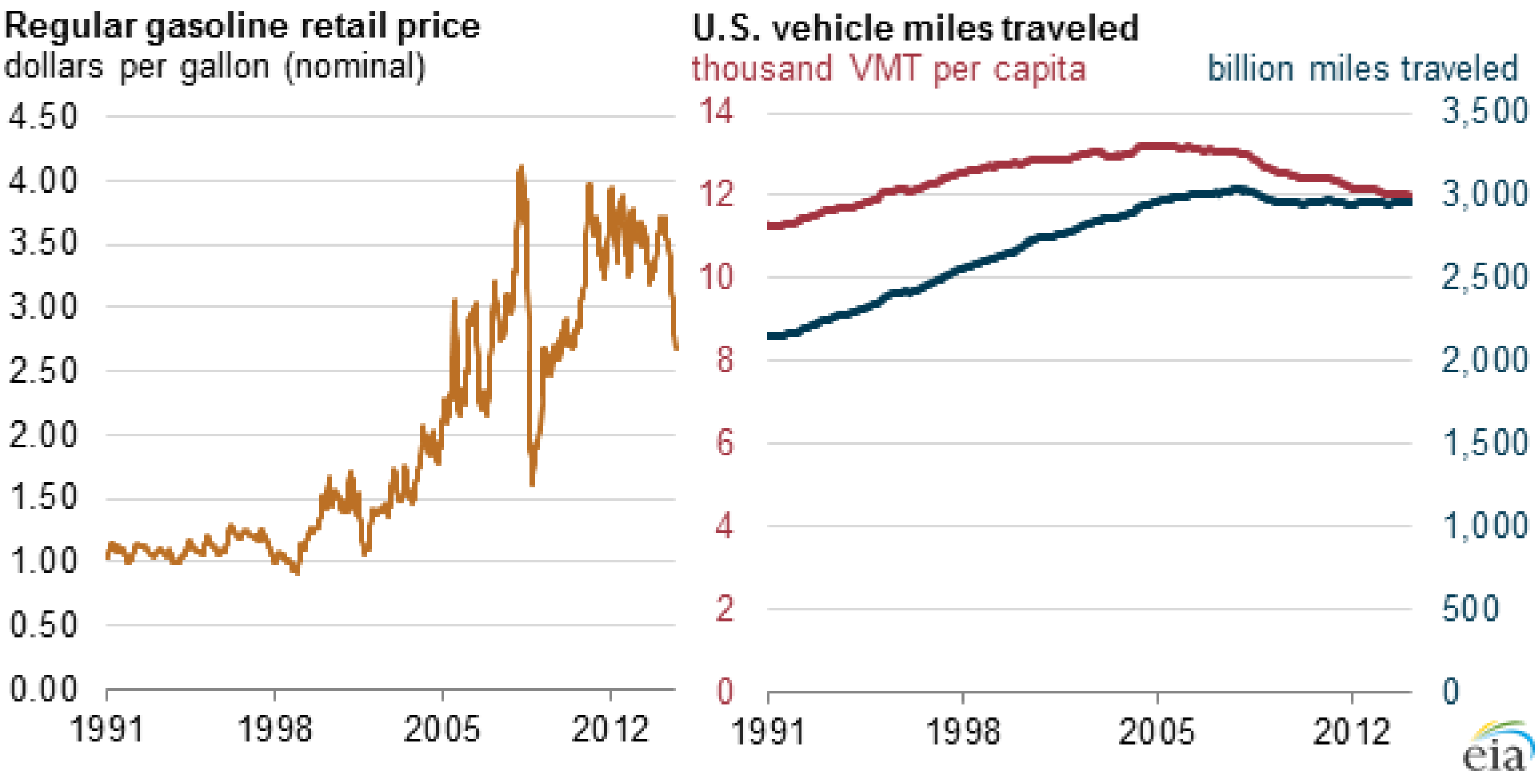


Source: Bertaud & Richardson

Figure 3.1. Vehicles per Thousand People: U.S. (Over Time) Compared to Other Countries (in 2002 and 2012)



