

On Teaching Energy:

Preparing Students Better for their Role as Citizens

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Grand Challenges

- in 1901, Hilbert (1901) published a list of 23 unsolved mathematical problems
 - a challenge to the mathematical community
 - inspiration for today's grand challenges
- *grand challenges* are calls to spur progress toward solving important societal and environmental problems in a variety of disciplines
- common characteristics:
 - social relevance;
 - significant economic impact;
 - solvability;
 - multidisciplinary research projects; and
 - need for investment of significant resources

Grand Challenges

- concept common in the scientific, engineering, technological, medical and social science communities
- partial list of disciplines issuing grand challenges:
 - engineering (NAE, 2008);
 - the chemical industry (NRC, 2005a);
 - disaster mitigation (NRC, 2005b);
 - global health (Varmus et al., 2003);
 - environmental sciences (NRC, 2001);
 - Earth and environmental sciences (Zoback, 2001);
 - Earth system science (Schellnhuber and Sahagian, 2002; Steffen et al., 2004); and
 - geosciences and energy (DePaolo and Orr, 2007).

Energy's Grand Challenges

- energy 's grand challenges are many, complex and multifaceted
 - vary in scale from local to regional to national to international
- broadly can be grouped into three classes:
 - supply
 - access
 - environmental impact (including climate change)
- are not isolated, but closely interrelated

Energy Solutions

- solutions to energy issues must be multifaceted as well
- historically, based on energy science, technology & economics
 - not always the most just solutions
- solutions are more sustainable, equitable and effective when additional perspectives are considered
 - environment, social institutions, culture, politics, etc.
 - demonstrated many places and times
 - usually only considered when there is excess wealth
- symbolically, this condition can be expressed as:

$$\text{solutions to energy issues} = f \left(\begin{array}{l} \text{energy} \\ \text{science} \end{array}, \text{technology}, \text{economics}, \pm \text{environment}, \pm \text{social}, \pm \dots \right)$$

Energy Solutions

- the additional perspectives of energy issues, i.e. economics, environment, social, etc., are defined by *social context*
- to illustrate, consider the following cases:
 - hydrocarbons: Norway and Nigeria
 - coal: U.S. and China
- including social context, our symbolic representation becomes:

$$\text{solutions to energy issues} = f \left(\text{energy science}, \text{technology}, \overbrace{\text{economics, } \pm \text{environment, } \pm \text{social, } \pm \text{.....}}^{\text{social context}} \right)$$

Energy Science: The Need

Using the worksheet you completed during dinner, let's fill in this table.

primary energy source	energy type			physical state	trading units	energy density units
	primary	secondary	tertiary			
<i>conventional</i>						
oil						
natural gas						
coal						
nuclear						

Energy Science: The Need

Using the worksheet you completed during dinner, let's fill in this table.

primary energy source	energy type			physical state	trading units	energy density units
	primary	secondary	tertiary			
<i>conventional</i>						
oil	chemical	radiant		liquid	bbbl, tonnes	Btu/bbl, Btu/tonne
natural gas	chemical	radiant		gas	TCF, MCF	Btu/ft ³ , Btu/TCF, Btu/MCF
coal	chemical	radiant		solid	tons, tonnes	Btu/lb, Btu/ton, Btu/tonne
nuclear	mass			solid	lbs U ₃ O ₈	Btu/lb

Energy Science

- multidimensional: biology, chemistry, Earth science, physics
 - requires explicit integration
- some key subject areas are absent in most undergraduate science courses:
 - thermodynamics
- uses a language in which every day words have special meanings, e.g. heat, work, energy, etc.
 - potential source of confusion for students (Solomon, 1983)

Energy Context & Technology

Let's complete this table, using the results from the worksheet you completed during dinner.

Question	Saudi Arabia	United States
What is the average daily oil production for -?		
How many barrels of oil does - produce each year?		
What was the daily production rate for an average - well in 1998?		
Estimate the number of producing wells in Saudi Arabia.		
With stripper wells (<10 b/d)		

Energy Context & Technology

Let's complete this table, using the results from the worksheet you completed during dinner.

