New Energy Plans

UC Irvine
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Dennis Silverman
Physics and Astronomy
U. C. Irvine
www.physics.uci.edu/~silverma/

Topics

Lecture 1:

- Update Summary on Global Warming Motivation
- Energy Plans being worked on
  - World
  - U.S.
  - California
  - Local Cities
- Individual Energy Possibilities
  - Transportation Related
  - Easy Household Actions

Lecture 2:

- Automotive Advances
- Greenhouse Gas Free Sources
  - Nuclear Power
  - Solar Thermal and Photovoltaic
  - Wind Power
  - Geothermal Power
  - The Smart Grid

Modifications to Energy Sources Due Anyway

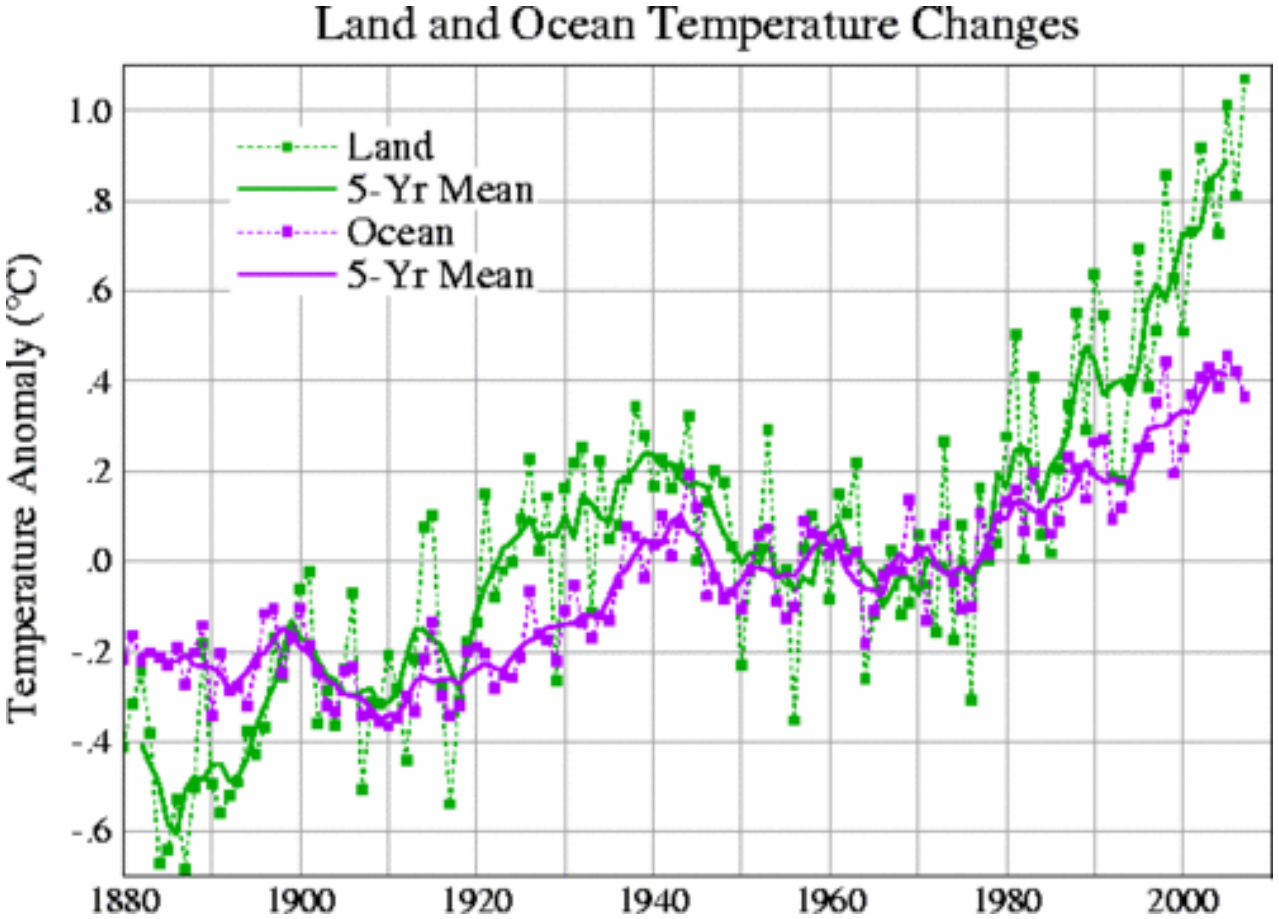
- Even without global warming, increasing use of all fossil fuels, dependence on cartel controlled foreign sources which also increase prices and involve instabilities, resource limitations, and rising prices would force a continual search for new energy sources and conservation anyway.
- US outflow to import oil at $80 a barrel is $400 Billion a year.
  - We import 2/3 of our oil.
  - A new UK study estimates that conventional oil will peak by 2030, and maybe by 2020.
  - Unconventional oil and oil sands then would be more expensive.
- Air pollution and smog from fossil fuels including NOx, particulates , SO2 acid rain, mercury contamination, and ocean acidification from dissolved CO2 are all worldwide health problems caused by continued fossil fuel usage.

Short Global Warming Update

- Atmosphere and Oceans Latest Warming Trends
- Extra Warming from Methane and gas interactions
- Extra Sea Level Rise from Greenland and Antarctic ice sliding increases prediction range to 1.5 to 3 feet by 2100
- Comments on dismissals of Global Warming:
  - Why haven't the fossil fuel industries funded a comprehensive institute, experiments or global modeling to prove that global warming is really due to "natural cycles" which were somehow missed by climate scientists, or to solar flares or sunspots causing rain?
  - Oil company profits totaled $656 billion during the last eight years.
  - They have had at least two decades to prove their case.
- *Super Freakonomics* suggests geoengineering with SO2 injections which would be required forever and cause acid rain and continually acidify the ocean.

Land (green) and Ocean (purple) Temperature Rises 1880 to 2007

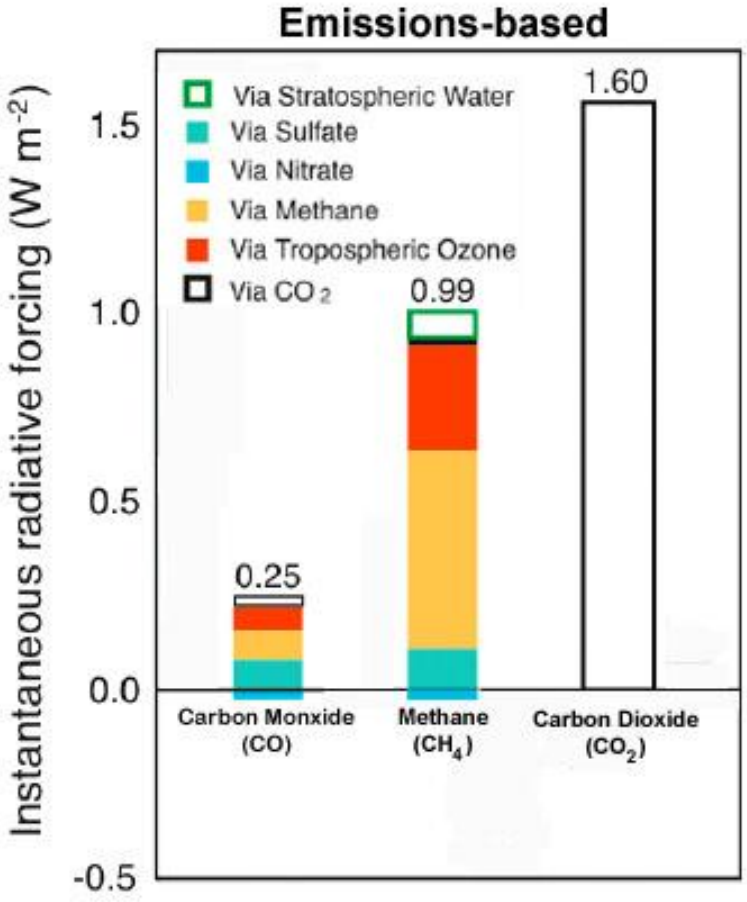
There are several periods where peaks followed by dips could have been misinterpreted as an end to warming and a downturn (1900 and 1940).
We also note that the land temperature (where we live and farm) has gone up 0.45 degrees C or 0.8 degrees F more than the rise in ocean temperature in the last 50 years.
The dip from 1950 to 1980 is attributed to new dirty coal plants producing SO2 → SO4 which is a cooling aerosol but also causes acid rain.



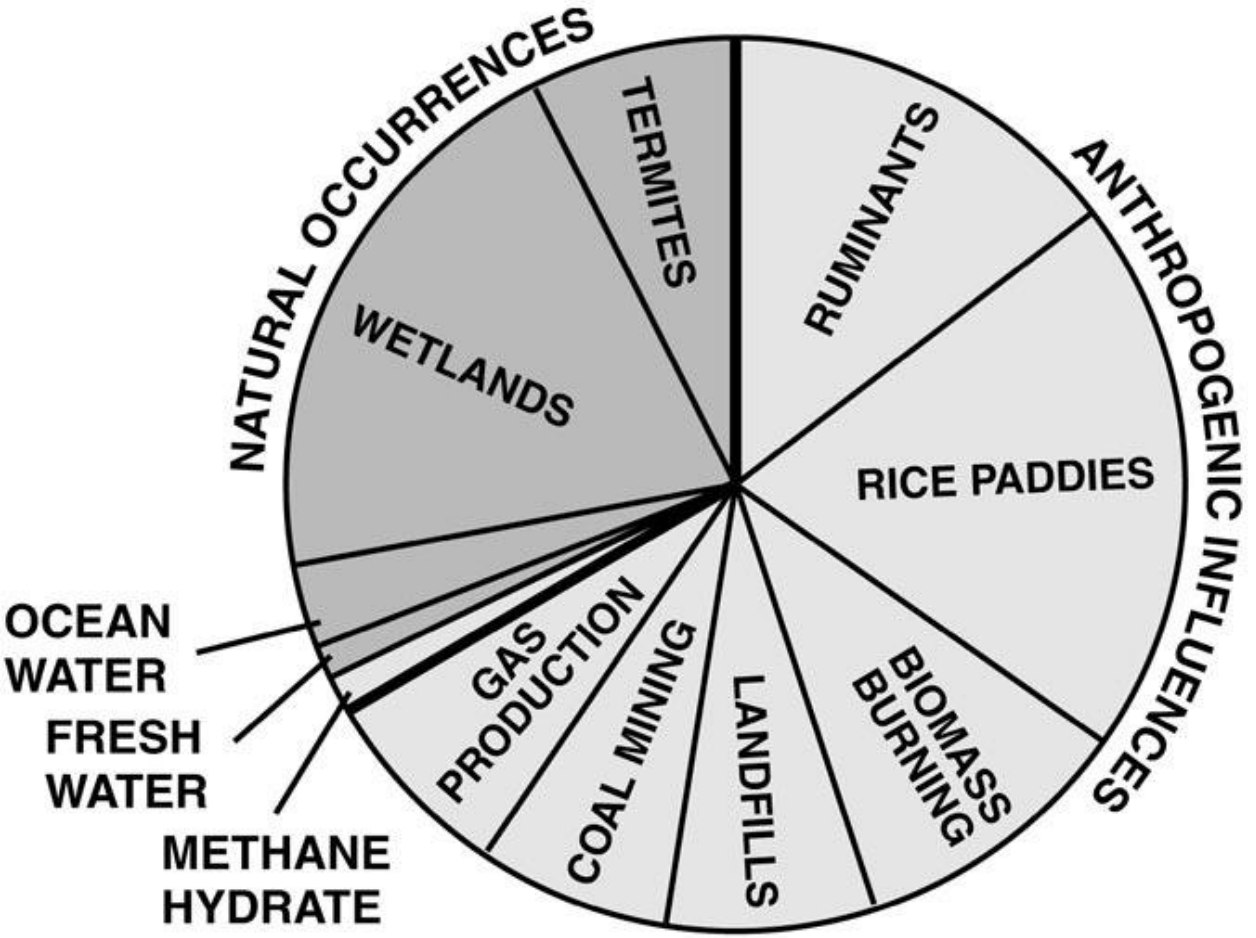
Increased Global Warming from Methane interaction with other Atmospheric Gases

Methane direct (yellow) and other gases enhanced by methane. This increases methane's contribution to warming by 20-40%.

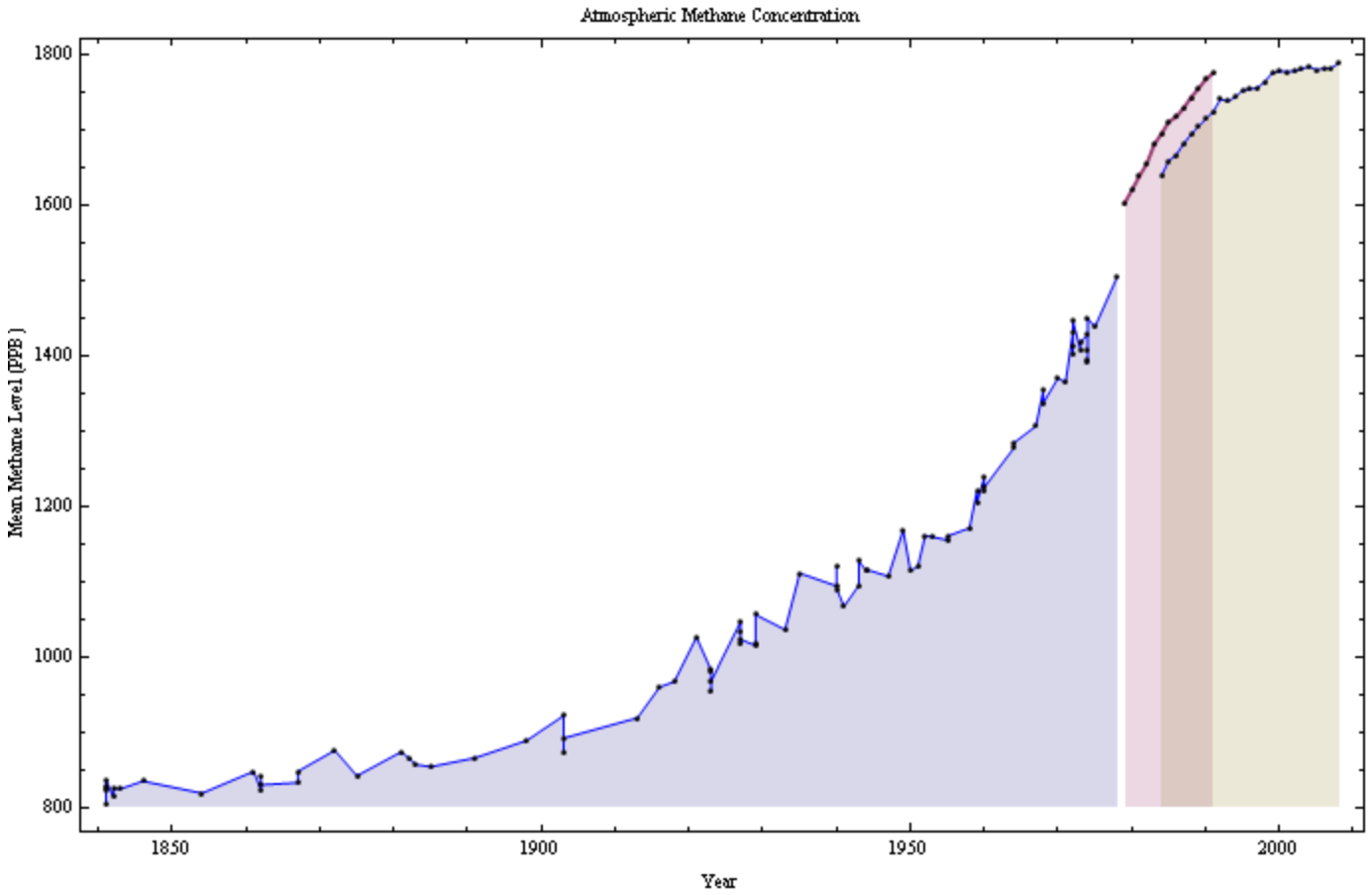
Methane eats up hydroxyl (OH) molecules, which would have converted SO2 to sulfate, SO4, which is a global cooling aerosol.