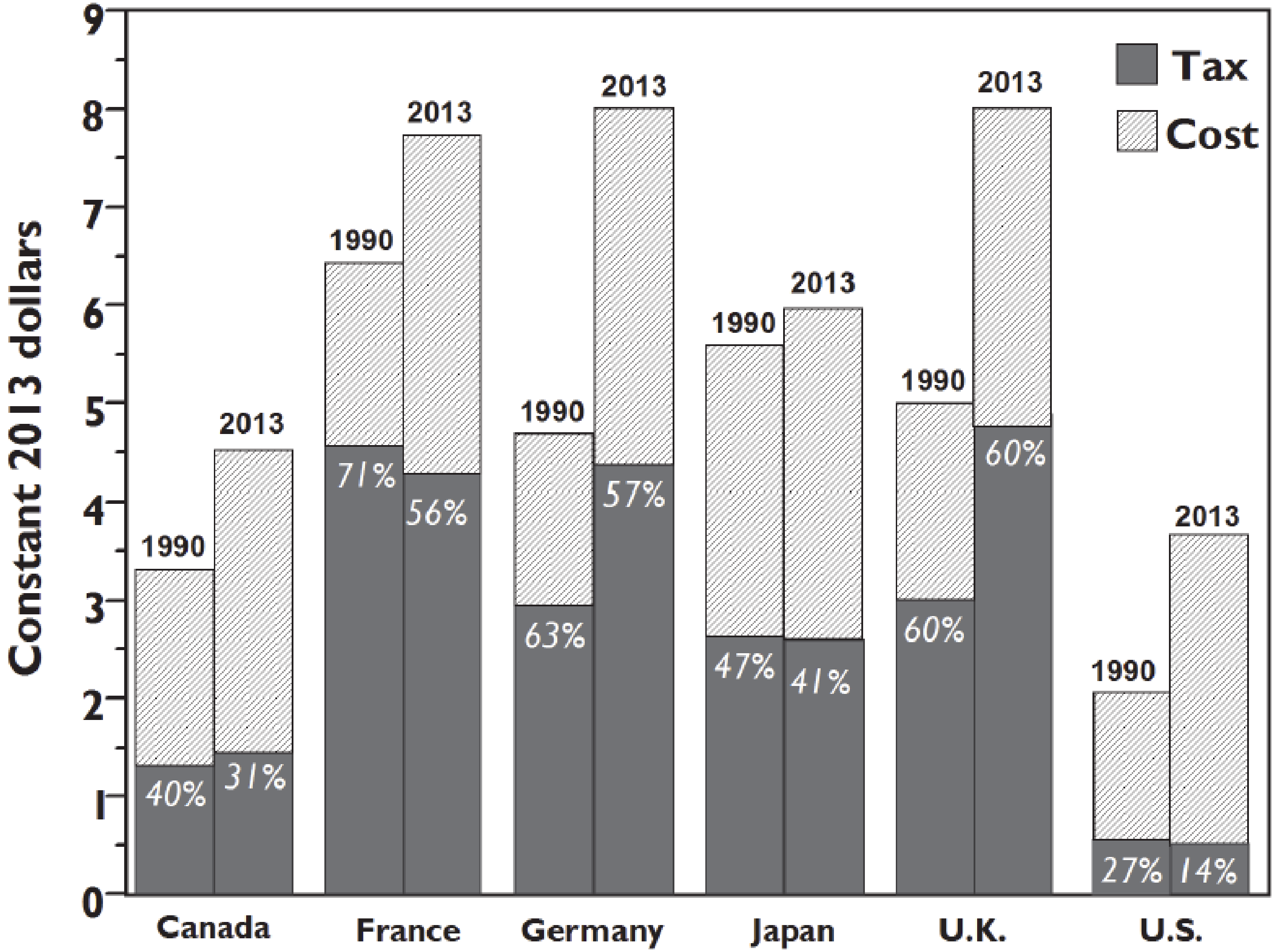
Gasoline prices tend to have little effect on demand for car travel



Source: U.S. Energy Information Administration, based on Federal Reserve Bank of St. Louis
Note: VMT is vehicle miles traveled. Per capita figures reflect U.S. population age 16 and over. Vehicle miles traveled figures are 12-month rolling averages.

US gasoline demand is fairly *inelastic* (demand doesn't change much in response to price). Meta-analysis study by Espey (1998) found short run (1 yr) elasticity of -.26, 10% price increase reduces demand by 2.6%.

Figure 10.2. Gasoline Prices for Selected Countries, 1990 and 2013



Source:
Table 10.1 and International Energy Agency, *Energy Prices & Taxes, Fourth Quarter, 2013,* Paris, France, 2014. (Additional resources: www.iea.org)