Question	Saudi Arabia	United States
What is the average daily oil production for -?	10.4×10^6 b/d	6.9×10^6 b/d
How many barrels of oil does - produce each year?	37.9×10^9 b	2.58×10^9 b
What was the daily production rate for an average - well in 1998?	5,140 b/d	11 b/d
Estimate the number of producing wells in Saudi Arabia.	2,023	627,272
With stripper wells (<10 b/d)		1,239,418

these simple calculations provide an entirely new perspective on “drill, baby, drill”

Saudi vs. U.S. Production

U.S. oil production



Saudi oil production

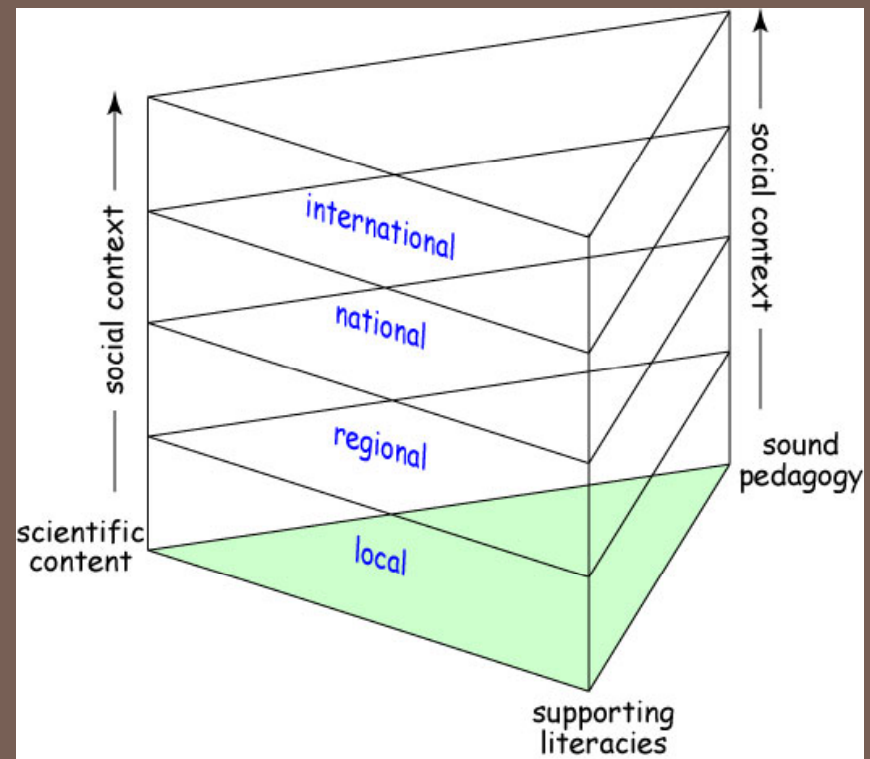


Technology

- indicates what is physically possible
- increasingly important as we reach the end of fossil fuel era and look for a new energy future
 - debates about wind and solar, all have key technological components
- switch to “green” energy will be heavily influenced by technology, e.g. biofuels
- these types of discussions are critical if we are to make a successful transition from fossil fuels
 - didn’t get it right for nuclear
 - can’t afford to make a similar mistake with green energy

Social Context

- social context provides relevancy for science
- context provided by:
 - addressing topical issues in the news
 - varying scope from local to international
- context introduces:
 - different viewpoints & perspectives
 - connection to students' lives



Energy Instruction

- energy instruction must be multi-dimensional
 - energy science and technology are critical - defined by subject area
 - social context necessary to connect subject and student - determined by instructor's interest
- effective learning requires, however, another dimension - pedagogy
 - ensures student success in the classroom
 - must facilitate transfer of classroom knowledge to real world
- energy instruction can be represented symbolically as:

$$\text{teaching energy} = f \left(\text{energy science, technology, } \overbrace{\text{economics, } \pm \text{environment, } \pm \text{social, } \pm \text{.....}}^{\text{social context}}, \text{ pedagogy} \right)$$

