Physics for Future Presidents

Breakthroughs in physics have had a huge impact on technology and society (See AIP slide)

(Professional Physicists have knowledge that can be applied to some of the most difficult and complex societal and political issues.)

Two examples are energy and radioactivity.

Failing to use this knowledge and make it widely available would be an example of unethical behaviour.

(See review by Dr Tina Karsberg, for example).

Use two extracts from R. Muller's book and course for UC Berkeley undergraduates. A *simplified and shortened version* is also now being prepared for the US presidential candidates

Easy short multiple choice quiz on the content (next Friday)

Table 2: Physics-based Technologies (AIP 1996)

Technology	**Order of magnitude improvement within the past few decades**
Energy	efficiencies of thin film photovoltaic cells have increased 500% since 1978
	more efficient motors and new lightweight materials for wind turbines have reduced costs by 90% since 1991
	light bulbs made using plasma physics and microwave technology don't burn out, produce full spectrum light, and use 66% less electricity than regular bulbs
	automotive emissions have been reduced by 70-90% in the US since the '70s
	microwaves require 1/10 the energy of thermal processing in some industrial processes
Materials	improved materials processing and a growing market have led to a 600% increase in the amount of recycled plastics from 1987 to 1993
	1995-plastic bags are 70% thinner and glass soda bottles with 31% less glass than in the 1970s as a result of technological advances
	the cost of 1 gram of nanocrystalline materials (used in sunscreens) decreases from $1000 to less than 10 cents
Computing	silicon microprocessor performance is 25,000 times better than 25 years ago
	a 3.5 inch disk can now store more data than 1000 of the original hard disks could (GIANT Magneto-resistance, 2007 Nobel prize)
Instrumentation	the accuracy of atomic clocks (the basis for Global Positioning Systems (GPS), etc.) has increased 1000% every decade since 1950
	the first GPS receiver for civilian use cost $150,000 in 1984 and required two people to carry it--In 1995, hand-held devices cost $200
Communication	the cost for a transatlantic phone channel has decreased from $60,000/year in 1956 to $60/year today

Physics for future Presidents

Supreme Court Justices, Congressmen, CEOs,
Diplomats, Journalists, and other World Leaders

Richard A. Muller

Excerpt from the preface of PffP

Physics for future Presidents? Yes, that is a serious title. Energy, global warming, terrorism and counter-terrorism, health, internet, satellites, remote sensing, ICBMs and ABMs, DVDs and HDTVs -- economic and political issues increasingly have a strong high tech content. Misjudge the science, make a wrong decision. Yet many of our leaders never studied physics, and do not understand science and technology. Even my school, the University of California at Berkeley, doesn't require physics. Physics for future Presidents (or PffP) is designed to address that problem. Physics is the liberal arts of high technology. Understand physics, and never again be intimidated by technological advances. PffP is designed to attract students, and teach them the physics they need to know to be an effective world leader.

Is science too hard for world leaders to learn? No, it is just badly taught. Think of an analogous example: Charlemagne was only half literate. He could read but not write. Writing was a skill considered too tough even for world leaders, just as physics is today. And yet now most of the world is literate. Many children learn to read before kindergarten. Literacy in China is 84% (according to the OECD). We can, and must achieve the same level with scientific literacy, especially for our leaders.

This course is based on several decades of experience I've had presenting tough scientific issues to top leaders in government and business. My conclusion is that these people are smarter than most physics professors. They readily understand complex issues, even though they don't relax by doing integrals. (I know a physics professor who does.) PffP is not Physics for Poets, Physics for Jocks, or for Physics for Dummies. It is the physics you need to know be an effective world leader.

An ideal student and an interesting anecdote

Liz, a former student of my class, came to my office hour, eager to share a wonderful experience she had had a few days earlier. Her family had invited a physicist over for dinner, someone who worked at the Lawrence Livermore National Laboratory. He regaled them through the dinner with his stories of controlled thermonuclear fusion, and its great future for the power needs of our country. According to Liz, the family sat in awe of this great man describing his great work. Liz knew more about fusion than did her parents, because we had covered it in our class.

There was a period of quiet admiration at the end. Finally Liz spoke up. "Solar power has a future too," she said.