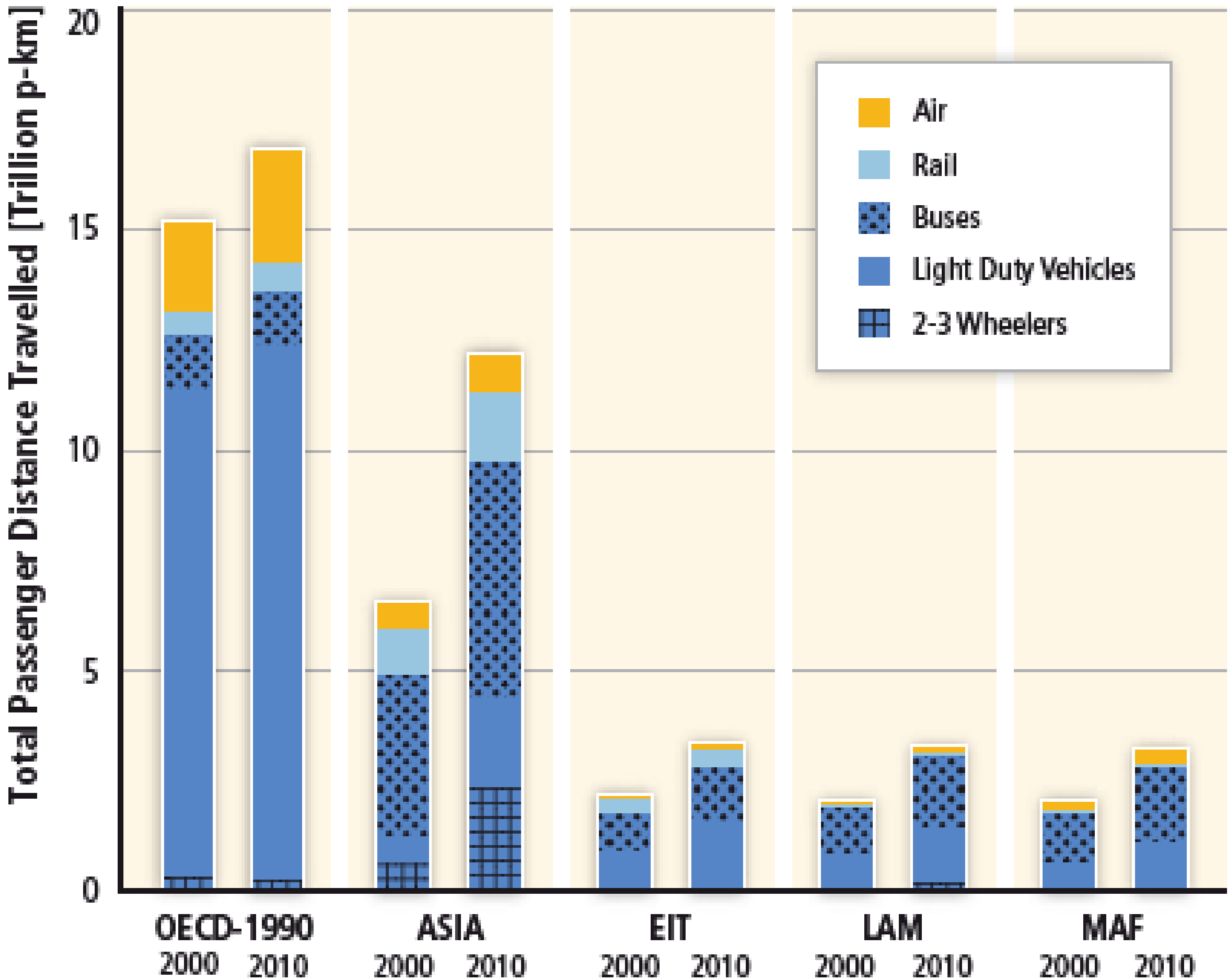
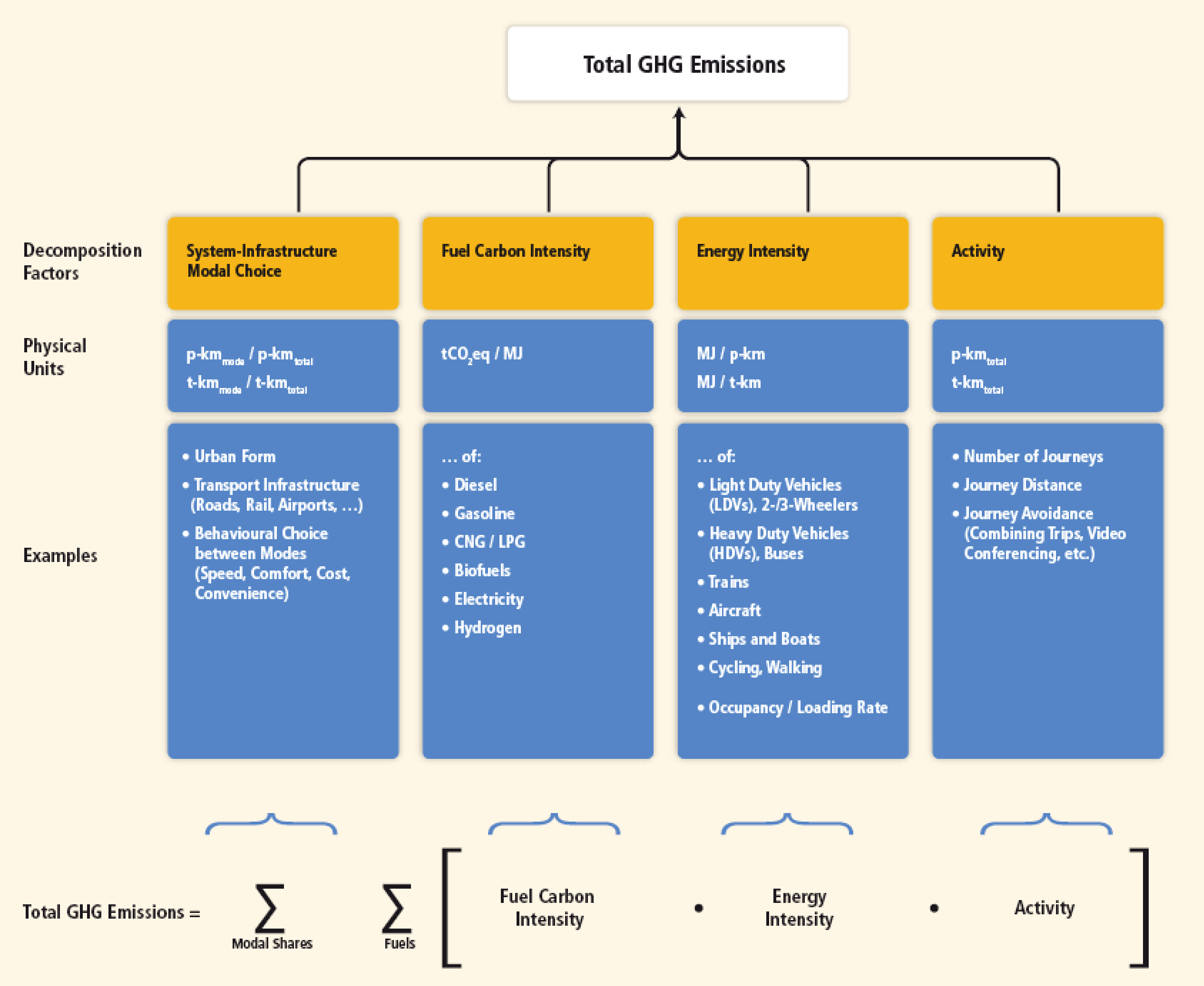