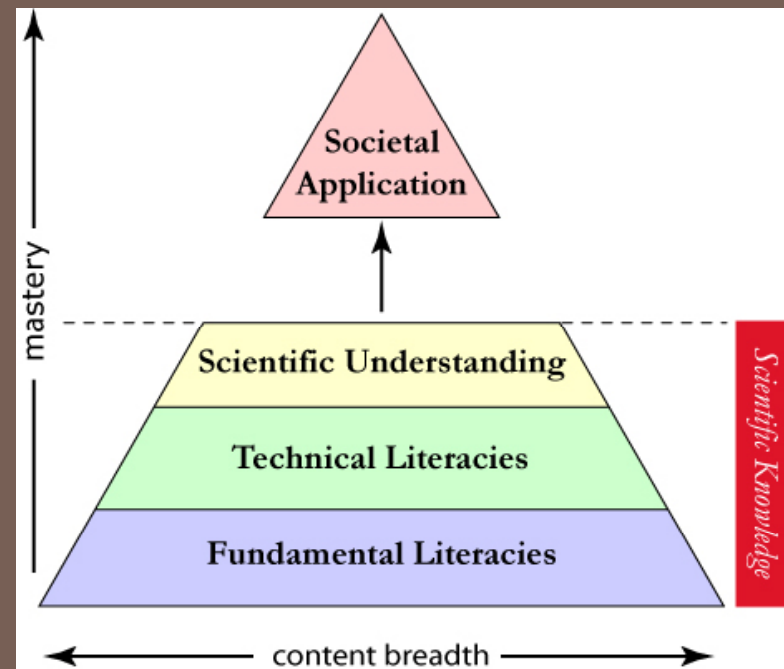
Energy Instruction: Pedagogy

$$\text{teaching energy} = f \left(\text{energy science, technology, } \overbrace{\text{economics, } \pm \text{environment, } \pm \text{social, } \pm \text{.....}}^{\text{social context}}, \text{ pedagogy} \right)$$

- includes, but goes beyond, classroom techniques
- aimed at developing a particular student skill set:
 - scientific literacy, ability to handle uncertainty and ambiguity, critical thinking, problem solving
 - specialized skills, e.g. reading maps
 - quantitative reasoning

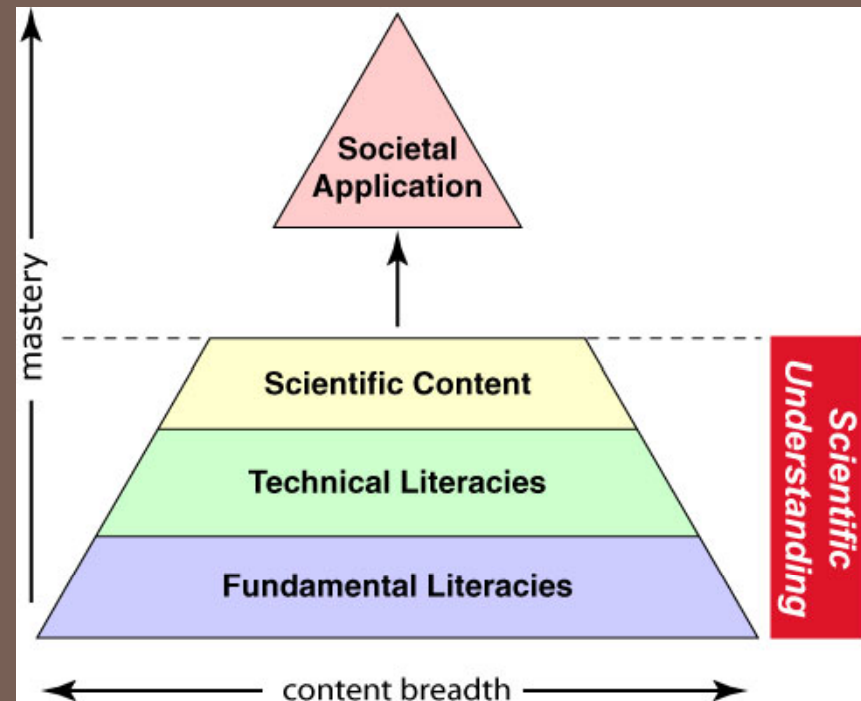
Literacies: Making Understanding

- *fundamental literacies*: ability to read & interpret data and make computations
- *technical literacies*: skills specific to a scientific discipline
- combined with scientific content, produce scientific understanding
- most science courses assume students :
 - have adequate fundamental & technical skills
 - will independently get help if they don't



