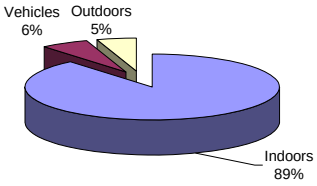
How much time do we spend inside?



Problem:

To save energy (heating, AC) today's homes are well insulated

→ longer pollutant residence times!

Where do indoor pollutants come from?

Indoor Air Pollutant Gases

Gas	Emission Sources
Carbon dioxide CO_2	Metabolic activity, combustion, garage exhaust, tobacco smoke
Carbon monoxide CO	Boilers, gas or kerosene heaters, gas stoves, wood stoves, fireplaces, tobacco smoke, garage exhaust, outdoor air
Nitrogen dioxide NO_2	Outdoor air, garage exhaust, kerosene and gas space heaters, wood stoves, gas stoves, tobacco smoke
Ozone O_3	Outdoor air, photocopy machines, electrostatic air cleaners

Table 9.3

Indoor Air Pollutant Gases

Gas	Emission Sources
Sulfur dioxide SO_2	Outdoor air, kerosene space heaters, gas stoves, and coal appliances
Formaldehyde HCHO	Particleboard, insulation, furnishings, paneling, plywood, carpets, ceiling tile, tobacco smoke
Volatile org. carbon VOC	Adhesives, solvents, building materials, combustion appliances, paints, varnishes, tobacco smoke, room deodorizers, cooking, carpets, furniture, draperies
Radon Rn	Soils

Table 9.3

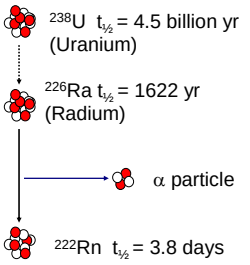
Sick Building Syndrome

The term "sick building syndrome" is used to describe situations in which building occupants experience acute health and comfort effects that appear to be linked to time spent in a building.

Causes of sick building syndrome:

- Inadequate ventilation
- Chemical contaminants from indoor sources (adhesives, carpeting, copy machines, cleaning agents)
- Chemical contaminants from outdoor sources
- Biological contaminants (Bacteria, molds, pollen, and viruses are types of biological contaminants)

Radon

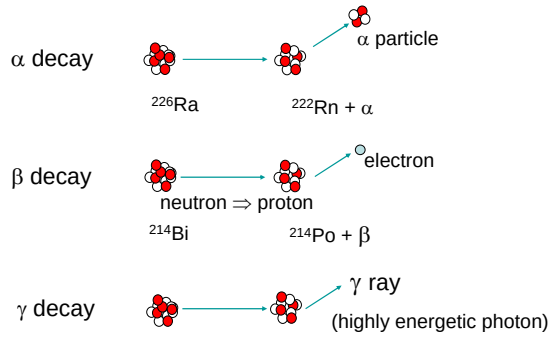


50% Uranium remains from the formation of earth

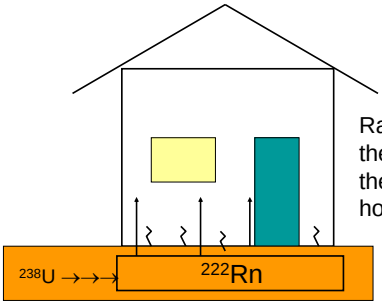
both Uranium and Radium are in the ground

Radon:
is a gas that can escape the ground and enter homes
it attaches to particles which can be deposited in the lung

Types of Radioactive Decay

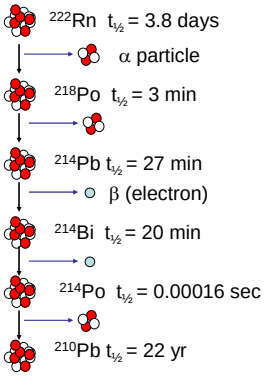


How does radon enter your home?



Radon enters from the ground through the foundation into homes

Why is Radon dangerous?

