# New Energy Plans

Science and Engineering Club
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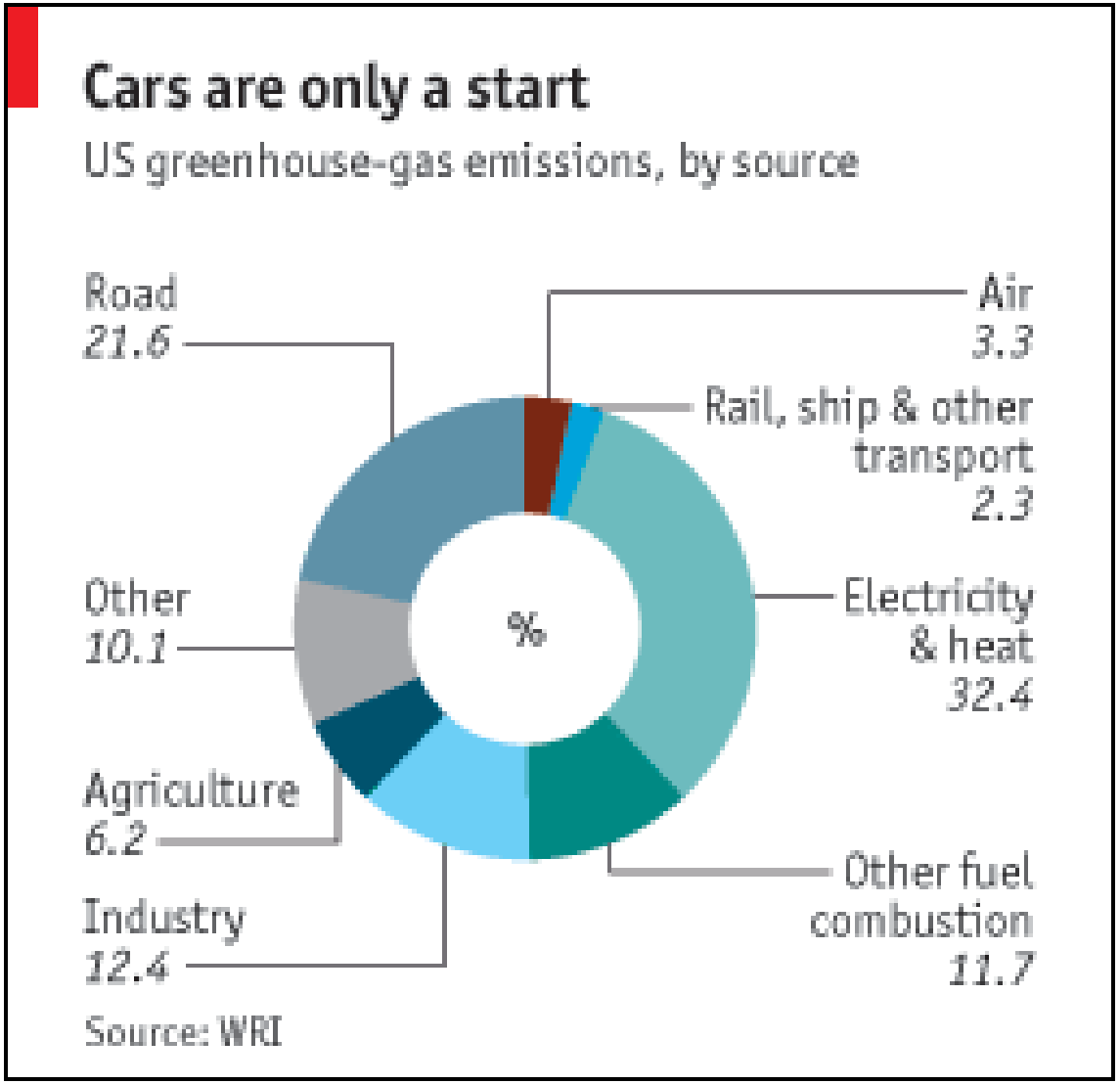
# Topics

- Greenhouse Gas Free Sources
  - Solar
  - Wind
  - Geothermal
  - Nuclear
- Automotive Plans
- Conservation
- Energy Efficiency

# Sources of US Greenhouse Gas Emissions

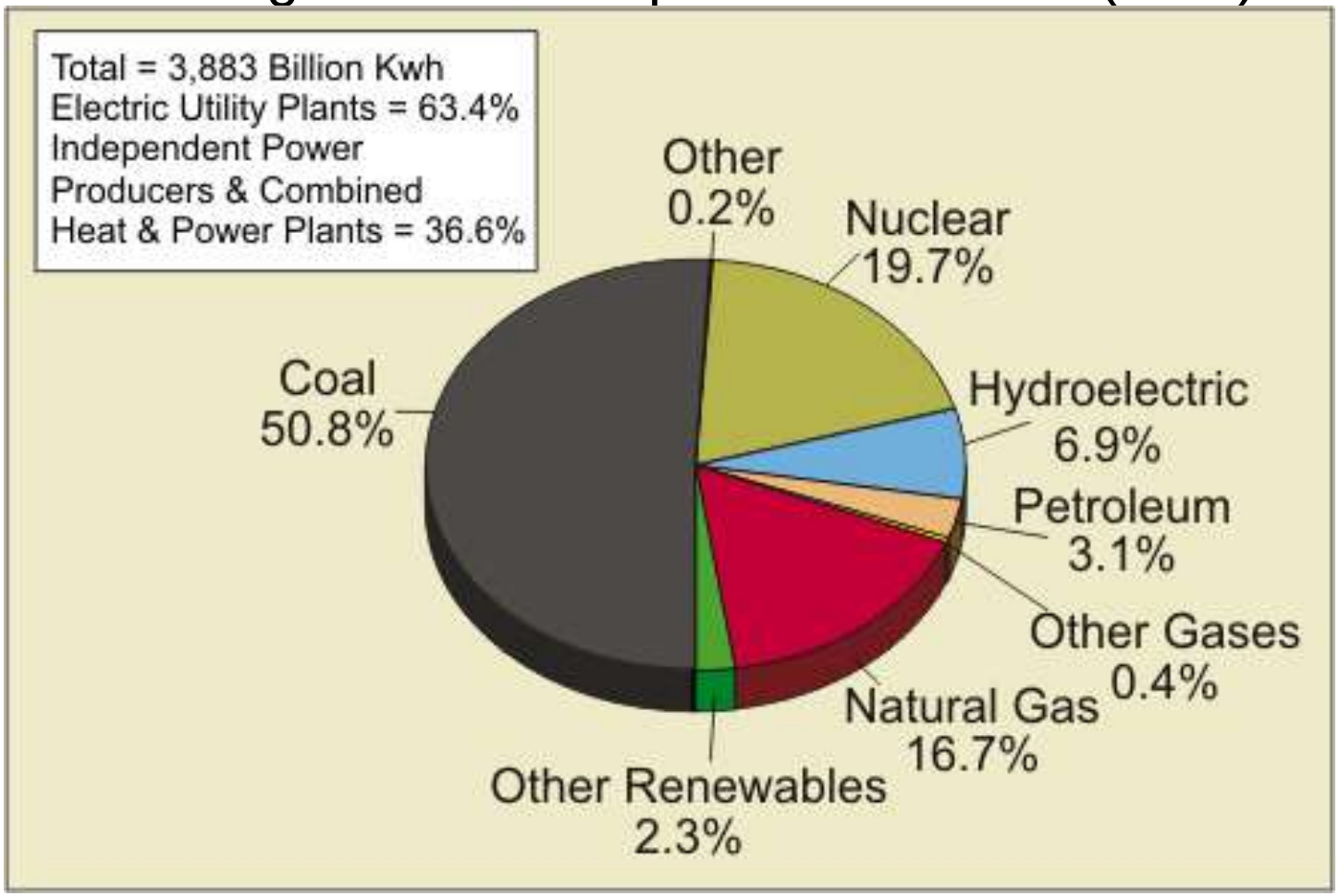


# Sources of US Electricity

On average, we use 460 Gigawatts (billion watts)

Summer demand is 760 GW (Gigawatts)

Average cost is 10¢ per kilowatt hour (kWh)



# Investments in New Power and Power Research in the Obama Administration

- The US will 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 goal is to cut CO2 emissions by 14% from 2005 levels by 2020, and 83% by 2050.
- 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.

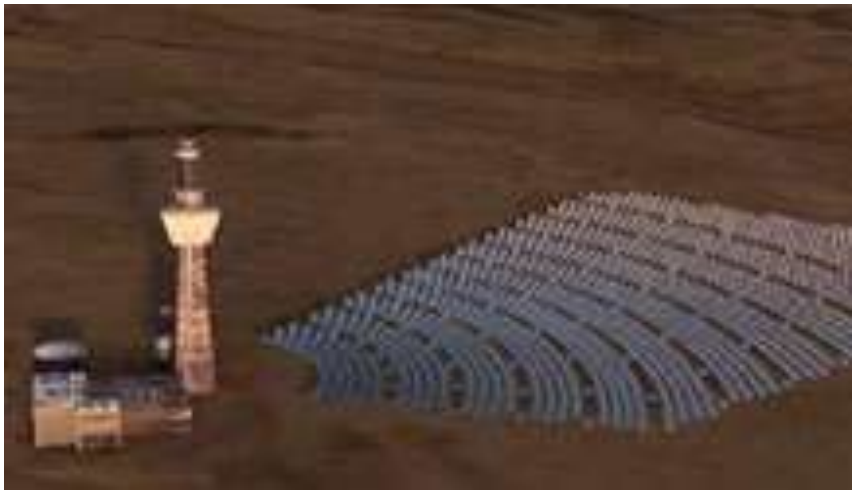
- DOE will host a new ARPA-E to fund high risk energy technology research that would not be funded by industry, with a starting $400 million.
- Investment of $8 billion in high speed rail with $5 billion to follow in succeeding budgets
- Overall, the President wants research and development to be increased 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.

# 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 use a solar trough heating a pipe with fluid that eventually boils water for a steam turbine.
- The Mojave Solar Park will be built by Solel by 2011 for PG&E and will have a capacity of 553 MW.
- It will also be solar trough and will cover 6,000 acres or 9 square miles at a cost of $2 billion.
- The year round average output of these plants is about 20% of peak power.

# Other California Solar Plans

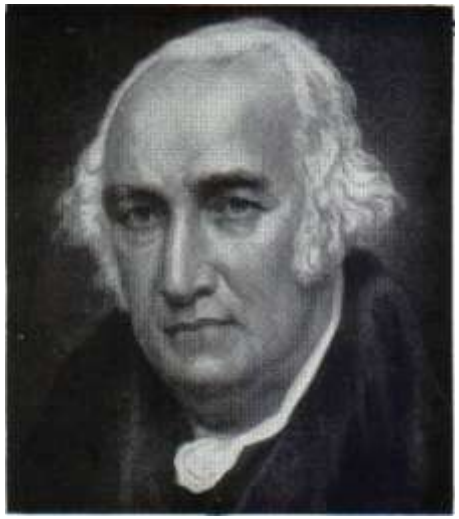
- A new SC Edison solar panel plan will cover 100 large rooftops of 2 square miles to generate 250 MW for $875 million.  This will take 5 years to complete.
- An FPL plant of solar trough thermal will also generate 250MW.
- PG&E with Ausra to build a 1 gigawatt solar water plant with heat storage for $3 billion.  It can produce power for up to 20 hours a day.
- PG&E is setting up 3 solar thermal projects for 500 MW, with Brightsource, composed of towers and heliostat mirrors. Hot salt holds heat for the evening. Cost of $2-$3 billion.



# Solar Photovoltaic Power

- Rooftop Silicon Based Solar Photovoltaic (PV) is a factor of 10 times more costly than even nuclear power.
- But Solar concentrator PV of 500 mirrors on a solar cell cost half that of panels.
- Solar thermal concentrator on a fluid driving a steam generator costs 1/3 to ¼ of solar PV panels and can carry energy into the night.
- 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, solar power is FREE, once installed.