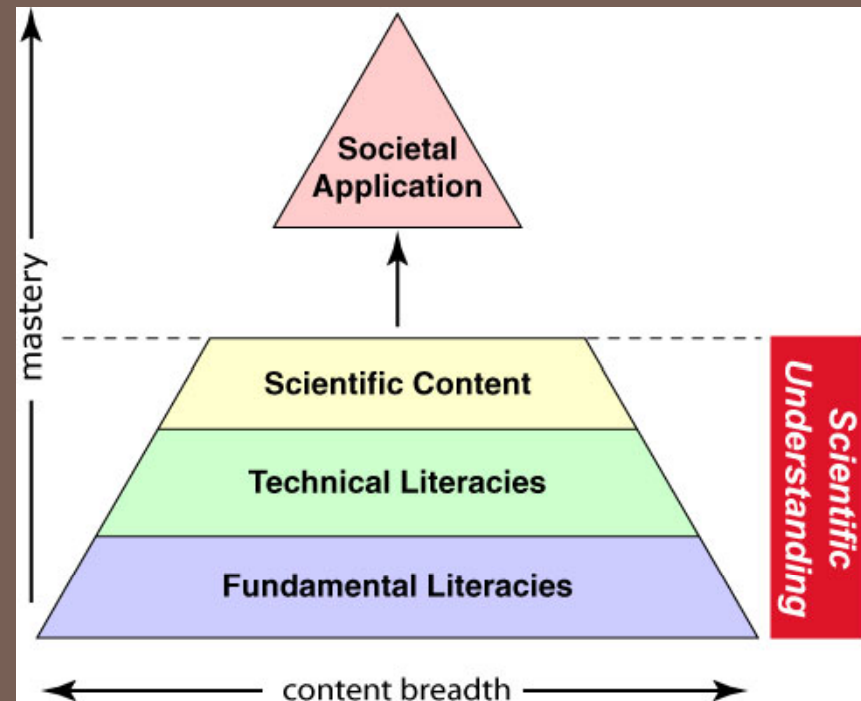
Literacies: Making Understanding

- mastery of literacies requires:
 - constant practice; and
 - application in a variety of contexts
- combined with scientific content, literacies produce scientific understanding



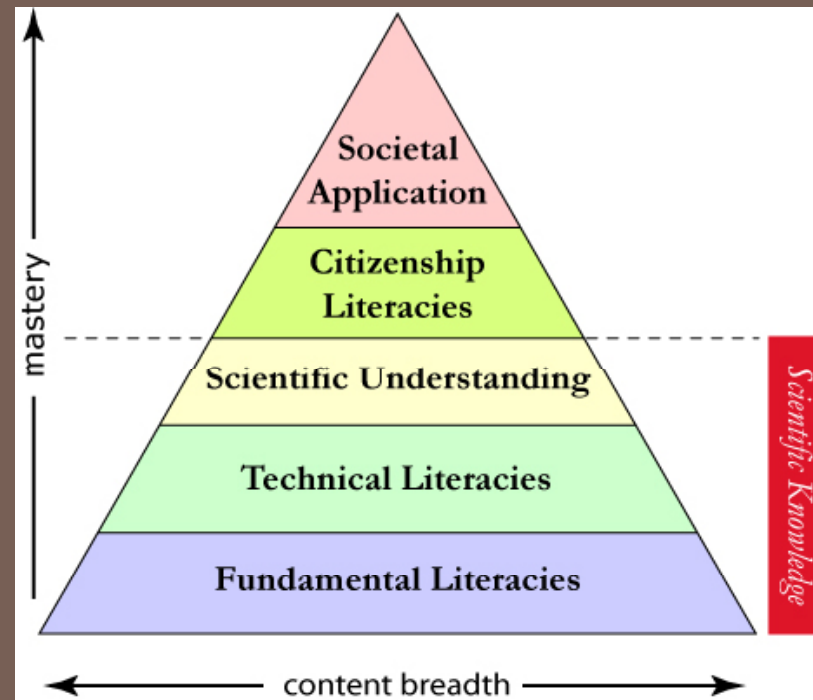
Literacies: A Missing Ingredient

- a liberal education is founded on concept of *transfer*
 - use of information/skills of one domain in another domain (Robins, 1996)
- many studies show little transfer between classes
- yet, introductory science courses assume implicitly transfer of science knowledge to real world
 - rare, even for best students