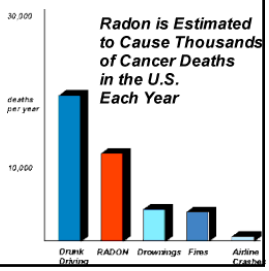


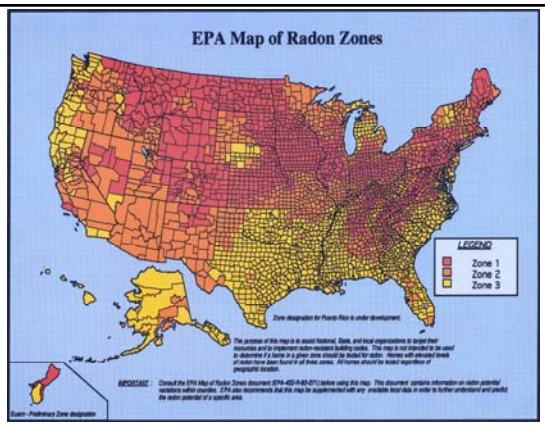
Radon-222 decays into Lead-210 in ~50 minutes radiating 3 α particles and 2 β particles

Health Effects of Radon

Radon attaches to particles that get deposited in the lung
→ radon decays in the lung
→ radioactive decays (ionizing radiation) destroys lung tissue

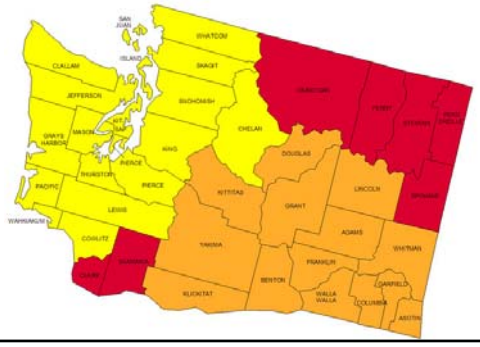
→ Lung Cancer



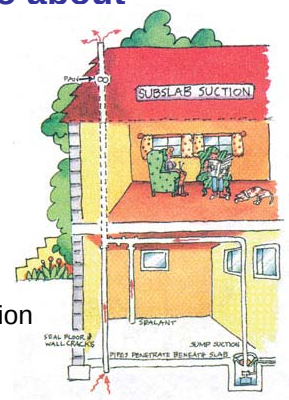


Low potential, **moderate potential**, and **highest potential** for elevated indoor radon levels.

EPA: Radon WA



What can we do about Radon?



- build a system system that ventilates radon from the ground under a home
- seal cracks in foundation

Indoor Air Pollutant Particles

Particle	Emission Sources
Allergens	House dust, domestic animals, insects, pollen
Asbestos	Fire retardant materials, insulation
Fungal spores	Soil, plants, foodstuffs, internal surfaces
Bacteria, viruses	People, animals, plants, air conditioners
PAHs Polyaeromatic hydrocarbons	Fuel combustion, tobacco smoke
Other	Resuspension, tobacco smoke, wood stoves, fireplaces, outdoor air

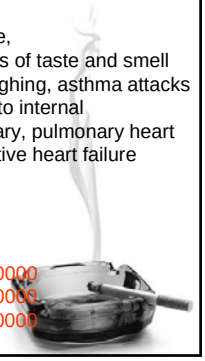
What is in cigarette smoke?

in mg/cigarette (with filter)

Component	Mainstream	Sidestream
Tar	10.2	34.5
Nicotine	0.46	1.27
CO	18.3	86.3
Formaldehyde	--	1.44
Phenols	0.23	0.6
Toluene	0.11	0.6
benzopyrene	0.00025	0.001

Some health effects of tobacco smoke

Mouth, nose, throat	cancer in mouth, tongue, sinus, larynx, loss of taste and smell
Pulmonary tract	lung cancer, coughing, asthma attacks
Cardiovascular tract	restricted blood supply to internal organs → coronary, pulmonary heart disease, congestive heart failure strokes
Skin	premature aging



In 1990 estimated death due to smoking

lung cancer	130000
cardiovascular diseases	180000
other pulmonary diseases	80000

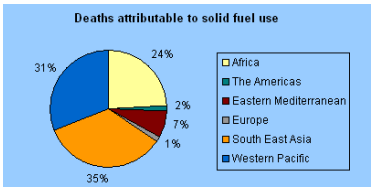
Comparison of Indoor with Outdoor Standards

Gas	Indoor (ppmv)	Outdoor (ppmv)	Outdoor California Standard (ppmv)
Carbon monoxide	35	9.5 (8-h)	9 (8-h)
Nitrogen dioxide	1 (15-m)	0.053 (annual)	0.25 (1-h)
Ozone	0.1	0.08 (8-h)	0.09 (1-h)

Outdoor standards tougher to protect entire population.
Outdoor standards for $NO_2(g)$ tougher since ozone forms outdoors, but not indoors, from $NO_2(g)$.