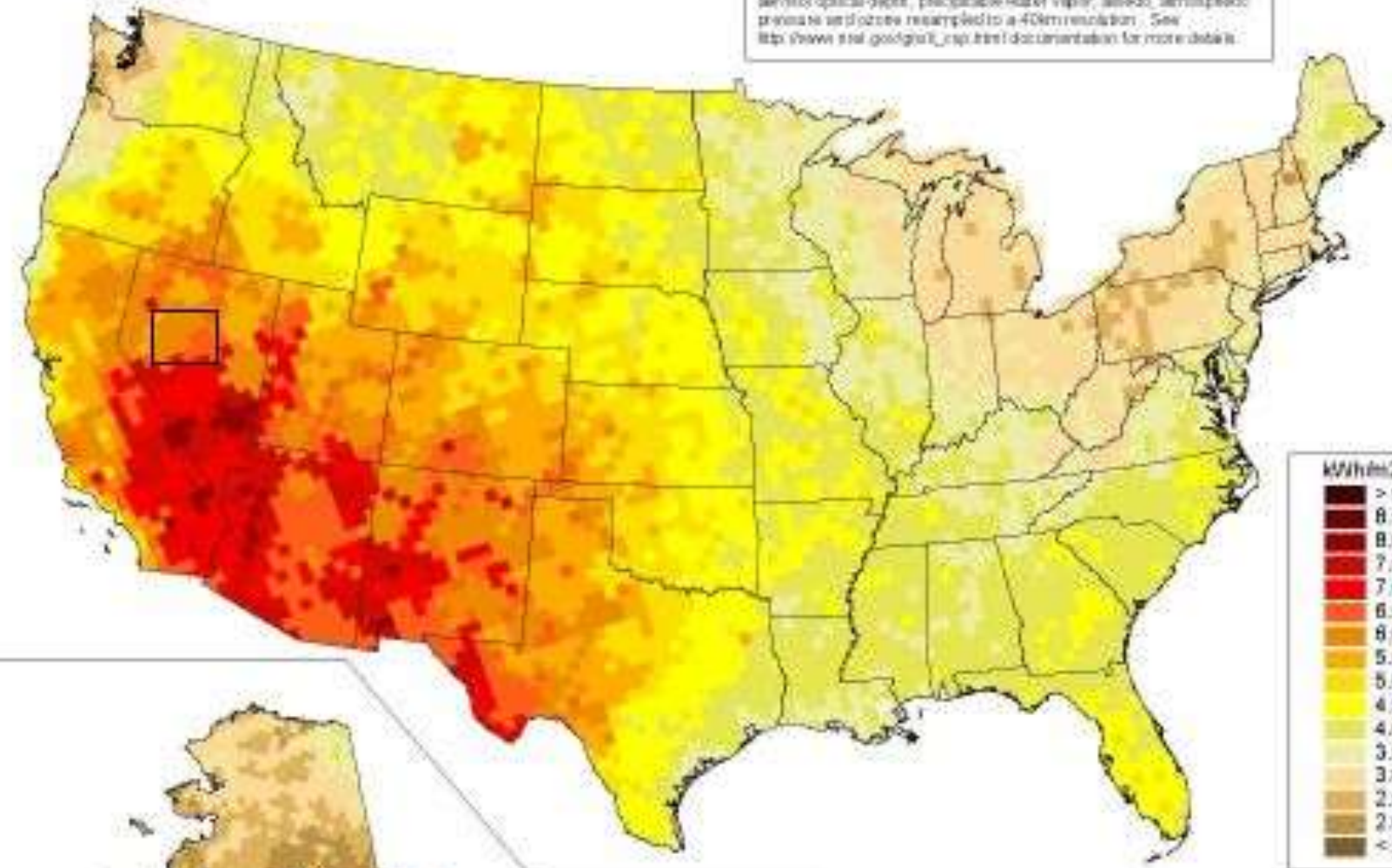
- Solar Power is less applicable to Northern or Eastern US.
- Already opposition to new power lines to the desert.
- It takes about 4 square miles of solar cells at 10% efficiency to generate a gigawatt (a billion Watts) of power at maximum exposure.
- Since total California electricity use peaks at 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, assuming storage, takes 20 square miles.
- 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.
- 38% of SC Edison power is already greenhouse gas free.
- 1 gigawatt = 1 billion Watts



# 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/cl_csp.html documentation for more details.




NREL

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

# Thin Film Solar Panel Breakthroughs

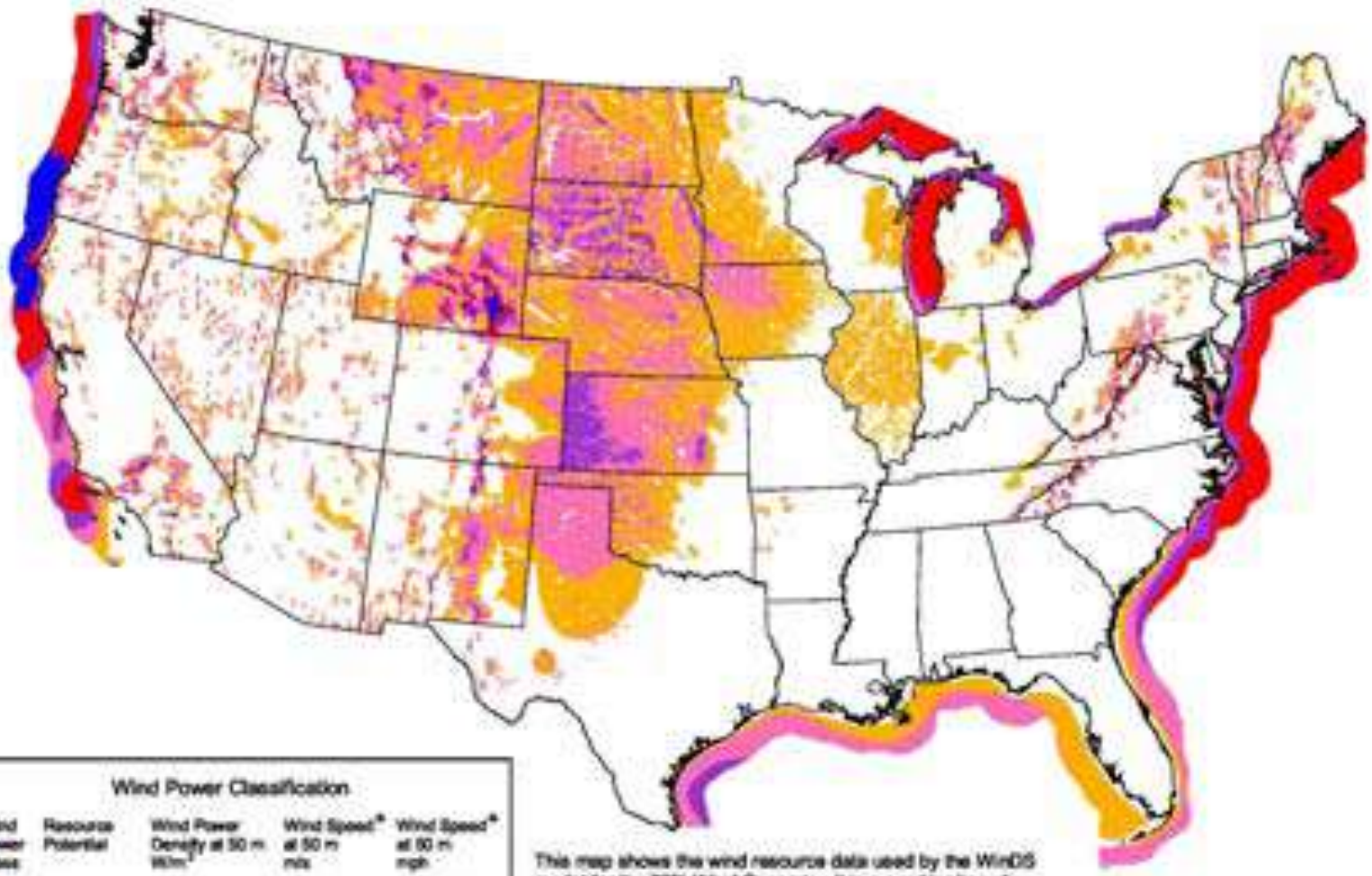
- The Nanosolar company in silicon valley has announced they are about to manufacture thin film solar panels that are printed on an electrode, for about $1 per Watt of power, and sell them for about $2 per Watt.
- This is to be compared to the current silicon based panels which are grown like computer chips, made at $3 per Watt and sold packaged for $6 per Watt.
- For comparison, a nuclear plant, which also is greenhouse gas free with small fuel cost, may cost $3-4 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 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.

- Nanosolar's plant in San Jose will produce 430 megawatts a year of panels.
- Venture capitalists have spent $344 million in this new thin film area, which also includes the companies Miasole, Solopower, Solyndra, and Ascent Solar.
- The printable nanoparticle thin film material called CIGS is made from copper indium gallium selenide
- The silicon cell industry is fighting back, however. CIGS thin film may be 15-16% efficient, but silicon is approaching 20-22%.
- 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 $4 per watt. They can cover windows or buildings.
- Per acre of field, PV electricity with a plug in hybrid goes150 times further than making bioethanol from the same acre.

# 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
- Average wind power is only 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.



## Wind Power Classification

| Wind Power Class | Resource Potential | Wind Power Density at 50 m W/m² | Wind Speed* at 50 m m/s | Wind Speed* at 50 m mph |
|---|---|---|---|---|
| 3 | Fair | 300 - 400 | 6.4 - 7.0 | 14.3 - 15.7 |
| 4 | Good | 400 - 500 | 7.0 - 7.5 | 15.7 - 16.8 |
| 5 | Excellent | 500 - 600 | 7.5 - 8.0 | 16.8 - 17.9 |
| 6 | Outstanding | 600 - 800 | 8.0 - 8.8 | 17.9 - 19.7 |
| 7 | Superb | 800 - 1600 | 8.8 - 11.1 | 19.7 - 24.8 |

*Wind speeds are based on a Weibull k value of 2.0

This map shows the wind resource data used by the WinDS model for the 20% Wind Scenario. It is a combination of high resolution and low resolution datasets produced by NREL and other organizations. The data was screened to eliminate areas unlikely to be developed onshore due to land use or environmental issues. In many states, the wind resource on this map is visually enhanced to better show the distribution on ridge crests and other features.

U.S. Department of Energy
National Renewable Energy Laboratory

# Wind Power

- A gigawatt max wind plant is estimated to cost $2 billion.
- Needs 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.
  - At 360 m size plus spacing, would stretch 360 km or 216 miles.
  - 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

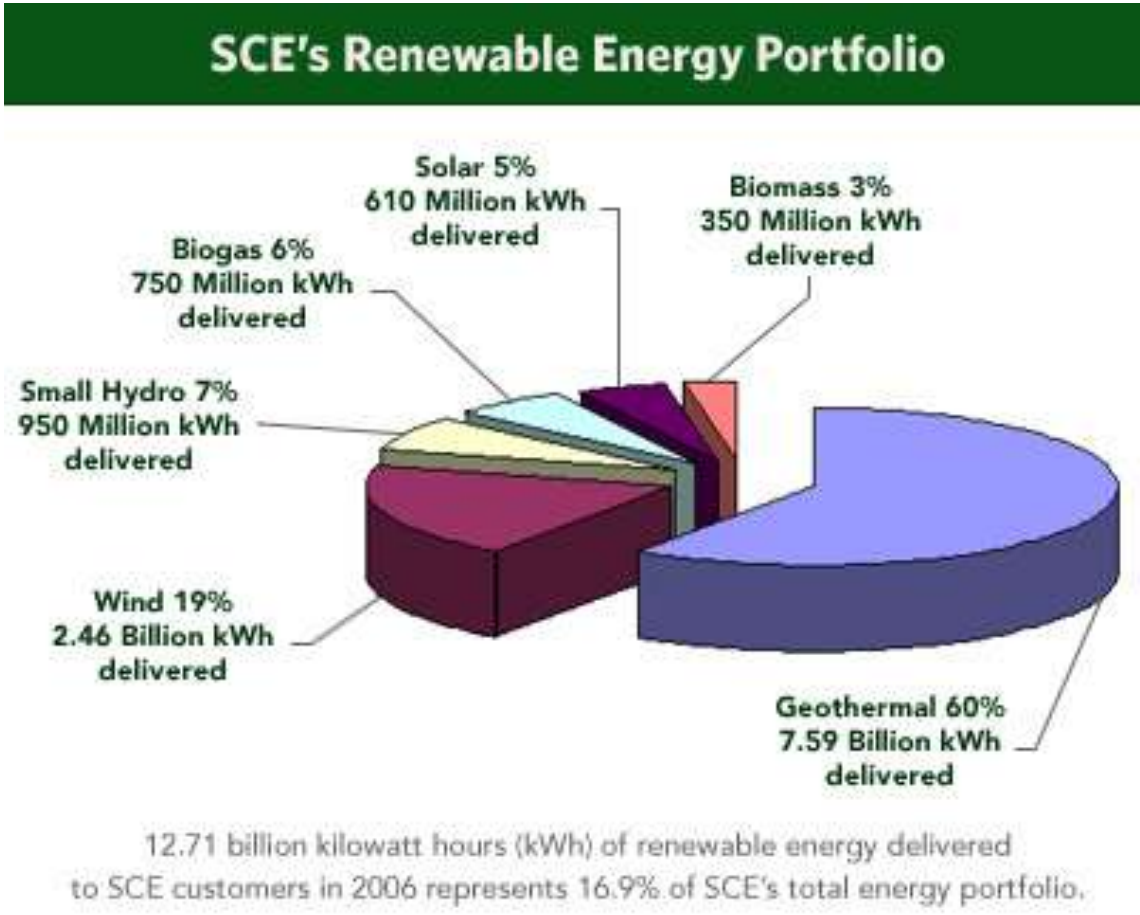
# California Geothermal Plants

- 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.