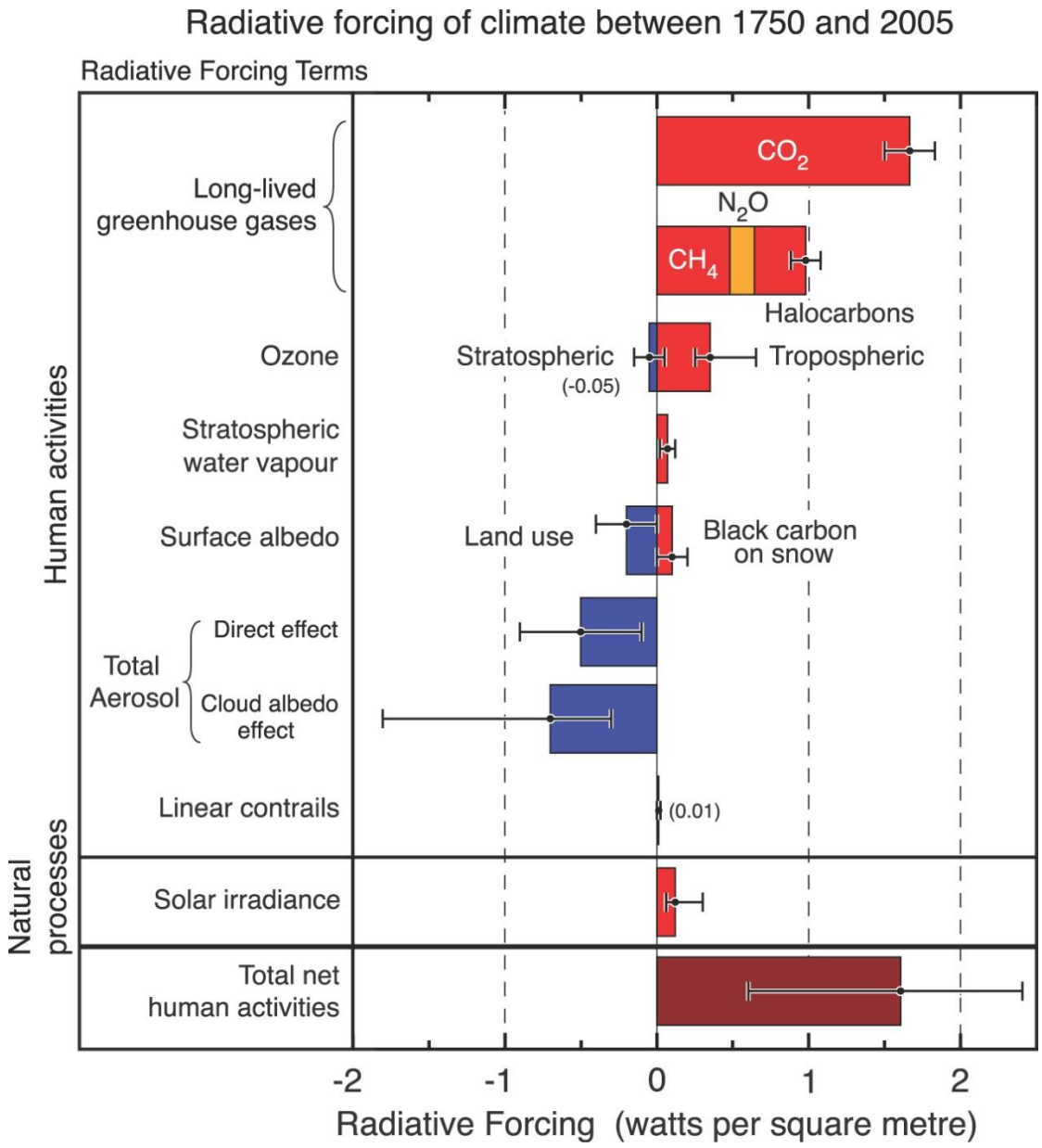


Methane Sources



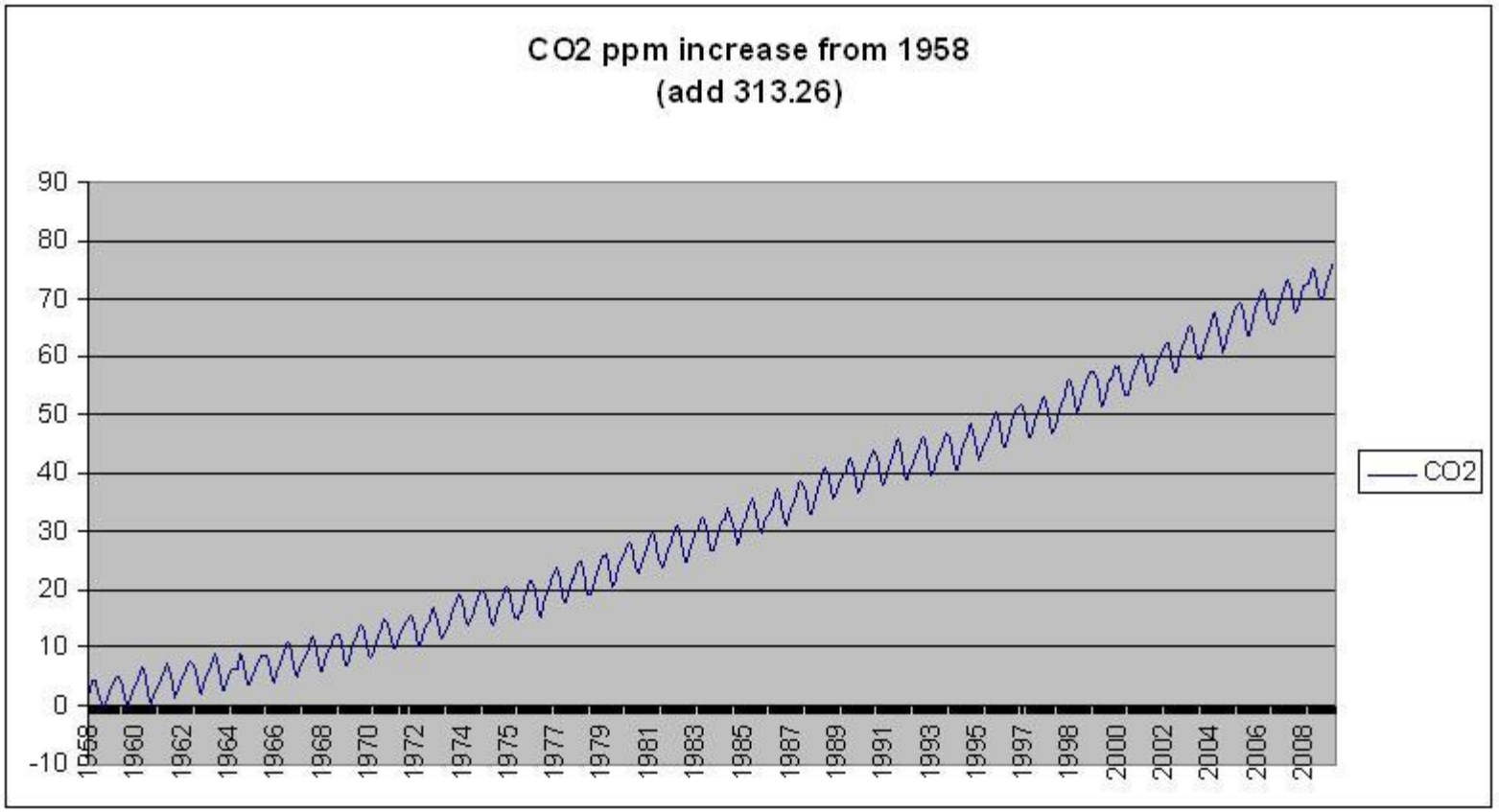
Methane levels from 1840 to present.
Previously methane was about 700 ppb, now it is 1800 and leveling off.
It is 25 times as potent a GHG per molecule than CO2.




Radiative forcing of climate between 1750 and 2005
Radiative Forcing Terms
Human activities
Natural processes
Long-lived greenhouse gases
CO_2
N_2O
CH_4
Halocarbons
Ozone
Stratospheric
(-0.05)
Tropospheric
Stratospheric water vapour
Surface albedo
Land use
Black carbon on snow
Total Aerosol
Direct effect
Cloud albedo effect
Linear contrails
(0.01)
Solar irradiance
Total net human activities
-2
-1
0
1
2
Radiative Forcing (watts per square metre)

CO2 Increase from 1958

1850 CO2 about 280 ppm; 1958 about 313 ppm (33 ppm increase)
Increase from 1958 is about 73 ppm to 386 ppm.
So 2/3 of the increase is in the last 50 years.



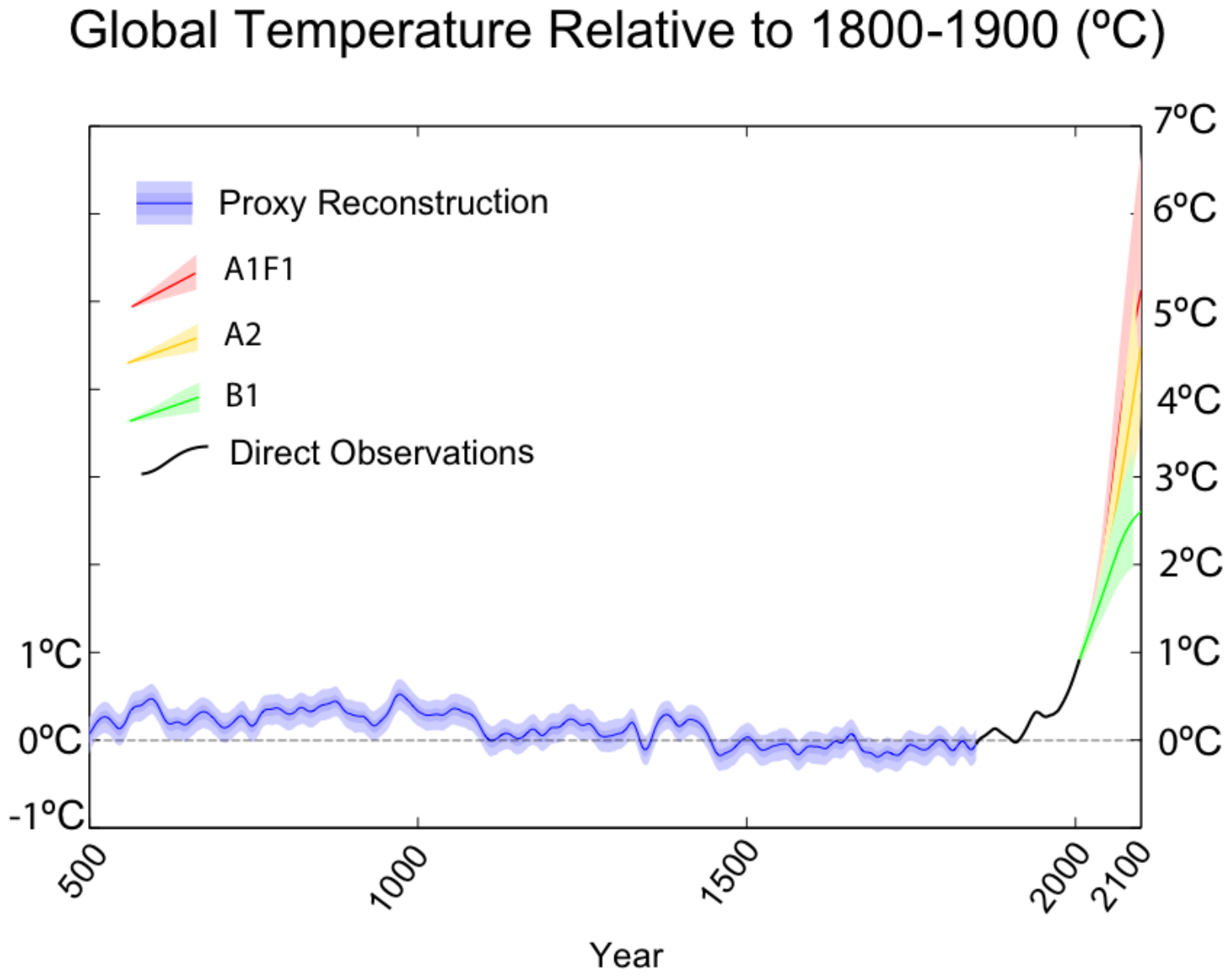


Figure 21: Reconstructed, observed and future warming projections (www.copenhagendiagnosis.com/)

Effects of Global Warming

- Sea level rise of around two feet by the end of the century.
  - Major river deltas are very slightly sloping and used for farming world wide.
  - Such rises displace tens of million of farmers.
  - They also bring salt water inland to further kill farming lands.
- Sea heating and acidification killing corals which serve as nurseries for much sea life.
- Major droughts are expected in addition to those that have increased over the last 30 years
  - Historic warm period of 800-1300 AD caused droughts in mid Africa and the US southwest, and was less than the current rise in temperature
- Lack of cold winters fails to kill bark beetles that are killing off pine trees, and now Aspens are dying.
  - Lack of cold also fails to kill mosquitoes which can spread North with their diseases, as well as other vermin and plant diseases.
- One quarter of all of Earth's species may perish by climate shifts.

Warming Effects in California

- In California and elsewhere, warmer winters provide less snow pack in the mountains, and cause it to melt earlier in the year.
  - The snow holds water that is released during the summer for farming and water use.
  - More dams or holding areas will have to be built.
  - Possible cost and greenhouse gas emissions to desalinate seawater.
  - The cheapest solution is to use less water or conserve.
  - Water restrictions due from current CA drought, and CA population to increase from 37 million to 50 million by 2030, and to 60 million by 2050.
  - Should vote for new CA water bill of $11 billion for water storage and recycling, and to okay but not pay for Delta peripheral canal to bring northern CA water south.
  - CA droughts and higher temperatures lead to wildfires and subsequent mudslides.

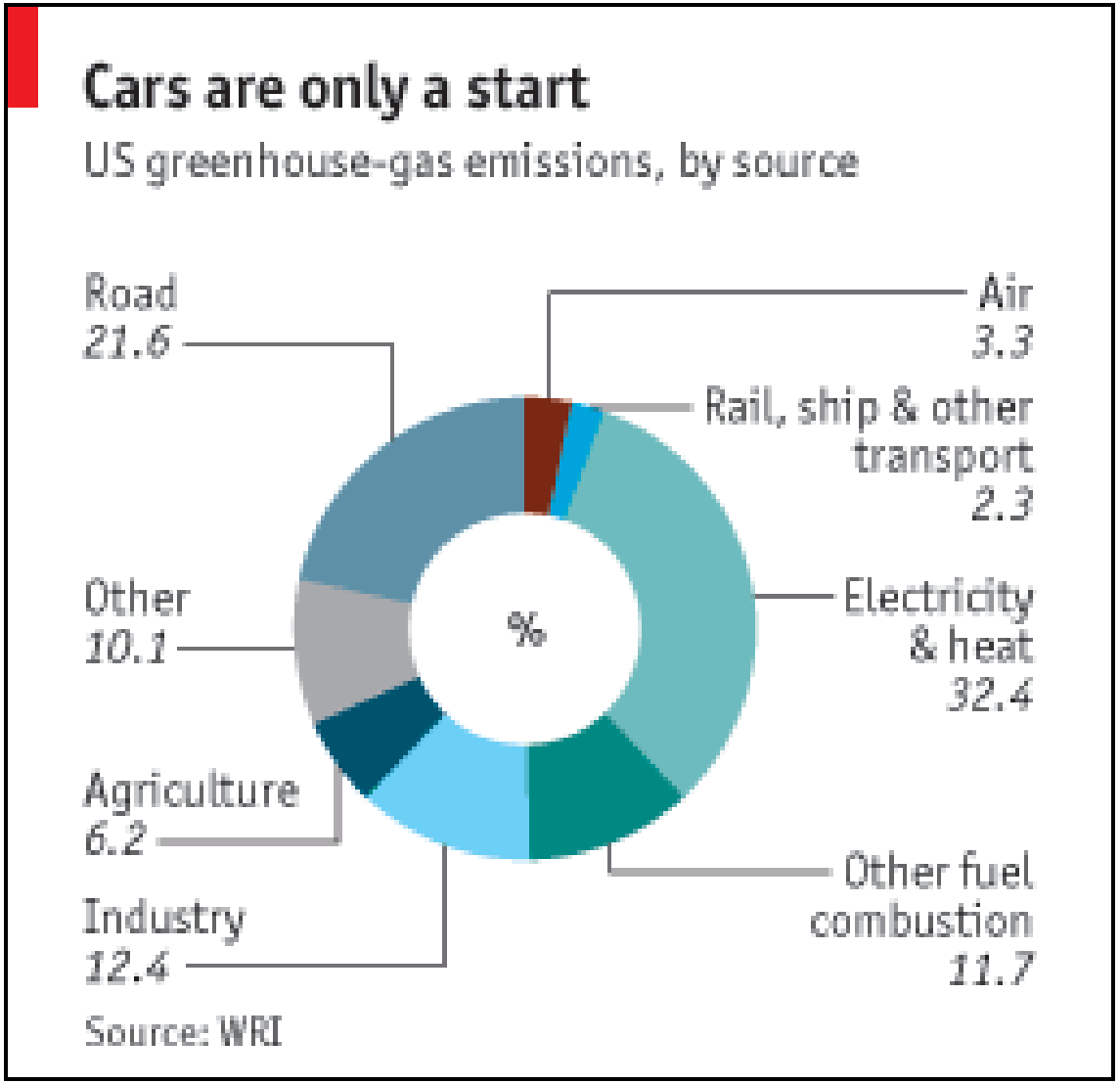
Worldwide Negotiations in Copenhagen 2009

- This December 7-18 in Copenhagen, the United Nations will meet in the UN Climate Change Conference to work on new greenhouse gas emissions limits and a framework to follow the Kyoto protocol that ends in 2012.
- President Obama will go to the talks, and proposes the US will drop its emissions by 17% by 2020, 42% by 2030, and 83% by 2050 from 2005 levels.
- This is the goal passed by the House in HR 2454, the American Clean Energy and Security Act of 2009 (ACES).
- The Senate will not take up its climate-energy bill until next spring, but drafts have the same goals.
- President Obama has committed a fair share of the $10 billion a year support for cleaner energy and adaptation in the developing world.
- China wants to reduce its carbon intensity, or CO2/unit of GDP, by 20% by 2010 and by 40-45% by 2020. Its GDP is expected to rise by 60% by then, so its emissions will stay about the same.
- India plans measures to reduce its carbon intensity by 25% by 2020.

