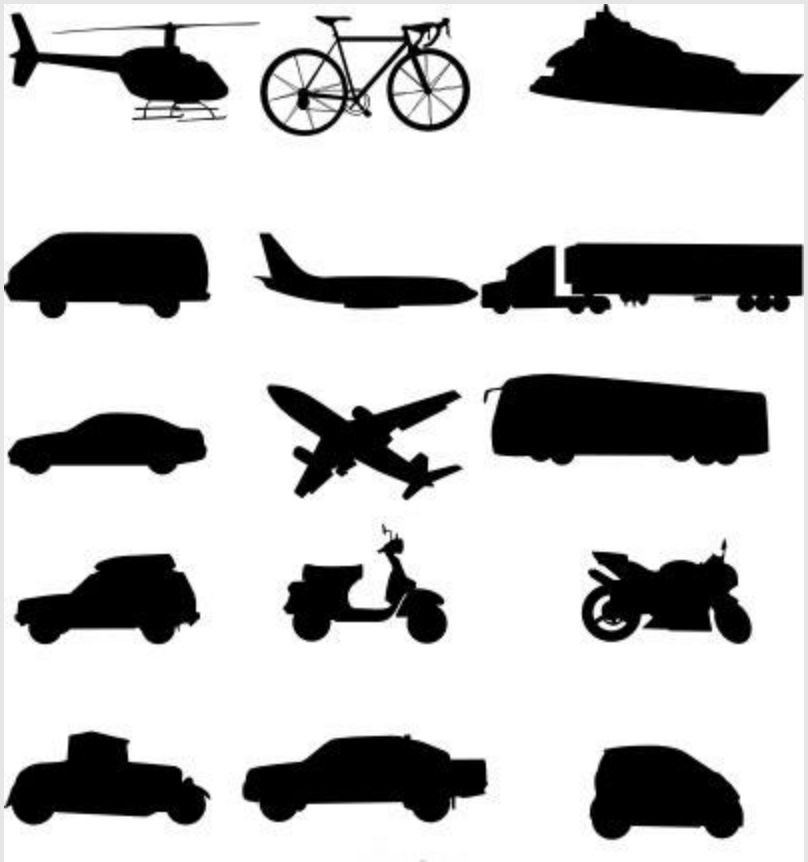
Last Time…

Mitigation Strategies: Transportation

Mitigation = Diminishing the severity of the problem



Transportation

14.4% of global emissions currently come from transportation

- 28.2% in high income countries (USA)
- 7% in low-middle income countries (China)