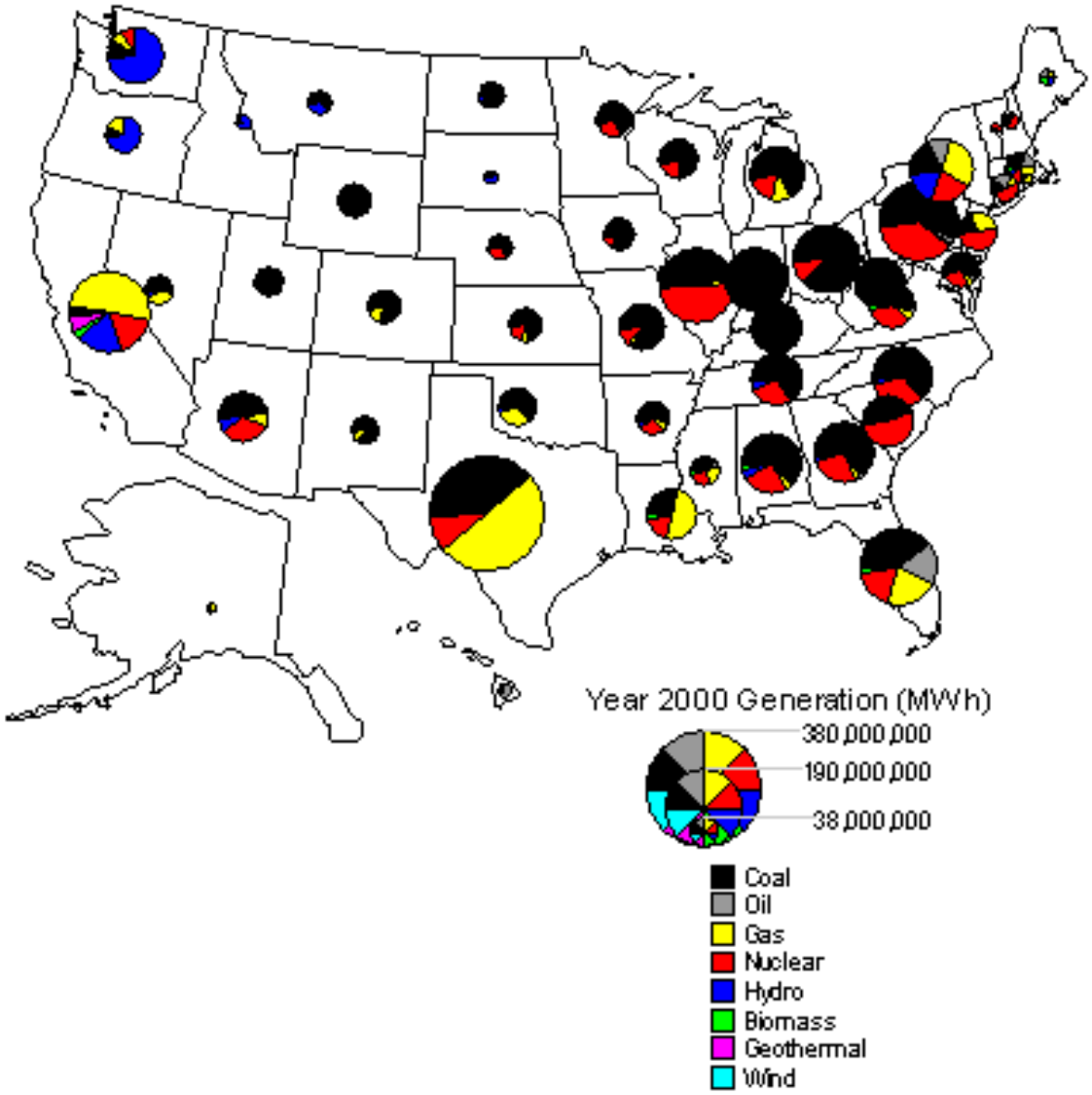
Photo of Geysers Geothermal Power Plant courtesy of Calpine

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

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



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



# 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 23 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.

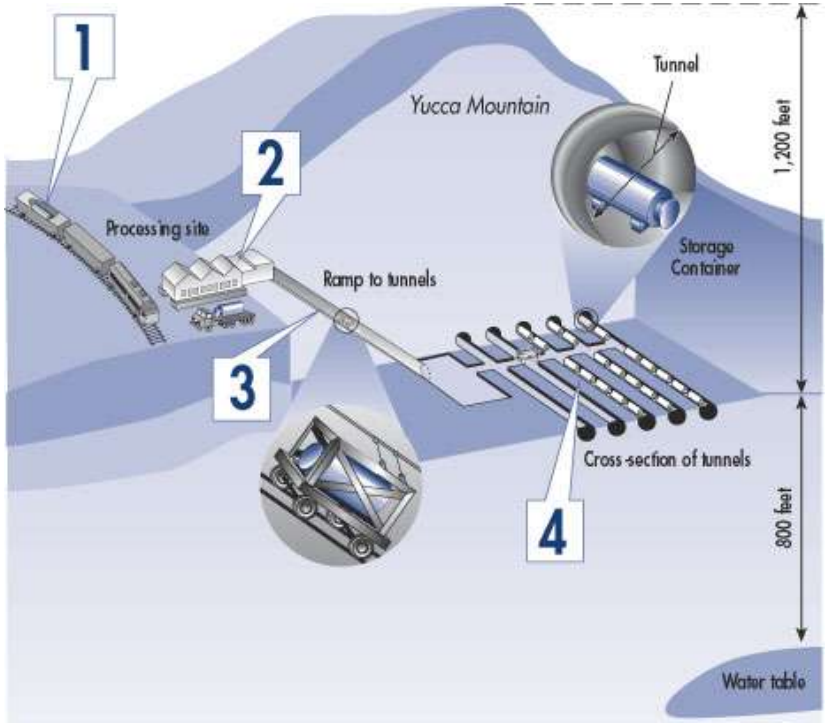
- Nuclear reactors do not produce CO2, SO2, mercury, or smog.
- Nuclear power is about a million times greater per atom consumed than fossil fuel power.
- French nuclear reactors are said to cost $2.5 billion or $5 billion.
- US plants will settle on one or a few designs for preapproval, and reactors 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 tonnes of enriched U per year, although from 25,000-100,000 tonnes of ore.
- A 1 gigawatt coal plant generates 7 million tonnes of CO2, 200,000 tonnes of SO2, 200,000 tons of fly ash, and also arsenic, mercury, and radioactive radon.
- Nuclear power saves 2.4 billion tonnes of CO2 each year.

# Nuclear Waste

- The waste turns out to be on the order of 100,000 times smaller than a coal plant.
- Each California nuclear plant, at 1.1 Gigawatts, is equivalent to 3.5 million tons of coal a year, which would produce 13 million tons of CO2.
- The 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.
- Yucca mountain is a well chosen site and a designed solution to the nuclear waste problem, and is being evaluated in its application for a license.
- 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.

# Yucca Mountain Nuclear Waste Depository

- 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 are welcomed by the locals.
- Also under consideration from the Bush administration 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.



# Detroit's Strategy on Light Vehicles

- The Federal 2020 average of 35 mpg over the present 26 mpg is really only a 30% reduction in fuel use, since you have to take the reciprocal to get gallons per mile.
- A better average would be on the tons of CO2 generated for a 15,000 mile average yearly usage, also presented by US Dept. of Transportation.
- The 30% reduction is on new cars in 2020, and will take about 15 more years to be present in most of the cars on the road.
- Detroit first plans more 85% ethanol capable cars to avoid the limits for such cars until 2014.
- They also will be putting out hybrid versions of most larger cars and light trucks.
- Other technology will be engines that shut down some cylinders at cruising speed, turbochargers for more air intake, pressurized fuel injection to get more uniform ignition, and variable valve timing such as Honda's VTEC.
- 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.