"Ha!" the physicist laughed. (He didn't mean to be patronizing, but this is a typical tone physicists affect.) "If you want enough power just for California," he continued, "you'd have to plaster the whole state with solar cells!"

Liz answered right back. "No, you're wrong," she said. "There is a gigawatt in a square kilometer of sunlight, and that's about the same as a nuclear power plant."

Stunned silence from the physicist. Liz said he frowned. Finally he said, "Hmm. Your numbers don't sound wrong. Of course, present solar cells are only 15% efficient… but that's not a huge factor. Hmm. I'll have to check my numbers."

YES!! That's what I want my students to be able to do. Not integrals, not roller-coaster calculations, not pontifications on the scientific method or the deep meaning of conservation of angular momentum. She was able to shut up an arrogant physicist who hadn't done his homework! Liz hadn't just memorized facts. She knew enough about the subject of energy that she could confidently present her case under duress when confronted by a supposed expert. Her performance is even more impressive when you recognize that solar power is only a tiny part of this course. She remembered the important numbers because she had found them fascinating and important. She hadn't just memorized them, but had thought about them and discussed them with her classmates. They had become part of her, a part she could bring out and use when she needed them, even a year later.

The typical physics major, even the typical Ph.D., does not know the material in this book. He (and increasingly she) knows little to nothing about nukes, optics, fluids, batteries, lasers, IR and UV, x-rays and gamma rays, MRI, CAT, and PET scans. Ask a physics major how a nuclear bomb works and you'll hear what the student learned in high school. For that reason, at Berkeley we have now opened this course for physics majors to take. It is not baby physics. It is advanced physics.

Physics Review (energy and power)

Energy measured in Joules MKS (or calories)

4000 Joules = 1 Calorie,

1 Calorie (food) = 1 kcal (physics)

What is Power ?

Answer: Energy/time or Joule/sec or Watts

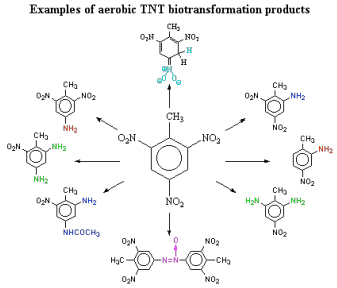
What is a kilowatt-hour (energy or power) ?

Answer: A quantity of energy. Used by the power company for billing. (1 kilowatt-hour ~1000 Calories)

Factual Information can change stereotypes and political opinions.

object	Calories (or Watt-hours)	joules	compared to TNT
bullet (at sound speed, 1000 ft per sec)	0.01	40	0.015
battery (auto)	.03	125	0.05
battery (rechargeable computer)	0.1	400	0.15
battery (alkaline flashlight)	0.15	600	0.23
TNT (the explosive trinitrotoluene)	0.65	2,723	1
modern High Explosive (PETN)	1	4200	1.6
chocolate chip cookies	5	21,000	8
coal	6	27,000	10
butter	7	29,000	11
alcohol (ethanol)	6	27,000	10
gasoline	10	42,000	15
natural gas (methane, CH_4)	13	54,000	20
hydrogen gas or liquid (H_2)	26	110,000	40
asteroid or meteor (30 km/sec)	100	450,000	165
uranium-235	20 million	82 billion	30 million

How can Chocolate Chip Cookies (CCC) have more energy (J/gram) than TNT ?



The difference is about a factor of 8.
Why don't we blow up buildings with CCC rather than TNT ?

Answer: one important difference involves *energy* versus *power*.

Power (W=J/sec) is different from Energy (J).

In TNT the *power* is large whereas in CCC only the *total energy* not the power is large. CCC requires human metabolism to release the energy. TNT can release its energy in 10^{-6} seconds

Energy

Factual Information can change stereotypes and political opinions.

Which country has the most reserves of fossil fuels ?

Ans: USA

Is Saudi Arabia in the top five ?

Ans: No

From what country does the US import the most oil ?

Energy

Factual Information can change stereotypes and political opinions.