Figure 8.4 | Total passenger distance travelled by mode and region in 2000 and 2010 (IEA, 2012c)

Car Registrations for Selected Countries, 1960–2012
(thousands)

Country	1960	1970	1980	1990	2000	2005	2008	2010	2012	Average annual percentage change 1990-2012
Argentina	474	1,482	3,112	4,284	5,060	5,340	6,244	7,605	9,100	3.5%
Brazil	[a]	[a]	[a]	12,127	15,393	18,370	21,884	25,541	29,566	4.1%
Canada[b]	4,104	6,602	10,256	12,622	16,832	18,124	19,613	20,121	20,750	2.3%
China	[a]	[a]	351	1,897	3,750	8,900	18,270	34,430	52,165	16.3%
France	4,950	11,860	18,440	23,550	28,060	30,100	30,850	31,300	31,600	1.3%
Germany[c]	4,856	14,376	23,236	35,512	43,772	46,090	41,321	42,302	43,431	0.9%
India	[a]	[a]	[a]	2,300	5,150	7,654	9,400	13,300	18,796	10.0%
Indonesia	[a]	[a]	[a]	1,200	[a]	3,850	4,750	8,891	10,494	10.4%
Japan	457	8,779	23,660	34,924	52,437	57,091	57,865	58,347	58,421	2.4%
Malaysia	[a]	[a]	[a]	1,811	4,213	6,402	7,190	9,115	9,833	8.0%
Pakistan	[a]	[a]	[a]	738	375	411	445	1,726	1,997	4.6%
Russia	[a]	[a]	[a]	[a]	20,353	25,285	32,021	34,350	38,482	5.5%[d]
South Korea	[a]	[a]	[a]	2,075	8,084	11,122	12,484	13,632	14,577	9.9%
United Kingdom	5,650	11,802	15,438	22,528	27,185	30,652	31,252	31,258	31,482	1.5%
United States	61,671	89,244	121,601	143,550	127,721	132,909	135,882	129,053	120,902	-0.8%
U.S. percentage of world	62.7%	46.1%	38.0%	32.3%	23.3%	21.5%	20.4%	17.8%	15.6%	
World total	98,305	193,479	320,390	444,900	548,558	617,914	667,630	723,567	773,323	2.5%

Source:
Ward's Communications, *Ward's World Motor Vehicle Data, 2013 Edition*, Southfield, MI, 2013, pp. 308–311 and annual. (Additional resources: www.wardsauto.com)