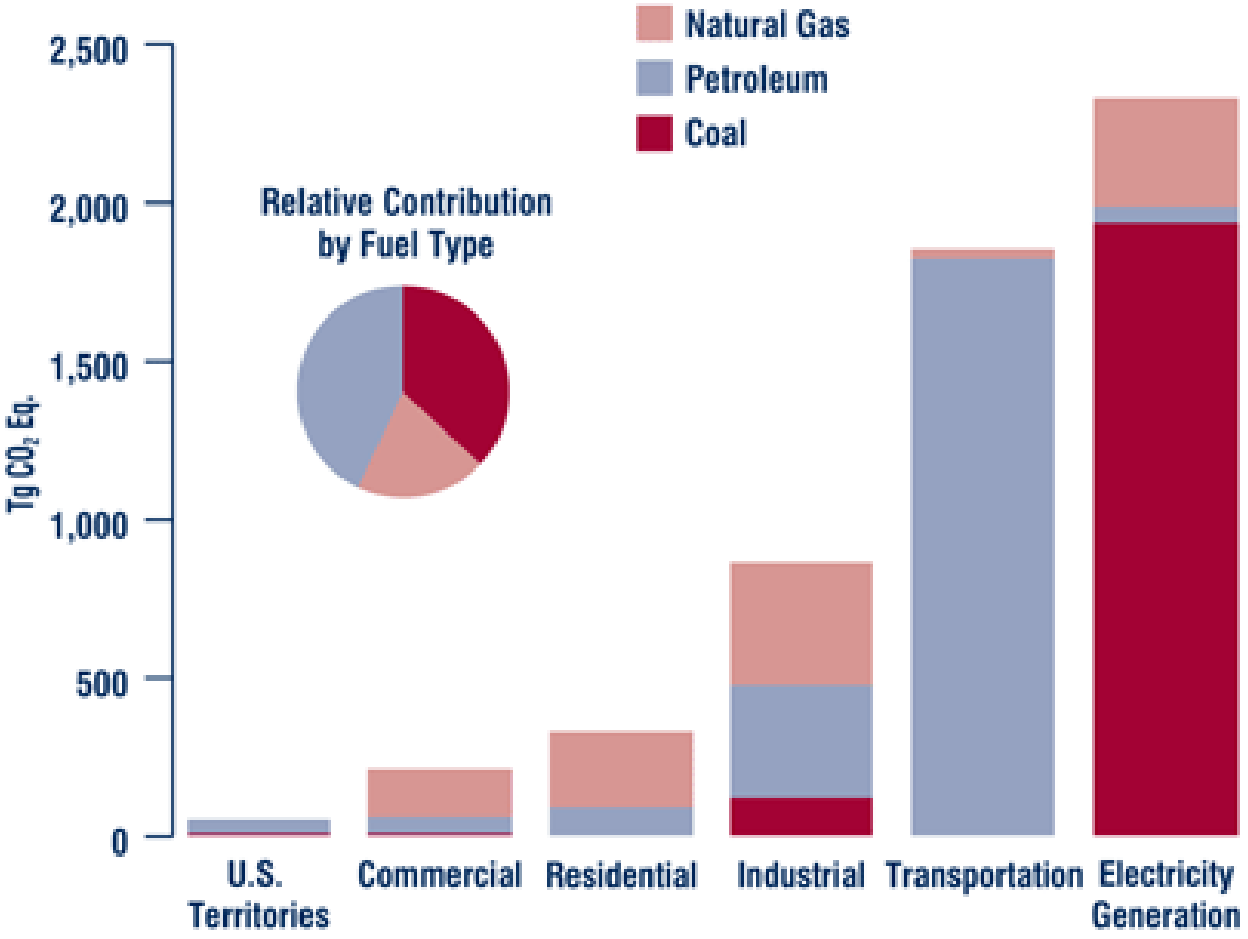
UN Climate Change Conference

- The talks are hoping for an interim agreement that does not yet require ratification or enforcement.
- The least UN goal may be a 50% reduction in greenhouse gases by 2050. This would be on the way to limit global warming to 2° F over the present temperature by the end of the century.
- The European Union goal is 20% below 1990 levels by 2020, called the “20-20-20” plan.
- European countries are setting goals of a 60% to 80% reduction by 2050.
- UN Climate Chief Yvo de Boer adds another question:
- “ How is the help needed by developing countries to engage in reducing their emissions and adapting to the impacts of climate change going to be financed?”
- France has suggested $10 billion a year for three years.

Sources of US Greenhouse Gas Emissions



2006 CO_2 Emissions from Fossil Fuel Combustion by Sector and Fuel Type



Note: Electricity generation also includes emissions of less than 0.5 Tg CO_2 Eq. from geothermal-based electricity generation.

Investments in New Power and Power Research in the US

- The US may invest $15 billion a year for development of renewable energy technologies in wind and solar, and for more efficient technologies for motor vehicles.
- Those funds would come from a cap-and-trade system on CO2 emissions starting in 2012.

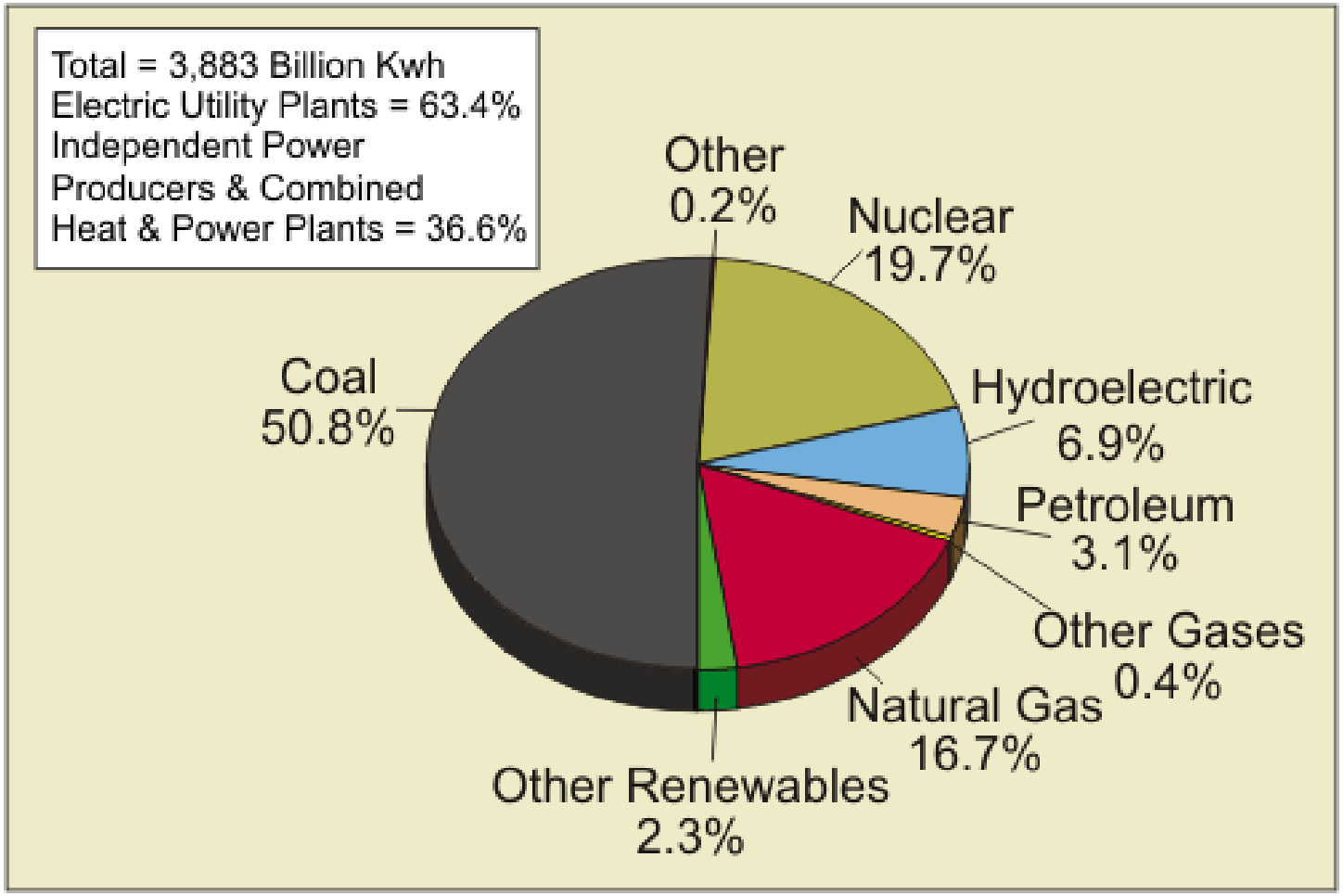
- The “2% Solution” recognizes that an 80% reduction by 2050 means that each of the 40 years until then we must impose a 2% cut. The mathematics really requires that if we build any set of power plants or renewables that will last 40 years, the facilities built must each be at an 80% reduction in emissions.
- We also must replace all present fossil fuel plants or sequester their CO2 output.
- The US 2020 goal for new vehicles of 35 mpg over the present 26 mpg average, is actually a 30% reduction in greenhouse gases per vehicle mile.
- Today, solving global warming is lower in priorities compared to the economy, unemployment, the housing market, and healthcare.
- The US goal is to cut CO2 emissions by 17% from 2005 levels by 2020, and 83% by 2050.

Sources of US Electricity

On average, we use 460 Gigawatts (billion watts)

Summer demand is 760 GW (Gigawatts)

Average cost is 10¢ per kilowatt hour (kWh)



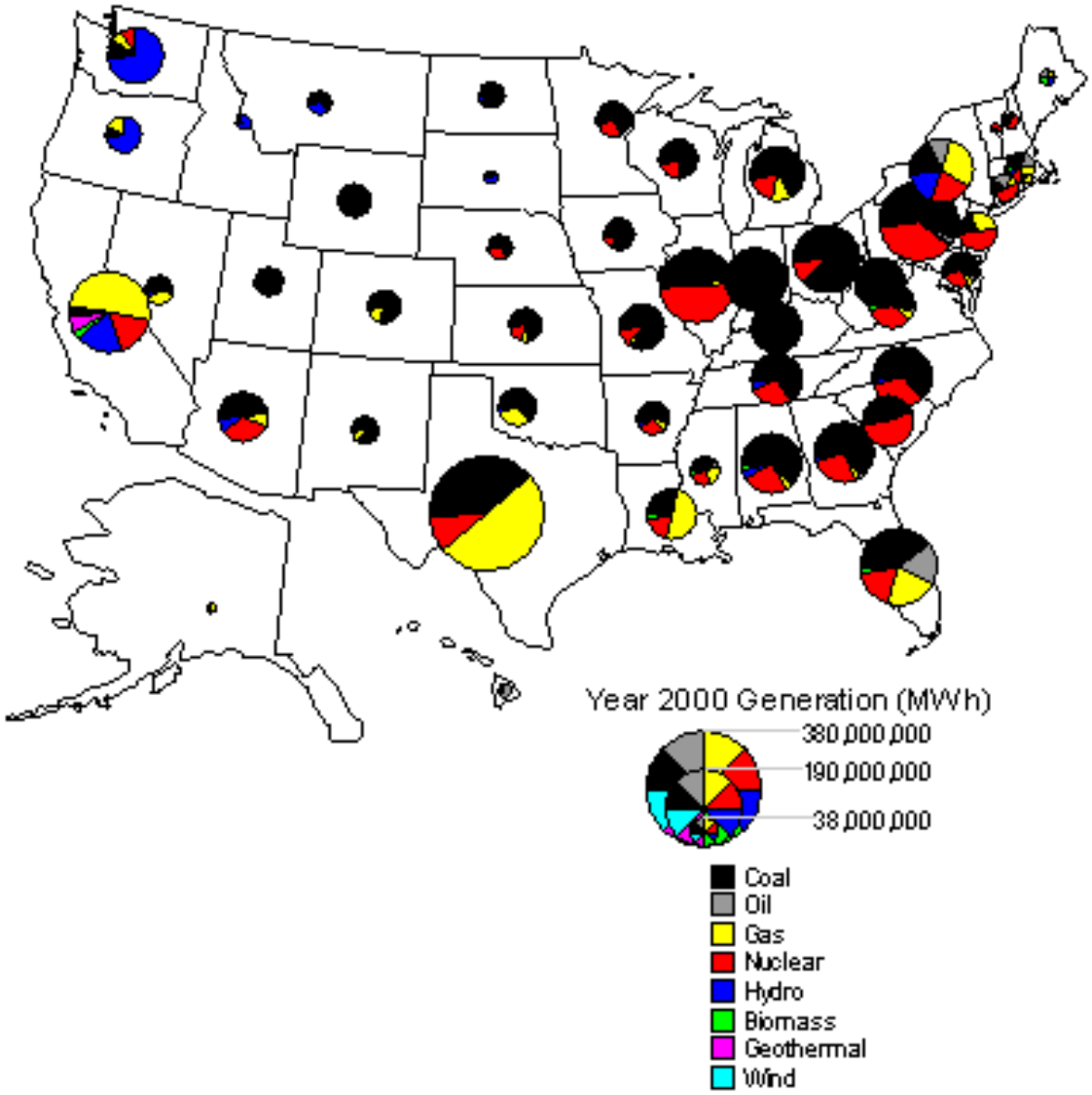
Cap and Trade

- In the new energy bill is a cap-and-trade system, whereby utilities get an allowance or cap on greenhouse gas emissions, and then must buy carbon credits to generate more.
- Generators that install technology to lower emissions can sell their excess credits.
- Non emitting energy sources such as renewables should also be able to sell their credits. Nuclear is not yet included. Steel has an exemption.
- However, 85% of the credits are initially to be given away free to existing industries.
- The emissions cap will decline about 2% a year:

  "utilities to supply an increasing percentage of their demand from a combination of *energy efficiency savings and renewable energy* (6% in 2012, 9.5% in 2014, 13% in 2016, 16.5% in 2018, and 20% in 2021-2039)", and for the longer term,

  "cap and reduce GHG emissions, annually, so that GHG emissions from capped sources are reduced to 97% of 2005 levels by 2012, 83% by 2020, 58% by 2030, and 17% by 2050"

US Power by State: Black is coal, yellow is natural gas, red is nuclear, and blue is hydro



Cost Analysis by the Congressional Budget Office

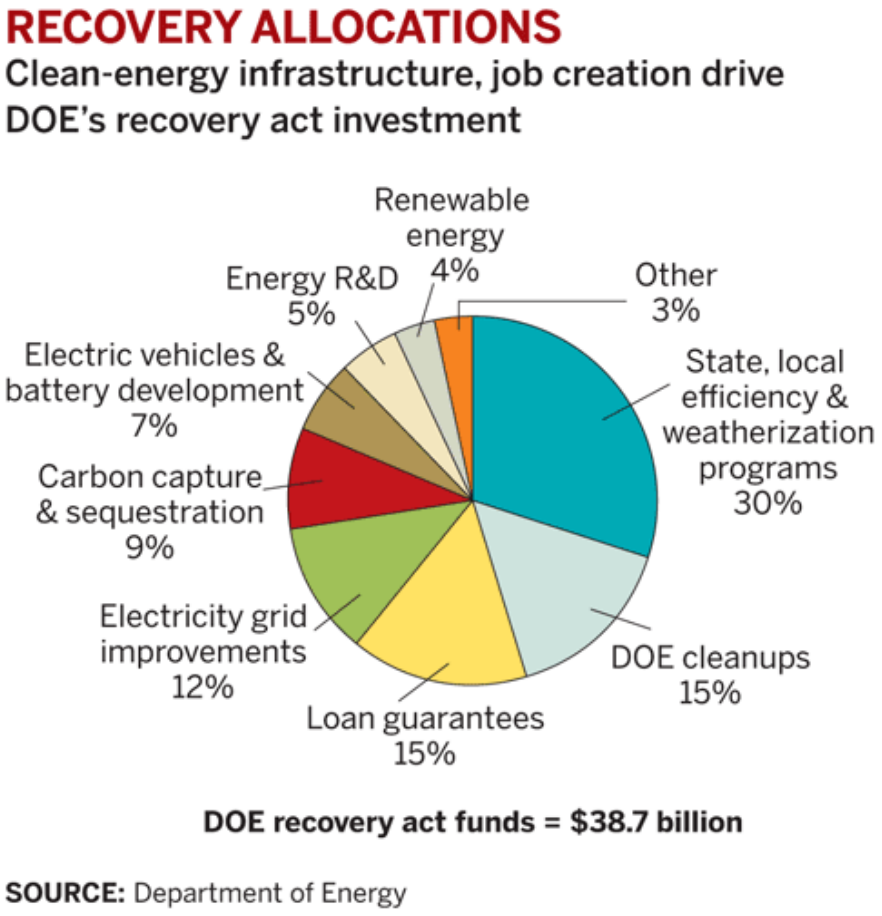
- The bill is called “The American Clean Energy and Security Act of 2009” (ACES)
- The bill has been passed by the House.
- The senate may debate its bill next spring.
- By 2020, the Congressional Budget Office estimates the net cost at about $175 per household, for a total cost of $22 billion. The carbon credits do go to companies to produce greener power, or to pay for carbon conservation or sequestration projects like forests.
- The cost per household is expected to be between $98 and $140 a year, if the household rebate from sale of credits is included in the bill, including about $1,000 in rebates for energy savings appliance and household energy savings.
- The alternate, a straight carbon tax, apparently would not pass in the US.