Fossil fuel reserves (billions of barrels of oil equivalent)

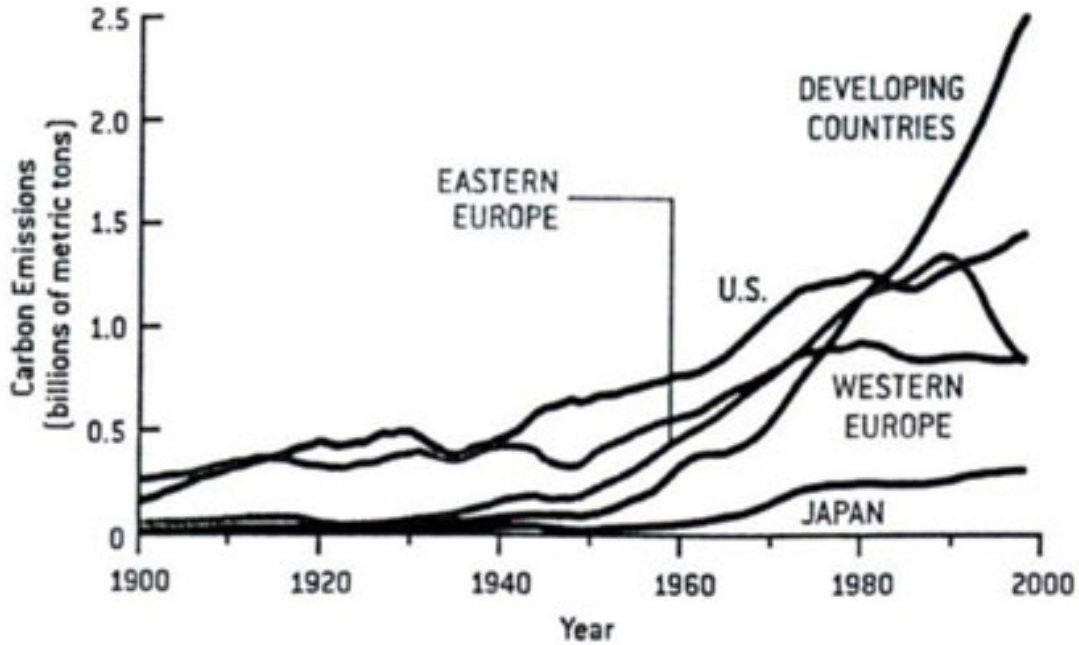
	Oil	Coal	Natural Gas	Total	Shale	total with shale
US	21	1184	32	1237	2500	3737
Russia	60	754	280	1094	250	1344
Australia	130	377	821	1328		1328
India	5	444	853	1302		1302
China	48	550	14	612		612
Iran	136		157	293		293
Saudi Arabia	260		0	260		260
Canada	179	32	9	220		220
Qatar	15		152	167		167
Brazil	8	49	2	59	80	139
Iraq	115		18	133		133
UAE	97		35	132		132
Kuwait	99		9	108		108
Venezuela	80	2	25	107		107
Mexico	12	17	5	34	100	234