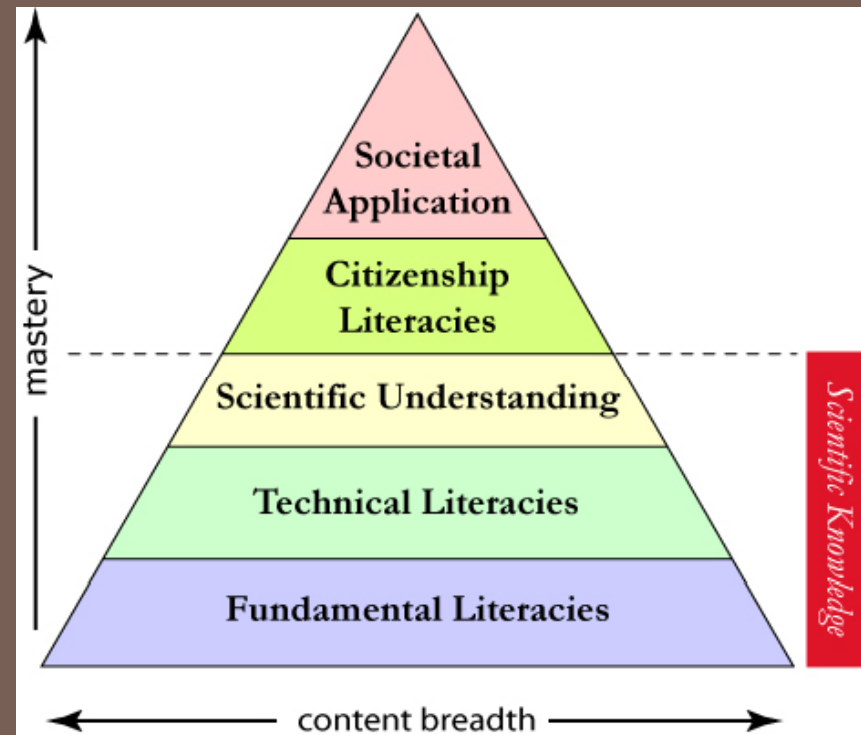
Literacies: A Missing Ingredient

- to facilitate classroom to real world transfer, Myers & Massey (2008) defined the *citizenship literacies*
- skills necessary to apply scientific understanding and knowledge to a variety of complex societal problems



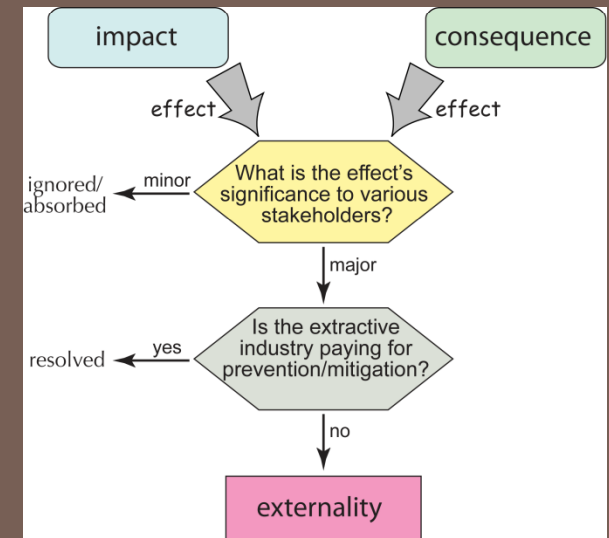
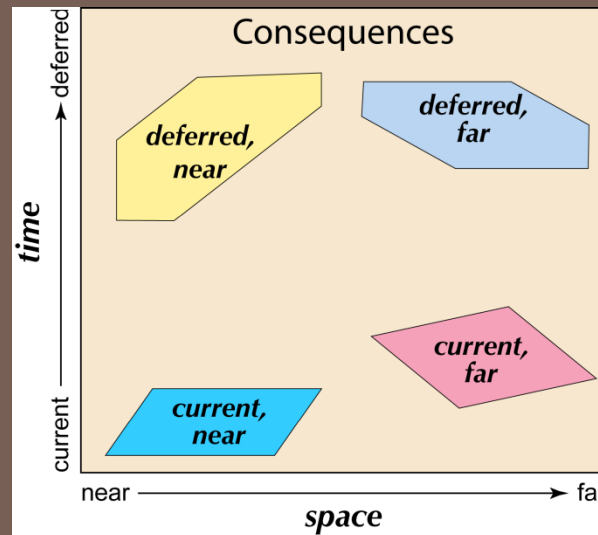
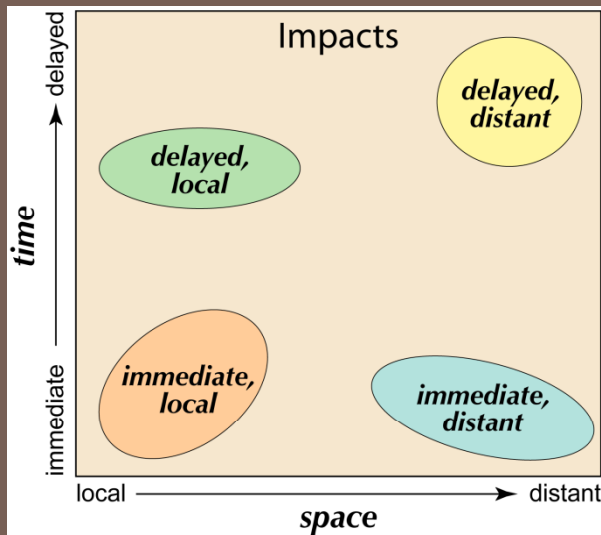
Literacies: Citizenship