Expected to increase by 25% from 2010-2030, mostly from passenger cars/trucks

Fuel Efficiency of light-duty vehicles

Hard to get people to drive less

Easier to get people to drive more efficiently

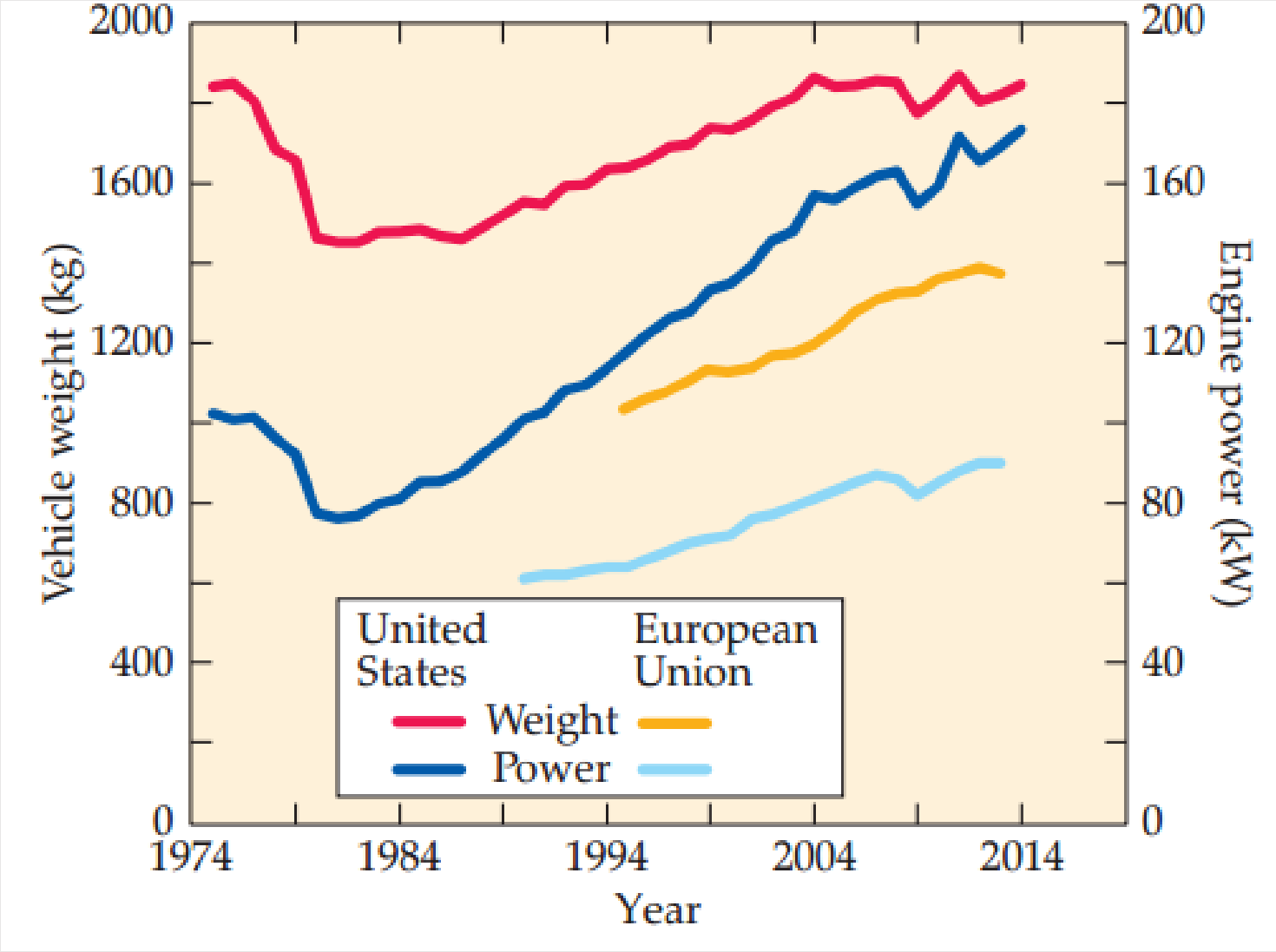