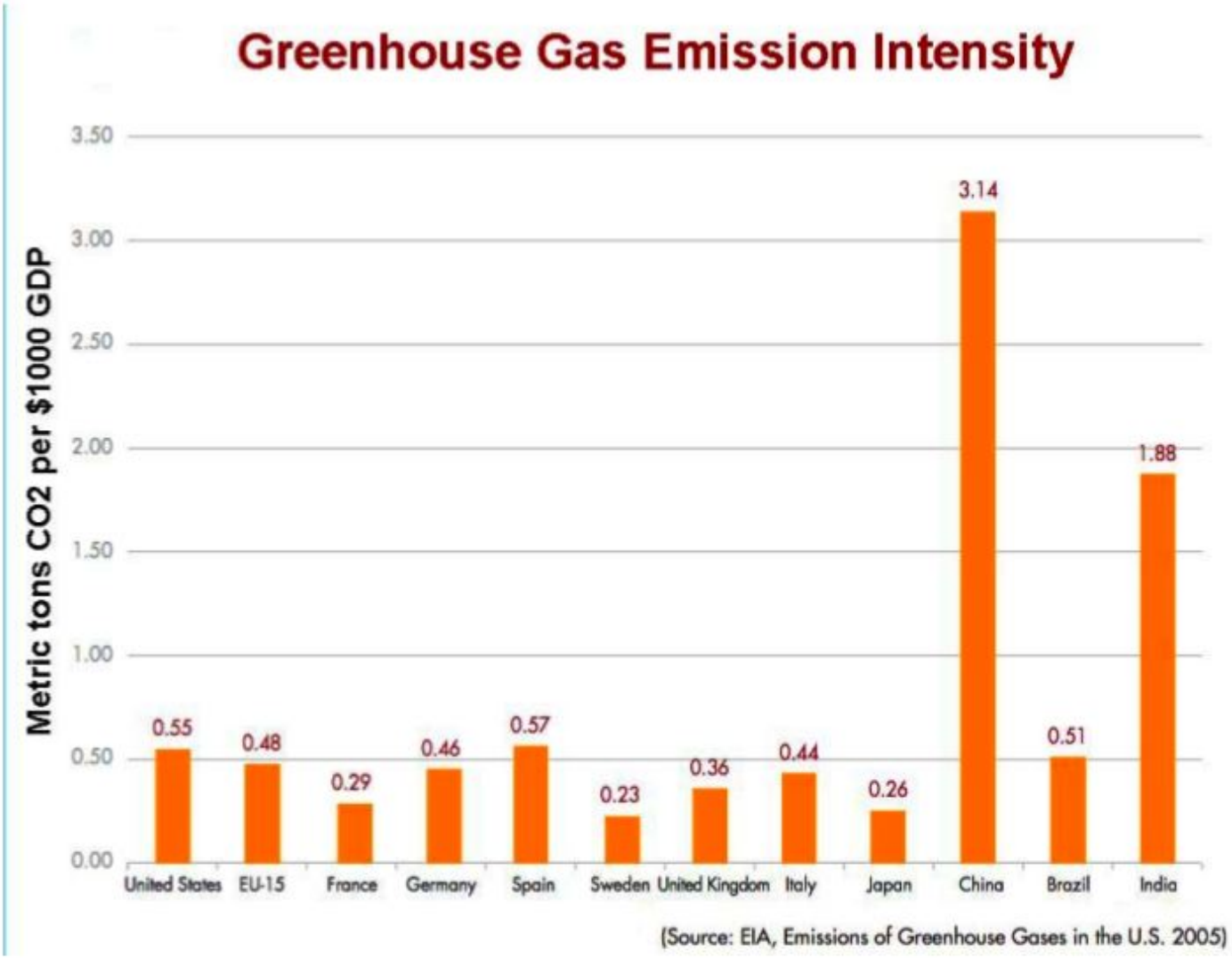
Factual Information can change stereotypes and political opinions.

fuel	market cost	**cost per kWh (1000 Cal)**	cost if converted to electricity
coal	$40 per ton	**0.4¢**	1.2¢
natural gas	$10 per million cubic feet	**3¢**	9¢
gasoline	$3 per gallon	**9¢**	27¢
electricity	$0.10 per kWh	**10¢**	10¢

NB: Coal is “dirt cheap”

Carbon emissions related to energy





N.B. Note normalization of y-axis !! China and India are poor but produce large emissions per unit of income

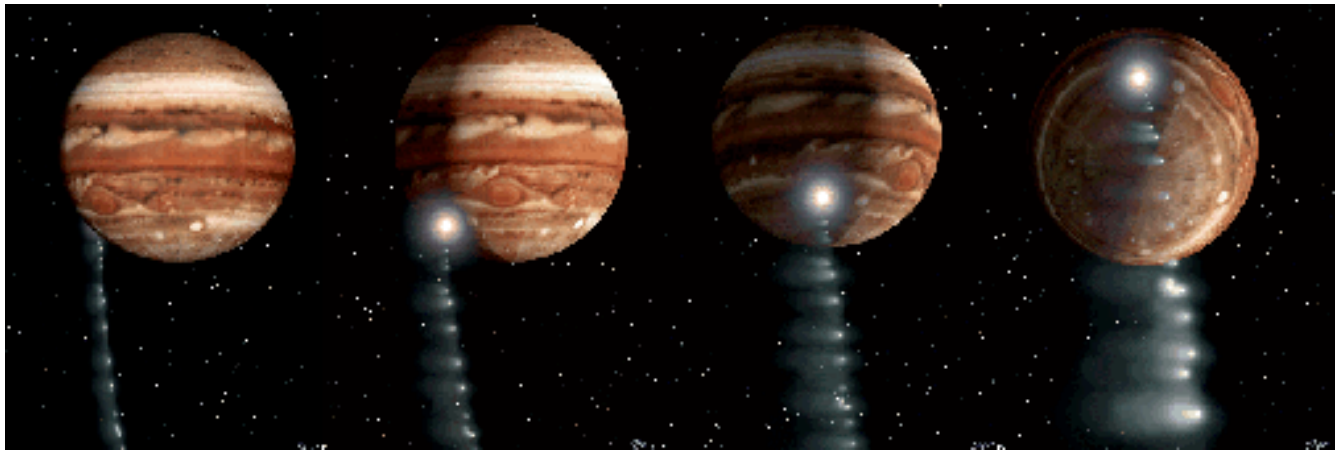
Some order of magnitudes that you should know