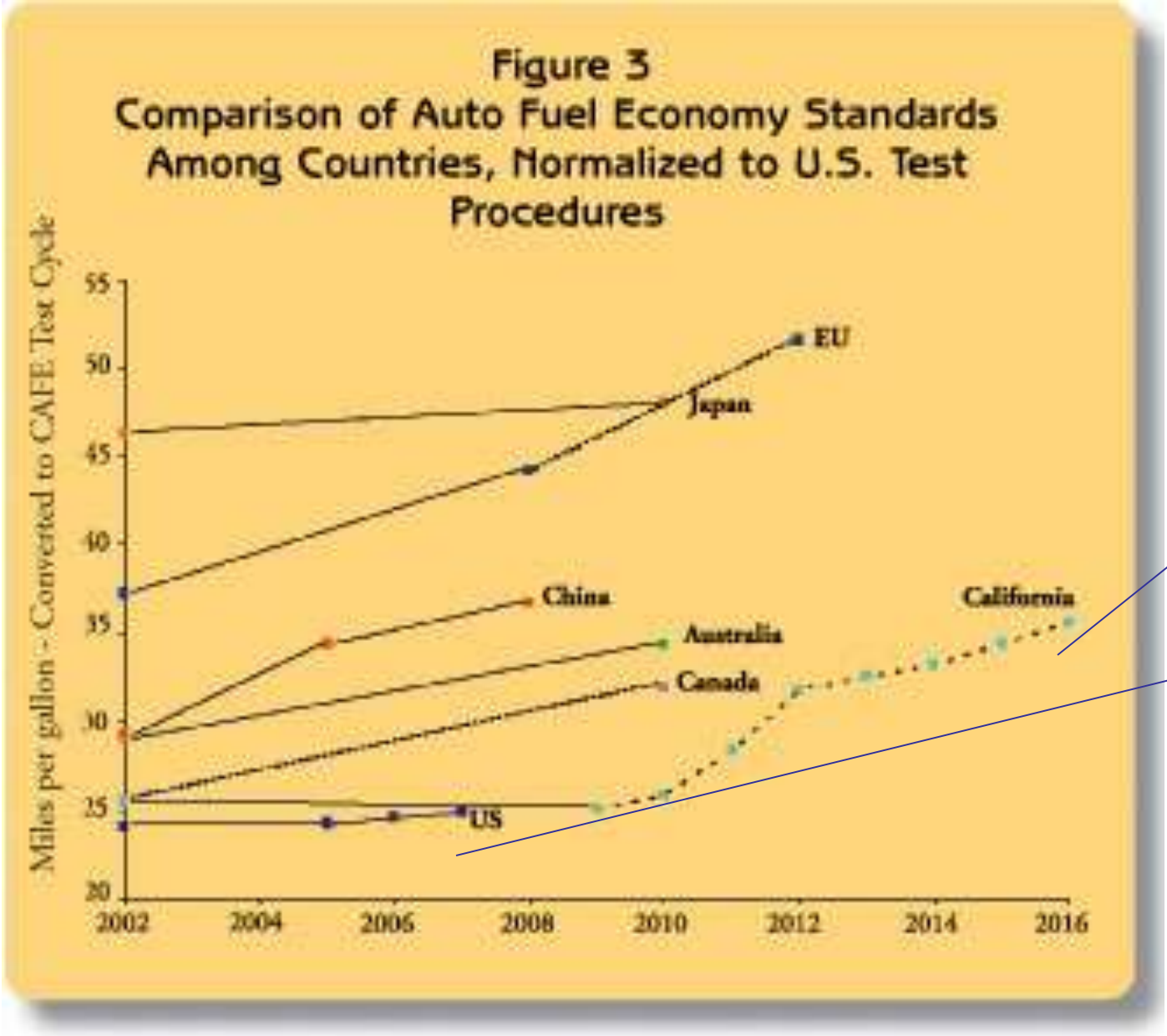


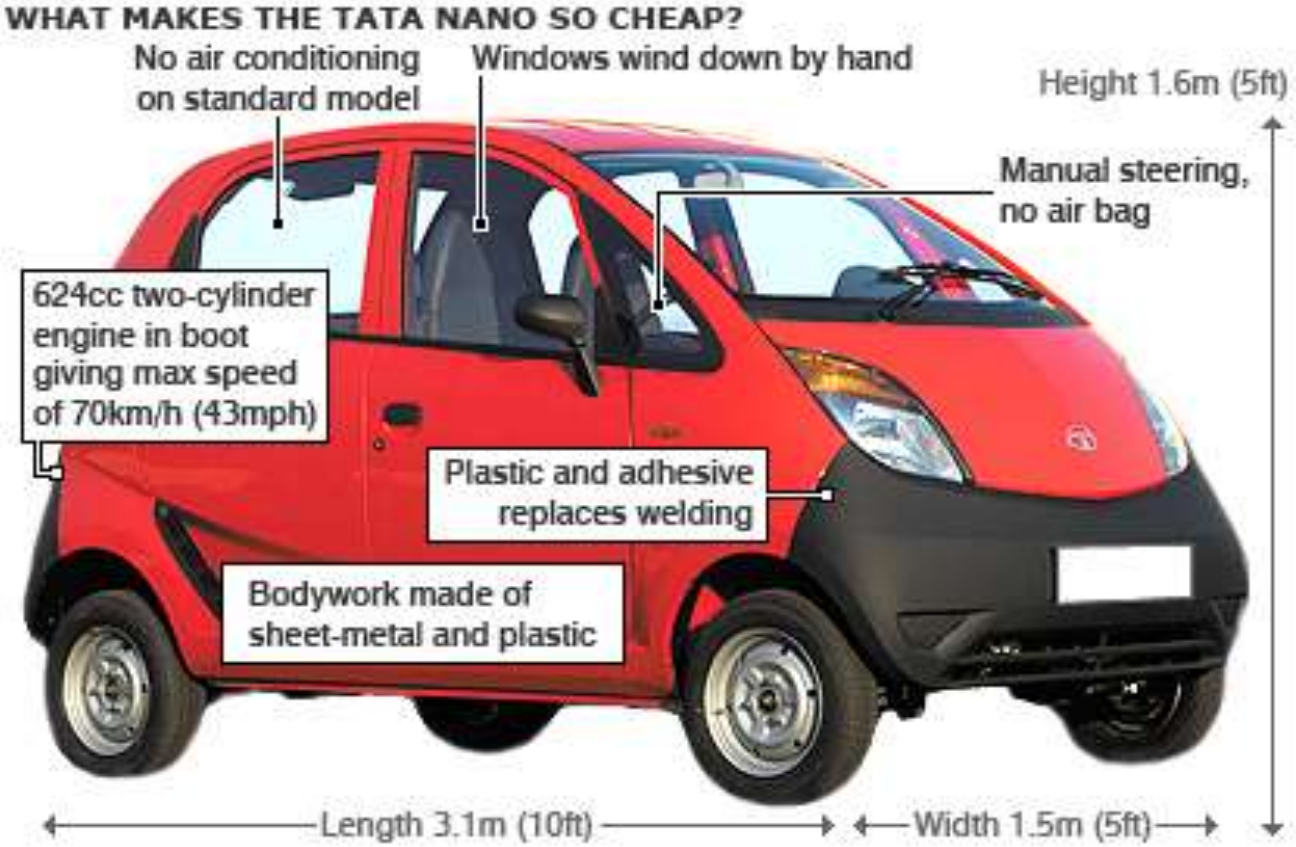
Figure 3
Comparison of Auto Fuel Economy Standards Among Countries, Normalized to U.S. Test Procedures
Miles per gallon - Converted to CAFE Test Cycle
55
50
45
40
35
30
25
20
2002
2004
2006
2008
2010
2012
2014
2016
EU
Japan
China
Australia
Canada
US
California

CA

US

2020

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



# Autos Elsewhere in the World

- We note that Europe (EU) and Japan are already over 45 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 to be produced. So far, only 7 out of a 1,000 Indians own a car.
- In the US, we own 700 cars for every 1,000 Americans.

# Chevy Volt Plug-in Hybrid and Tesla 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 is $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 of120 mpg
- 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

# Plug-in Hybrid and Electric Car Emissions

- Automotive internal combustion engines are only 15% efficient in delivering the power in gasoline to the wheels.
- Electric motors are 80% efficient.  Electric power plants are 33% efficient, and natural gas has 40% less CO2 emission than gasoline.
- So plug in hybrids driving on electricity or electric cars, when electricity is supplied by natural gas, can get effectively over 100 mpg when comparing their emissions to that of an internal combustion engine.
- Of course, greenhouse gas free electricity would be equivalent to no gasoline consumption.
- An accounting of spare electricity production in the US on a 24 hour basis shows that 73% of US driving could be delivered by electricity with suitable cars.
- Unfortunately, only about 25% of California driving could be powered by spare capacity.
- Even a coal plant coupled to generate electricity for an average present car made as an electric plug-in hybrid, can give the hybrid a fuel equivalent of 67 mpg.

# Challenges for Plug-in Hybrids and Electric Cars

- The problem is in making cheaper, lighter, large, long lived, and safe batteries, with Lithium ion being the current best candidate, but with limited range.
- The touted GM Chevy Volt plug-in hybrid with a 40 mile electric range will probably be delayed beyond 2010.
- A Saturn Vue with a 10 mile electric range will be produced sooner.
- Toyota is planning a plug-in Prius in 2010 with an 8 mile electric range. (More important, it is planning cheaper stripped down Prius hybrids.)
- Prius's are hybrid electric gas vehicles that already get about 45 mpg highway and 55 mpg in the city, using regenerative breaking.
- Also the new Honda Insight gets 50 mpg, and the Ford Fusion hybrids get 41 mpg.
- There is a law of diminishing returns, since the CO2 emissions come from gallons per mile (the reciprocal of mpg), which are diminished already for a Prius compared to an SUV.
- Further mpg increases from a Prius only diminish an already small fuel use, especially if carpooling can be factored in.
- We have won the battle for technological fuel economy, but have yet to win the war by replacing SUVs.

# 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
- 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
- Over 800 cities have signed the Mayor’s Climate Protection Agreement, which is to satisfy the Kyoto protocol of cutbacks to 1990 levels minus 5% or 7% in greenhouse gas emissions.
  - Harder to satisfy if there has also been population growth, and with a 2012 target year.

# Automotive Emission Savings

- Automobiles are by far the largest CO2 emitters that individuals have control over.
  - A large commuting SUV emits 13 tons of CO2 a year, as much as 3 residences
  - 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 CO2 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, 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

# 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 with return trip uses 100 gallons of fuel per passenger, and generates about a ton of CO2 per passenger.
  - It also costs about $140 in jet fuel per passenger.
- With the average of 9 passengers, buses are equivalent to 27 mpg per passenger.
- But filled buses at 3 mpg with 55 passengers gives 165 mpg per passenger
- Walking is equivalent to 235 mpg
- Bicycling is equivalent to 635 mpg

# 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 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 a carpooler to UCI is $500 in gas and $500 in parking for a total of $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
- 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 money 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%.

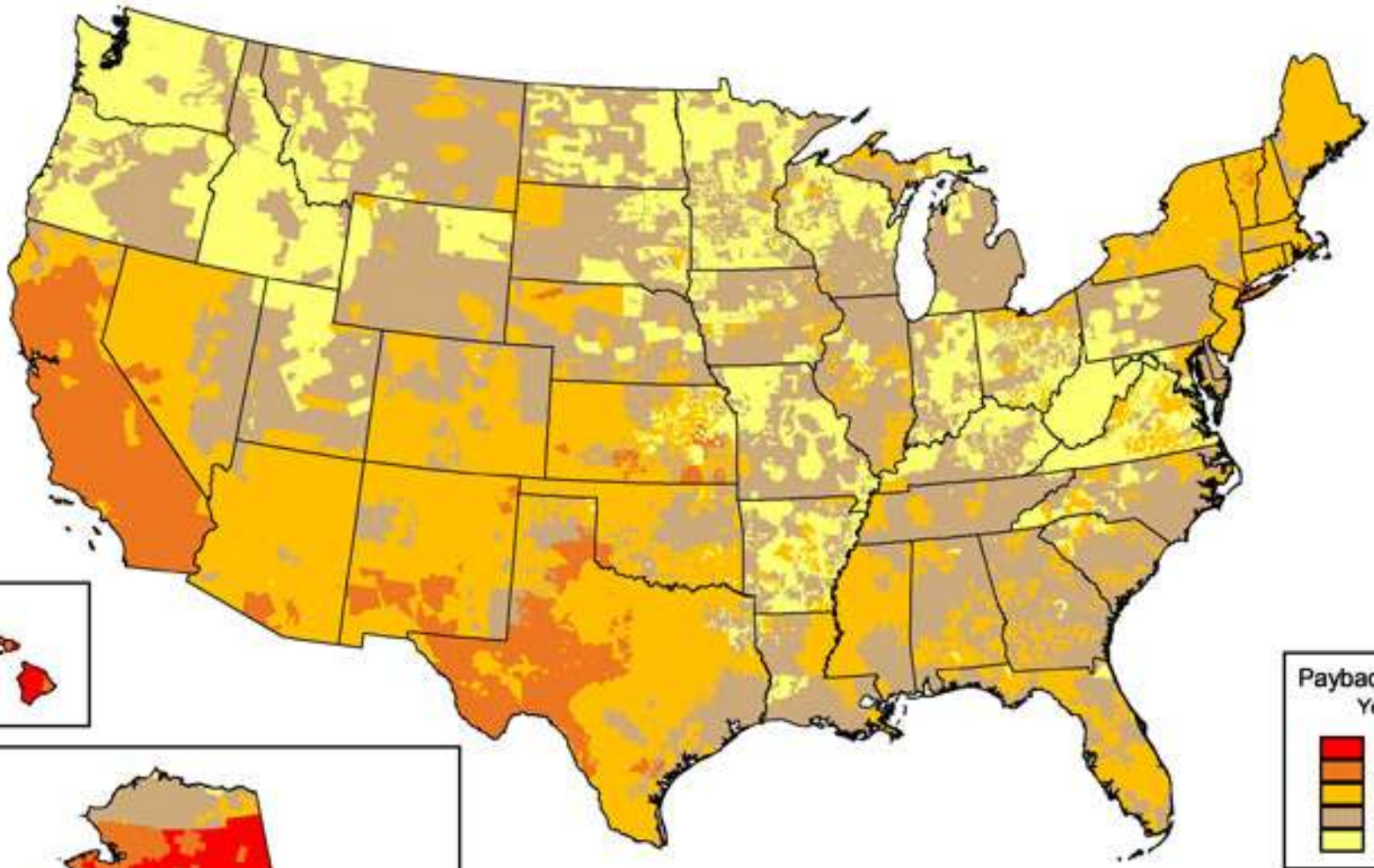
# Residential Energy Conservation

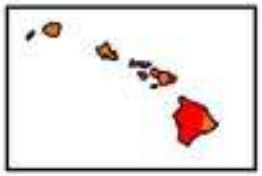
- Household electricity of 6,000 kWh per year in Southern California generates 4,000 lbs CO2.
  - A single plasma TV can use 10% of household electricity
  - Lighting is 22% of household electricity. CFLs cut lighting down to ¼ from incandescent bulbs. This reduces household electricity by 17% or about 1,000 kWh ($100) per year or 700 lbs of CO2.
  - Replacing an old refrigerator and discarding a second one saves money and energy.
  - In SC Edison, 38% of electricity generated is already GHG free.
  - 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 up to $2,000. Total cost then only $10,500. (Caveat: solar roofs don't work at night, when you might need most of your power.)
  - Best bet: wait a few years for rooftop solar to drop to a third of cost.
  - Recycling has been done since ancient times, saves mining for metals, cutting down trees for newspaper and cardboard, and petroleum for plastics

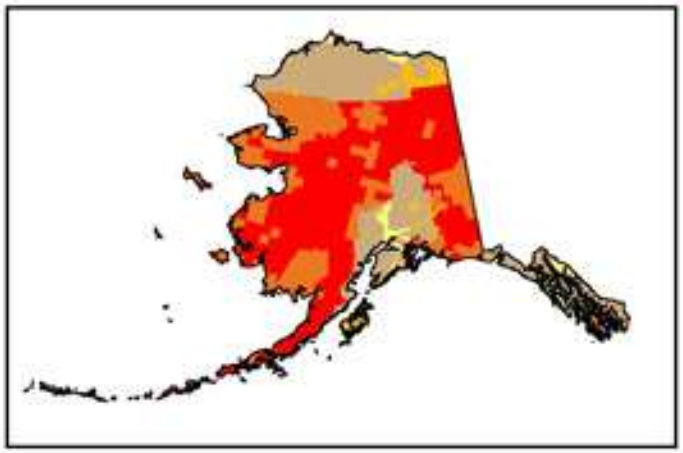
# Household Water Heating

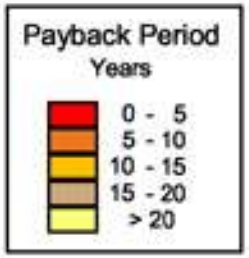
- Household water heating generates 2,300 lbs CO2, about half that of household electricity.
- Rooftop solar water heating can cut 2/3 of your water heating, at a cost of about $5,000, minus state rebate of $1,500 and 30% Federal tax credit on the rest (about $1,000) for a net $2,500 cost.
- Other water 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

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# Household Space Heating

- Household space heating -- 2,300 lbs CO2 per year
  - Housing and building design 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 house.
- Household water use adds another 18-25% to household energy use in Southern California (about 1,900 lbs CO2), because of the long distance the water is pumped.