Source: IPCC, AR5 – Transport, 2014

Modes to decrease fuel consumption

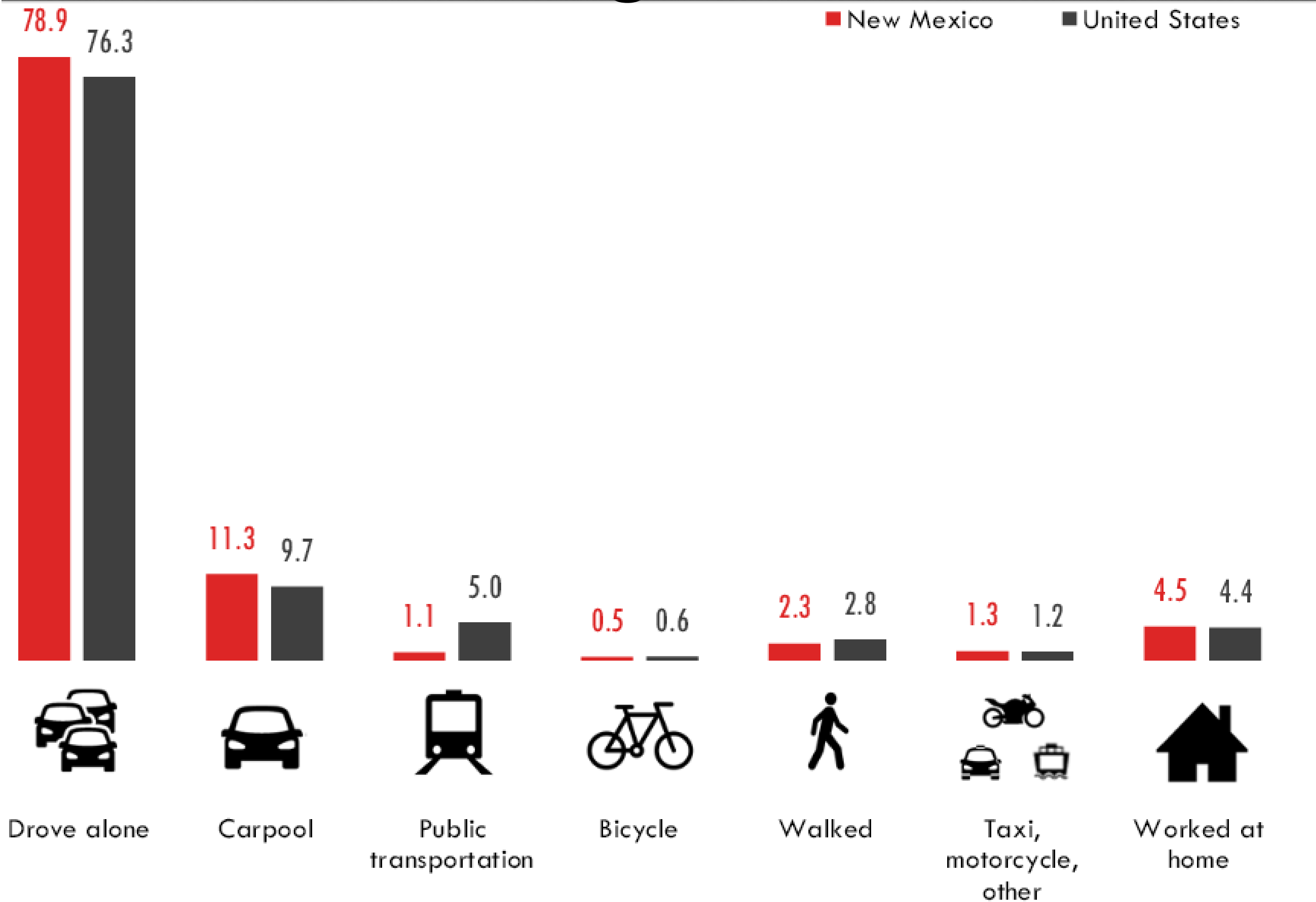
Type	Examples
Fuel Switching	•Using electric or hybrid automobiles, provided that the energy is generated from lower-carbon or non-fossil fuels. •Using renewable fuels such as low-carbon biofuels.
Improving Fuel Efficiency with Advanced Design, Materials, and Technologies	•Developing advanced vehicle technologies such as hybrid vehicles and electric vehicles •Reducing the weight of materials used to build vehicles. •Reducing the aerodynamic resistance of vehicles through better shape design.
Improving Operating Practices	•Reducing the average taxi time for aircraft. •Driving sensibly (avoiding rapid acceleration and braking, observing the speed limit). •Reducing engine-idling. •Improved voyage planning for ships, such as through improved weather routing, to increase fuel efficiency.
Reducing Travel Demand	•Building public transportation, sidewalks, and bike paths to increase lower-emission transportation choices. •Zoning for mixed use areas, so that residences, schools, stores, and businesses are close together, reducing the need for driving.

http://www.epa.gov/climatechange/ghgemissions/sources/transportation.html

Important principles

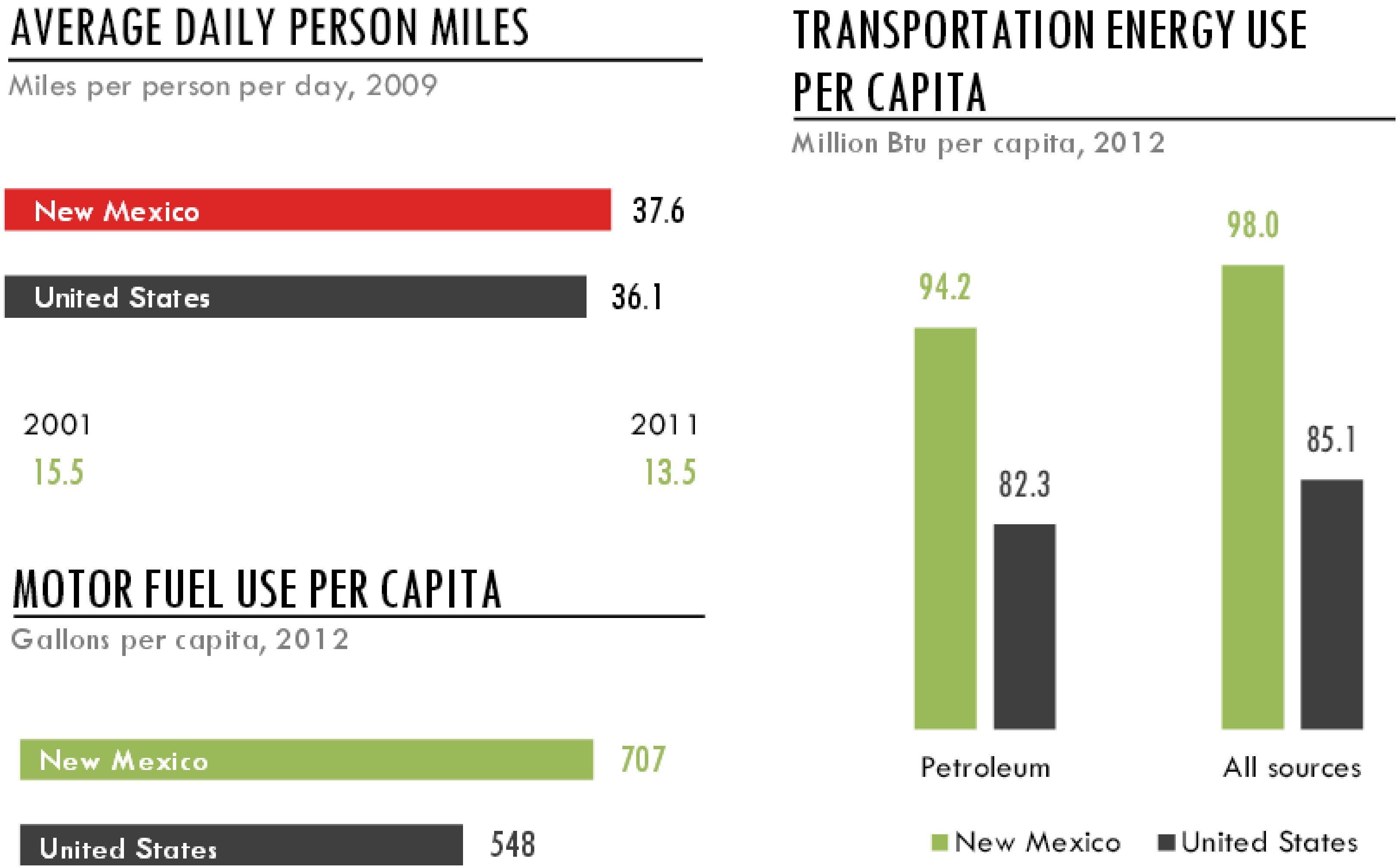
- In short distance travel
  - Lighter vehicles, less stops, move slower
- In long distance travel
  - Good aerodynamics, move slower
- Improve energy conversion efficiencies