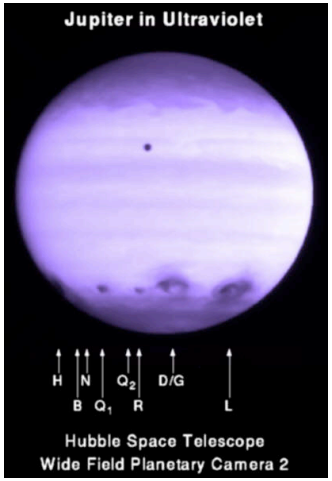
value	equivalent	example of that much power use
1 watt	1 joule per second	flashlight
100 watts		bright light bulb; heat from a sitting human
1 horsepower (1 hp)	≈ 1 kilowatt[A]	typical horse (for extended time) human running fast up flight of stairs
1 kilowatt (1 kW)	≈ 1 hp[B]	small house (not including heat); power in 1 square meter of sunlight
100 horsepower	≈ 100 kW[C]	small automobile
1 megawatt (MW)	1 million (10^6) watts	electric power for a small town
45 megawatts		747 airplane; small power plant
1 gigawatt = 1 GW	1 billion (10^9 watts	large coal, gas, or nuclear power plant
400 gigawatts = 0.4 terawatts		average electric power use US
2 terawatts	= 2 x10^{12} watts	average electric power for World

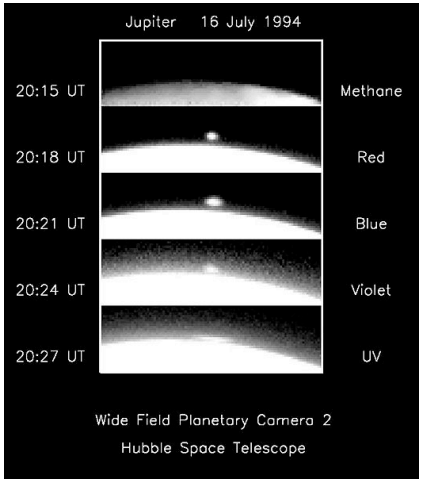
Examples of large energy release in cataclysmic events

~Six million (1,000,000-6,000,000) megatons of TNT equiv released

Views of collision of comet Shoemaker-Levy with Jupiter







Artist rendition of the KT extinction event that may have caused the extinction of the dinosaurs

Estimated energy ~ 96 teratons of TNT equiv, 4.0×10^{23} J

Fossil with KT layer (65 million years ago)

Intermediate layer contains 1000 times more Iridium (R. Muller)

Geologists have found a large crater in Mexico from candidate event

PAN-STARRS project on Haleakala (Maui) scans the sky to detect near earth asteroids and other dangerous objects

Calculation of the demise of the dinosaurs

$$v = 30 km/\sec$$

Velocity of earth around the sun.
(To calculate use the earth-sun distance and length of a year, $\pi \times 10^7$ sec)

Asteroid diameter = 10 km

Asteroid mass = 1.6×10^{12} tons (1.6 teratons)

(Use density of rock [$3 g/cm^3$] and radius)

Calculate kinetic energy = $\frac{1}{2} m v^2$

Convert to units of TNT equiv (x 165)

Energy is 2.6×10^{14} tons of TNT equiv.