# California, US and International Goals
## Ordered by Completion Date

- Californians already only emit 60% of the greenhouse gases of the US average per capita.
- California goal of 20% electricity renewables by 2010, and 33% by 2030.
- Mayors Climate Protection Agreement of 840 cities (121 from California) is to match Kyoto Agreement of a 7% reduction below 1990 emissions by 2012.
- Laguna Woods, Irvine and Laguna Beach are local participants in this agreement.
- 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.
- US 2015 goal of 10% ethanol in motor fuel.
- California Million Solar Roof plan to generate 3 gigawatts by 2016.
- The European Union goal is 20% below 1990 levels by 2020, called the “20-20-20” plan.
- European countries are setting goals of between a 60% to 80% reduction by 2050.

# Longer Range Goals

- California AB32 goal is reduction to 1990 emissions by 2020, a reduction of 25%.
- California Low Carbon Fuel Standard a 10% reduction in carbon in fuel by 2020, meaning 10% renewables.
- 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.
- Congress is discussing a cap and trade program, or a carbon tax. The goal is an 83% reduction from 2005 by 2050.
- The US-CAP industry and environmental group coalition goal is an 80% reduction from 2005 by 2050.
- California's goal is an 80% reduction in emissions from 1990 levels by 2050.
- 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 yearly net building must be at an 80% reduction.
- UN goal may be 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.

# 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 turbine followed by 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 cheaper, and stores cold and hot water for daytime use
- US natural gas production could be lower in a decade with future reliance on imports including Liquid Natural Gas terminals on both coasts and the Gulf of Mexico.

# Solutions That Are Ready Now

- Energy Conservation – three cheers
- Carpooling
- Small or hybrid cars
- Household solar water heating
- Energy efficient appliances
- Compact fluorescent bulbs
- Recycling
- Energy efficient buildings and homes
- Wind power
- Solar thermal plants
- Replacing coal plants with efficient natural gas plants
- Cogeneration of power and water heating
- Nuclear Power – disposal approval needed
- Almost all of the above also save money in the long run

# 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.

# Handouts for Lectures in Irvine

- UC Irvine University Club Forum
  - Wednesdays Lunch at 11:30
  - Buffet with dessert and drinks: $13.50
- OLLI: UC Irvine Osher Lifelong Learning Institute
  - About 44 classes a quarter in science, humanities and sociology. $160 a year.
  - Lectures in Woodbridge and UCI University Club
  - Or Laguna Beach $10 per class
  - unex.uci.edu/olli/
- This talk on my website:
  - www.physics.uci.edu/~silverma/

# Extra Slides

# 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

# 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.
- Also investments in national or international forestation or CO2 saving projects could receive credits.
- The bill is called “The American Clean Energy and Security Act of 2009”
- The European market found that they had a problem during the recession, when less power was generated, and the value of the credits dropped to be of little value.
- 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.
- The alternate, a straight carbon tax, apparently would not pass in the US where our very successful free market system is at work.

# 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.

# Coal Deficiencies

- A convenient unit of power for plants is a billion Watts, or a gigawatt.
- Per capita California usage is about a thousand Watts, called a kilowatt.
- So a gigawatt plant serves about a million Californians.
- A gigawatt plant uses about 6 million tons of coal a year, and generates about 9 million tons of CO2 a year.
- This coal plant also emits 100,000 tons of sulfur dioxide (acid rain), nitrous oxides (smog), particulates (asthma), and mercury (neurotoxin).
- The cost of coal has dropped back to from $40 ton to $70 per ton.
- So the gigawatt plant would now run about $240 to $420 million per year for its coal supply.
- An average coal plant lasts 50-76 years.  Current average age is 35 years.
- Even though we may have 250 years of coal remaining, the price may rise as we get to less clean coal and harder to mine coal deposits.
- US National Academy of Sciences has called for a new modern five year assessment of coal resources, which are subject to modern detection, mapping, mining and safety practices.  The last assessment was in the 70s.
- Anticipating conservation, a carbon tax, and local opposition, of the 151 new plants proposed in 2007, 60 have been dropped.

# Coal is An Embedded Resource

- We cannot easily discard coal, because of its massive infrastructure that provides 50% of US electricity.
- It provides 44% of Los Angeles' energy, to be phased out by 2027.
- There are 1500 coal burning plants in the US.
- Also, we may have 250 years of coal available in the US, making it our largest energy source, and a key to energy independence.
- Coal burns at 34% efficiency, but generates about twice the CO2 as a natural gas plant, since it only burns carbon.
- Can increase efficiency to 50% by a gasification process before combustion.
- Can increase efficiency to 80% by cogeneration by using excess heat for water heating.
- A present coal plant coupled to generate electricity for an electric plug-in hybrid, can give the hybrid a fuel equivalent of 67 mpg.

# 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 an 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 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.

# US, California and World Fuel Economy Standards

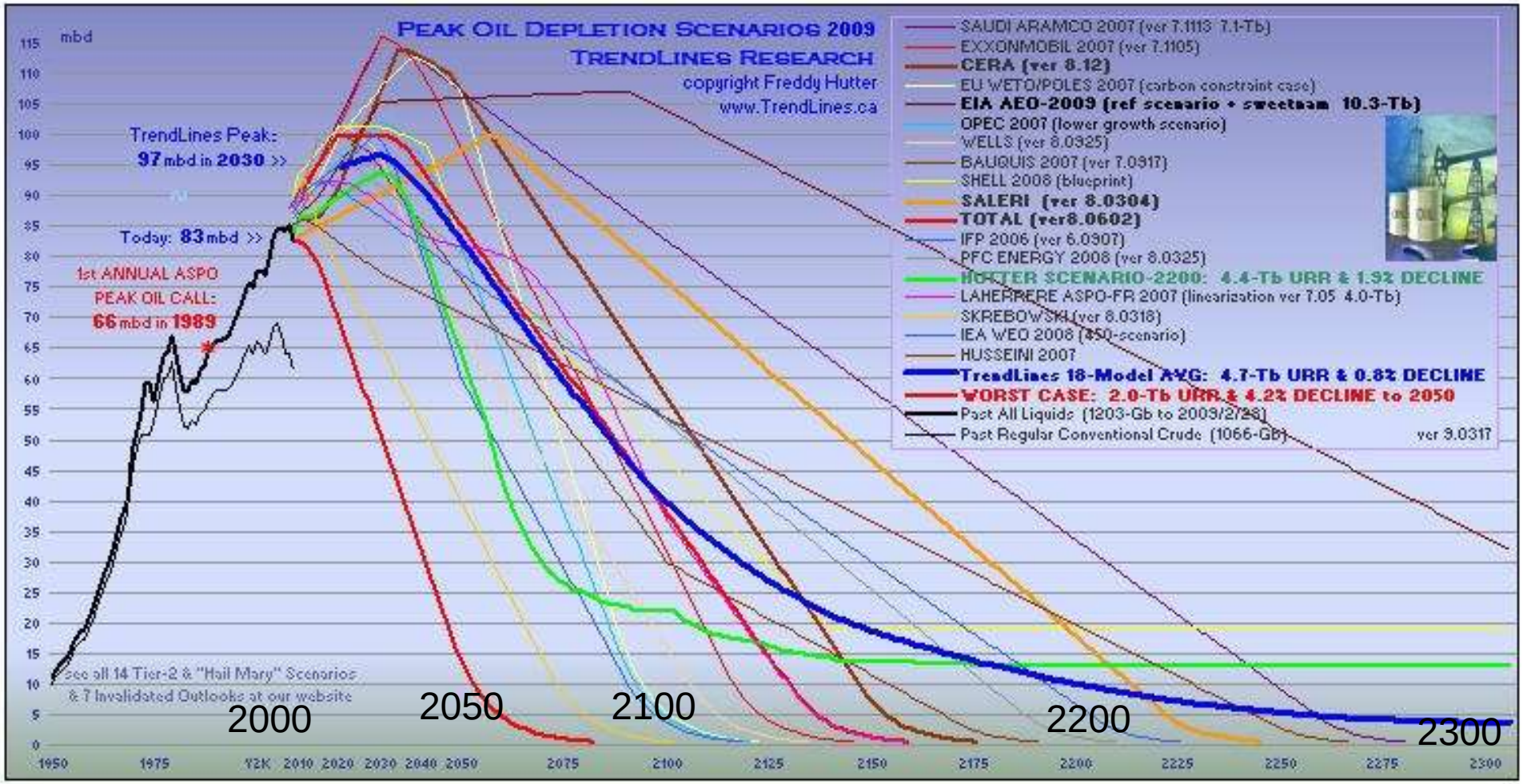
- The US plan has specific improvements targeted for inclusion such as cylinder deactivation (6% savings), variable valve timing (2-14%), and turbocharging which can reduce engine size by 30%.
- The cost of the improvements would be repaid more than doubly in gas savings over a ten year period.
- US plan in 2020 is 35 mpg average.
- California's GHG emissions standards would rise faster than the US new plan.
- CA (44 mpg average in 2020) would save 74% more emissions than US (35 mpg).
- Inclusively, CA plan would save double (or 69%) of the emissions by 2020.

# Household Water Use

- Household water use adds another 18-25% to household energy use in Southern California (about 1,900 lbs CO2), because of the long distance the water is pumped.
  - 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
- As of May 1, 2008 (LA Times) California water is in danger of shortages
  - the Sierra snowpack is only 67% of normal
  - runoff into streams and reservoirs is only 55-65% of normal
  - deliveries from the Delta are cut to protect endangered smelt

# Long Term World Oil Projections
# Highest Peak at 115 million barrels per day

- Oil Reserves are uncertain by a factor of two, between one and two trillion barrels.
- Temporary higher price favored more recovery, and substitutes as tar sands, and syngas from coal. These are now being setback.
- Plateau timeline likely as infrastructure costly. Worst case here is two trillion barrels.