Fuel efficiency is influenced by:

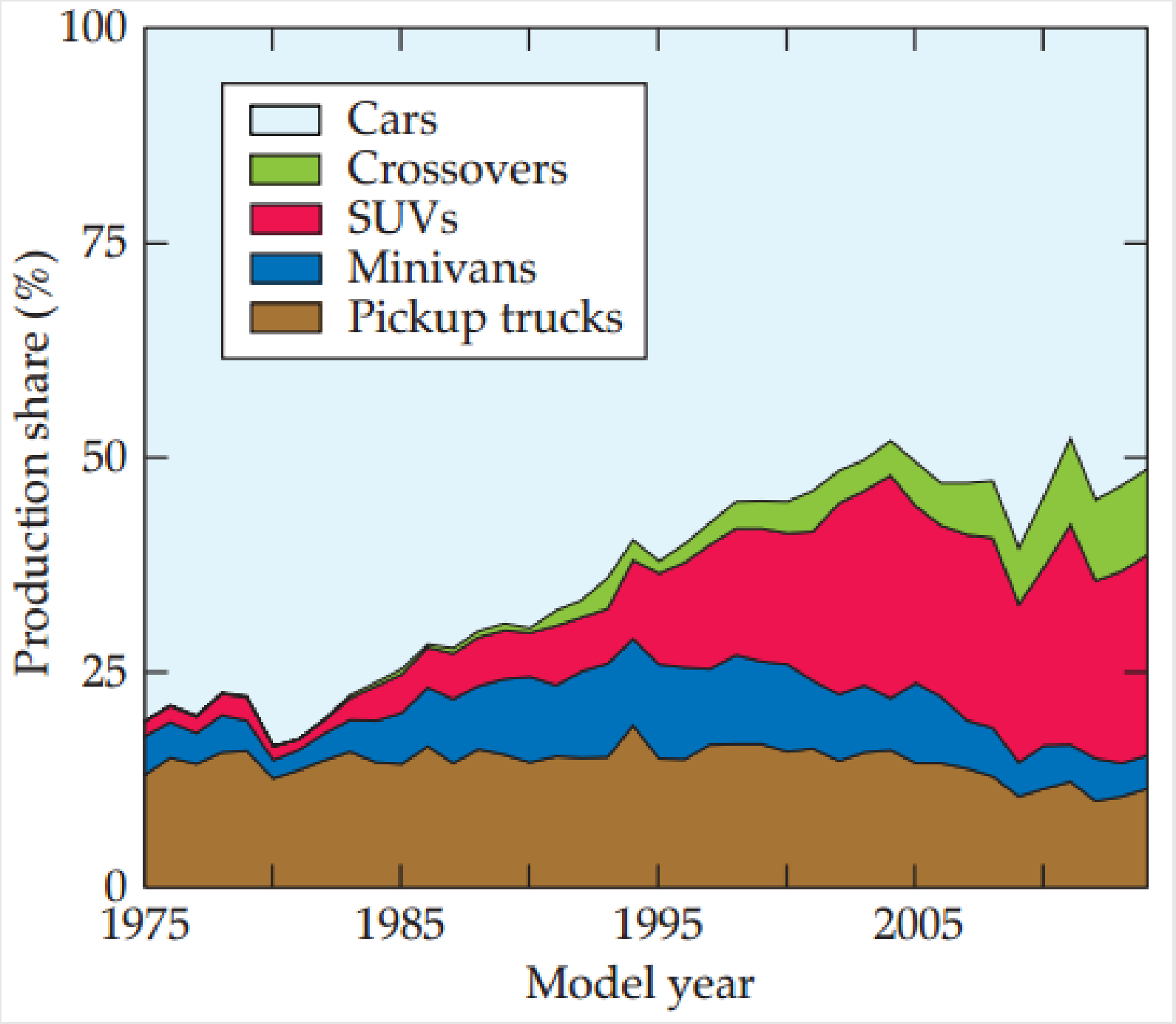
- Driving conditions
- Taxes on petroleum and vehicles
- Consumer preferences
- Use of diesel-powered vehicles
- Agreements with automobile manufacturers