Table 9.4

Deaths Attributed to Solid Fuel Use



http://www.who.int/indoorair/health_impacts/burden_regional/en/index.html

More than 3 billion people world wide depend on solid fuels for their energy needs.

Removing Indoor Air Pollution after Emission?

House plants (NASA Plant Studies):

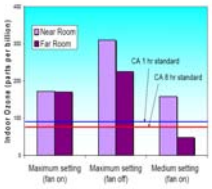
- Show that some house plants can absorb common indoor air pollutants such as formaldehyde, benzene, and carbon monoxide (CO)
- Pollutant removal thought to occur from soil bacteria, rather than from the plant itself
- Critics argue that the rate of removal may not be sufficient, and that other methods (such as ventilation) are more effective

Air Cleaners (Ozone Generators)

Ozone (O_3) air generators are NOT recommended.

Manufacturers can refer to ozone as "activated oxygen" or "energized oxygen". The claim is that ozone can react with pollutants such as particles, mold, and viruses cleaning the air. In fact this is not an effective way to remove these pollutants, except at very high (extremely unsafe) concentrations of ozone.

Ionizers and electrostatic precipitators can emit ozone as a by product, but at levels lower than ozone generators.



http://www.arb.ca.gov/research/indoor/ozone_gen_fact_sheet-a.pdf

No government agency has the authority to fully regulate such devices.

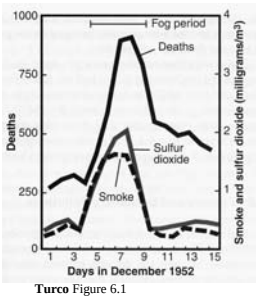
For a list of air cleaners to avoid, and to find safe air cleaners, go to:

http://www.arb.ca.gov/research/indoor/ozone.htm

Example of an air cleaner (ozone generator) that is NOT recommended:

http://www.air-zone.com/

London Smog of 1952



Turco Figure 6.1

BBC News
http://news.bbc.co.uk/1/hi/england/2543875.stm

Fog + smoke from coal burning
Worst single pollution episode in the UK. December 5-8 1952: 4,000 people died, another 8,000 died in the weeks-months that followed

Los Angeles smog (1940s+1950s)

Factories + cars

Colors in Los Angeles Smog (Dec. 2000)

Mark Z. Jacobson

The Chemistry of Ozone (O_3) Formation

O_3, in both the stratosphere and troposphere, forms from the following reaction:

$O + O_2 + M \rightarrow O_3 + M$

where M = inert "third body" (such as N_2) that absorbs excess energy from the reaction of O and O_2

There is plenty of O_2 everywhere in the atmosphere (21%). The key is how "atomic oxygen" (O) forms. The difference between how stratospheric and tropospheric O_3 forms is how O ("atomic oxygen") is generated.

Generation of atomic oxygen in the stratosphere (10-50 km altitude)

Atomic oxygen (O) in the stratosphere is generated from photolysis of O_2. "Photolysis" means that sunlight breaks apart a molecule.

O_2 + sunlight (UV) $\rightarrow$ O + O

This photolysis reaction requires ultraviolet (UV) light. There is not enough UV light in the troposphere for this reaction to be significant.

The atomic oxygen (O) then reacts with abundant O_2 to produce O_3:

$O + O_2 + M \rightarrow O_3 + M$

Generation of atomic oxygen in the troposphere (0-10 km altitude)

Atomic oxygen (O) in the troposphere is generated from photolysis of NO_2. "Photolysis" means that sunlight breaks apart a molecule.

NO_2 + sunlight (visible) $\rightarrow$ NO + O

This photolysis reaction requires visible light. There is plenty of visible light in the troposphere during the day (or else we could not see).

The atomic oxygen (O) then reacts with abundant O_2 to produce O_3:

$O + O_2 + M \rightarrow O_3 + M$

Generation of NO_2

Now we know that we need NO_2 to generate tropospheric O_3. So how do we get NO_2?

NO_2 is formed by oxidizing NO. NO is emitted directly from the tailpipe of our cars. NO is oxidized by HO_2 or RO_2.

$NO + HO_2 \rightarrow NO_2 + OH$

or

$NO + RO_2 \rightarrow NO_2 + RO$

So how do we get HO_2 and RO_2?

Generation of HO_2 and RO_2

HO_2 forms from the oxidation of CO. CO is emitted from the tailpipes of our cars.