Costs of the Cap and Trade Bill

- The report by the Congressional Budget Office involve large cancellations of costs and rebates, so the smallness of the results seems questionable.
- They also did not include the benefits of mitigating the consequences of global warming, estimated by the UN to be $49 to $171 billion a year, but possibly 2-3 times as much as that.

Quintile	**Net Cost $/yr**	**% of Income**	**% share of cost**
Lowest	-40	-0.2	-5
Second	40	0.1	5
Middle	235	0.4	28
Fourth	340	0.4	41
Highest	245	0.1	31
All Households	165	0.2	100

Recovery Act $39 Billion Funding for the Department of Energy



U.S. Energy Research and Development

- From the American Recovery and Reinvestment Act (ARRA) stimulus bill, the Department of Energy will receive $39 billion for clean energy research, development, demonstration, and deployment.
- $6 billion will be in new loan guarantees will stimulate tens of billions in new financing for renewable energy facilities.
- DOE would have hosted a new ARPA-E to fund high risk energy technology research that would not be funded by industry, with a starting $400 million. The eight forefront research labs in different energy areas have now been reduced to one by congress with a funding of $35 million.
- 46 Energy Frontier Research Centers will be funded over 5 years with $777 million.
- For example, in the new battery sector for automobiles, $2.4 billion is going to existing manufacturers as a stimulus, but little is going to research.
- Investment of $8 billion in high speed rail with $5 billion to follow in succeeding budgets
- Overall, the President wants research and development to be increased to 3% of the GDP from the present 2.7%, by adding $46 billion a year.
- Two thirds of R&D is contributed by the private sector, and one third by the government.

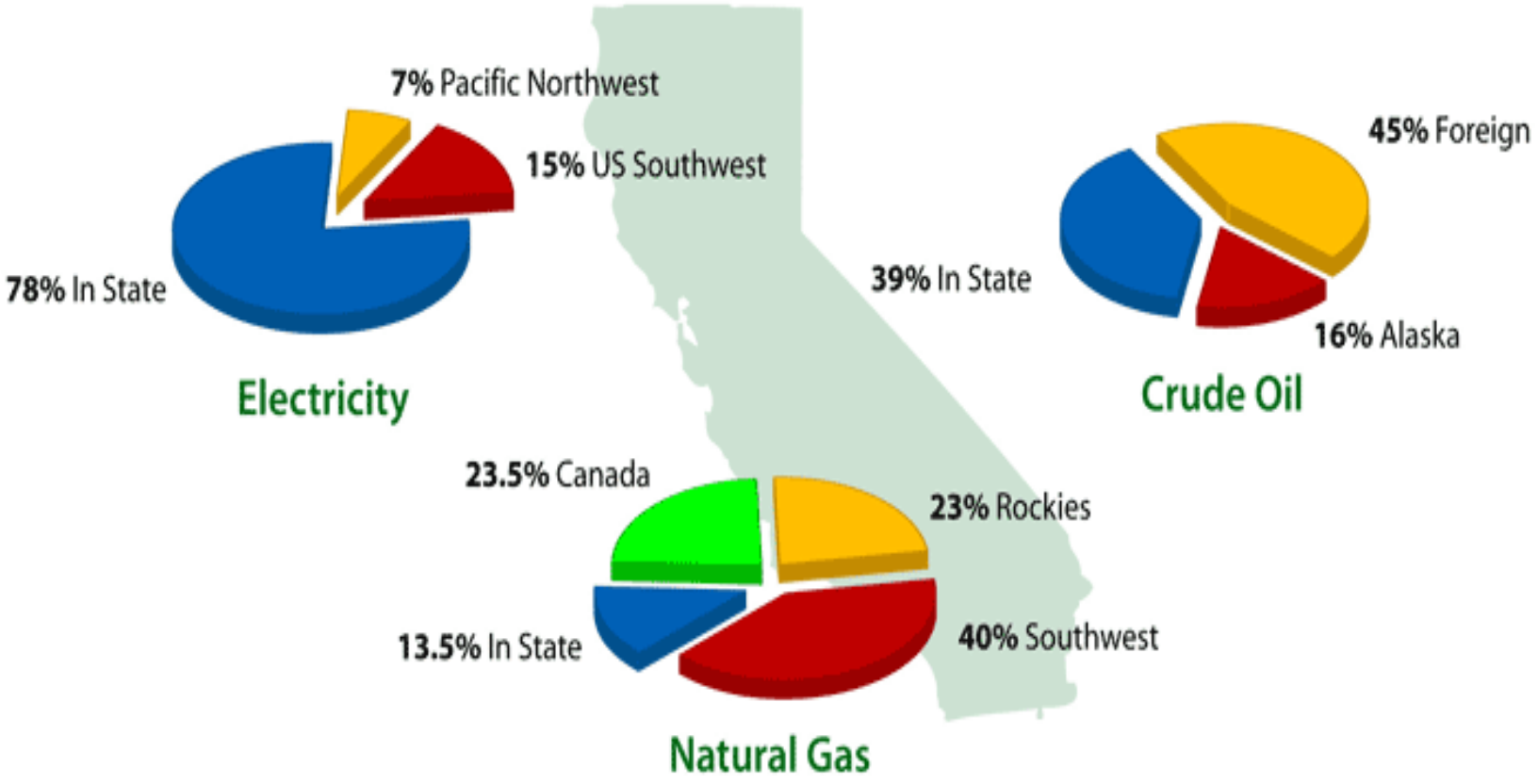
California Goals

- Californians already only emit 60% of the greenhouse gases of the US, per capita.
- "Renewables" does not include large hydro or greenhouse gas free nuclear power.
- For example, SC Edison already generates 38% of its power greenhouse gas free.
- California has a goal of 20% electricity renewables by 2010, although it may not be reached until 2013, with PG&E, SC Edison, and SDG&E behind in reaching the goal.
    - One delay is from needed approval for power lines and siting to sources in the east of the state or in Arizona.
- This week the legislature has passed two bills to require 33% renewables by 2030. These are SB14 and AB 64. They require that 80% of the sources should be in the state to enhance state jobs, but the Governor vetoed them since out of state power might be cheaper. Instead he made an executive order to reach the same goal.

California's Goals

- California AB32 goal is reduction to 1990 emissions by 2020, a reduction of 25%.
- On a per capita basis this has almost been satisfied in California.
- But state population has increased by 20% since 1990, so a cut of emissions by 22% would be needed to satisfy Kyoto by 2012.
- California Million Solar Roof plan is to generate 3 gigawatts by 2016.
- California Low Carbon Fuel Standard is a 10% reduction in carbon in fuel by 2020, meaning 10% renewables.
- California's goal is an 80% reduction in emissions from 1990 levels by 2050.

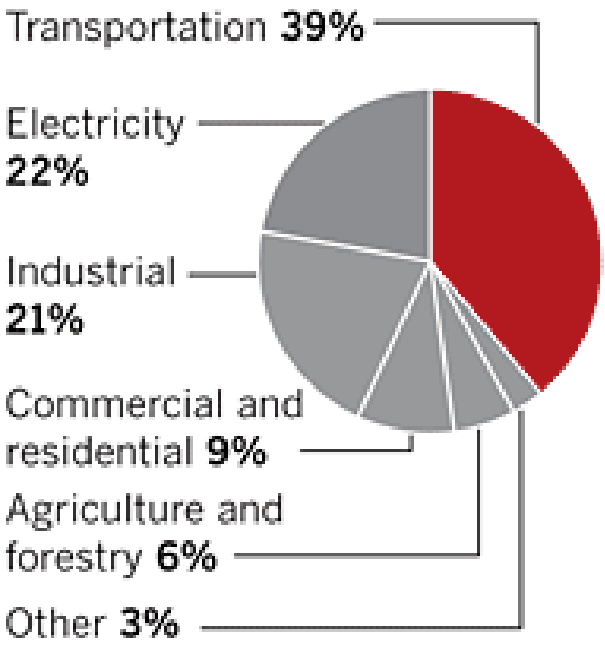
California Energy Sources



California GHG Emissions and Cap and Trade

California could become the first state with a cap-and-trade program to curtail greenhouse gases, part of its mandate to cut overall emissions by 15% below today's levels by 2020.

California's greenhouse gas emissions



How cap and trade would work

1. Government sets cap on overall emissions.

2. Government assigns "allowances," each one representing one ton of emissions, so that the total number equals the cap.

3. Companies are required to monitor and report their emissions.

4. At the end of the year, every regulated company is required to turn in allowances equal to their emissions for that year.

5. Businesses that don't reduce emissions enough must buy allowances from others that have met their targets.

Sources: California Air Resources Board, Environmental Defense Fund.
Graphics reporting by JULIE SHEER

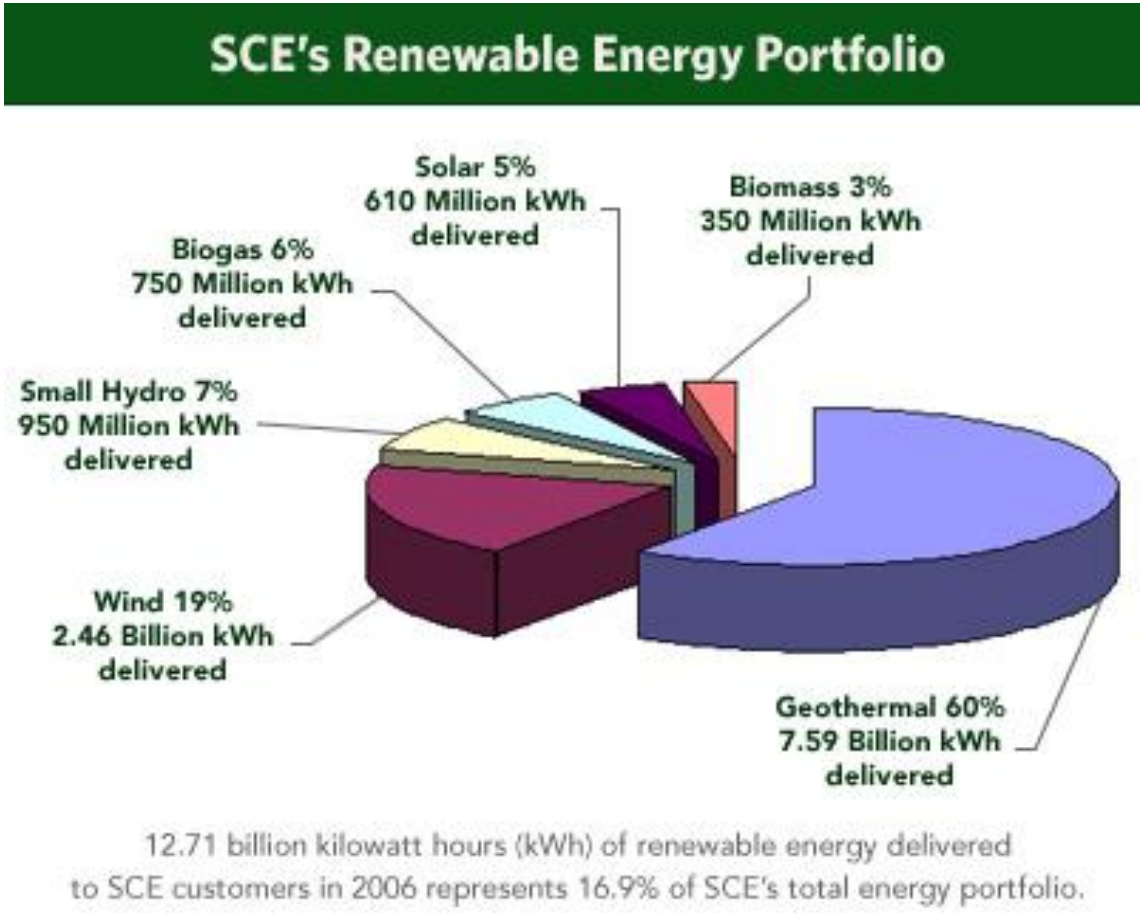
Los Angeles Times

Goals of U.S. Cities

- The Mayors Climate Protection Agreement of 969 cities (121 from California) is to match the Kyoto Agreement of a 7% reduction below 1990 emissions by 2012.
- These agreements cover 85 million Americans.
- Laguna Woods, Irvine, Laguna Beach and Santa Ana are local participants in this agreement. Newport Beach has a Task Force on Green Development.
- Los Angeles has an ethereal goal of eliminating its 44% coal power by 2020 and making renewable energy 40% of its portfolio.
- Local goals start with greening city government operations and buildings.
    - The California Green Building Code just took effect for public buildings, and parts will be compulsory in 2010 and 2011, including 20% water savings.
- Next are public transportation aids.
- Also are expediting private solar cells or solar water heating, and other energy saving building improvements.
- Included are public information programs on energy saving practices.

SC Edison Power Sources
Our Power is 38% CO2 emission free

- SC Edison power (serves 13 million people):
- Natural gas is 54%
- Coal is 8%
- Greenhouse gas free:
- Nuclear is 17%
  - San Onofre and Palo Verde reactors
- Renewables are 16% →
- Large hydro is 5%



Solutions in Conservation

- The cheapest and easiest solutions are in Conservation
- We are personally in control, and we can start now.
- Early mitigation of global warming saves costs in adaptation and suffering
- Conservation saves money as well as greenhouse gases
- For electricity, there is a factor of three leverage in savings of CO2 pollution since most fossil fuel plants are only 34% efficient.
- "Technology" already present to solve auto pollution:
  - Drive smaller, more fuel efficient cars.
  - Work at home some days or use communications to replace car trips.
  - Carpool or vanpool
  - Use modern communications instead of airline business trips
- Carbon offset investing to end deforestation or burning of agricultural wastes rather than plowing them under.
  - Deforestation generates a fifth of CO2 emissions worldwide
  - Require companies and government to pay for carbon offsets for required airline travel by their employees

Carpooling

- There are 24 bus routes connecting in Irvine
- But there are 90,000 single commuter routes driven daily in Irvine
- About 50 commuters leave within two miles of your home and go to work within two miles of your work
- Drivers can pick you up and drop you off at a standard time without walking to a bus stop and waiting, or requiring a bus transfer
- Commuters get to use the carpool lane
- Total savings to an employee carpooler at UCI is $500 in gas and $500-$750 in parking for a total of over $1,000 per year per carpooler.
- It also saves 8,000 miles driving on average, saving 4 tons of CO2 for each carpooler beyond the first (without each driver having to buy a Prius)
- Some industry or business employees can save much more on parking
- Carpooling also saves on smog and particulate pollution
- A fair amount of carpooling can save the state money that would have been needed for new freeway lanes
- A fair amount can also save time and emissions from stalled traffic
- About 10% carpool now, but new interest can bring this up to 15%.

Automotive Emission Savings

- Automobiles are by far the largest CO_2 emitters that individuals have control over.
  - A large commuting SUV emits 13 tons of CO_2 a year, as much as 3 residences emit
  - A typical car driven 15,000 miles emits 7 tons a year
  - A Prius emits 4.5 tons a year for the same distance
  - Average GHG emissions are about 22 tons of CO_2 per capita in US
- There are several simple things that people can do *now* to bring down these emissions, save money, maybe lower the price of gas, and save on highway construction
  - If you have two available vehicles, on long trips or regular commutes, drive the one with the lowest emissions
  - Obey the speed limits, and don't drive with rapid accelerations and braking
  - Driving 90 mph burns 40-50% more gas per mile than driving 65 mph
  - Combine trips
  - Keep windows closed, AC off, use econ mode for air
  - When available, switch to low friction tires

Residential Energy Conservation

- Nationally, households use 12,000 kWh per year, generating 16,000 lbs CO2.
- Californians use only 8,000 kWh per year due to decades of energy efficiency requirements on appliances.
- In SC Edison, 38% of electricity generated is already GHG free.
- Household electricity of 6,000 kWh per year with SC Edison generates 4,800 lbs CO2. About ¾ is provided at about 12¢ per kWh. After that the rate doubles to 24¢ per kWh. So initial conservation efforts pay off doubly!