Consumer Preferences

- Large vehicles
- Fast acceleration
- Powerful engines

Since the mid 1980s, vehicles in the US and Europe have gained weight, more powerful engines, and faster acceleration




100
75
50
25
0
Production share (%)
Cars
Crossovers
SUVs
Minivans
Pickup trucks
1975
1985
1995
2005
Model year

2014 in the US:

- Sales of pickup trucks, vans, SUVs, and crossovers grew five times faster than cars during 2014, increasing to a production share equal to cars
- Sales of gas-electric hybrid vehicles declined 9%

Fuel efficiency is influenced by:

- Driving conditions
- Taxes on petroleum and vehicles
- Consumer preferences
- Use of diesel-powered vehicles
- Agreements with automobile manufacturers

Diesel-Powered Vehicles

- Diesel fuel is denser than gasoline
- Contains 11% more energy per volume
- Diesel engines more efficient than gasoline engines
  - Operate at higher pressures and temperatures
- Diesel engines are 40% more fuel efficient per volume of fuel than gasoline engines of the same power.


RAM 2500


53yd³

Diesel personal vehicles

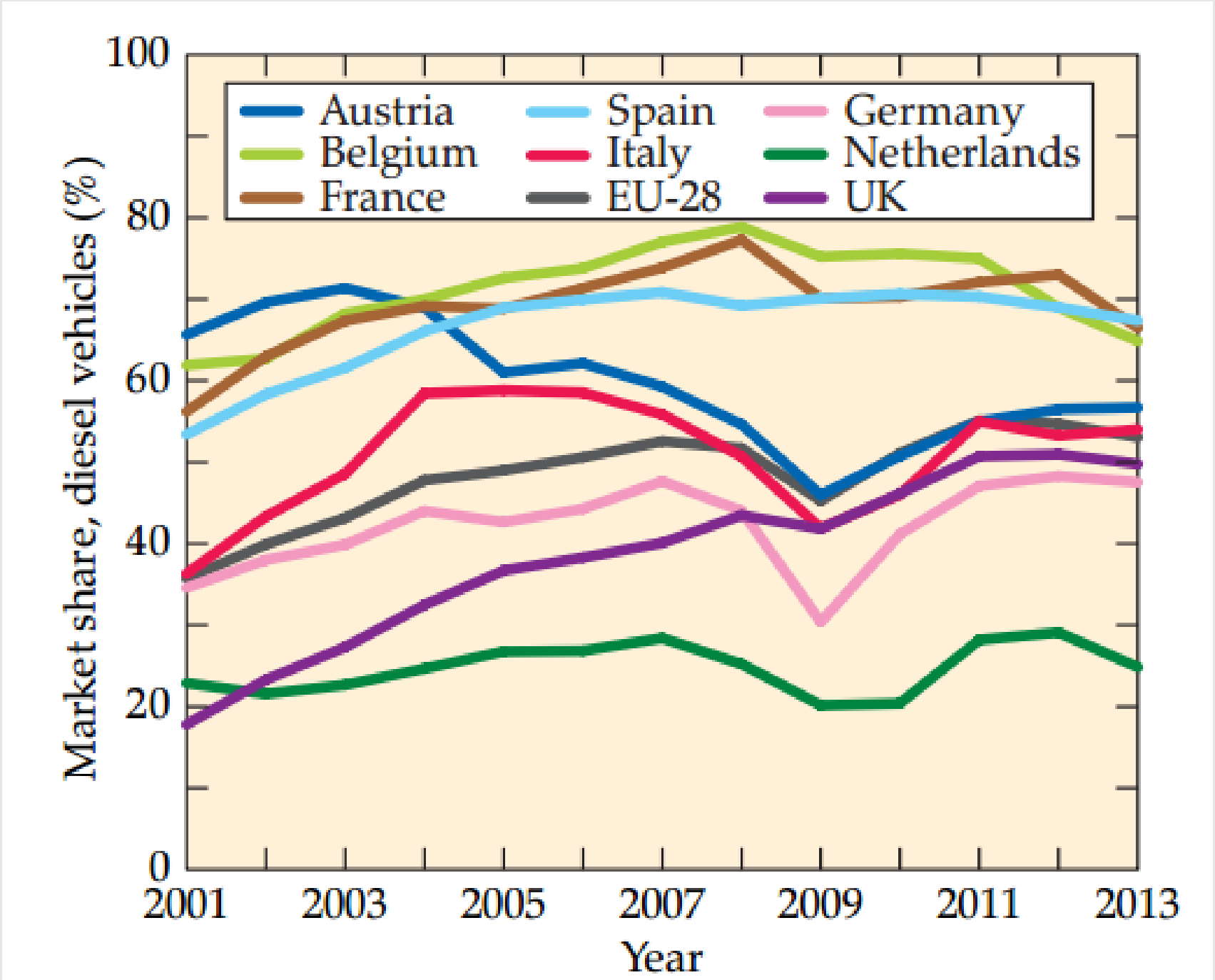
Past Problems:

- Noisier
- Generate more vibrations
- More difficult to start
- Emit thick black smoke in their exhaust
- Slower acceleration than gasoline

Diesel personal vehicles

- Technological advances:
  - Computer-controlled electronic ignition
  - Turbocharged direct fuel injection

- In Europe, diesel powered light duty vehicles now account for half of all new vehicles.


Austria
Belgium
France
Spain
Italy
EU-28
Germany
Netherlands
UK
Market share, diesel vehicles (%)
100
80
60
40
20
0
2001
2003
2005
2007
2009
2011
2013
Year

Diesel and GHGs

- More fuel efficient (11%)
- Release 15% more CO_2 per volume of fuel
- Larger, heavier engines (high pressure and temperature)

Diesel-powered light-duty vehicles emit 5% to 30% less GHGs per distance traveled than gasoline equivalents

Nitrous Oxide (N_2O)

- Diesel engines emit 20% more than gasoline engines
  - –GHG, smog
- Manufacturers use technology to remove N_2O
- Volkswagen: trap absorbs N_2O. Chemical reaction transforms it to gas and water

- 11 million cars (2009-2015) were intentionally programed to cheat on N_2O emission tests
- Computer detects fuel test is happening, purges N_2O more frequently
- During tests, fuel efficiency = 43 mpg
- Normal driving, fuel efficiency =55 mpg; N_2O emissions increase by 5 to 40%

Fuel efficiency is influenced by:

- Driving conditions
- Taxes on petroleum and vehicles
- Consumer preferences
- Use of diesel-powered vehicles
- Agreements with automobile manufacturers

Agreements with Manufacturers

1975, US Congress enacted the Corporate Average Fuel Economy (CAFE) regulations.