How residents got to work, 2012



Source: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/new_mexico.pdf

NM transport statistics



Source: http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/new_mexico.pdf

Efficient Transport

Bicycles

A 64 kg (140 lb) cyclist riding at 16 km/h (10 mph) requires about half the energy per unit distance of walking: 43 kcal/mi, 27 kcal/km or 0.03 kWh/km

Walking

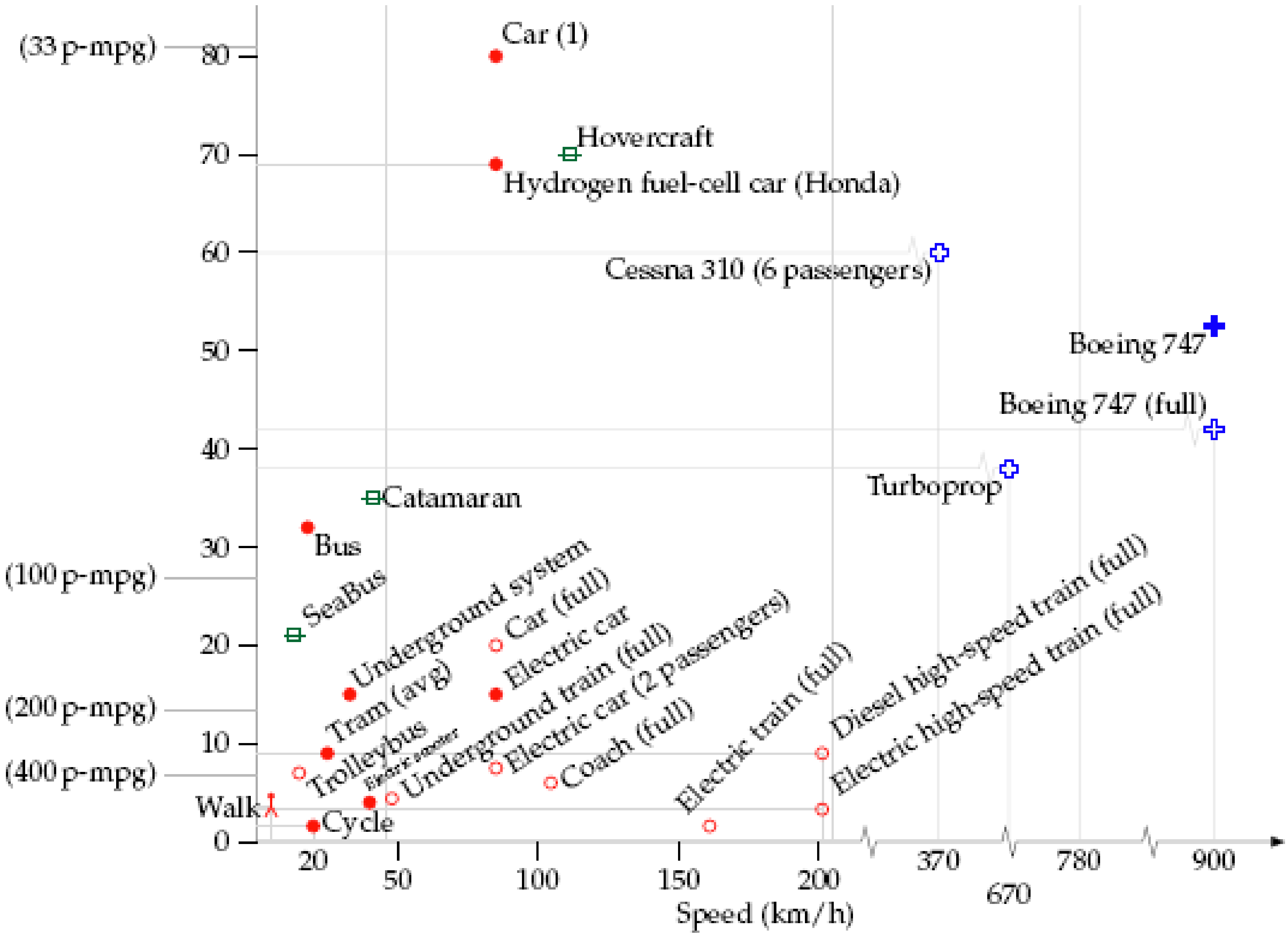
A 68 kg (150 lb) person walking at 4 km/h (2.5 mph) requires approximately 210 kilocalories (880 kJ) of food energy per hour, which is equivalent to 0.06 kWh/km