This corresponds to over 10^8 nuclear bombs (10,000 times the US-Soviet cold war arsenal)

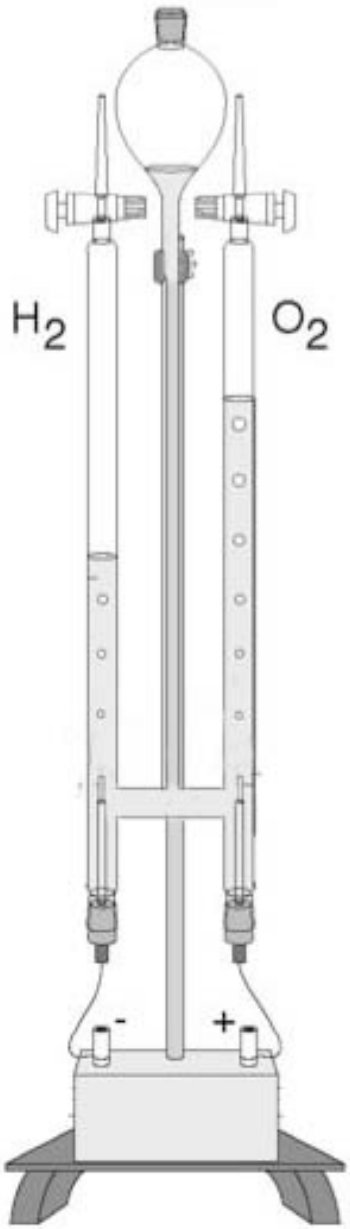
[11] The Earth-Sun distance is $r = 93 \times 10^6$ miles $= 150 \times 10^6$ kilometers. The total distance around the circumference is $C = 2 \pi r$. The time it takes to go around is one year $t = 3.16 \times 10^7$ seconds. Putting these together, we get the velocity of the Earth is $v = C/t = 30$ km/sec. (Note that the number of seconds in a year is very close to $t \approx \pi \times 10^7$. That is a favorite approximation used by physicists.)

[12] Taking the radius to be 5 km $= 5 \times 10^5$ cm, we get the volume $V = (4/3) \pi r^3 = 5.2 \times 10^{17}$ cubic centimeters. The density of rock is about 3 grams per cubic centimeter, so the mass is about 1.6×10^{18} grams $= 1.6 \times 10^{12}$ metric tons.

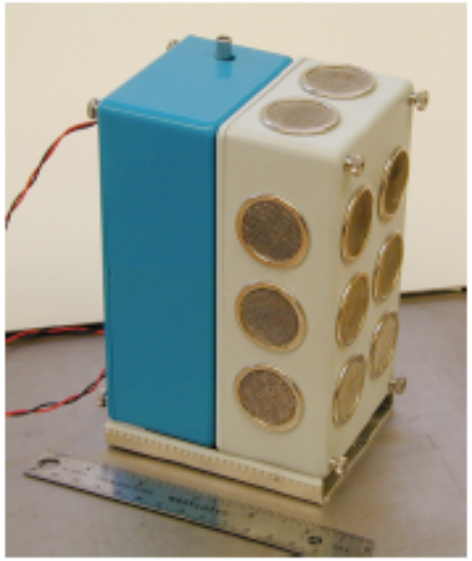
[13] The Hiroshima bomb had an energy equivalent of 13 kilotons = 0.013 megatons of TNT. The largest nuclear weapon ever tested was a Soviet test in 1961 that released energy equivalent to 58 megatons of TNT.

Comments on various energy alternatives

“The Hydrogen Economy”



Electrolysis run “backwards”



Fuel cell developed by NASA. Hydrogen gas enters through the inlet on the top. Air enters though some of the circular openings, and carbon dioxide leaves through the others. The electric power comes from the wires in the back.

Problem: Hydrogen is not very dense (0.071g/cm^3); about a factor of ten less than gasoline but 2.6 times more energy per mass

Remember this: Compared to gasoline, **liquid hydrogen** has

3 x *more* energy per gram (or per lb)
3 x *less* energy per gallon (or per liter)

Here's another approximate rule that is easy to remember. In terms of energy that can be delivered to a car:

1 kilogram of hydrogen ≈ 1 gallon of gasoline

Hydrogen liquid is dangerous to store since it expands by a factor of a thousand if warmed. If you protect against that with a thick-walled tank, you might as well store the hydrogen as a high-pressure gas. At a pressure of 10,000 pounds per square inch (66 times atmospheric pressure) the gas is almost half as dense as hydrogen liquid. But that factor of half makes it even harder to fit hydrogen into a reasonable space.