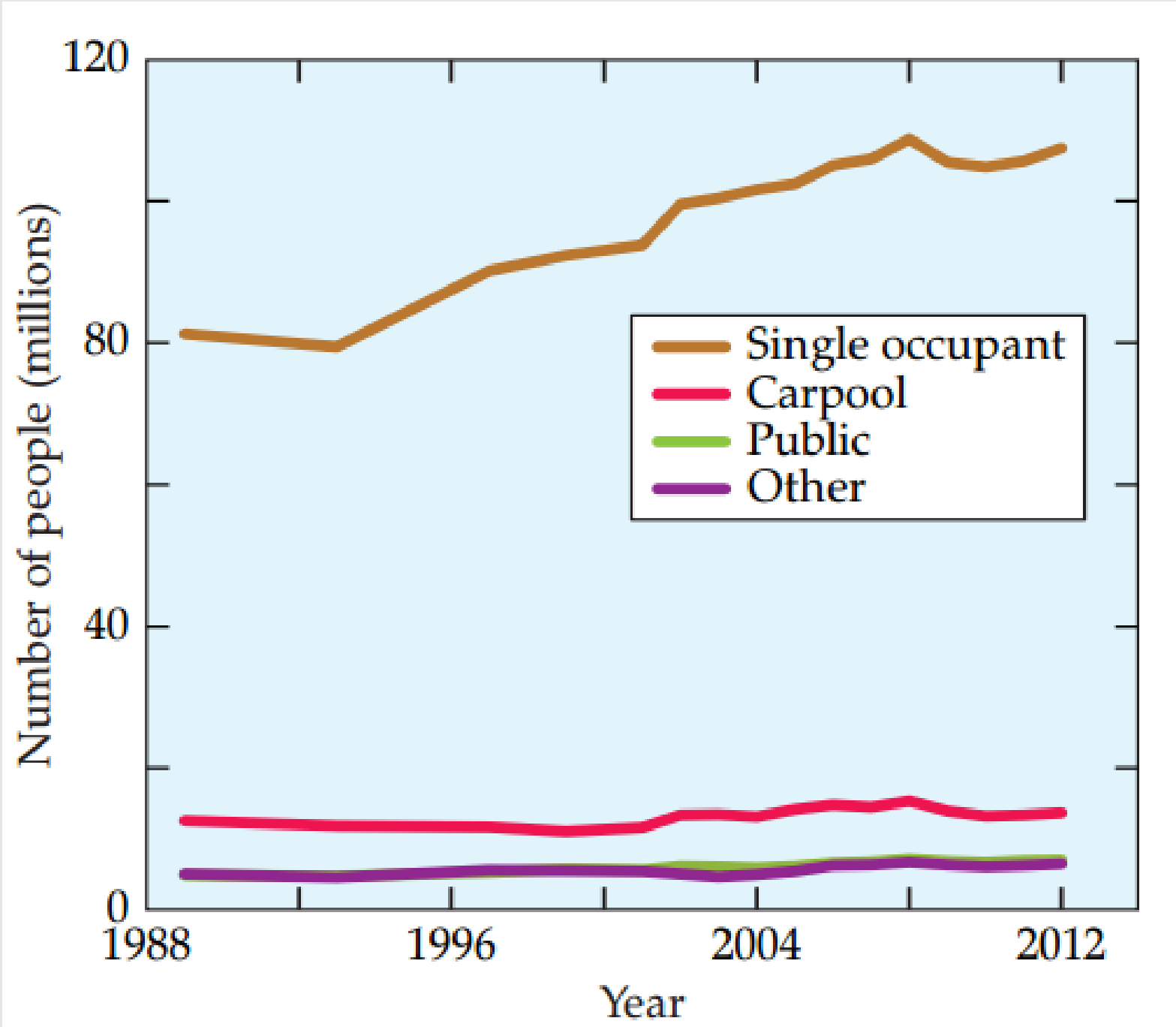
- Passenger cars: 18mpg in 1978 and 27.5 mpg in 1985
- Small trucks: 17.2 mpg in 1979 and 21.6 mpg in 1985

2012: New CAFE Regulations

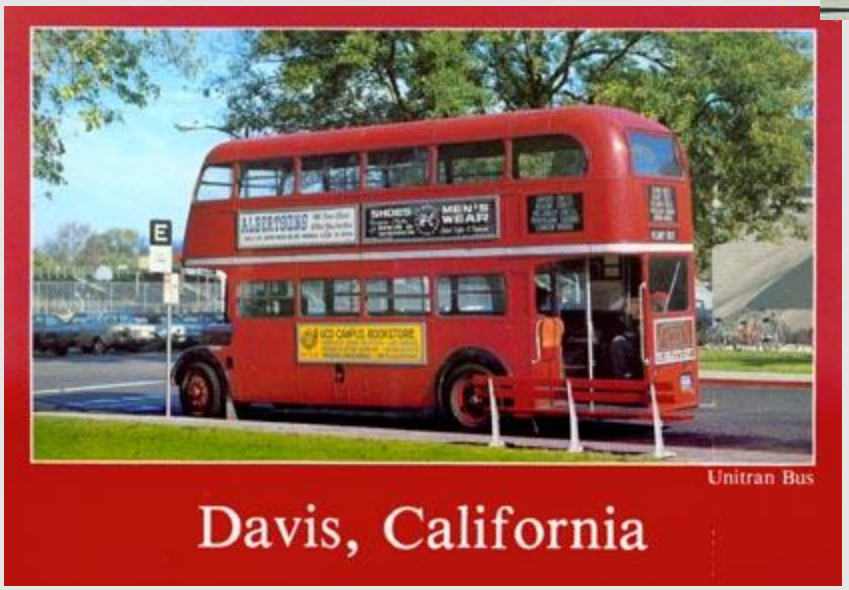
Light-duty vehicles: 40.3 mpg by 2021, 48.7 mpg by 2025