- three classes:
 - critical thinking
 - understanding social context
 - informed engagement
- designed to:
 - help students connect science to real problems in meaningful and effective way
 - enable them to be effective spokespersons



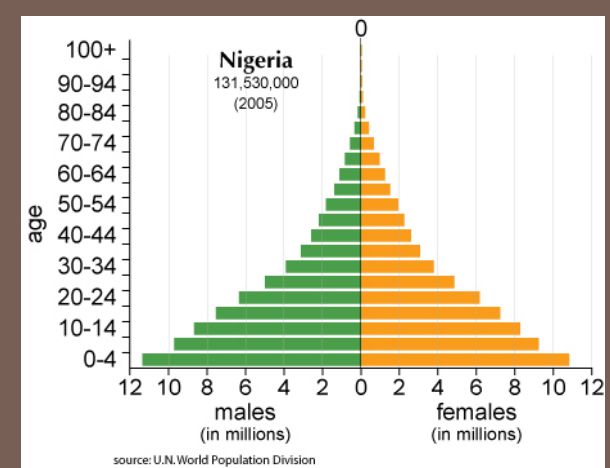
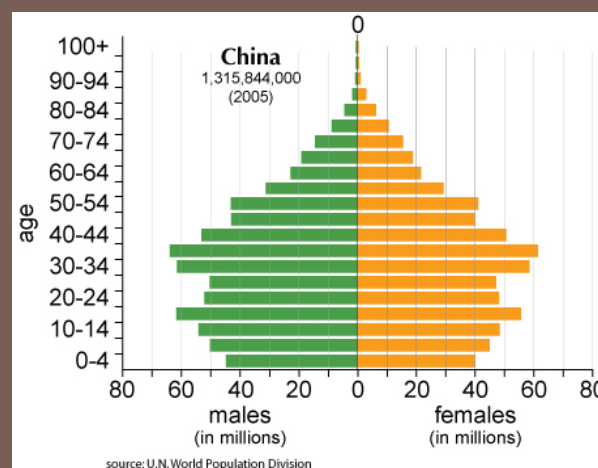
Citizenship Literacies

- **critical thinking**: procedures and methods necessary to analyze scientific “solutions” to geologically influenced issues from cultural, economic, political and social perspectives
 - recognize impacts to physical environment
 - identify social, cultural & political consequences
 - ascertain economic externalities (unanticipated, hidden & shared costs)



Citizenship Literacies

- **understanding social context:** skills useful for understanding cultures and societies affected by geologically influenced “problems”
 - appreciating historical background and significance
 - understanding population demographics
 - acknowledging economic extent
 - recognizing different cultural & social viewpoints/perspectives



Our Case-study Library: Energy

Resource	Country	Case Study	Modules
petroleum	Nigeria	Oil, Wealth & Conflict in Nigeria	I. Using Geology to Find Petroleum II. Is There Enough Crude to Produce? III. Wealth vs. Social Impact
	Saudi Arabia	Saudi Arabia, OPEC & Global Oil	I. Tapping the World's Largest Oil Fields II. OPEC & the Economics of Oil III. Energy Dependency: An OPEC Perspective
	United States	USA, Oil and ANWR	I. Understanding ANWR's Geology II. Getting ANWR's Oil to the Lower 48 III. Is ANWR the Path to U.S. Oil Independence?
coal	China	China, Energy and Kyoto	I. Planning Coal Lease Development II. Coal Power Plants: Maintain, Retrofit or Replace? III. Can Kyoto be Made to Work?