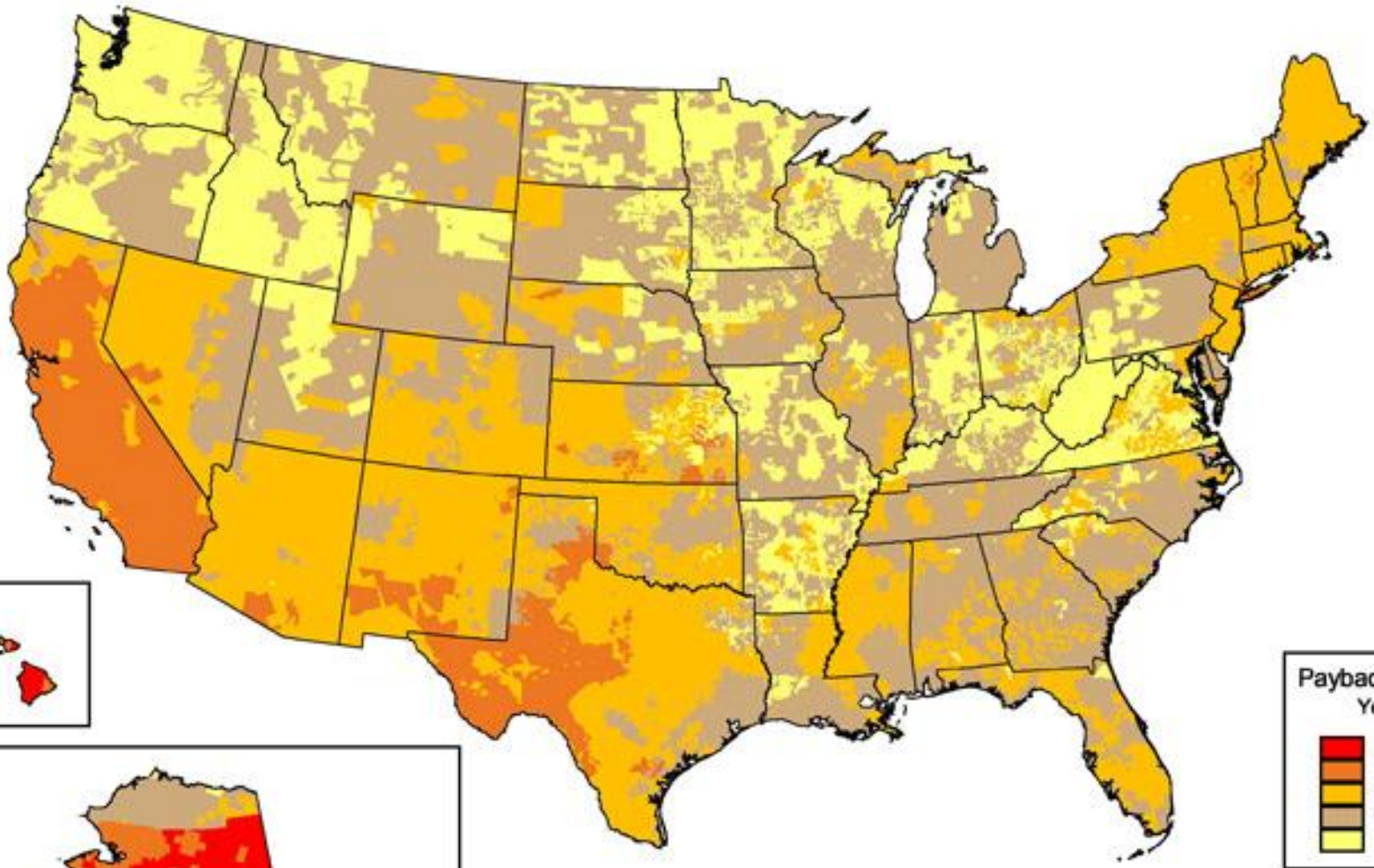
Energy Saving Tips

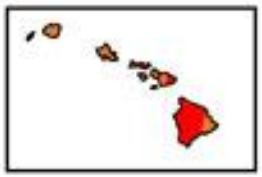
- A single plasma TV can use 10% of household electricity
  - A plasma TV can use 360 W compared to an LCD TV at 140 W.
  - Also the heat a plasma TV gives off may require that an air conditioner be used to cool the room.
- New TVs have energy conserving modes for less brightness at night
- Lighting is 22% of household electricity. CFLs cut lighting down to ¼ from incandescent bulbs. This reduces household electricity by 17% or about 1,000 kWh ($240 at higher rate) per year or 800 lbs of CO2.
  - The EU just banned new incandescent lights, and the US will in 2012.
- Replacing an old refrigerator and discarding a second one saves money and energy.
- California Million Solar Roof Program with typical 3kWatt system, costs about $20,000, but prices may come down soon. $7,500 CA rebate followed by 30% Federal Tax rebate ($3750). Net cost to the buyer is then only $8,750.
  - At 12¢ per kWh, the savings are $630 a year, at 24¢ per kWh, the savings are $1260 a year.
  - The 3 kWatt max only averages 3/5 kW year round, but gives 5300 kWh a year, which is most of a household's use.
- Recycling has been done since ancient times, and saves mining for metals, cutting down trees for newspaper and cardboard, and petroleum for plastics.

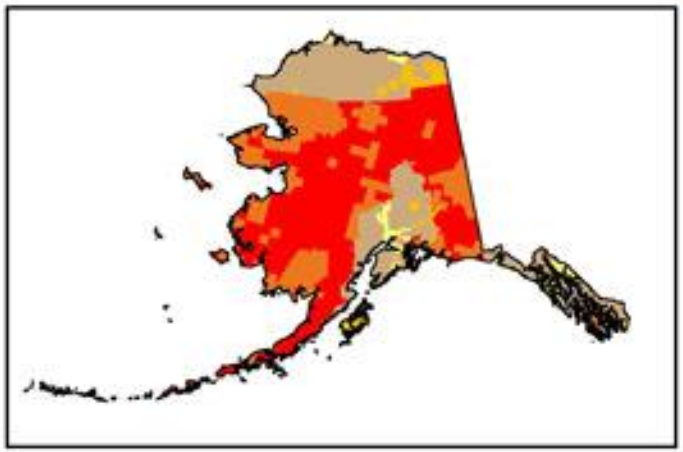
Household Water Heating

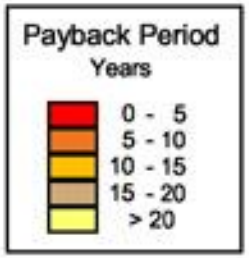
- Household water heating generates 2,300 lbs of CO2, about half that of household electricity.
- Rooftop solar water heating can supply 2/3 of your water heating, at an initial cost of about $5,000, minus state rebate of $1,500 and 30% Federal tax credit on the rest (about $1,000) for a net $2,500 cost.
- So solar water heating cuts half the CO2 of solar PV, but at ¼ the price.
- Other water heating savings are washing clothes in cold water (also stops shrinking) and using the dishwasher econ mode.
- Setting the water heater thermostat as low as is workable is another option.

Solar Hot Water: 2004 Payback Period









Assumptions:

1. Annual average solar resource potential using a tilt = latitude collector.
2. 2004 commercial electricity rates for utilities extracted from Platts POWERmap and POWERdat, ©2006, and supplemented by state average 2004 commercial electricity rates reported by the Energy Information Administration.
3. System cost = $900 per sq. m.
4. System efficiency = 40%

U.S. Department of Energy
National Renewable Energy Laboratory

NREL
05-JUL-2006 1.2.2

Household Space Heating

- Household space heating -- 2,300 lbs CO_2 per year
  - Design housing and buildings for less winter heating and less summer air conditioning
  - Passive solar: Eaves, awnings, outside shades, window tinting, window shades, drapes, shade trees, double panes, skylights, cool roofs, insulation, and fans, will protect against summer heat, and some winter heat loss.
- Heat and cooling conservation:
  - Control thermostat, manually or automatically.
  - Sleep with comforter, wear sweaters in winter.
  - Isolate unused rooms from heating in winter and a/c in summer.
  - Better insulation.
  - Turn off heat or a/c when leaving the house.

Household Water Use

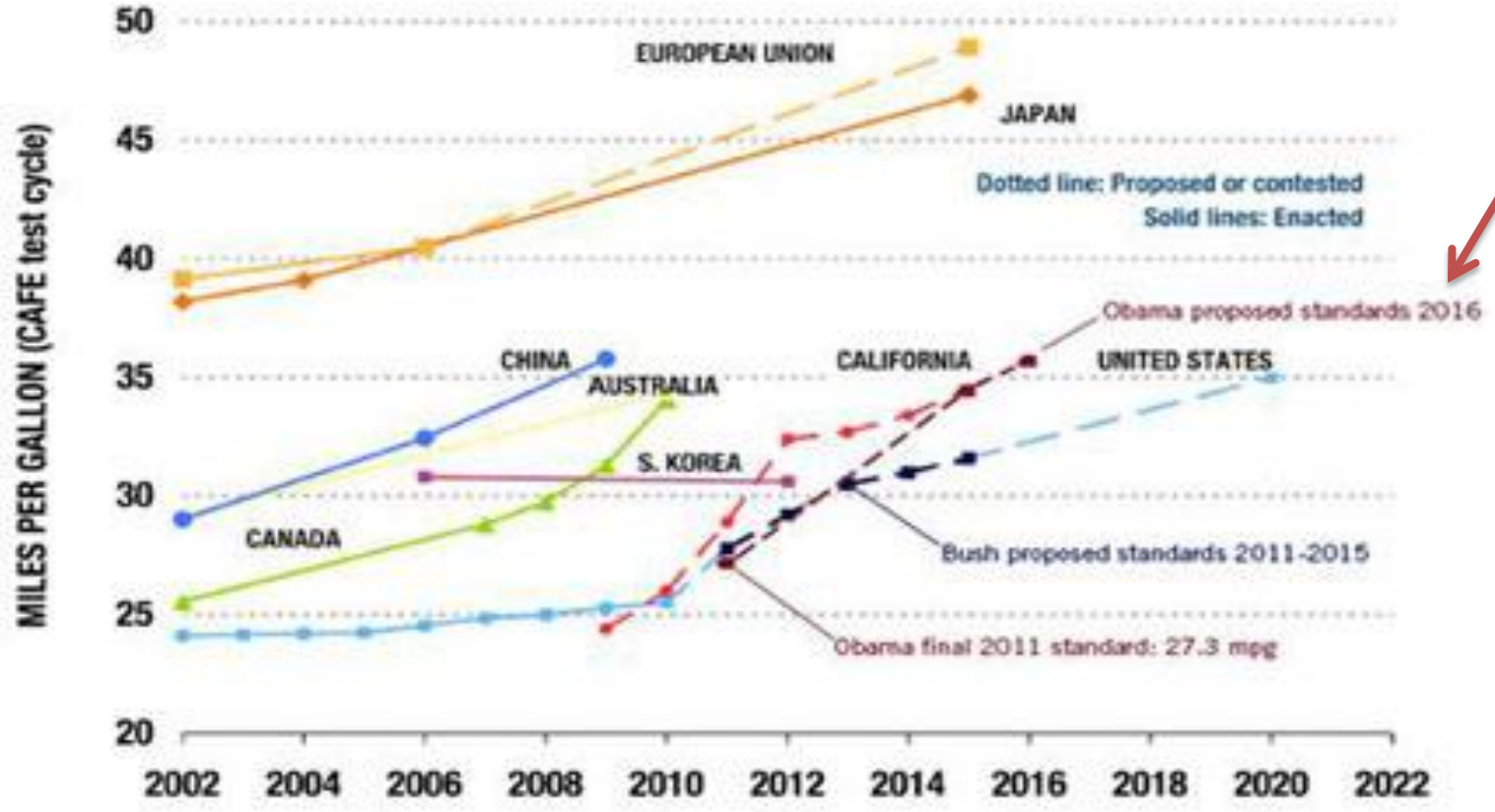
- Household water use adds another 18-25% to household energy use in Southern California (about 1,900 lbs CO_2), because of the long distance the water is pumped and the 2,000 foot high Tehachapi pass.
  - Half of the water is used outside for irrigation
  - Plants are often watered twice as much as needed
  - Use low water and drought tolerant plants and lawns
  - Water permeable paving will save water
  - Low flow shower heads and toilets are equipment related savings
  - Behavioral modes are taking shorter showers, using economy cycles in dishwashers and washing machines, shutting off the water during tooth brushing, and switching to an electric shaver
- These measures may also be needed if the Western drought continues
- The average SC residential water use is 125 gallons per person per day.
- The Governor's goal is to reduce per-capita urban water use by 20% over the next decade
- In 2008, California water was in danger of shortages
  - the Sierra snow pack was only 67% of normal
  - runoff into streams and reservoirs was only 55-65% of normal
  - deliveries from the Delta are cut to protect endangered smelt

Total Household CO2 Emissions

- SC Edison household total pounds of CO2 emissions are:
  - ✓ 4,800 electricity
  - ✓ 2,300 water heating
  - ✓ 2,300 space heating
  - ✓ 1,900 water delivery

  - ✓ 11,300 lbs CO2 Total or 5.7 tons of CO2 a year per household.
- Average car at 25 mpg going 15,000 miles per year uses 600 gallons and generates 12,000 lbs CO2 or 6 tons a year.
- So they are comparable, except that there may be 2 or 3 cars to an average three occupant household.
- So cars are the main pollution source that we have personal control of.

Actual and Projected Fuel Economy for New Passenger Vehicles by Country/Region, 2002-2022



Source: *Passenger Vehicle Greenhouse Gas and Fuel Economy Standards: A Global Update*, ICCT, December 2008 update.

Solutions That Are Ready Now

- Energy Conservation
- Carpooling
- Small or hybrid cars
- Energy efficient appliances
- Compact fluorescent bulbs
- Recycling
- Energy efficient homes
- Household solar water heating
- *All of the above also save money in the long run and are under our individual control and personal responsibility.*
- Wind power
- Solar thermal and photovoltaic plants
- Cogeneration of power and water heating
- Replacing coal plants with twice as efficient natural gas plants
- Nuclear Power
- *CO2 generated now lasts over 100 years in the atmosphere. Climate effects of it will be paid for by ourselves, our kids, our grandkids, our great grandkids, and maybe our great-great grandkids.*

Action Plans

- We must hasten to fund research and construct pilot plants to learn about new energy production, transportation or sequestration technology.
- We need a strong science education system to provide the scientists, engineers, and educated public as the backbone of this progress.
- Decisions can be phased in as we learn more year by year.
- Yet goals for 2050 must begin soon, since any power plants, homes, or businesses we build now will be present then.
- The 2% per year reduction in CO2 will lead to 80% reduction by 2050
- When we replace power plants or power generating industry infrastructure, however, we must replace them with 80% emission savings now.
- Cars, especially SUVs, can last 30 years, and it will take 5 years of automotive plant conversion to start replacing them, so we have to start planning to replace them now.
- Personal conservation choices in cars, solar water heating, and household electricity and heating are under our control.
- Considering the total invention and continual replacement of energy sources and uses that occurred over the last century, the future cannot be predicted, but we must explore as many possibilities as we can, and not prematurely close any off.

How to Approach Energy in a Recession

- Start with actions that save money and energy instantly
  - Car pooling, van pooling
  - Economical heating and cooling settings
- Invest in actions with shorter term monetary payoffs of 5-10 years
  - Insulation, minimize solar overheating
  - New fridges, rooftop water heating
  - Support loans if needed for these, as adding to mortgage
  - If buying a new car, make it an energy saving one
- Put stimulus money into energy saving projects and job creation projects, as well as research into making cheaper renewables and increasing efficiency
- If you are planning a project someday and have the money, do it now as prices are lower and you can stimulate the economy
- Avoid showy but expensive photovoltaic cells
- Utilities can invest in less expensive renewables such as wind and solar thermal

Lectures in Irvine

- UC Irvine University Club Forum
  - Wednesdays Lunch at 11:30 am
  - Buffet with dessert and drinks: $13.50
  - www.uclub.uci.edu

- OLLI: UC Irvine Osher Lifelong Learning Institute
  - On the web at : unex.uci.edu/olli/ (or just google: UC Irvine olli)
  - About 44 classes a semester, in science, humanities and sociology.
  - Membership is $150 a year for two semesters.
  - Covers Lectures at Woodbridge, UCI University Club and Laguna Beach
  - Laguna Beach lectures only: $20 to join, and $10 per class

- UC Irvine Public Lectures
  - today.uci.edu/calendar/

- This talk and my other articles and talks are on my website:
  - www.physics.uci.edu/~silverma/
  - Or just google: Dennis Silverman

New Energy Plans

UC Irvine
Osher Lifelong Learning Institute
Laguna Beach, CA
November 30 and December 7, 2009

Dennis Silverman
Physics and Astronomy
U. C. Irvine
www.physics.uci.edu/~silverma/

Topics

Lecture 1:

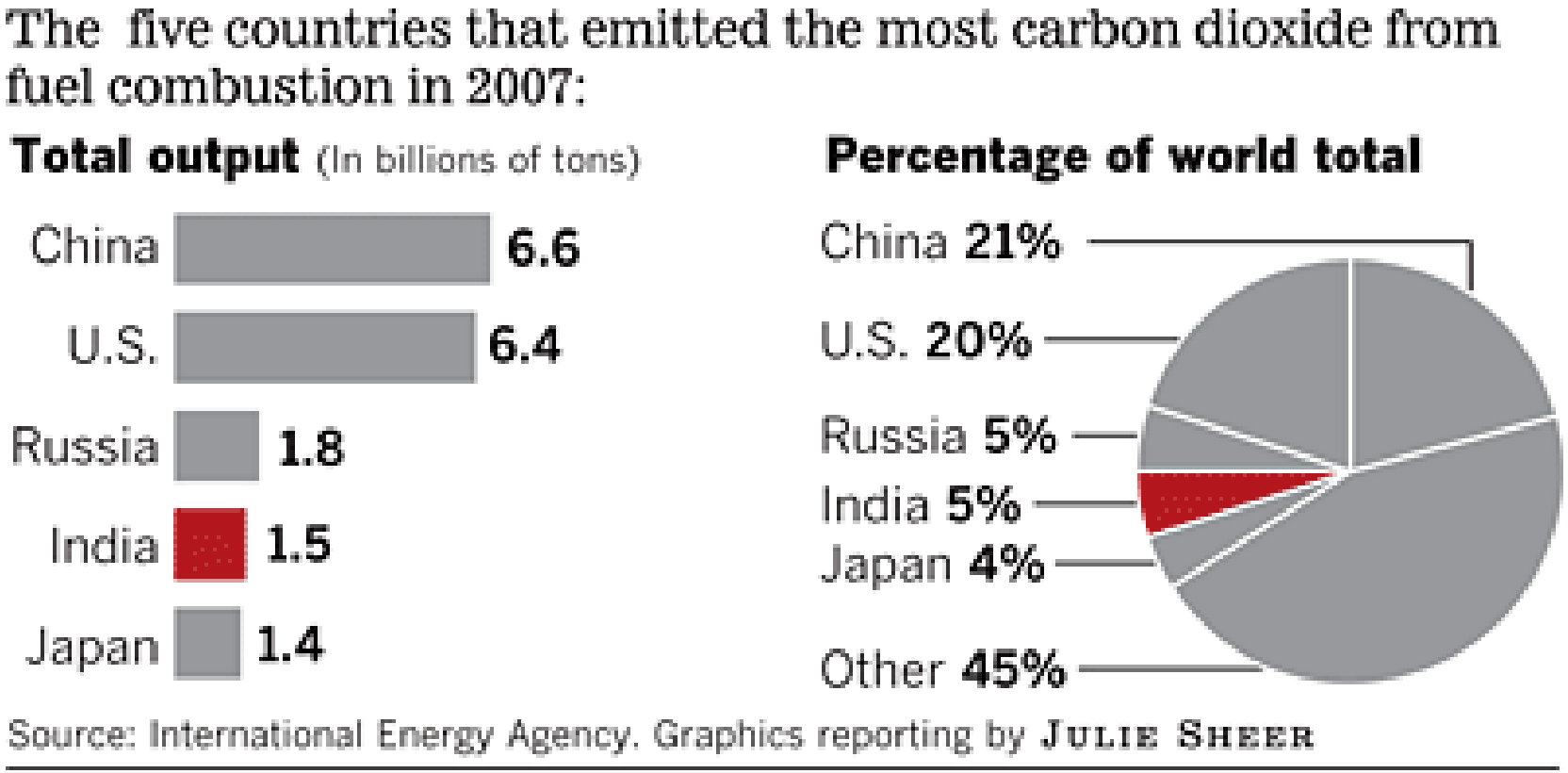
- Update Summary on Global Warming Motivation
- Energy Plans being worked on
  - World
  - U.S.
  - California
  - Local Cities
- Individual Energy Possibilities
  - Transportation Related
  - Easy Household Actions

Lecture 2:

- Automotive Advances
- Greenhouse Gas Free Sources
  - Nuclear Power
  - Solar Thermal and Photovoltaic
  - Wind Power
  - Geothermal Power
- Fossil Fuel Summary

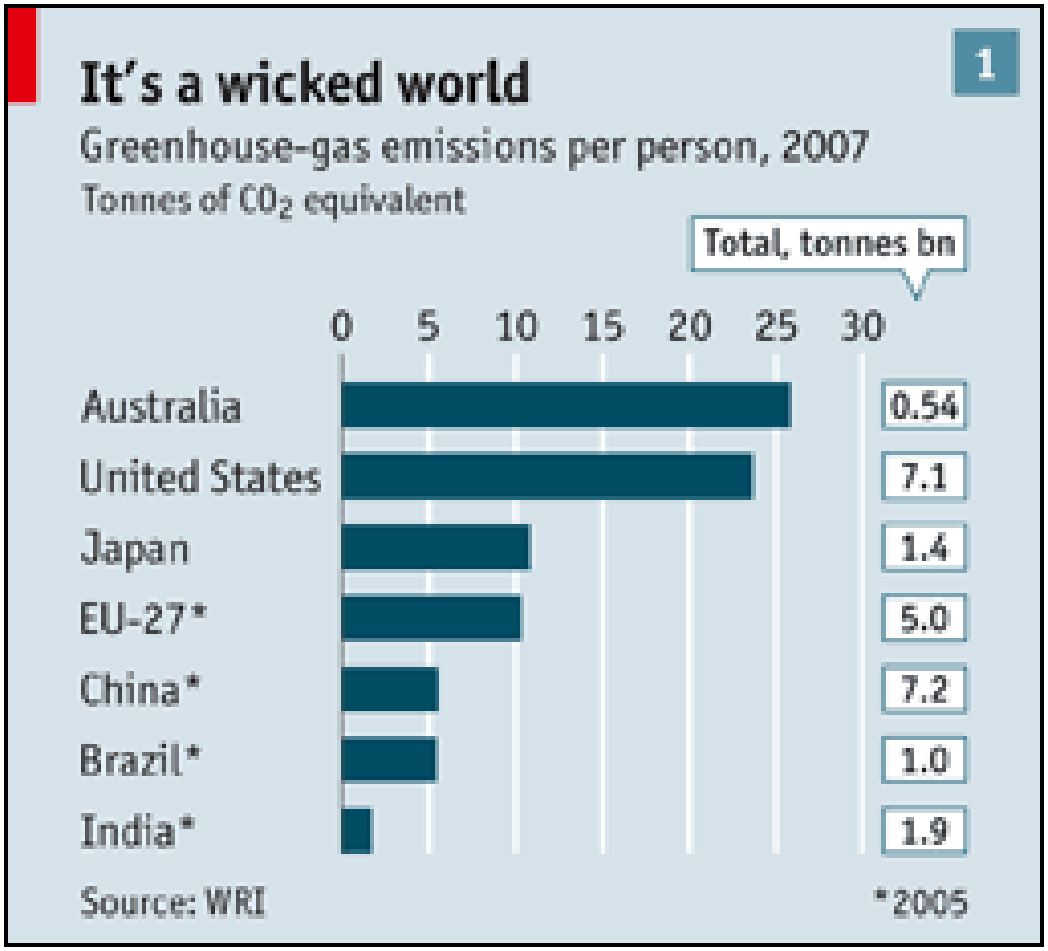
Top Five CO2 Emitting Nations

L. A. Times, Nov. 28, 2009



Countries Greenhouse Gas Emissions Per Person

U.S. Emissions have increased 17% since 1990



UN Climate Change Conference – COP 15
Copenhagen, Dec. 7 to 18

- Six simultaneous sessions
- Seven webcasts, both live and on demand
- Time on their schedule is Central European Time (CET), which is 9 hours ahead of Pacific coast time.
- 192 nations participating.
- Proposed cuts are close to what is needed.
- Official web site en.cop15.dk , also with a link to webcasts
- Direct webcast link unfcc.int/2860.php
- US goal is to limit CO2 to 450 ppm (now 386 ppm), which would limit total temperature rise to 2° C from preindustrial

Worldwide Negotiations in Copenhagen 2009

- This December 7-18 in Copenhagen, the United Nations will meet in the UN Climate Change Conference to work on new greenhouse gas emissions limits and a framework to follow the Kyoto protocol that ends in 2012.
- President Obama will go to the talks, and proposes the US will drop its emissions by 17% by 2020, 42% by 2030, and 83% by 2050 from 2005 levels.
- This is the goal passed by the House in HR 2454, the American Clean Energy and Security Act of 2009 (ACES).
- The Senate will not take up its climate-energy bill until next spring, but drafts have the same goals.
- President Obama has committed a fair share of the $10 billion a year support for cleaner energy and adaptation in the developing world.
- China wants to reduce its carbon intensity, or CO2/unit of GDP, by 20% by 2010 and by 40-45% by 2020. Its GDP is expected to rise by 60% by then, so its emissions will stay about the same.
- India plans measures to reduce its carbon intensity by 25% by 2020.

US Goals on Light Vehicles

- The previous Federal average of 35.5 mpg by 2020 has been moved up to 2016, consistent with California's goals.
- Over the present 26 mpg this is really only a 30% reduction in fuel use, since you have to take the reciprocal to get gallons per mile to calculate fuel use.
- Cars will average 42 mpg and light trucks and SUVs will average 26 mpg.
- The 30% reduction is on new cars in 2016, following increases of about 5% a year from 2012.
- It will take about 15 more years to be present in most of the cars on the road.
- Detroit will be putting out electric hybrid versions of most larger cars and light trucks.
- Other technology will be engines that shut down some cylinders at cruising speed (displacement on demand), turbochargers for more air intake, pressurized fuel injection to get more uniform ignition, and variable valve timing such as Honda's VTEC cams.
- Automobile efficiency has actually increased 46% since the CAFE standards were initiated in 1978, but that has all been used to increase vehicle weight, and not to improve mileage.
- California is already considering future standards beyond 2016, now that it has the legal right to set its own standards in regulating CO2 as a pollutant.

Autos Elsewhere in the World

•We note that Europe (EU) and Japan are already over 42 mpg in gas efficiency. Europeans use 1/6 the gas of Americans due to public transport, city structure, smaller cars, motorcycles, bikes, and walking. Half of European trips use public transport or walking.

•China is now producing 12 million vehicles a year, about the same rate as the US. However, it will take them 20 years at that rate to produce as many vehicles as the US has. About 40 out of every 1,000 Chinese owns a car. Their new cars must already average 35 mpg.

•India's new $2,000 car is said to get 50 mpg, and there are only 1-2 million a year being produced. So far, only 7 out of every 1,000 Indians own a car.

•In the US, we own 700 cars for every 1,000 Americans.

Chevy Volt Plug In Hybrid

- The Chevy Volt, due in 2010, is a plug in hybrid car. This means it has an electric motor and can run on gas, but also has a battery for electric only or combined power.
- The Lithium-Hydride battery pack uses batteries similar to computer batteries, weighs about 1,000 pounds, and stores 8 kWh of electricity. (Your 12.6 V car battery holds 0.5 kWh)
- The Volt can go 40 miles on battery power alone, and 70% of car trips are within that range.

Chevy Volt Equivalent CO2 Mileage

- The Chevy Volt can get 50 mpg as a hybrid operating on gasoline.
- Based on a trip of 40 miles electric only plus the 11 mile EPA mpg test course using gas, it was quoted as going 230 miles per gallon of *gas* used.
- However, since greenhouse gas CO2 emission is important for evaluating automobile systems, we have evaluated the electric only mode using the CO2 emissions from the utilities that produced the electricity to charge the battery .
- We then compare that to the 20 lbs of CO2 emitted per gallon of gas burned by a gas engine, and get an equivalent CO2 pollution miles per gallon.

Equivalent CO_2 mpg for the Chevy Volt or Nissan Leaf from different Electrical Utilities

- Weighting the power mixes of various utilities by their CO_2 generation gives the lbs of CO_2 per kWh for that utility. The equivalent mpg are:

Utility	CO_2 Equiv. mpg	Equiv. gallons for 15,000 miles
PG&E	145	100
SC Edison	100	150
Sacramento MUD	94	160
San Diego G&E	84	180
Los Angeles DWP	70	220
US Average	60	250
Coal Plant	38	390
Natural Gas Plant	68	220

Comparison of Electric with Gas and Hybrid Cars

- We note that the US Average electricity equivalent is only 60 mpg in all electric mode. This is only a 17% reduction in pollution from a 50 mpg Prius hybrid gas car. Yet the cost of the Volt is estimated at $40,000 versus the $25,000 Prius.
  - This is because half of US electricity is coal powered.
- Orange County or SC Edison gets an impressive equivalent 100 mpg rating.
- Yet a look at equivalent CO2 gas pollution production for a 15,000 mile distance shows a law of diminishing returns:
  - Cadillac Escalade city at 15 mpg, 1,000 gallons;
  - Present average gas car at 25 mpg, 600 gallons;
  - Average gas car in 2016 at 35 mpg, 430 gallons
  - Toyota Prius at 50 mpg, 300 gallons;
  - Chevy Volt US Average, 250 gallons;
  - Chevy Volt in Orange County, 150 gallons.

But Do Electric Cars Save Money Locally?

- We look at a 50 mpg gas car driven 40 miles, the Volt electric range, using 4/5 of a gallon at $3.00 a gallon costing $2.40.
- Now we assume that your increased electricity usage for charging the Volt takes you out of your Tier 1-2 cheap range, and into your 27¢/kWh Tier 4 range.
- (Charging 8kWh per day is about an additional 1/3 above average state usage.)
- Charging the Volt battery for 8kWh for the same 40 miles costs $2.16.
- So you save 24¢ a day.
- If you drive 40 miles electric each day, you travel 14,600 miles a year, and saving $0.24 each day you save $88 a year.
- If you could invest the $15,000 difference in the Prius versus Volt costs at 0.6% interest, you could make back the $88 to pay for the extra gas expense, and still keep the principal.

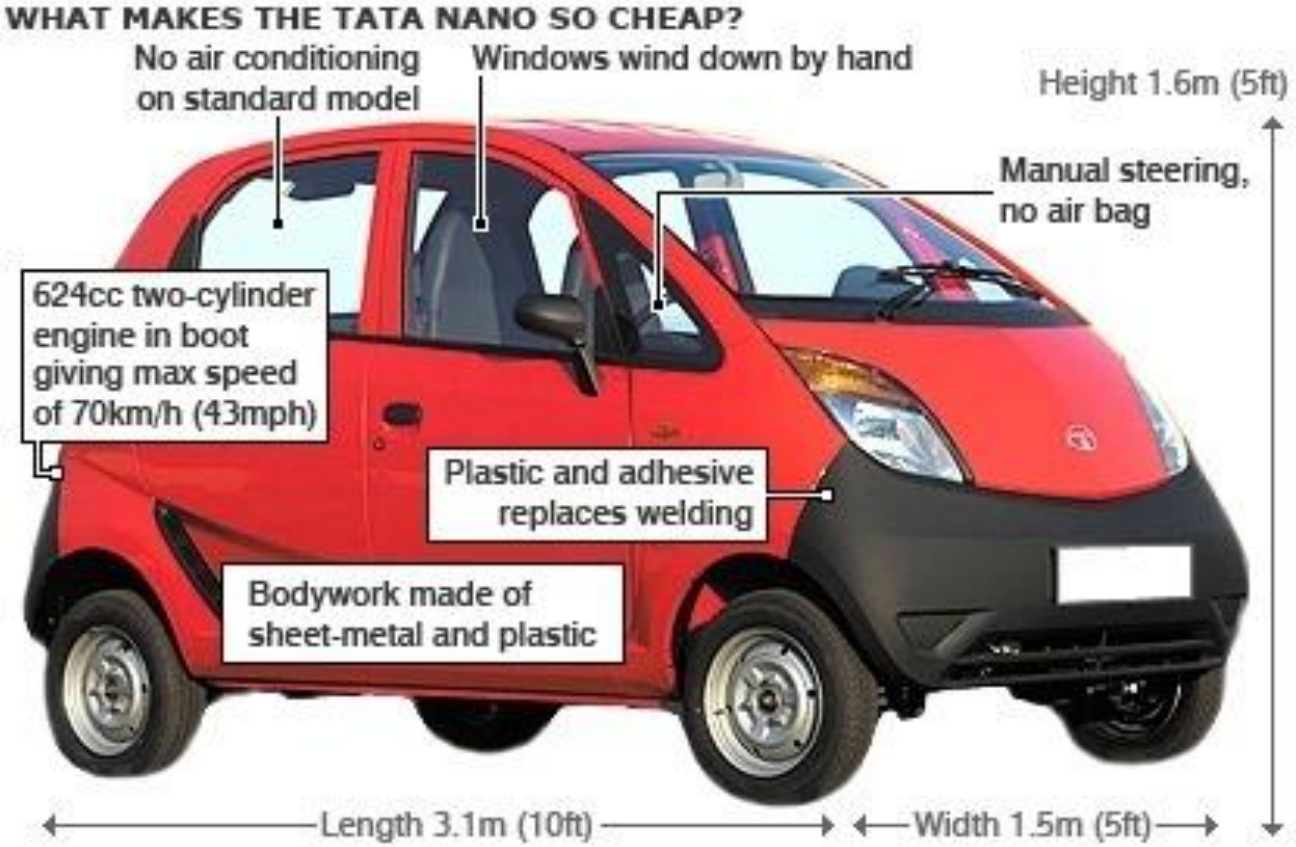
Nissan Leaf Electric Car

- In 2010 Nissan will come out with the Leaf which is all electric with a 100 mile per charge range, enough to cover 98% of daily trips.
- The battery has 24 kWh capacity, so the efficiency of 4 miles per kWh is the same as for the Volt and the table of equivalent CO2 emission mpg.
- The battery can be recharged in 4-8 hours on 220V, or 16-18 hours at 110V. It can be recharged in half an hour at a quick charge station.
- Mass production will begin in 2012 at a plant in Tennessee.

Tesla All Electric Roadster

- The Tesla Roadster is all electric with a range of 244 miles.
- It is made by Lotus and costs $100,000. The battery pack costs $20,000.
- It goes 0-60 mph in 3.9 seconds. Top speed is 120 mph
- It uses 177 W-h per mile
- It is 90% efficient, and has a gasoline equivalent of 120 mpg (where?)
- The battery is composed of 6,831 Li-ion cells as in a computer battery
- Its motor has 248 hp or 185 kW
- Its interim transmission will burn out in a few thousand miles

India's Tata Nano costs 1 Lakh or $2250
Gets 50 mpg and top speed 43 mph



Comparison Transportation

- An average 25 mpg car driven 15,000 miles per year uses 600 gallons of gas.
- Flying is equivalent to about 50 mpg per passenger.
  - So a 2,500 mile trip with return uses 100 gallons of fuel per passenger, and generates about a ton of CO_2 per passenger.
  - It also costs about $140 in jet fuel per passenger.
  - Modern communication technology can be used to save a lot of business air travel.
- With the average of 9 passengers, buses are equivalent to 27 mpg per passenger, about the current car average.
- But filled tour buses at 3 mpg with 55 passengers gives 165 mpg per passenger
- Walking is equivalent to 235 mpg
- Bicycling is equivalent to 635 mpg

Nuclear Power

- There are 440 nuclear plants worldwide.
- They generate 18% of worldwide electricity, at 350 gigawatts
- There are 103 US nuclear plants generating 20% of our electricity
- There are plans for 28 new nuclear power plants in the US
- 5 nuclear plants of 1.1 gigawatts serve California, for 16% of our electricity
- France now generates 80% of its electricity from 63 nuclear power plants and Japan generates 30% from its 44 nuclear power plants.
- The energy cost associated with producing the nuclear fuel is only 5% of the power generated.