$CO + OH$ ("hydroxyl radical") $\rightarrow CO_2 + H$

$H + O_2 \rightarrow HO_2$

RO_2 forms from the oxidation of hydrocarbons (HC or RH). Hydrocarbons have many sources, such as motor vehicles, solvents, and plants.

$RH + OH$ ("hydroxyl radical") $\rightarrow R + H_2O$

$R + O_2 \rightarrow RO_2$

Summary of O_3 formation in the troposphere

There are 3 steps in the chemistry of tropospheric O_3 formation:

1) Formation of HO_2 (a) or RO_2 (b) :

(a) $CO + OH \rightarrow CO_2 + H$ $\quad$ $H + O_2 \rightarrow HO_2$

(b) $RH + OH \rightarrow R + H_2O$ $\quad$ $R + O_2 \rightarrow RO_2$

2) Conversion of NO to NO_2:

$HO_2 + NO \rightarrow NO_2 + OH$ or $RO_2 + NO \rightarrow NO_2 + OHv$

2) Photolysis of NO_2 to generate atomic oxygen:

NO_2 + sunlight (visible) $\rightarrow NO + O$

Atomic oxygen (O) then reacts with molecular oxygen (O_2) to form O_3:

$O + O_2 + M \rightarrow O_3 + M$

Is the air clean or dirty?

Air Quality standards

National primary ambient air standards:
Levels of air quality which the Administrator (of EPA) judges are necessary, with an adequate margin of safety, to protect the public health.

National secondary ambient air standards:
Levels of air quality which the Administrator (of EPA) judges are necessary to protect the public welfare (visibility, animals, crops, buildings) from any known or anticipated adverse effects of a pollutant.

National Primary Air Quality Standards

Ozone	
1 hour average	120 ppbv (not to be exceeded more than once/year)
8 hour average	75 ppbv (not to be exceeded more than 4x/year)
CO	
1 hour average	35 ppmv (not to be exceeded more than once/year)
8 hour average	9 ppmv
NO_2	
annual average	53 ppbv
SO_2	
24 hour average	140 ppbv
Pb (lead)	
Quarterly average	1.5 $\mu g/m^3$
PM_{10}	
24 hour average	150 $\mu g/m^3$
$PM_{2.5}$	
24 hour average	35 $\mu g/m^3$

Air Quality Index (AQI)

A numerical scale vs. air quality criteria, normalized for the different pollutants, scale of 0-500

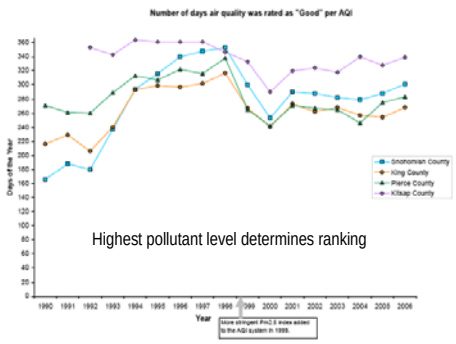
AQI	Scale relative to standard	Example: O_3 mixing ratio
50	Half standard	37.5 ppbv
100	Standard	75 ppbv
150	50% larger than standard	112.5 ppbv
200	Factor of 2 larger than standard	150 ppbv
300	Factor of 3 larger than standard	225 ppbv
500	Factor of 5 larger than standard	475 ppbv

For 75 ppbv 8-hour standard

Air Quality Index (AQI)

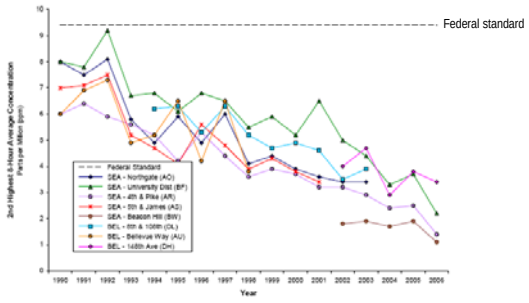
AQI		Health warnings
0-50	Good	None
51-100	Moderate	Sensitive people should limit outdoor exertion.
101-150	Unhealthy for sensitive groups	Active children and adults, and people with respiratory disease, should limit outdoor exertion.
151-200	Unhealthy	Active children and adults, and people with respiratory disease, should avoid outdoor exertion; everyone else, especially children, should limit outdoor exertion.
201-300	Very unhealthy Stage-1 episode (200-275) Stage-2 episode (275-400)	Active children and adults, and people with respiratory disease, should avoid all outdoor exertion; everyone else especially children, should limit outdoor exertion.
301-500	Hazardous Stage-3 episode (>400)	Everyone should avoid all outdoor exertion