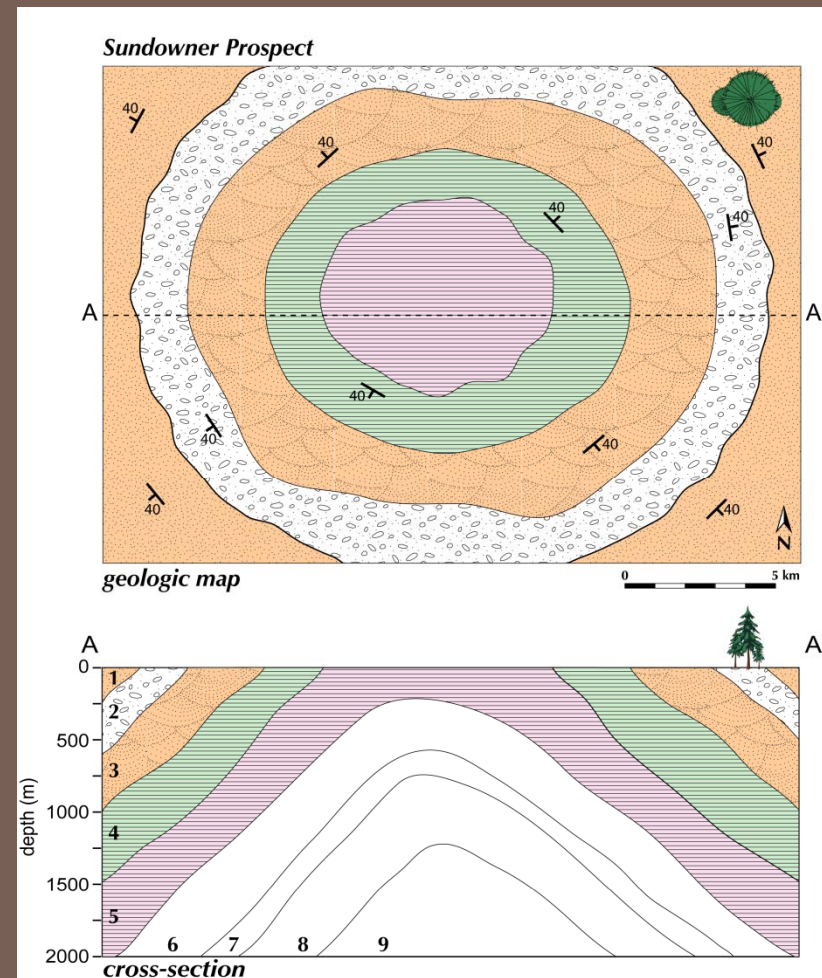
Our Case-study Library: Energy

Resource	Country	Case Study	Modules
nuclear power	Iran	Power, Weapons & Iran	<ul style="list-style-type: none">I. Designing a Uranium MineII. Choosing a Reactor Design and Fuel CycleIII. Iran, the West and Nuclear Non-proliferation
biofuels	Brazil	The Future of Global Energy?	<ul style="list-style-type: none">I. The Production of BiofuelsII. Economic Reality: Biofuels vs. PetroleumIII. Food vs. Fuel: The Global Implications of Biofuels

Saudi Arabia, OPEC & Global Oil

I. Tapping the World's Largest Oil Fields

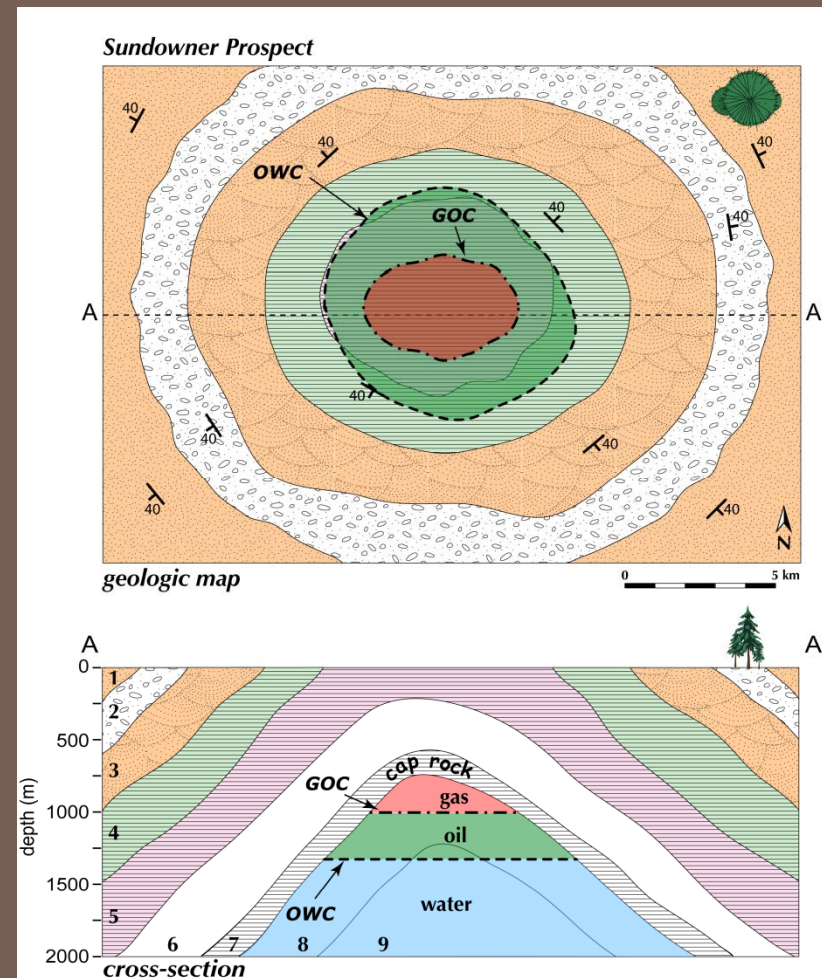
- use geologic principles to devise exploration program
 - where to drill
 - how deep to drill
 - what logs to run
- interpret results
 - locate hydrocarbons
 - determine types present
- present findings orally and in writing
 - make recommendation which leases to evaluate and which to abandon