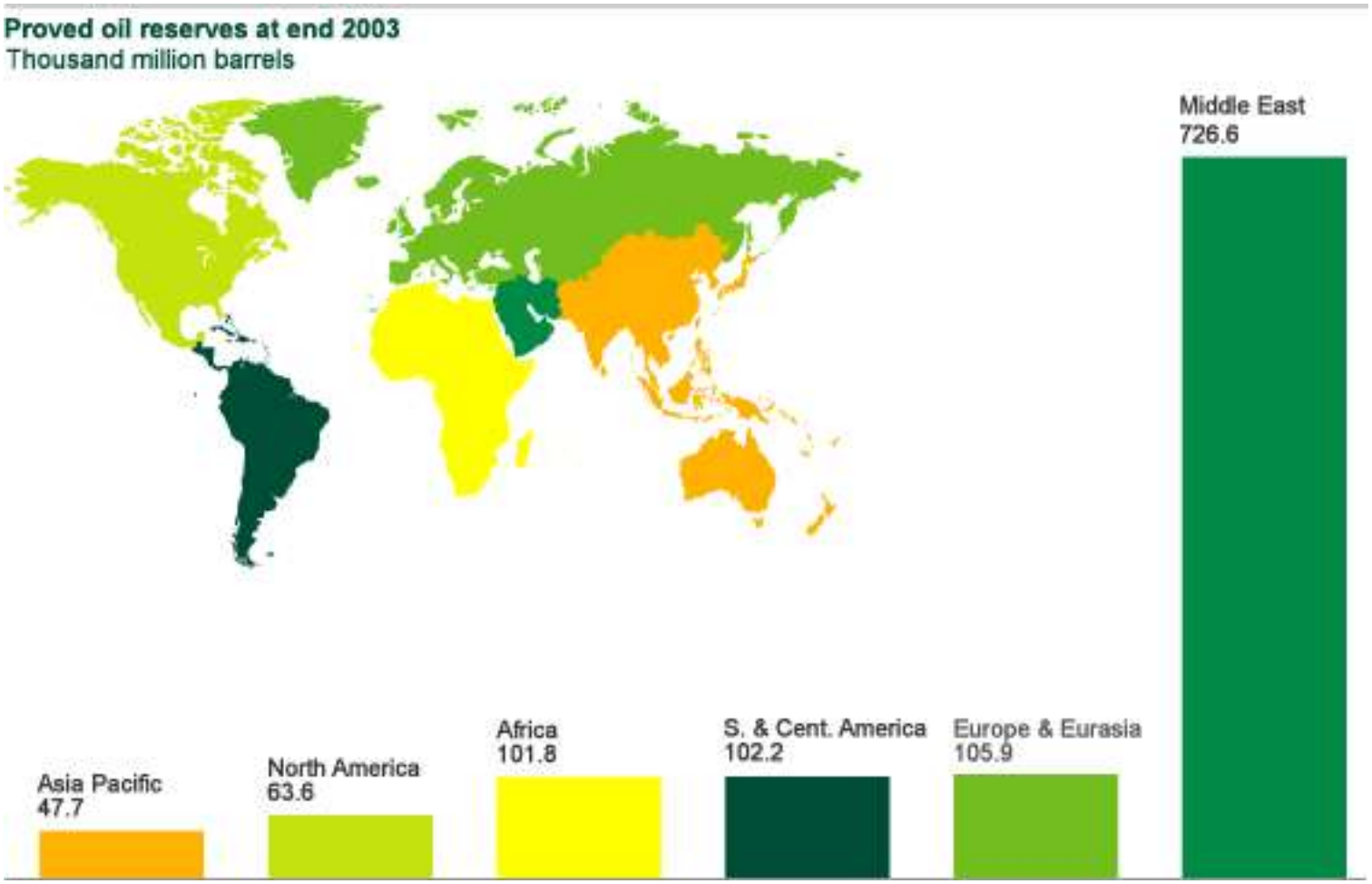


# World Proven Oil Reserves by Region (2003):

## Total 1,150 BBls, 31 BBls yearly usage.

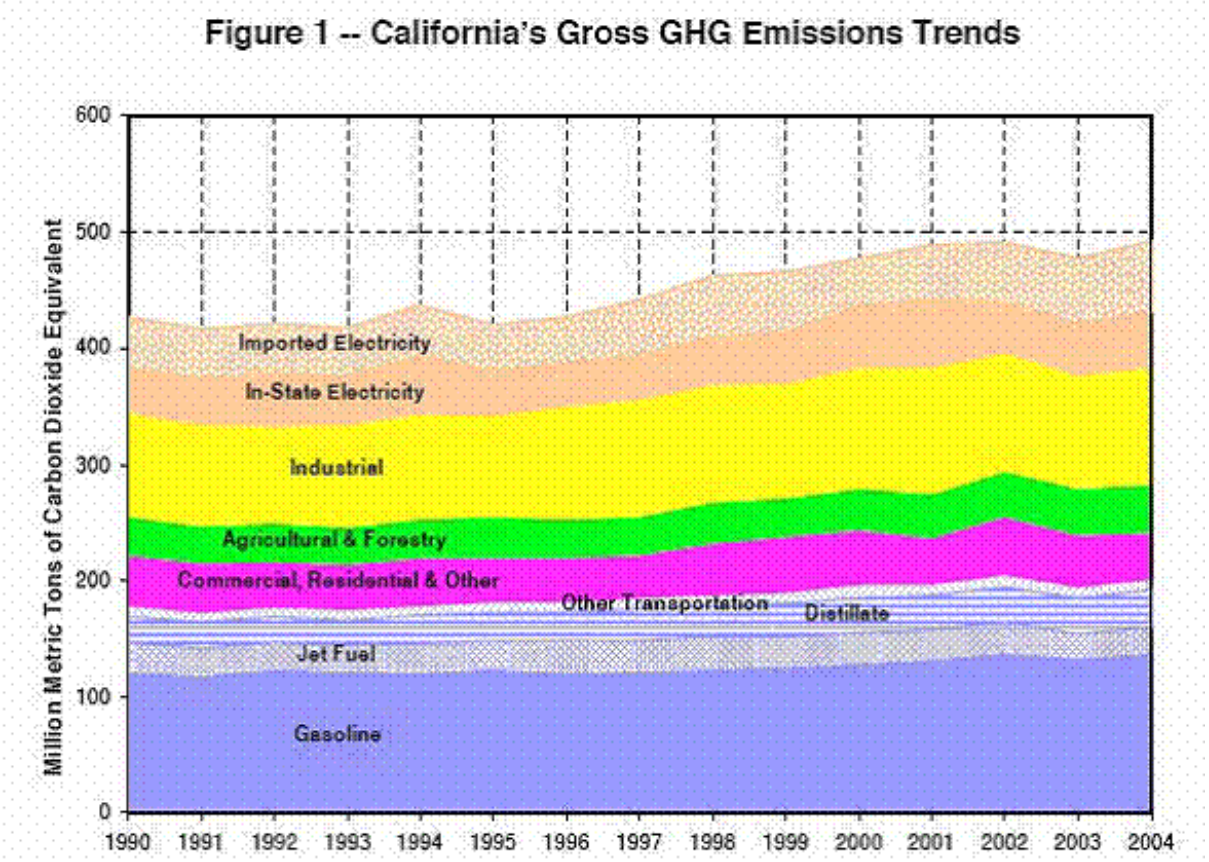
63% is in the Middle East. Iraq has 10% of the reserves.

80% are in nationalized oil companies.



# California Energy Growth

- First, California per capita only generates 60% of the GHG of the US, or 15 tons or 30,000 lbs CO2 per capita per year. (Warm climate, electrical efficiency, lack of heavy manufacturing, renewable sources, natural gas)
- From 1990 to 2004, population grew 20%, transportation 17%, electricity 35%, and others stayed level.



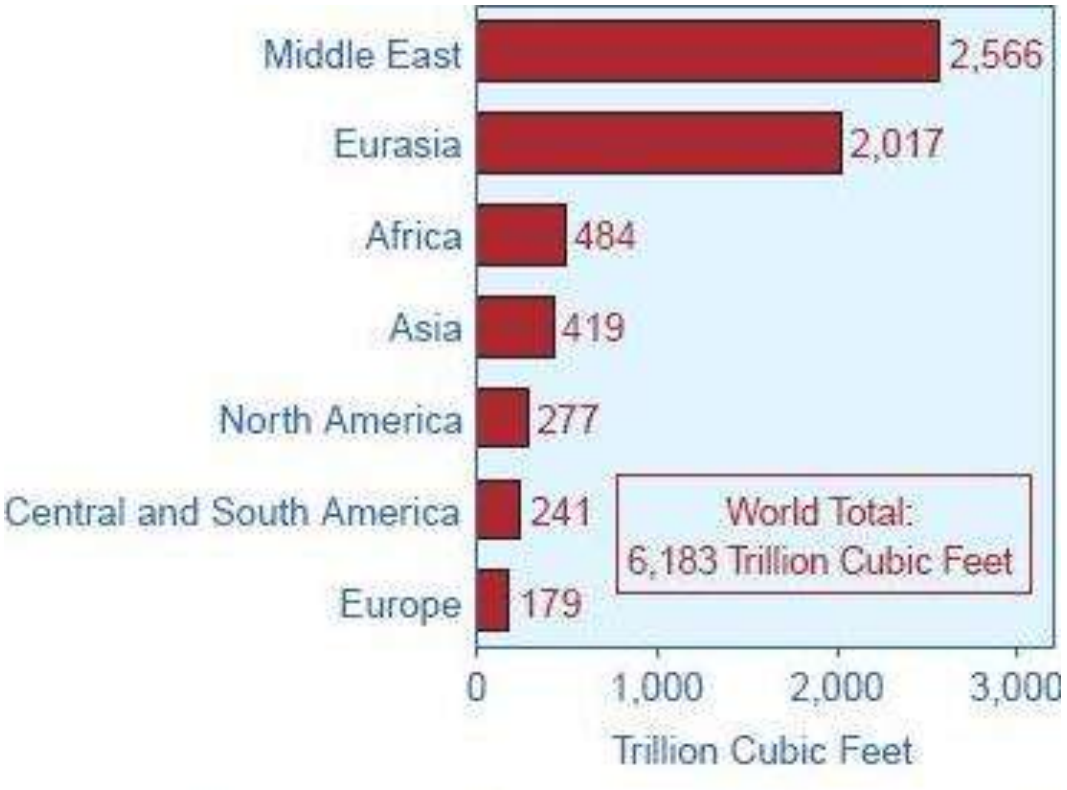

Source: California Energy Commission, Greenhouse Gas Inventory, Dec. 2006

# Cost of the Oil to Us

- Consider the lower oil reserve case at 1,000 Bbls (a trillion barrels).
- At $50 / barrel, the world's reserve is worth $50 trillion.
- For comparison, the GDP is $14 trillion and the national debt is $11 trillion.
- Assume the US still keeps using a quarter of the world's oil, and the imports are at least 66% of this.
- Then the US will buy $8 trillion in imported oil in the future.
- With 300 million citizens, this amounts to at least $27,000 per capita that will go abroad regardless of when the peak or plateau occurs.
- The US uses 7.7 Bbls a year at a cost of $400 billion at $50 per barrel.
- For comparison, total credit card debt is $800 billion.
- Oil company profits were $120 billion last year.
- OPEC is expected to make a trillion dollars this year.
- Oil has risen from $20 per barrel to the present $50 a barrel because:
  - The value of the dollar has dropped by half compared to the euro.
  - Increased international demand, and the rigidity of US usage (only dropping 1% in past years, but finally a 7% drop in 2007).
  - Investments have left housing and the stock market to go into commodities, so part of this could be a bubble in price.
- Gas has also risen due to refining shortage, and there are 42 gallons in a barrel of oil. So $50 a barrel is about $1.20 per gallon of gas before shipping, refining and taxes.

# US Natural Gas

- We produce about 26 trillion cubic feet a year.
- Proven reserves of natural gas are about 280 trillion cubic feet each.
- That gives us about 11 years of proven reserves, but much more is supposed to be available.