Public Transportation

- Central factor for fuel efficiency: passenger occupancy
- Doubling passenger occupancy nearly halves the effect of GHG emissions per distance traveled


120
80
40
0
Number of people (millions)
1988
1996
2004
2012
Year
Single occupant
Carpool
Public
Other


W COWELL
UNITRANS
4171
1217895

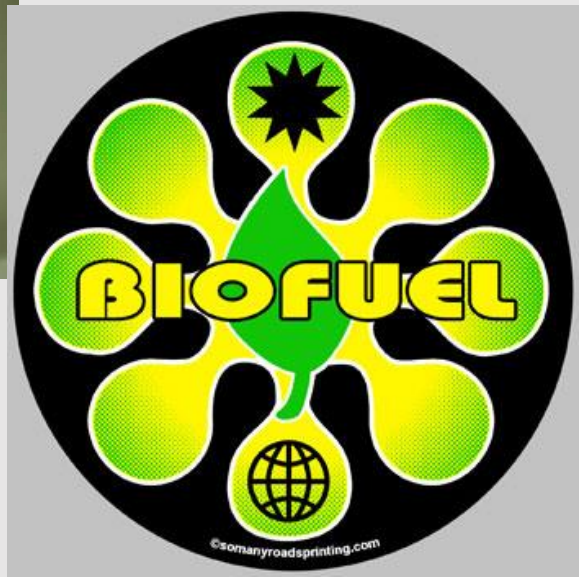

E
Unitran Bus
Davis, California


90368
90368
Amtrak


VPSI Commuter Vanpool
1-800-VAN-RIDE


BART
bart
1195

Alternative Fuels



Natural Gas

Extracted from oil wells, coal beds, natural gas fields, landfills

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{energy}$$

Compressed Natural Gas

- Low energy content at normal atmospheric pressure
- Compressed. Pressurized to several hundred times normal atmospheric pressure
- ¼ or less of the energy content in gasoline
  - –Requires larger storage tanks
  - –Slower refueling

Large Storage Tanks

Compressed Natural Gas

"Clean" fuel:

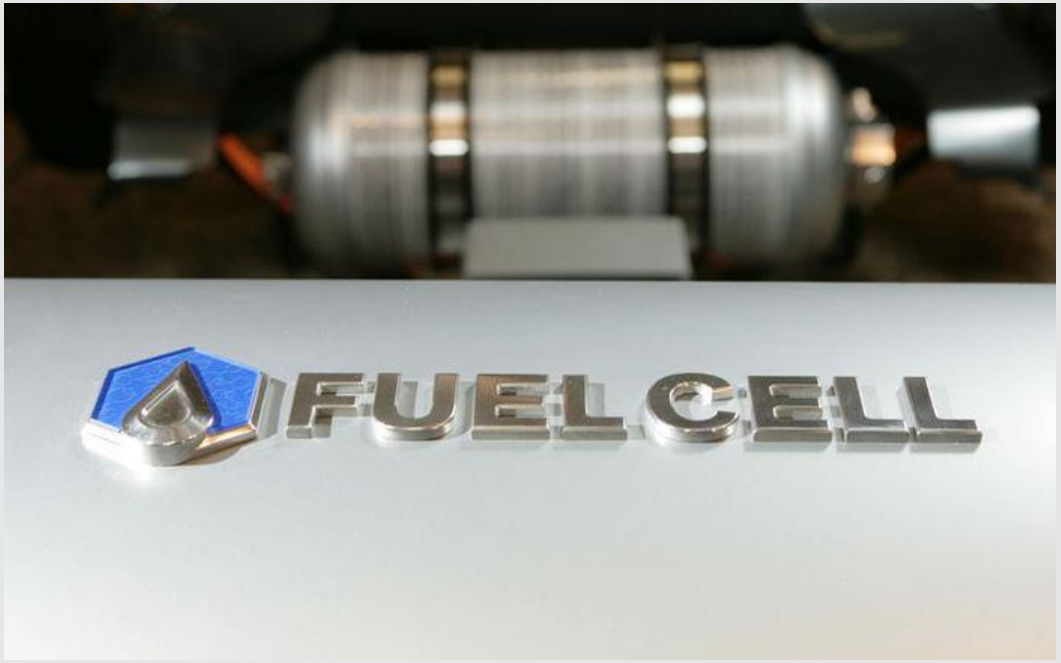
- Produces fewer particulates, non-methyl hydrocarbons, and NO_x than gas or diesel
- Great for cities with smog problems