Good Air Quality Days in Puget Sound



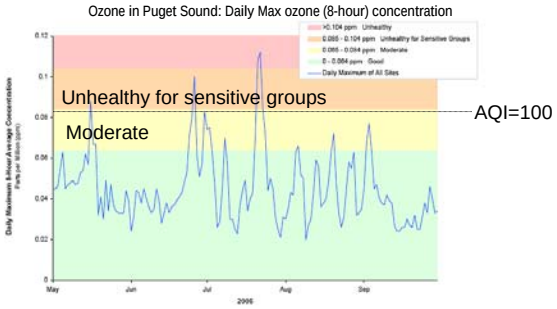
Highest pollutant level determines ranking

CO in King County (8 hour)



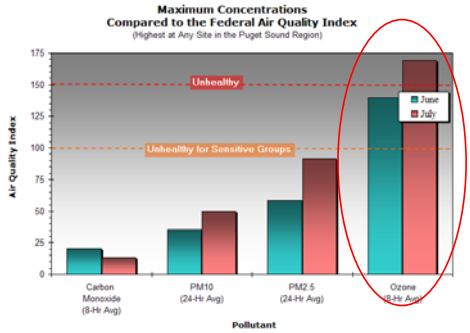
Puget Sound Air Quality Agency
http://www.pscleanair.org/ds04/docs/2006AQDSFINAL.pdf

Ozone in Puget Sound: Summer 2006



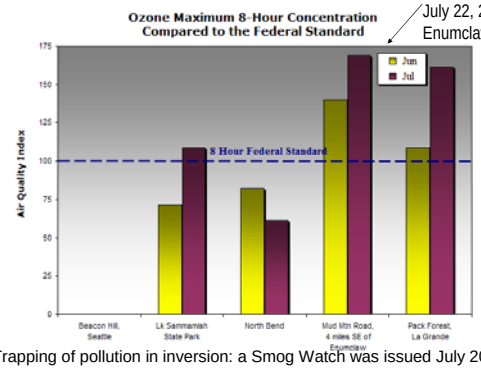
Puget Sound Air Quality Agency
http://www.pscleanair.org/ds04/docs/2006AQDSFINAL.pdf

June and July 2006 Puget Sound



Puget Sound Clean Air Agency: http://www.pscleanair.org/airq/aqsumm/06-07.aspx

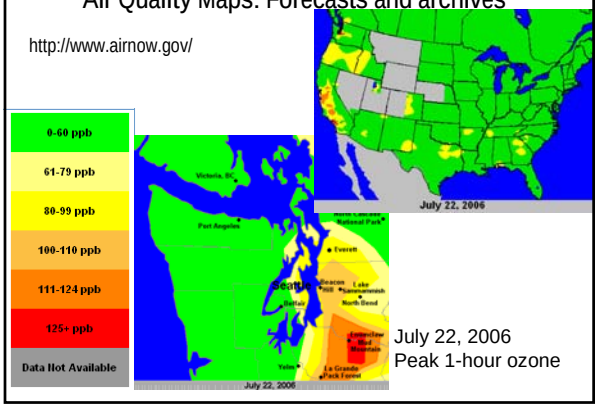
Peak occurred July 22, 2006 in Enumclaw



Trapping of pollution in inversion: a Smog Watch was issued July 20-July 24, 2006 particularly for the downwind foothill areas south and east of the Everett-Seattle-Tacoma urban corridor.