http://en.wikipedia.org/wiki/Energy_efficiency_in_transportation

Walkscore

City	Zip Code	Walk Score	Transit Score	Bike Score	Population
Albuquerque *(the largest city in New Mexico)*	87120	40	30	61	545,852
Hobbs		40	--	--	34,122
Santa Fe		36	--	--	67,947
Clovis		34	--	--	37,775
Las Cruces		32	--	--	97,618
Roswell		31	--		
Carlsbad		31	--		
Farmington		29	--		
Gallup		26	--		
Alamogordo		23	--		
South Valley		22	--		
Rio Rancho		13	--		

	Description
90–100	**Walker's Paradise** Daily errands do not require a car.
70–89	**Very Walkable** Most errands can be accomplished on foot.
50–69	**Somewhat Walkable** Some errands can be accomplished on foot.
25–49	**Car-Dependent** Most errands require a car.
0–24	**Car-Dependent** Almost all errands require a car.



Source: Sustainable Energy without the hot air, p 128

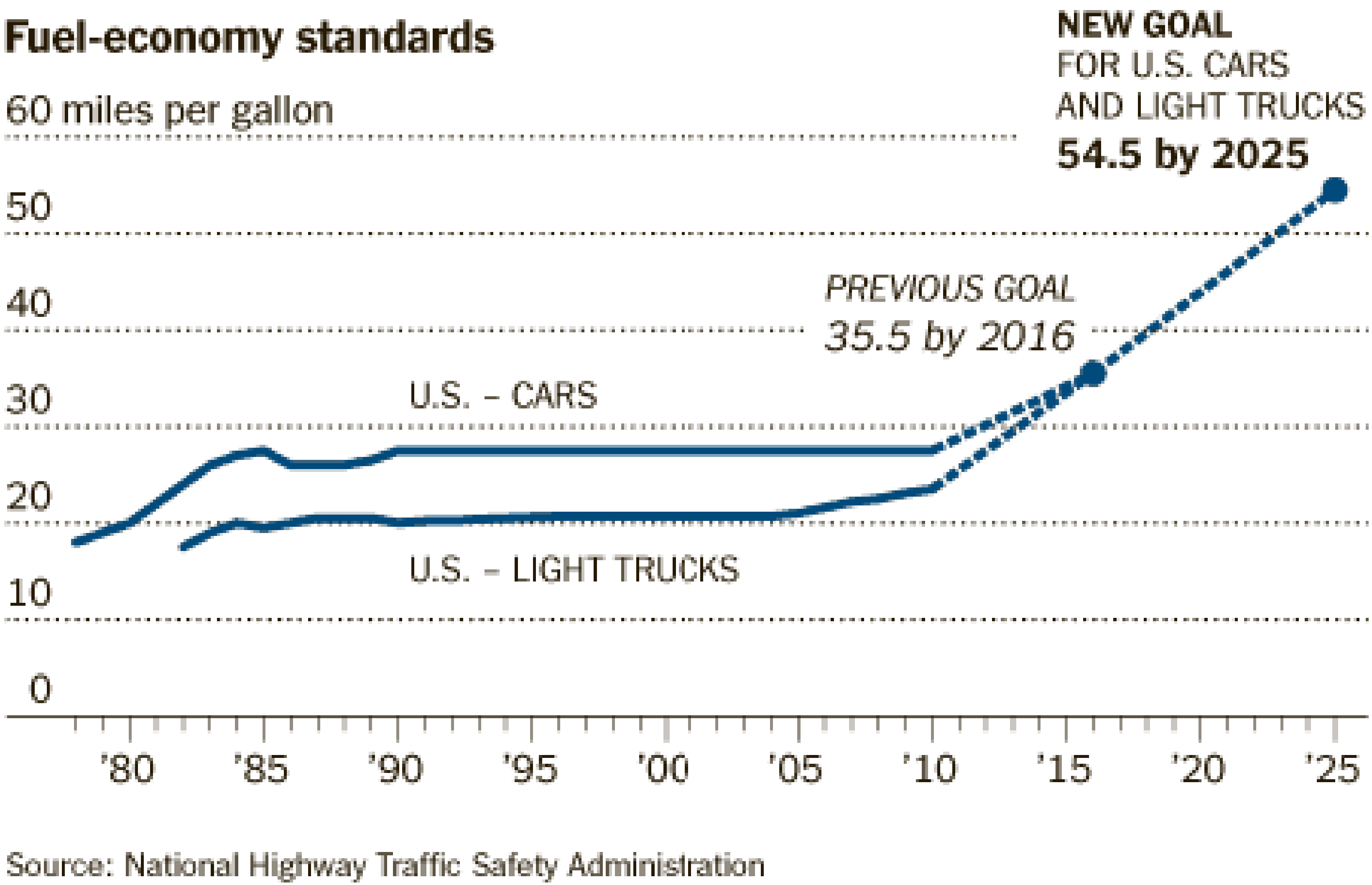
From IEA Report, 2010

- Eco-driving is the operation of a vehicle in a manner that minimises fuel consumption and emissions. It includes:
  - Optimising gear changing.
  - Avoiding vehicle idling, *e.g. by turning the engine off when the vehicle is stationary.*
  - Avoiding rapid acceleration and deceleration.
  - Driving at efficient speeds. The most efficient speed for most cars is between 60 km/h and 90 km/h. Above 120 km/h, fuel efficiency falls significantly in most vehicles.
  - Reducing weight by removing unnecessary items from the car, and reducing wind resistance by removing roof attachments such as ski racks.
- Used together, these steps could save up to 20% of the fuel used by some drivers and possibly 5% to 10% on average across all drivers on a lasting basis.

Levers to encourage purchase of efficient cars

- Gasoline tax
  - “market-based interventions, such as moderate carbon and gasoline taxes, are unlikely to produce substantial consumer substitution toward fuel efficient vehicles” (Langer & Miller, 2012)
- Purchase tax in proportion to lifetime gasoline consumption of vehicle
- Parking privileges for efficient cars
- Fuel rationing
- CAFE standards

Corporate Ave Fuel Efficiency (CAFE)



Electric vehicles

	2014 Chevrolet Spark EV	2014 Honda Fit EV	2014 Nissan Leaf	2014 Fiat 500e
Personalize Edit Vehicles	Electric Vehicle  Automatic (A1) MSRP: $26,685 - $27,010	Electric Vehicle  Automatic (A1) MSRP: $36,625	Electric Vehicle  Automatic (A1) MSRP: $28,980 - $35,020	Electric Vehicle  Automatic (A1) MSRP: $31,800