Compared to gasoline, compressed gas hydrogen has
6 x *less* energy per gallon (or per liter)

And the tank to contain the hydrogen typically weighs 10 to 20 times as much as the hydrogen itself. That takes away the weight advantage too.

hydrogen is not a *source* of energy.
It is only a means for *transporting* energy.

Hydrogen powered demonstration vehicles from Honda and GM

Cost is ~$400,000 and liquid hydrogen refills of fuel cells is complicated.
Companies are now pursuing electric vehicles and selling lots of hybrids.

President George Bush started a crash program on hydrogen power in 2003 not pursued by President Obama

President George Bush started a crash program on hydrogen power in 2003 not pursued by President Barack Obama

- In 2009 the U.S. Secretary of Energy, Stephen Chu, (also Physics Nobel Prize winner) stated that fuel cell hydrogen vehicles "will not be practical over the next 10 to 20 years". He cited difficulties in the development of the required infrastructure to distribute hydrogen as a justification for cutting research funds.[77] The National Hydrogen Association and other hydrogen groups criticized the decision.[78] Secretary Chu told MIT's Technology Review that he is skeptical about hydrogen's use in transportation because "the way we get hydrogen primarily is from reforming [natural] gas. ... You're giving away some of the energy content of natural gas. ... So that's one problem. ... [For] transportation, we don't have a good storage mechanism yet. ... The fuel cells aren't there yet, and the distribution infrastructure isn't there yet. ... In order to get significant deployment, you need four significant technological breakthroughs. ... If you need four miracles, that's unlikely: saints only need three miracles".[33] Congress reversed the funding cuts in its appropriations bill for 2010,[7] but the Department of Energy plans to decrease funding for Fuel Cell Vehicle development in its 2012 budget.[79]

The Interisland Wind project proposes to connect up to 400 megawatts of renewable wind energy from Molokai and Lanai via undersea cable to Oahu. The project would play an important part in helping to achieve the Hawaii Clean Energy Initiative goal of 70 percent clean energy for electricity and ground transportation by 2030.

The State of Hawaii, First Wind Hawaii, Castle & Cooke and Hawaiian Electric Company are committed to working collaboratively with the public on the project, which has four major parts:

1) a 200 megawatt wind farm on Lanai;
2) a 200 megawatt wind farm on Molokai;
3) an interisland, undersea cable system connecting the wind farms to Oahu;
4) upgrades to the O‘ahu grid to enable integration of substantial amounts of intermittent wind power.

Maui Wind farm
(20 1.5 megawatt
windmills)

A "forest" of wind turbines has been proposed for construction on the ocean, off the coast of Massachusetts, to supply commercial power. In case you are interested, here are some of the details: there will be 170 large windmills in a 5 mile by 5 mile square, connected to land via an undersea cable. Each windmill would rise 426 feet, from water level to the tip of the highest blade (the height of a 40- story building). They would be spaced 1/2 mile from each other. The maximum power this forest can deliver will be 0.42 gigawatts. The major opposition to the idea appears to be coming from environmentalists who argue that the array destroys a wilderness area, would kill birds, and creates noise that could disturb marine animals. (Reference: New York Times, "Offshore Harvest of Wind is Proposed for Cape Cod", Karen Lee Ziner, April 16, 2002.)

Proposed wind turbine park in Massachusetts (Dept of Energy)

Next Friday:

Easy Multiple Choice quiz on Physics for Future Presidents (Energy)

22. A large nuclear power plant delivers energy of about

( ) 1 megawatt
( ) 1 gigawatt
( ) 100 gigawatts
( ) 1000 gigawatts

3. The asteroid that killed the dinosaurs exploded because

( ) it was made of explosive material ( ) it was made out of U-235
( ) it got very hot from the impact
( ) it didn't explode. It knocked the Earth out of its normal orbit.

14. Compared to TNT, a typical meteor with the same mass has energy that is

( ) 10 times smaller
( ) equal
( ) 10 times larger
( ) 100 times larger

1. "Smart Rocks" are considered for

( ) geologic dating
( ) ballistic missile defense
( ) nuclear power
( ) solar power