Compressed Natural Gas

- Combustion emits smaller amounts of GHGs than any fuel except hydrogen
- CNG vehicles emit 12% less GHGs than gas powered vehicles.
- Leakage during extraction, refining, distribution and combustion is a problem
  - Mostly methane
  - Leakage amount unclear

Hydrogen Fuel Cell

Hydrogen reacts with oxygen to form water and generates electricity to power the vehicle



Hydrogen Fuel Cell

Expensive

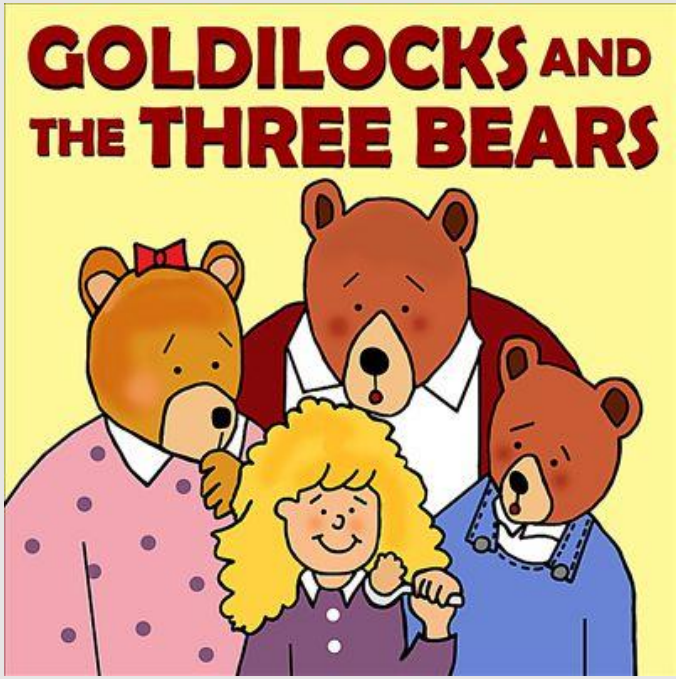
- Catalyst contains platinum, costs over $30 per gram
- Currently a typical fuel cell vehicle contains over $30,000 of platinum.

Dependability

Cars go through a lot!

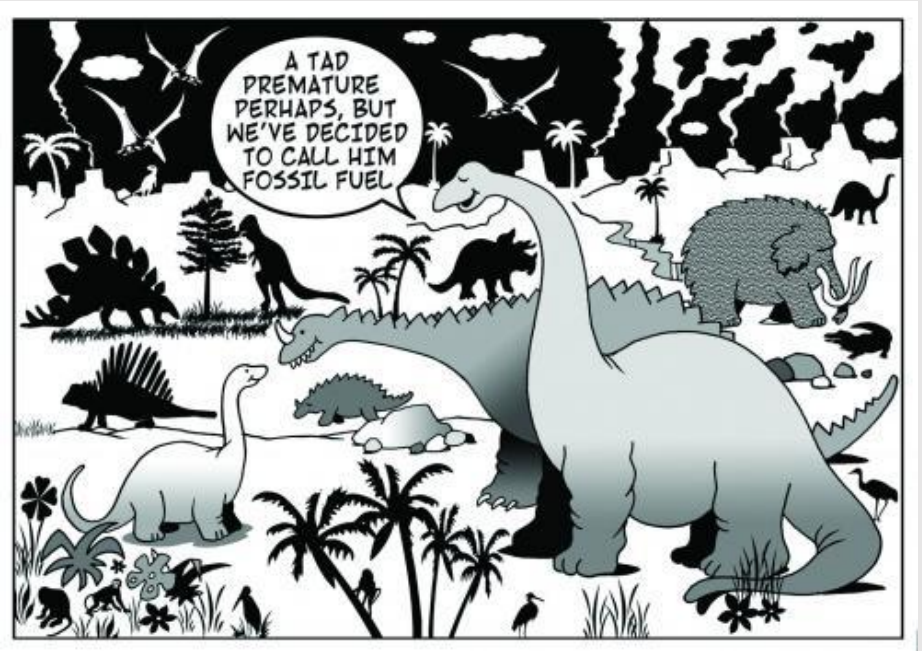
- Constant vibration
- Rapid temperature changes
- Frequent bombardment with dirt and water
- Neglect/incompetence