Nuclear Facts

- Nuclear reactors do not produce CO2, SO2, mercury, or smog.
- Nuclear power is about a million times greater per atom consumed than fossil fuel power per atom.
- New French nuclear reactors are costing over $5 billion, however.
- US plants will settle on one or a few designs for preapproval, and reactors are estimated to cost $3 billion for construction to $5-6 billion including financing.
- California has a law against new nuclear plants until a waste disposal method has been approved by Congress. The cancellation of Yucca Mountain could set this back. The state is not including such plants in its future.
- A 1 gigawatt nuclear plant consumes 24 tons of enriched U per year, although from 25,000-100,000 tons of ore.
- An equivalent power 1 gigawatt coal plant generates 8 million tons of CO2, 200,000 tons of SO2, 200,000 tons of fly ash, and also arsenic, mercury, and radioactive radon.
- Nuclear power saves 2.4 billion tons of CO2 each year.

Nuclear Waste

- The direct plant waste from nuclear turns out to be on the order of 100,000 times smaller than from a coal plant.
- The highly radioactive waste of a US nuclear plant is about 50 tons a year.
- If all electricity were from nuclear plants, 50 years of waste for a family would be the size of a hockey puck.

Coal Strip Mining. Truck holds 400 tons of coal. This is enough for all the energy needs of one American for 60 years.

Yucca Mountain Nuclear Waste Depository

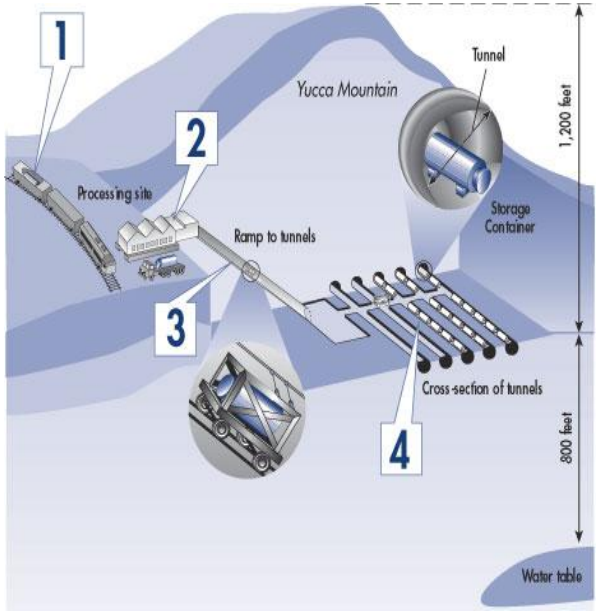
•Yucca mountain is a well chosen site and a designed solution to the nuclear waste problem.

•It also wouldn't be sealed for over a hundred years, and can be improved if needed. $10 billion has been spent on Yucca Mountain.

•However, development of Yucca Mountain has been halted and it use rejected by the present administration, although its license application is going forward, and may take three years.

•A blue ribbon panel will study disposal options, which may include on-site storage, or a few national sites which would be welcomed by the locals.

•Also under consideration is the option of reprocessing and recycling nuclear fuel which separates the bomb worthy plutonium. The recycling gives back about 30% of the initial fuel.



Counters to Nuclear Plant Criticisms

- The water inside the nuclear plant is never released. A separate water system drives the steam turbines.
- Nuclear plant safety has increased since the two nuclear accidents, with safety features being increased in monitoring and communications. No one was injured in the TMI accident, and the confinement vessel worked.
- There has not been a meltdown accident in the last twenty years, and new plants will be designed with more fail safe features.
- But, nuclear plants can't be built on small scales, so their costs may be $5 to $9 billion dollars each, with needed government guarantees for the financial risk of their non-completion.
- There are about 20 nuclear plants being planned for the US
- Present nuclear plants need some repairs and upgrades to extend their licenses for another 20 years from 40 to 60 years.
- After that they will need to be replaced to continue the 20% of US electricity that is generated greenhouse gas free by nuclear power.
- Building US plants does not lead to proliferation of nuclear weapons.
- The Central and Northeast states do not have the plentiful renewable energy resources of the West, and nuclear power is a more viable option for them.
- Still nuclear power in the US might not grow to be a much larger percentage of the electricity source, but its share should not be diminished.

Solar Photovoltaic Power

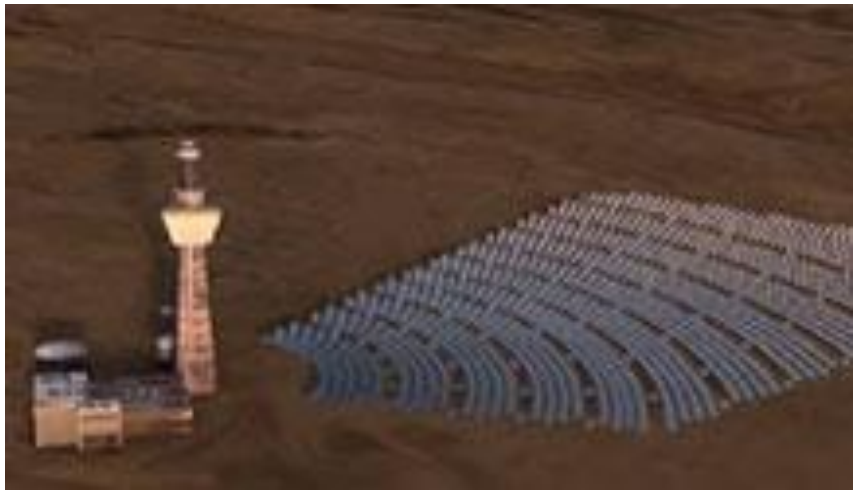
- Rooftop Silicon Based Solar Photovoltaic (PV) has recently come down in cost due to increased manufacturing and the economic slowdown.
- Solar concentrator PV of 500 mirrors focused on a more expensive but more efficient single solar cell is also competitive with straight solar cells.
- Solar power is for daytime, but misses the 4pm peak power needs.
- 30% efficiency loss if not tracking the sun.
- Year round average is only 1/5 of maximum capability paid for.
- Need to clean off dirt from cells.
- Need a south facing roof.
- But, the solar power source is present without continual mining or drilling.

Solar Energy Generating Systems (SEGS), and Mojave Solar Park in California

- The SEGS solar plant is the world's largest at 354 MW (megawatt or million Watts) covering 1600 acres. They have 936,000 mirrors.
- They use a reflective solar trough heating a pipe with oil at 300-400° C that eventually boils water for a steam turbine. End to end, the mirrors would stretch 229 miles.
- The Mojave Solar Park will be built by Solel by 2011 for PG&E and will have a capacity of 553 MW. It will have 1.2 million mirrors and 317 miles of tubing.
- It will also be a solar trough and will cover 6,000 acres or 9 square miles at a cost of $2 billion. This is about $3.60 per Watt. The oil and steam generators require water for cooling, however.
- The cost of sunshine never rises or is subjected to speculative bubbles.

Other California Solar Plans

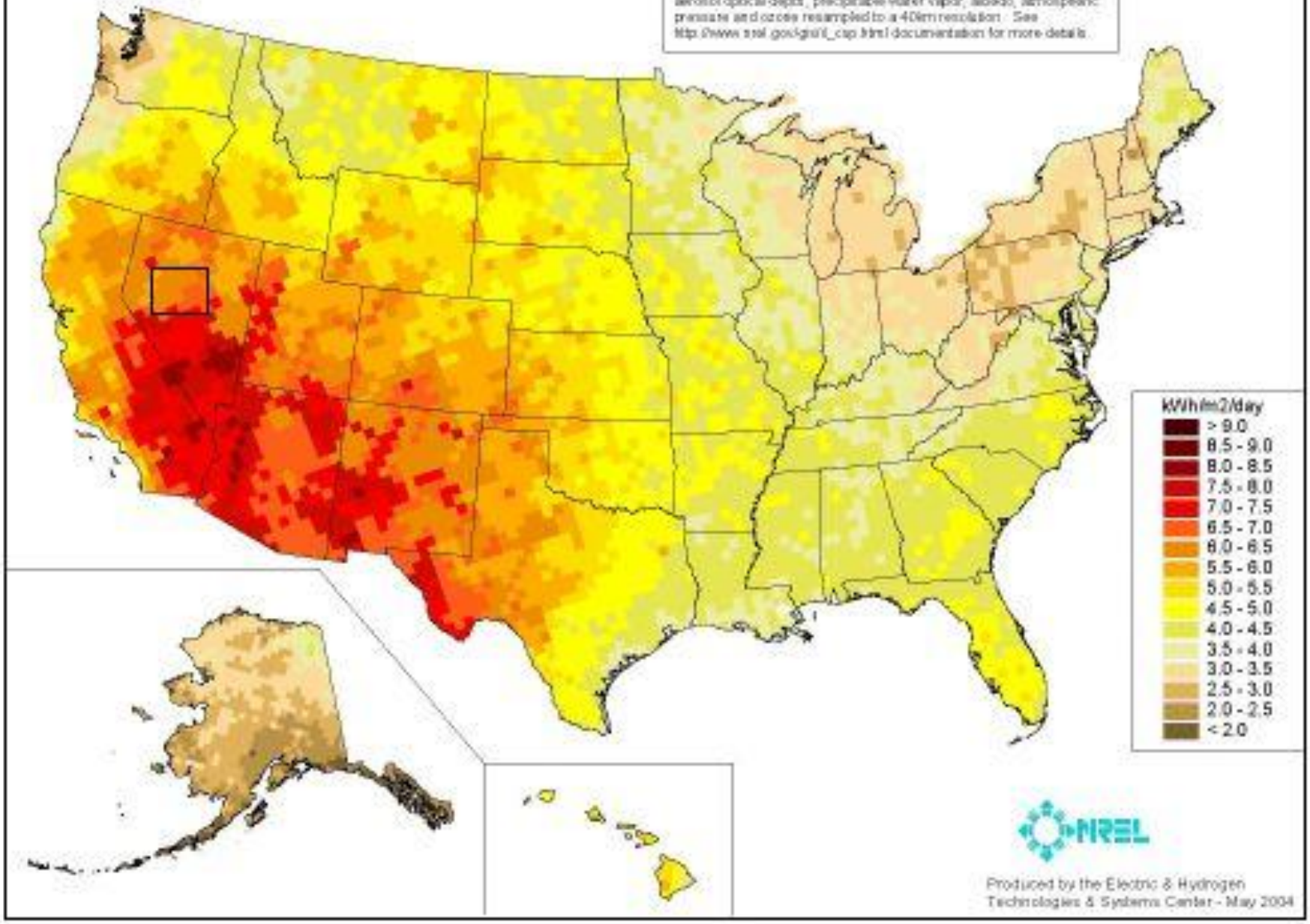
- A new SC Edison solar panel plan will cover 100 large rooftops of 2 square miles to generate 250 MW for $875 million. It will take 5 years to complete at $3.50 per Watt.
- PG&E with Ausra will build a 1 gigawatt (billion Watt) solar water plant with heat storage for $3 billion, at $3.00 per Watt. It can produce power for up to 20 hours a day.
- Total California announced solar plans are:
  - PV and Thin Film PV, 1400 MW;
  - Solar Trough, 3000 MW;
  - Solar Towers, 1800 MW;
  - Stirling Engines, 1600 MW.
  - ----------
  - Total: 7800 MW: Yearly average power is then 1.6 gigawatts.
- Solar power will receive salable carbon credits under the cap and trade bill.



Direct Normal Solar Radiation (Two-Axis Tracking Concentrator)

Annual

Model estimates of monthly average daily total radiation using inputs derived from satellite and/or surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure and ozone resampled to a 40km resolution. See http://www.nrel.gov/gis/sl_cap.html documentation for more details.



NREL

Produced by the Electric & Hydrogen Technologies & Systems Center - May 2004

Sizes of Solar Facilities

- Solar Power is less applicable to Northern or Eastern US, where it is a factor of two lower in intensity.
- There is already opposition to new power lines to the desert, and to disturbing any desert wildlife.
- It takes about 4 square miles of solar cells at 10% efficiency to generate a gigawatt (a billion Watts) of power at maximum exposure.
- Since total California electricity use peaks at 50 gigawatts it would take 200 square miles of photocells at peak sunlight to replace all of our electricity with photovoltaic power.
- To generate an *average* of a gigawatt in the California dessert, at 10% efficiency, takes about 13 square miles.
- Very large battery storage facilities are being investigated to smooth out the cloud fluctuating output of solar PV.
- Even large amounts of solar, such as 50%, only allow a reduction of 20% in natural gas plants used to cover the fluctuations in solar power.

Comparing Costs of Various Solar Power Sources

- The typical $20,000, 3kW max rooftop solar installation averages $7 / Watt max. However, with a 1/5 capacity factor, this is $35 / Watt average.
- Comparing the $3.50 / Watt max cost of utility solar in the desert or on large rooftops, to the house rooftop at $7 / Watt, shows that residential solar is twice as expensive as utility solar.
- Also, rooftop solar cannot track the sun, losing 30% in average efficiency.
- However, the cost to the subsidized buyer is only about $3.50 / Watt.
- Does the taxpayer get any benefit from subsidizing half the cost of installation? Subsidizes a nascent industry, cuts overall emissions, gift of savings and house value but owner must invest a lot of own money.
- Best buy: rooftop solar water heating now, at $5,000 per home, then subtract rebates of $2500.
  - Heating is free once installed and paid for.
  - Also, you can't buy hot water from a utility as you can electricity.
- For a house, solar water heating cuts half the CO2 of solar PV, but at ¼ the price.
- 38% of SC Edison power is already greenhouse gas free.
- Solar power is independent of foreign suppliers for fuel.

Thin Film Solar Panel Breakthroughs

- The Nanosolar company in silicon valley has announced they are about to manufacture thin film solar panels that are printed on an electrode, for about $1 per Watt of power, and sell them for about $2 per Watt.
- This is to be compared to the current silicon based panels which are grown like computer chips, sold at new low prices of $2 to $3.50 per Watt.
- For comparison, a nuclear plant, which also is greenhouse gas free with small fuel cost, may cost $3-6 per Watt. However, the solar cells still have the 1/5 utility factor.
- This also makes the new cells competitive with utility based solar thermal power and concentrating 500 mirrors on high efficiency solar cells.
- The printable nanoparticle thin film material called CIGS is made from copper indium gallium selenide.
- Venture capitalists have spent $344 million in this new thin film area, which also includes the companies Miasole, Solopower, Solyndra, and Ascent Solar.

- The thin film cells are also more efficient under low light and low angle light.
- They are produced in rolls and are much lighter than silicon or glass based panels.
- Thin films use less than 1% of the semiconductor material of silicon solar cells.
- New research is focused on depositing CIGS by a liquid, rather than by evaporation and deposition in a vacuum. Such an application may be 5 years off.
- There will also be thin silicon crystals less than 1/100 the thickness of the present ones. They have 8% efficiency and sell for about $1 per watt. They can cover windows or buildings.
- Per acre of field, a plug in hybrid charged with photovoltaic electricity is said to go 150 times further than making bioethanol from the same acre of corn.