EPA Fuel Economy 1 gallon of gasoline=33.7 kWh	**Electricity** **119** MPGe combined city/highway 128 city, 109 highway 28 kWh/100 mi Electricity 82 miles Total Range	**Electricity** **118** MPGe combined city/highway 132 city, 105 highway 29 kWh/100 mi Electricity 82 miles Total Range	**Electricity** **114** MPGe combined city/highway 126 city, 101 highway 30 kWh/100 mi Electricity 84 miles Total Range	**Electricity** **116** MPGe combined city/highway 122 city, 108 highway 29 kWh/100 mi Electricity 87 miles Total Range
Unofficial MPG Estimates from Vehicle Owners Learn more about "My MPG" Disclaimer	User MPG estimates are not yet available for this vehicle	User MPG estimates are not yet available for this vehicle	Average based on 2 vehicles **155.6** MPG 150 Lo → 162 Hi View Individual Estimates	User MPG estimates are not yet available for this vehicle
You save or spend* Note: The average 2015 vehicle gets 24 MPG	**You SAVE** **$5,250** in fuel costs over 5 years compared to the average new vehicle	**You SAVE** **$5,250** in fuel costs over 5 years compared to the average new vehicle	**You SAVE** **$5,000** in fuel costs over 5 years compared to the average new vehicle	**You SAVE** **$5,250** in fuel costs over 5 years compared to the average new vehicle
Annual Fuel Cost*	$500	$500	$550	$500
Cost to Drive 25 Miles	$0.84	$0.87	$0.90	$0.87

Comparing new Nissan Leaf (all electric) to new Honda Civic

- Assume you drive 11,400 miles/year, you drive each car for 12 years, you access a loan at 7% interest, and the average price of gasoline over this time period is 3.50 $/gallon (anyone's guess!!).
- A 2014 Honda Civic has an MSRP of $19,000 and gets a combined (cty/hwy) mileage of 33 mpg.
- A 2014 Nissan Leaf has an MSRP of $29,000, a range of 73 mi per charge, and an efficiency of 29 kWh/100 mi. Assume electricity costs 0.12 $/kWh.
- Find the annualized capital cost, fuel costs, total annual costs, and annual emissions (assume you are getting your electricity from PNM, 0.66 kg CO_2/kWh).

Honda Civic vs Leaf

- Annualized capital cost: 2392 $/yr
- Gas: 1198 $/yr
- Total annual cost: 3591 $/yr
- Emissions: 3,043 kg CO_2/yr

- Annualized capital cost: 3651 $/yr
- Electricity: 393 $/yr
- Total annual cost: 4044 $/yr
- Emissions:2,162 kg CO_2/yr