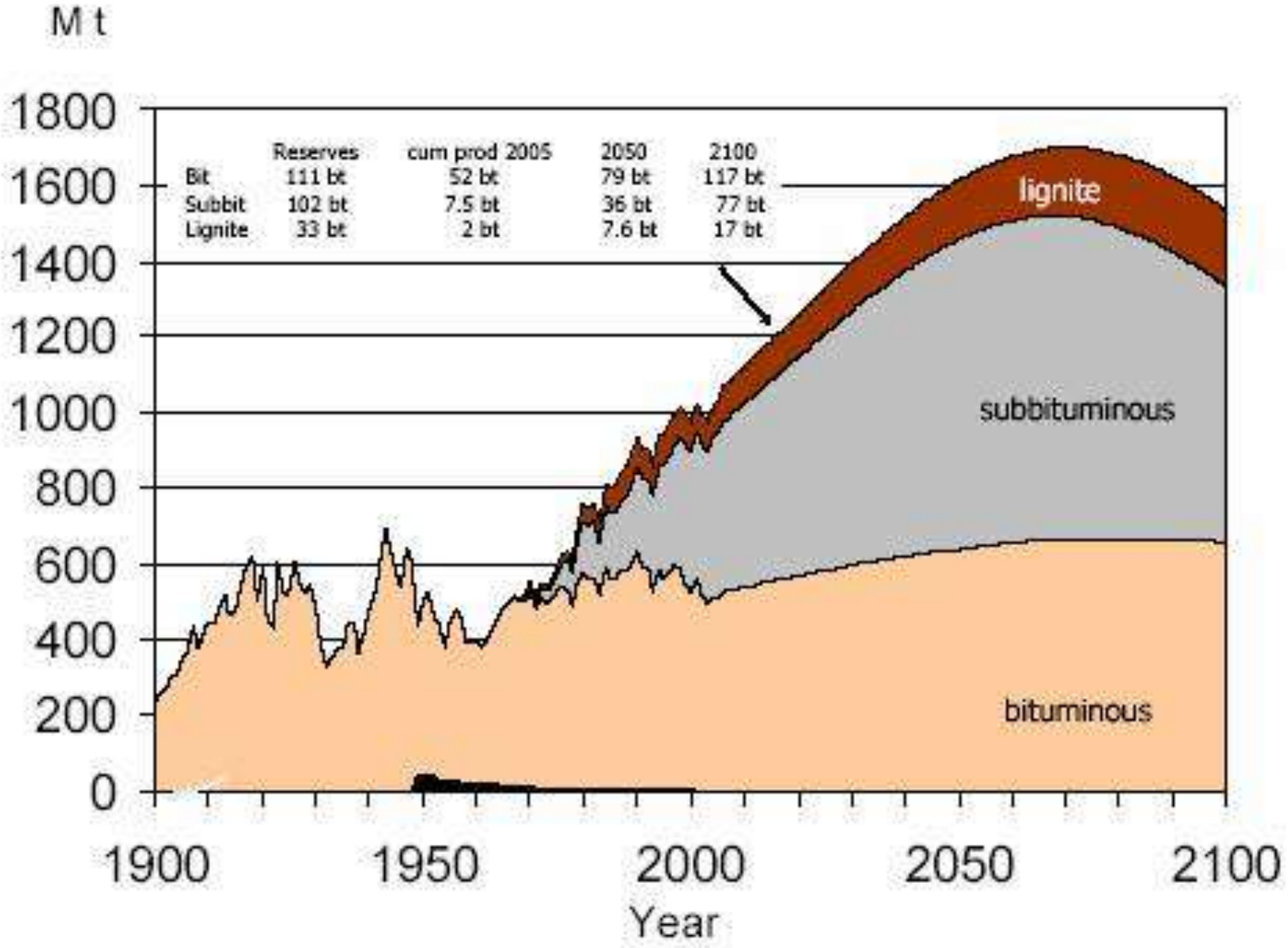
# Natural Gas Imports to 2030

- Canadian natural gas is delivered by pipeline, and may decline to process tar sands to petroleum.
- Imports to rise to 6 Trillion cubic feet (Tcf) by 2030, out of a total now of 22 Tcf.
- Liquified Natural Gas (LNG) to be imported by tankers with giant pressurized spherical tanks. Need port factories, tankers and sources.

# Existing LNG Terminals

## 40 more are being considered, but only 12 may be built

# Possible coal production in USA, if 1998 reserves are realistic

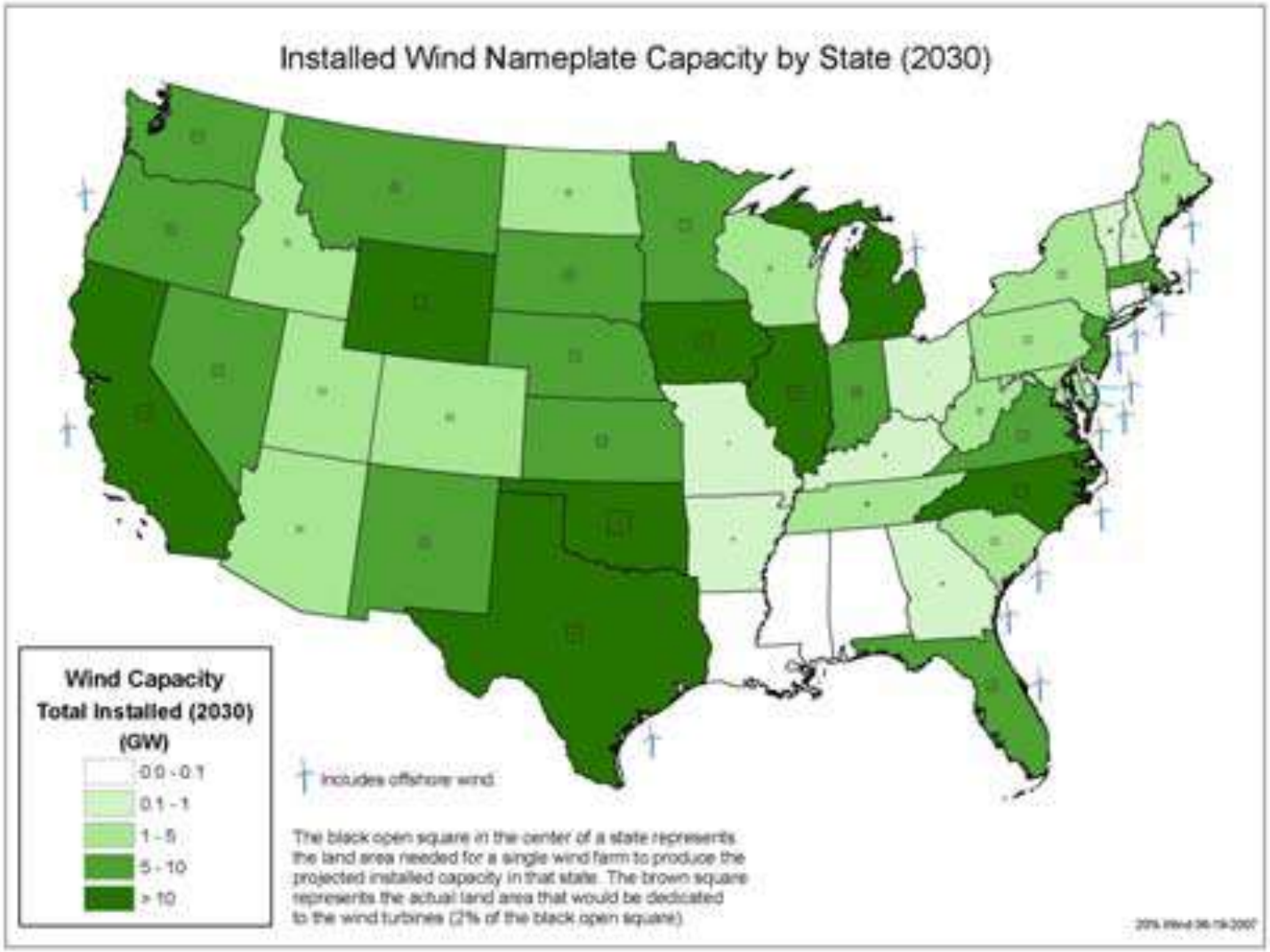


Coal Strip Mining. Truck holds 350 tons of coal. This is enough for all the energy needs of one American for 60 years.


# $CO_2$ Sequestration

- Sequestration is a method to capture $CO_2$ at a power plant, transport it to burial sites, and inject it underground.
- Sequestration would require burning of 20%-50% more coal for the same power, yet the extra $CO_2$ could also be sequestered.
- Four of the coal gasification prototype plants with sequestration (FutureGen) would be needed to equal a 1.1 gigawatt (billion watt) power plant, which would then cost $6 billion.
- With an extra 30% for sequestration, the annual coal cost would be about a billion dollars.
- This puts coal sequestration well above the $3-$4 billion dollars for a pollution free nuclear power plant of the same power.
- Also needed is more transportation for more coal in railroads and ships.
- Industry hopes to add sequestration to present plants by capturing $CO_2$ in a fluid, then heating the fluid to release the $CO_2$ under pressure to pipeline it to a sequestering site.
- But present power plants are not located over fields or domes where the $CO_2$ would go. Need pipelines, or new plants with further transmission lines.

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



# Fuel Economy Standards

| Vehicle Type | Present Values | 2015 | 2020 |
|---|---|---|---|
| Cars | 31.3 mpg | 35.7 mpg | |
| Light Trucks | 23.1 | 28.6 | |
| US Avg. | 25 | 31.6 | 35 mpg |
| CA Plan | | | 44 mpg |
| Europe | 44.2 | | |
| Japan | 45 | | |

Joe Klein: How Al Gore Could Save The Democrats

Hillary Clinton On Why She Won't Quit

R.E.M. Rises from The Dead

# TIME

## The Clean Energy Myth

BY MICHAEL GRUNWALD

Politicians and Big Business are pushing biofuels like corn-based ethanol as alternatives to oil. All they're really doing is driving up food prices and making global warming worse—and you're paying for it

# Biofuels: Reality Check on Corn Ethanol

- Direct ethanol production from corn is about neutral as far as global warming is concerned. It takes about as much energy to produce ethanol as is contained in it, due to farming, heating for fermentation, and fertilizer production.
- Corn also uses a lot of water and the fertilizer produces nitrous oxides greenhouse gases.
- Ethanol also cannot be pipelined since it absorbs water and damages pipes, so it must be train and truck delivered.
- Corn ethanol is correctly only referred to as an “energy independence” fuel since it can be produced from US fossil fuels without using imported oil.
- Even if the entire initial corn crop was used for ethanol, it would only supply 15% of US gasoline. Currently about 22% of the US corn crop is used for ethanol production.
- The price of corn has doubled. Almost half of corn was used for feedstock, and almost half for food additives. The price is now set by the price of gas that the ethanol can replace.
- Since wheat farms are being converted to produce corn, the price of wheat has doubled. Also being converted are soy farms, and soy is up 40%.
- Corn ethanol is being subsidized at 51¢ a gallon.
- The latest assessment for global warming is that the destruction of Amazon rain forest for ethanol farms or to replace food crops would require on the order of 100 years of production to break even on the climate change damage caused by destroying the rain forest.

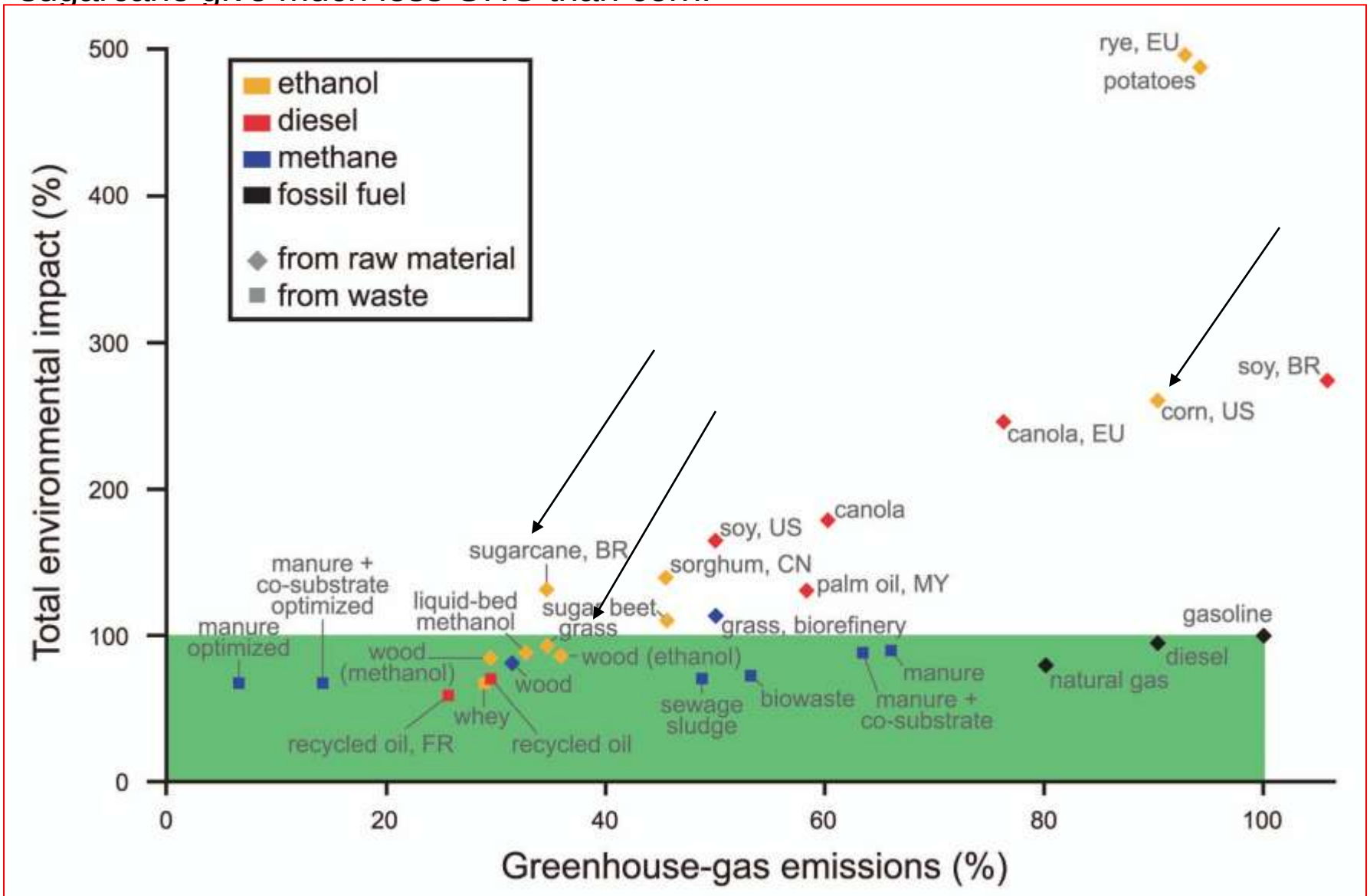
# Biofuels:  Cellulosic Conversion

- Using corn stalks, or switchgrass is dependent on being able to convert their cellulosic fiber into ethanol.
- This would work well for making a more renewable fuel with less greenhouse gases used in its production.
- Switchgrass also does not require much water and can be used in areas where it does not take away from the food supply.
- Pipeline fuels of heavier alcohols propanol and butanol are being investigated.
- Much research on this is funded by the BP oil company at UC Berkeley and Stanford.