Air Quality Maps: Forecasts and archives

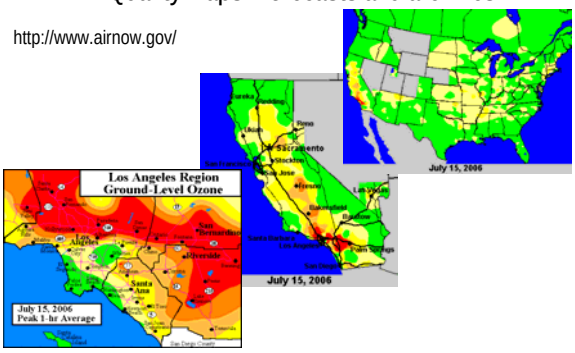
http://www.airnow.gov/



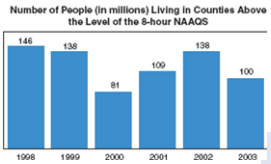
July 22, 2006
Peak 1-hour ozone

Air Quality Maps: Forecasts and archives

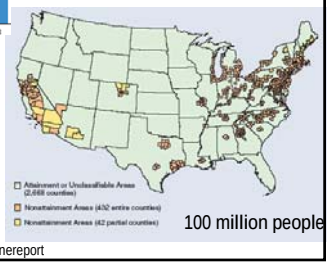
http://www.airnow.gov/



Ozone (8-hour) non-attainment areas in US



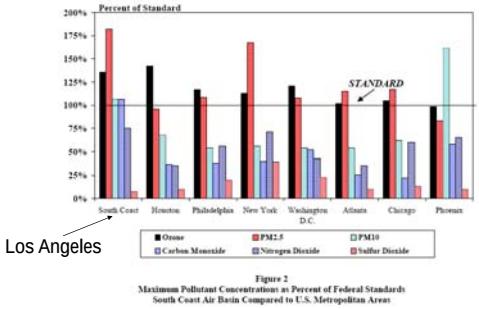
Non-attainment areas for 2003



EPA 2003 ozone report
http://www.epa.gov/airtrends/aqtrnd04/2003ozonereport

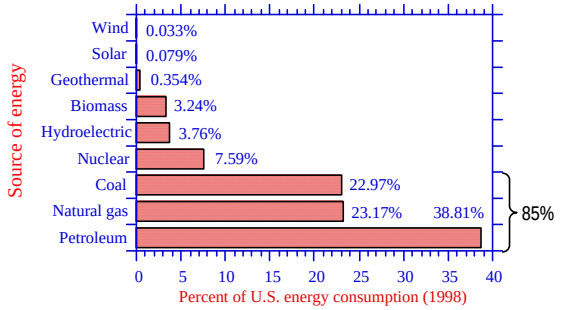
100 million people

Maximum Pollutant concentration in Major U.S. Metropolitan Areas (2002)



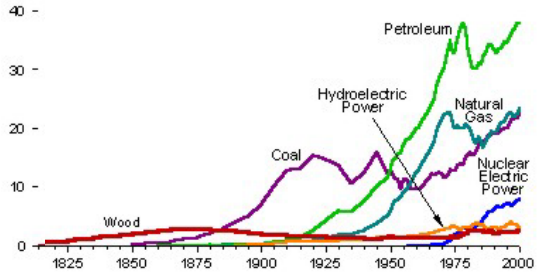
South Coast AQMD
http://www.aqmd.gov/smog/AQSCR2002/aq02web.pdf

Sources of Pollution: U.S. Energy Consumption by Source (1998)



Jacobson, Figure 8.3

U.S. Energy Consumption by Source 1800-2000

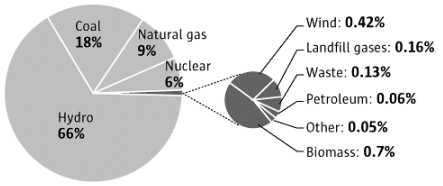


http://www.eia.doe.gov/emeu/aer/eh/frame.html

Electricity sources in Washington State

Where our energy comes from

In 2004, Washington customers got about 66 percent of their electricity needs from hydro and 33 percent from coal, nuclear and natural gas. The rest came from the renewable resources advocated by I-937 supporters, such as wind, solar and biomass.



Note: Numbers do not add up to 100 percent because of rounding

Source: Washington State Department of Community, Trade and Economic Development

THE SEATTLE TIMES
May 9, 2006

Alternative energy

Solar

Wind

Nuclear

Geothermal

Hydroelectric

Biomass

Alternative fuels for cars

Electric cars

Ethanol

Natural gas

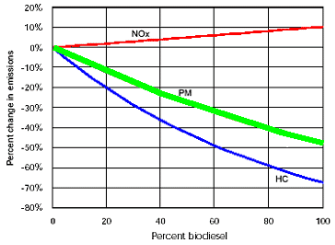
biodiesel

Electricity
Biodiesel
Ethanol
Methanol
Natural gas
Hydrogen

Hydrogen car (BMW)

Biodiesel and Pollution

Figure 1: Tailpipe Emissions of Biodiesel relative to Conventional Diesel*



http://www.ucsusa.org/clean_vehicles/big_rig_cleanup/biodiesel.html