- Fuel cell membranes are thin (permeable to gas). Venerable to contamination by dirt or CO.
- Principal reaction generates water. If fuel cell floods, reaction will stop.
- Too little water, reaction will stop
- Water freezes, reaction will stop
- Water boils, reaction will stop



Hydrogen Production

- Over 95% of hydrogen generated today comes from fossil fuels.
- $CO + H_2O \rightarrow CO_2 + H_2$

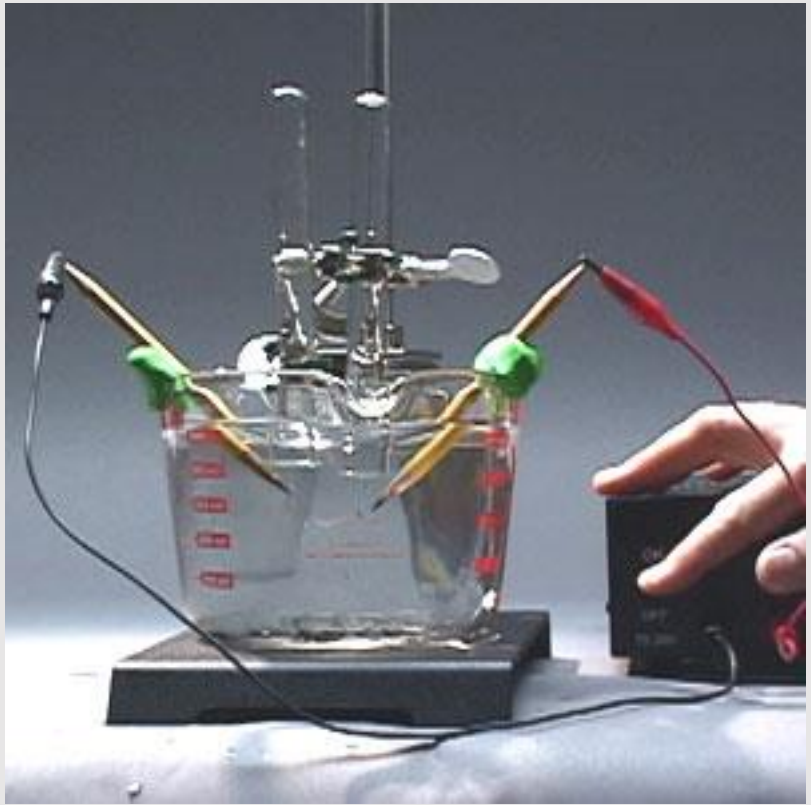


Electrolysis

- Electrolysis: electric current passes through water and releases hydrogen and water
- Requires energy

(electricity)

- Not very efficient



Under Investigation:

- Splitting water at very high temperatures
  - could be done using heat produced from nuclear reactors or solar collectors with modifications
- Biological production
  - Nitrogen fixation releases hydrogen gas
  - Cyanobacteria and green algae in anaerobic conditions release hydrogen

Hydrogen Distribution

Need refueling stations

- Could produce hydrogen in large factories and ship it long distances
- Or could produce locally at small facilities
- Hydrogen gas pipelines

Hydrogen Fuel

- Could be a good long term solution
- Not ready for general adoption

Electric Vehicles

Require batteries to carry electricity

Lead-acid batteries are inexpensive and reliable

Top speed of 40 mph, range of 25 miles, recharge in 8 hours

Tesla Model X, Lithium Ion Battery

$132,000

155 mph

0-60 in under 4 seconds

Range of 260 miles

Recharge in 20 min

Electric Vehicles

Advantages

- Very efficient energy conversion
- Vehicle emits no GHGs
- Recharge at night, not peak hours
- Less maintenance, just tires and brakes
- Breaking can be used to recharge the battery

Disadvantages

- Limited range
- Long recharge time
- High costs
- Power plants to generate electricity produce GHGs