# Biofuels versus Plug-in Hybrids with Solar Photovoltaic

- As for the future of biofuels, if plug-in hybrids can saturate a fair part of the market, we can compare biofuels to solar cells.
- Photosynthesis is only 3% efficient, and requires water and fertilizer, with ethanol processing and transportation, and goes into an internal combustion engine which is only 15% efficient.
- Photovoltaic cells covering the same field is up to 22% efficient, requires none of the above resources every year, and goes into an electric motor at 80% efficiency.
- Thus electricity is at least 35 times as efficient a use of the field as is even full conversion of the crops grown, and produces no greenhouse gases.
- It also can be used on marginal crop land or desert and denies food to nobody.

Fuels in the shaded area are considered advantageous in both their overall environmental impacts and greenhouse-gas emissions. Switchgrass and sugarcane give much less GHG than corn.



# Universal Carbon Emission Accounting

- I am proposing a universal accounting of our carbon emissions in terms of pounds or kilograms of CO2 or equivalent greenhouse gases being generated.
- In our energy bills, you have to be an engineer to handle or convert all of the units used to the actual GHG generated.
- We pump gas in gallons, use electricity in kilowatt hours, heat water and houses in therms, take airline flights in miles, and use water in gallons.
- Only utilities know how much GHG is generated for a kWh, and only airlines know how much is generated for the mileage and route that we traveled.
- So the proposal is that gas stations have signs posted on each pump to convert gallons pumped to CO2 that will be generated in their usage.
- Electric company bills should come each month not only with the kWh listed, but also the CO2 generated for their mix of energy sources.
- Gas company bills should convert the gas supplied to CO2 generated.
- Water bills would also have these figures for the delivery area.
- Airline tickets also should print next to the miles traveled the CO2 generated by fuel typically used on the specific flight that you are taking.
- People then could even buy small calculators in which they can total all of these figures to find their “carbon footprint”.
- This should be required by federal law, and monitored by the EPA for accuracy standards.

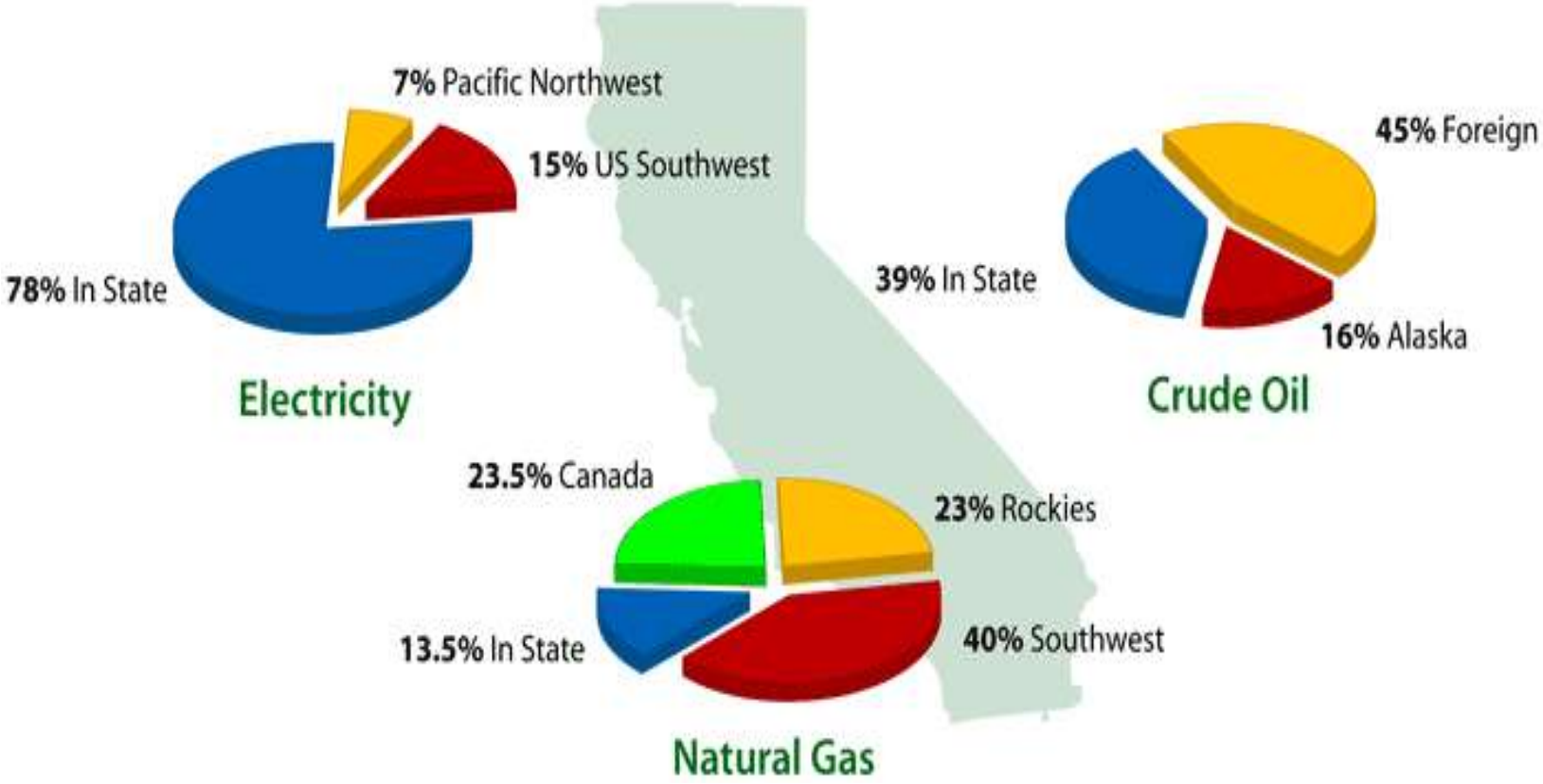
# References

- This talk, my other talks, and OLLI energy course talks by others are on my website: www.physics.uci.edu/~silverma/
- Conservation information on SC Edison and SC Gas Co. websites, and many others
- New book covering all areas of energy: *Earth: The Sequel,* by Fred Krupp, President of the Environmental Defense Fund, and Miriam Horn
- Coverage in the LA Times, New York Times, Washington Post, Economist, Scientific American, Nature and Science.
- Osher Lifelong Learning Institute: unex.uci.edu/olli/

# 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
- Tri-alpha fusion research off campus

# California Energy Sources



# The Power of Commuting in Irvine

- As an example of the ease of pairing commuter partners, we examine Irvine by scaling 2000 census data up by 50% and rounding off
  - 200,000 residents, 110,000 commuters, 8% carpool, 5% walk, 5% work at home
  - City area 46 square miles (roughly 7 miles x 7 miles)
  - Density 4,300 per square mile
- Carpooling capability
  - 90,000 drive alone, so density of lone drivers is 2,000 per square mile
  - average commuting time 23 minutes
  - assume that is a 15 mile distance, draw a circle
  - Work area pi x 15^2 = 700 sq miles
  - So about 130 people in Irvine commute to the same square mile work area
  - That is 3 commuters in each square residential mile, to the same square mile work area, or 12 from a distance of two miles residential, or 50 for a two mile work and residential radius
- Comparison to buses
  - **There are about 24 bus routes connecting in Irvine**
  - **But there are 90,000 single driver routes driven daily in Irvine**
  - **Fifty leave within two miles of your home and go within two miles of your work, and can pick you up and drop you off at a standard time, without walking to or waiting at a bus stop, or requiring a bus transfer**

# Carpool Savings

- Gasoline Savings
  - A 20 mile commute for 200 work days a year is 8,000 miles.
  - At 25 miles per gallon, that saves each extra carpooler 320 gallons, or over $1,000.
  - If 2 commuters split that, they each save $500 per year.
- Parking Savings
  - Employers should reimburse you for the cost of the parking space that they no longer have to buy for you if you car pool
  - Or you just save from having to park at a pay lot.
  - Using UCI as an example, the $570 per year parking permit is reduced to $72 per person per year for carpoolers. So each carpooler saves $500 per year in parking.
- **Total savings per carpooler to UCI is $1,000 per year for just two, and $1250 per person for four, plus savings of 8,000 miles of servicing costs**

# PROGRAMS THAT WILL IMPACT the FUTURE OF NUCLEAR POWER

- Nuclear Power 2010: Government-industry cost sharing effort to identify sites, develop new plant technologies and demonstrate new regulatory procedures. Guaranteed loans for first plants
- Global Nuclear Energy Partnership: US and other advanced nations develop fuel market, spent fuel recycling technology and reduce proliferation risks
- Generation IV: International initiative to develop 6 next-generation reactors that are safer, more reliable, more cost-effective, and more proliferation resistant.
- ITER: International R&D project to demonstrate scientific and technical feasibility of commercial fusion power. Unfortunately, congress completely cut our contribution this year of $160 million.

# Hydrogen Power

- Can’t pipeline hydrogen as it is so small it leaks out. (Also can’t keep such a car in an enclosed garage).
- Need research for a carrier for the hydrogen to allow it to pipeline.
- Present cost of fuel cells at $36,000 versus a car engine at a tenth of that cost.  Needs more research and development.
- Takes 15 minutes to fill the tank.
- Less range than a conventional car.
- Need CO2 free energy source to generate the electricity to make the hydrogen.

# Energy Efficient Building Standards

- California's Title 24 Building Standards are being revised for 2008.
  - "California's building efficiency standards (along with those for energy efficient appliances) have saved more than $56 billion in electricity and natural gas costs since 1978. It is estimated the standards will save an additional $23 billion by 2013."
  - Most buildings can achieve energy efficiency 20% to 40% greater than that of Title 24
- Other standards are those of:
  - US Green Building Council LEEDS
  - American Institute of Architects AIA
  - Engineers in heating and air conditioning ASHRAE
  - Build it Green
  - City of Irvine
- SC Edison and the SC Gas Company have advice webpages

# Grand Solar Plan for 2100
# Scientific American, January 2008

Ken Zweibel (NREL), James Mason, Vasilis Fthenakis (BNL)

- Almost all of US power to be generated by solar plants in the Southwest.
  - Allows for 1% yearly growth in total power, to 2.5 times current usage by 2100
  - Meets 90% of transportation with hydrogen (why not electric?)
  - Reduces CO2 emissions 92% below 2005 levels
- Total of 12.7 Terawatts solar power (1TW = 1,000 Gigawatts)
  - 5.2 TW direct solar power (2.9 TW is PV, 2.3 TW is concentrated)
  - 7.5 TW solar power through DC power lines to local compressed air plants for 24 hour power retrieval
- Extra power sources
  - 1.3 TW distributed PV
  - 1 TW wind farms
  - 0.2 TW geothermal power, 0.5 TW geothermal water heating
  - 0.25 TW biofuels
- Uses 165,000 square miles of PV and concentrated solar power plants. Coincidentally, this is the area of California. Needs only $420 billion in subsidies to start up. The rest from utility payments.

# The Solar Connection

- Most of our energy comes from our sun, a star.
- Without the atmosphere, it helps heat the earth to 0° F.
- With the greenhouse atmosphere, it heats the earth to an average temperature of 59° F.
- The sun provides our light.
- Through photosynthesis it grows the world's plants, trees, sea plants, phytoplankton, and our crops.
- The sun drives our weather
  - It evaporates water to fall as rain giving us drinking water and fresh water for plants, trees and farming
  - That water produces hydropower
  - The sun drives the winds, which produce wind power
- The sun-grown plants of the 200 million years of the carboniferous age were deposited and converted to the abundance of fossil fuels that we have today