Natural Gas Efficiency Increases

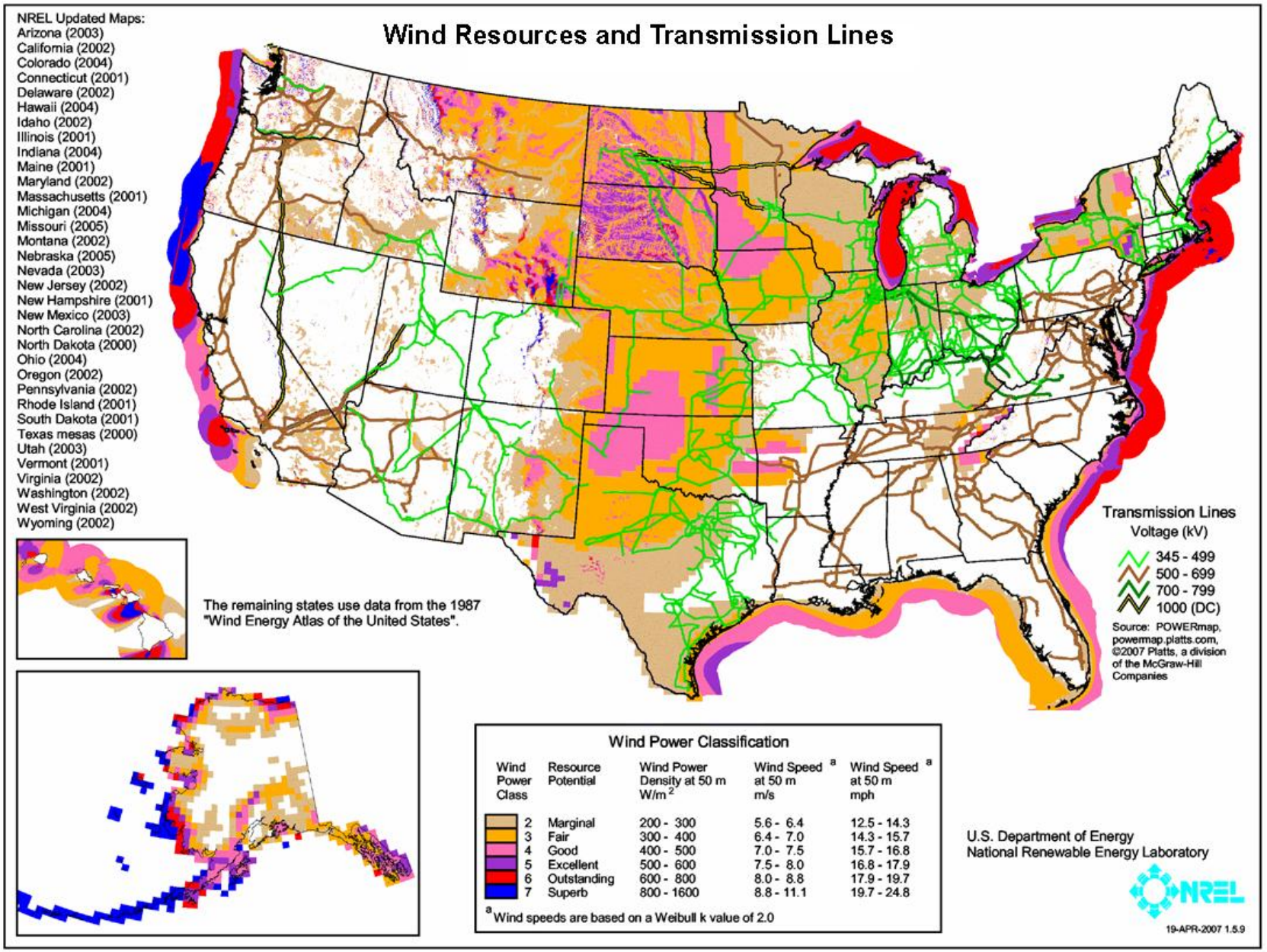
- Natural gas is methane, CH_4, which burns both its carbon and hydrogen, and is only half as polluting as coal, which only burns carbon to CO2.
- Natural gas provides 20% of US electricity.
- "Clean" natural gas plants with steam turbines only operate at 34% efficiency.
- Conservation Maxim: An amount of energy saved is three times the energy equivalent of fossil fuel that is not burned.
- The efficiency can be increased to 50% with new combined cycle gas products turbine followed by a steam turbine.
- With cogeneration of water heating where possible (CHP, combined heat and power), can increase efficiency up to 89%.
  - ConEd feeds steam to 100,000 buildings in New York
  - Also can do in small distributed power units
  - UC Irvine cogenerates most of its electricity from natural gas at night when gas is cheaper, and stores cold and hot water for daytime use

Wind Energy has been used for 2000 years
Sometimes, windmills *are* scenic

Wind Power

- The problem is that the wind fluctuates on all time scales:
  - Seasonally (highest in springtime, next in summer)
  - Varies with weather
  - Day – night switch in direction between ocean and desert in California
  - Dies out around sunset when peak power is needed
  - High velocity gusts are much more efficient than average wind
  - Wind velocity range of 12 to 30 mph is useable
- Yearly average wind power is only about 1/3 of the maximum capacity that the turbine is built for
- Tall is better: a 3 megawatt Vesta V90, has a 70 m tower, with 90 m diameter rotor.
- If built in an 18 m ocean depth, it goes down another 30 m into the seabed.
- Spacing needed is 3-5 times diameter side to side, and 5-10 times diameter in depth.

US Wind with Offshore Potential



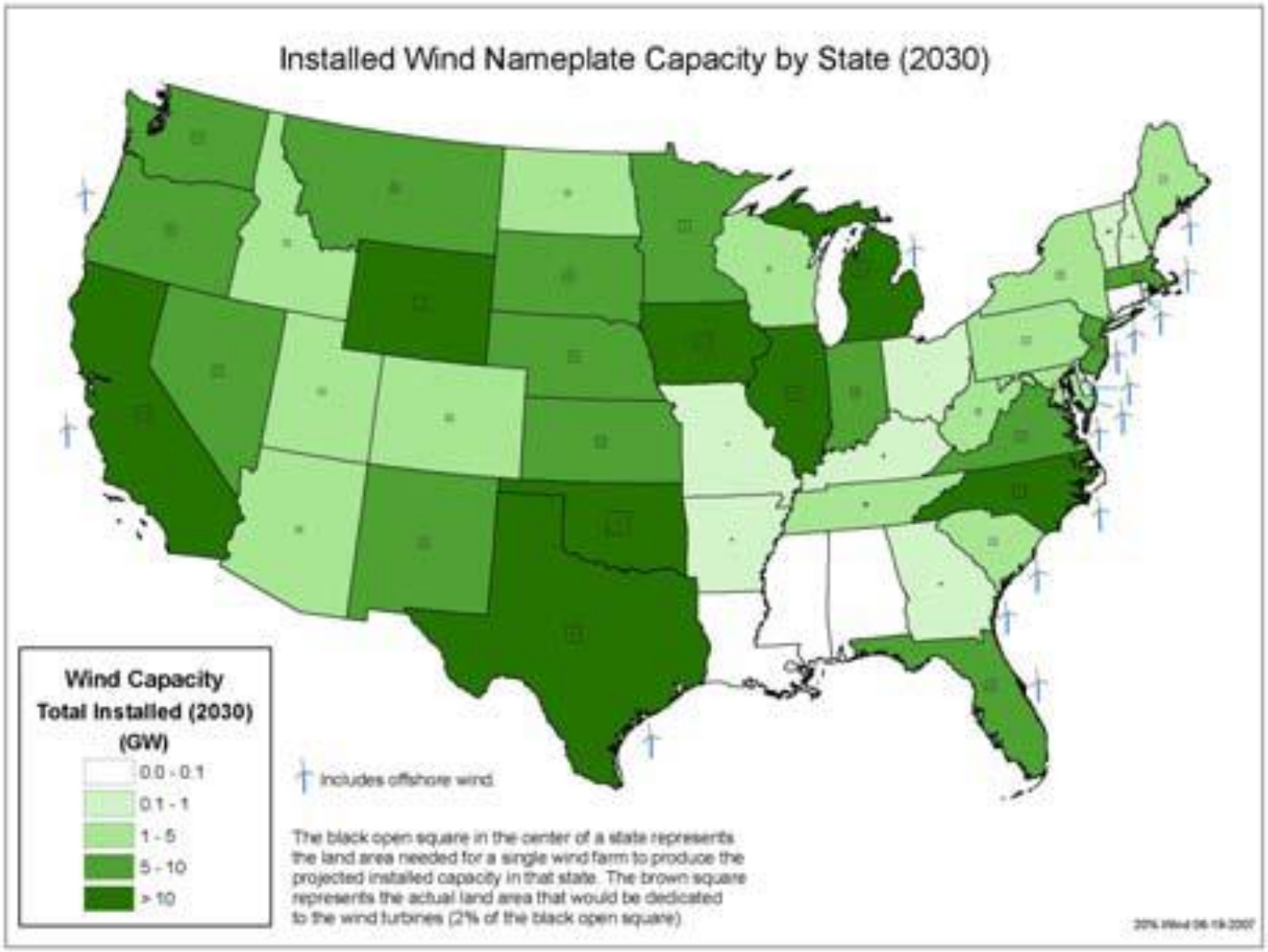
Wind Power

- A gigawatt max wind plant is estimated to cost $2 billion.
- Need 1,000 large and separated 3 MW wind towers to generate a gigawatt *on average*, as in a nuclear plant or a large coal plant.
- The *gigawatt average* plant would then cost $6 billion or $6/W.
  - At 360 m size plus spacing, it would stretch 360 km or 216 miles in a line
  - Spaced at 630 m deep, a 50 x 20 array would occupy 227 km^2 or 82 square miles
- Needs special mountain passes or mountain tops, or far out in the ocean, or a Northern or Midwest State
- The wind turbines have over 8,000 components, and requires a two person crew to maintain 8 of them.
- Europe has orders for the next two years of US production.

The Twenty Percent Wind Power Plan

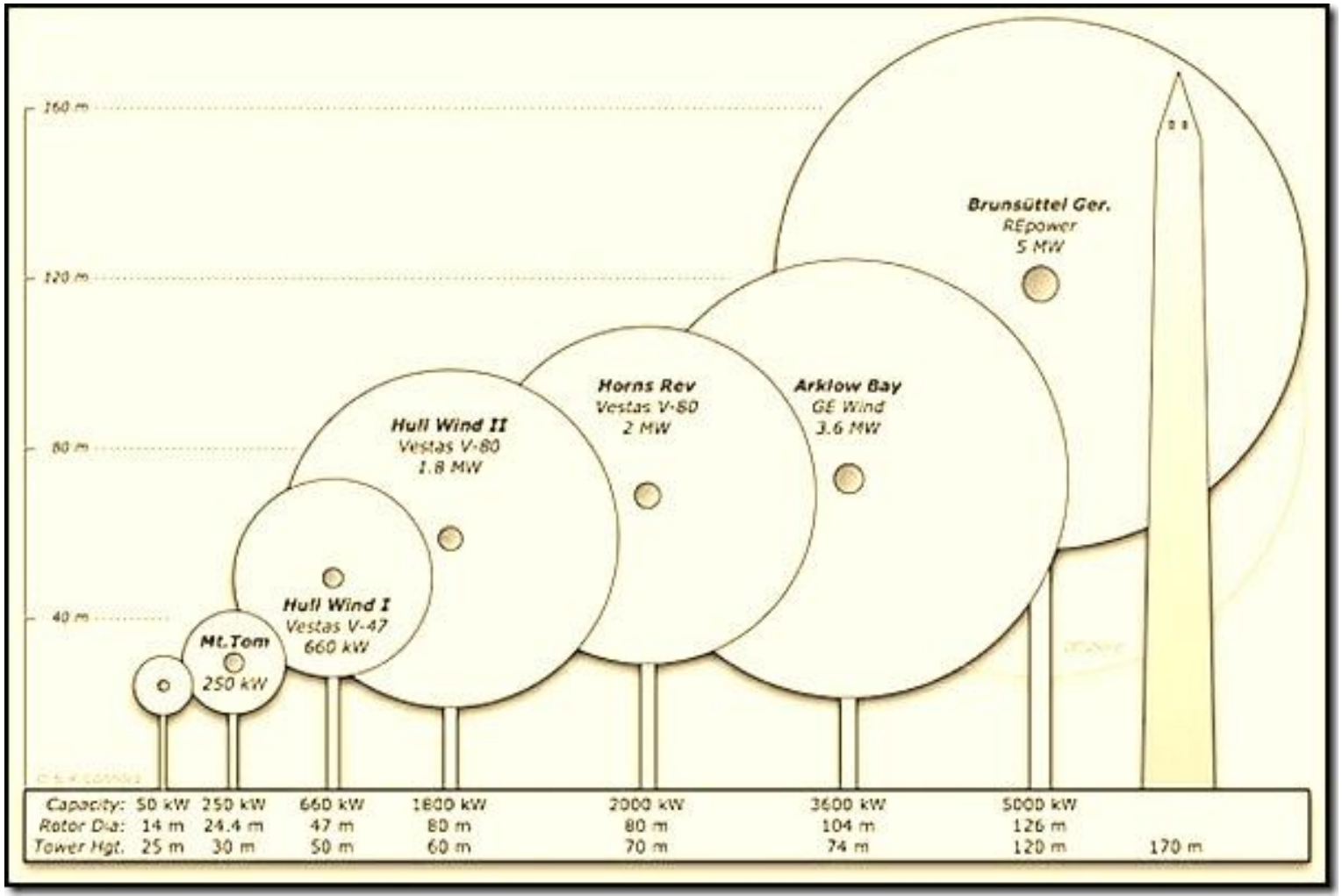
- A DOE plan is to provide 20% of US electric power by wind by 2030.
- It would have a capacity of 300 gigawatts, which on average would be 100 to 150 gigawatts, about as much as we now get from nuclear reactors.
- 240 gigawatts of this would be from wind turbines on land, and 54 gigawatts would be offshore.
- The average cost of US electricity is about 11¢/kWh.
  - The best land sites will cost 6-8¢/kWh (on 15 million co-used acres).
  - The best offshore sites will cost 10-12¢/kWh
- The plan would ideally add only 50¢/month to the average household bill.
- It would reduce utility natural gas by 50%, thereby reducing the price of natural gas to offset the costs of the wind turbines.
- It reduces utility coal by 18%, and avoids 80 gigawatts of new coal plants.
- Details of the plan are at www.20percentwind.org

DOE Plan for 20% of electricity from wind power by 2030
241 GW land, 54 GW offshore
50,000 square km, but only up to 5% actual structure
replaces 50% of natural gas, but only 18% of coal



Windmill Sizes

3.6 MegaWatt Windmill has a 74 m (81 yds) high tower, and a 104 m (114 yd) rotor diameter (Arklow Bay)



California Geothermal Plants

- California produces about 2 gigawatts of geothermal energy in 43 plants.
- This is about 5% of California's electricity.
- This is also about 40% of the world's production.
- There is the possibility of another 4 gigawatts from other sites in California.

Photo of Geysers Geothermal Power Plant courtesy of Calpine

What is the Smart Grid, Nationally?

- The smart grid is an electrical grid with modern information technology. Or, it is a candy store for whatever a given business or government agency wants it to be.
- Nationally, it will coordinate the phase of AC over a vast region maybe 20 times a second so that power is not wasted by interference.
- There are 3,000 utilities participating in the grid. The new grid will prevent overall collapse from local interruptions. It will help diagnose and route around such disruptions.
- Crucial elements will be above ground to allow for swift repair.
- It will be adapted to adding intermittent wind and solar power renewable sources.
- It would include large capacity, high voltage DC lines from Midwest wind sources to the eastern US ($200 billion estimate by Pickens).
- The grid will also have better cyber security from being hacked, as well as physical security from endangering power lines and equipment from natural or terrorist dangers.

What is the Smart Grid, Locally?

- The Obama Administration will support 40 million smart meters that transmit the power usage say every 5 minutes. Such meters are now used by utilities to record usage every month by driving by and picking up the signals.
- Computer and phone data programs will allow users to keep track of their immediate usage, and the current price of power in a smart metering system.
- Since peak power demand relies on using expensive backup sources, consumer behavior in avoiding such periods will save money and the need for peak power backup units which are only used a small part of the time.
- It may also encourage the use of energy saving appliances, good conservation behavior, and lowering air conditioner usage.

Comparison of Greenhouse Gas Free Power Sources

- When we compare costs on a 24/7 yearly average basis, we have to use a 1/5 capacity factor for solar and a 1/3 factor for wind, and 0.9 for nuclear after a number of years.
- Residential Solar PV $ 35/Watt
- Utility Solar Thermal $18/Watt
- Wind $ 6/Watt
- Nuclear $ 7/Watt

Solutions That Are Ready Now

- Energy Conservation
- Carpooling
- Small or hybrid cars
- Energy efficient appliances
- Compact fluorescent bulbs
- Recycling
- Energy efficient homes
- Household solar water heating
- *All of the above also save money in the long run and are under our individual control and personal responsibility.*
- Wind power
- Solar thermal and photovoltaic plants
- Cogeneration of power and water heating
- Replacing coal plants with half as polluting natural gas plants
- Nuclear Power
- *CO2 generated now lasts over 100 years in the atmosphere. Climate effects of it will be paid for by ourselves, our kids, our grandkids, our great grandkids, and maybe our great-great grandkids.*

UC Irvine Research Institutes in Energy and in the Environment

- Combustion Laboratory (UCICL) 1970
- National Fuel Cell Research Center 1998
- Urban Water Resource Center 2001
- Institute of Geophysics and Planetary Physics (IGPP) Multi-Campus Research Unit at UCI 2001
- Newkirk Center for Science and Society 2001
- Atmospheric Integrated Research for Understanding Chemistry at Interfaces (AirUCI) 2002
- School of Physical Sciences Center for Solar Energy 2007
- Henry Samueli School of Engineering Endowed Chair and Assistant Professor Position In Nuclear Waste Remediation
- UC Irvine Environmental Institute: Global Change, Energy and Sustainable Resources, 2008, with 8 new positions (postponed)
- Tri-alpha fusion research off campus

Tri Alpha Energy is a local fusion oriented company

- They hope to use the reaction:

  Boron11 (5p,6n) + Proton → 3 He4 (2p,2n)

  - This gives off energy as the He4 (alphas) are tightly bound.
  - The He4 are charged and their energy may be extracted electrically.
- Compare to usual fusion ITER in Tokomak:

  D (p,n) + T (p,2n) → He4 (2p,2n) + n

  - The neutron gives off energy by heat and radioactively decays
  - Tritium has to be produced by the n absorption on Li blanket
- But the Coulomb repulsion of the positive protons requires about 5 times as much energy in the Boron 11 case: 5x1, versus 1x1 in the D-T fusion, and hence about 5 times the plasma temperature for tri alpha.