Saudi Arabia, OPEC & Global Oil

II. OPEC & the Economics of Oil

- examination of technology and economics of oil and gas production
- two general tasks:
 - evaluate economic value of each reservoir
 - devise a production plan
- present findings orally and in writing
 - make recommendation which lease(s) to develop



Saudi Arabia, OPEC & Global Oil

The U.S. View

New Trend in Biofuels Carries New Risks

By ELISABETH ROSENTHAL
ROME — In the past year, as the diversion of food crops like corn and palm to make biofuels has helped to drive up food prices, investors and politicians have begun promoting newer, so-called second-generation biofuels as the next wave of green energy. These, made from non-food crops like reeds and wild grasses, would offer fuel without the risk of taking food off the table, they said.

But now, biologists and botanists are warning that they may bring consequences: newer crop label invasive weeds — their high biofuel plant cent farms create corridors for them to spread, they say.

At a United Nations Convention on Biological Diversity, scientists presented a report about the risks of biofuels. Some of the recommendations include: do not plant biofuels in areas that are ecologically sensitive; do not plant biofuels in areas that are ecologically sensitive; do not plant biofuels in areas that are ecologically sensitive.

Control plants could experts said financial losses International variation of the message invasive bio country.

To reach scientists co most popular biofuels will species and degree of evaluation before plant. "With bio a hurry," said an invasive the Internet operation of are started from the U.S.

are eager to generate biofuels within a couple of years and also, as you might guess, they don't want a negative assessment. The biofuels industry said the risk of those crops morphing into weed problems is overstated, noting that proposed biofuel crops, while they have some potential to become weeds, are not plants that inevitably turn invasive. "There are very few plants that are 'weeds,' full stop," said Willy De Groot, incoming secretary general of EuropaBio, an industry

instrument — is a fast-growing, thirsty species that has drained wetlands and clogged drainage systems in other places where it has been planted. It is also highly flammable and increases the risk of fires. From a business perspective, the good thing about second-generation biofuel crops is that they are easy to grow and need little attention. But that is also what creates their invasive potential. "These are tough survivors, which means they're good pro-

KHURAIS OIL FIELD JOURNAL

Saudi Oil Project Brings Skepticism to the Surface

By ROBERT F. WORTH

KHURAIS OIL FIELD, Saudi Arabia — For mile after mile, there is nothing but flat and unrelenting sand on every side, with a few black camels wandering in the desert glare.

Then, suddenly, it rises into view, like some vast industrial mirage. The Khurais oil field's processing plant resembles nothing so much as an oversize Erector Set, its unlikely vertical tubes and steel scaffolding gleaming in the sun.

But this remote patch of desert could hold the key to the soaring price of gasoline around the world.

Khurais, about 90 miles east of Riyadh, the Saudi capital, is one of the planet's last giant oil fields. The Saudis say that it holds 27 billion barrels of oil — more oil than all the proven reserves of the United States — and that it will significantly bolster the king-

dom's production capacity once it starts pumping a year from now, easing global need. Some oil traders and analysts doubt that. Their pessimistic forecasts of dwindling oil supplies have helped propel the current increase in prices, which pushed past \$140 a barrel last week and seem to be heading higher.

To help counter the skeptics, the Saudis flew a contingent of journalists from Jidda, on the Red Sea coast, to Khurais last week. The tour was largely a scripted one, with little opportunity to wander the grounds or verify official claims.

Still, one thing is clear: a gargantuan effort is under way here at the heart of the Arabian desert, with some 20,000 helmeted laborers working long shifts in 110-degree heat. What was an empty expanse of rust-colored sand just over two years ago is now a town-size industrial plant. Its basic structures appear to be complete already, including stadium-size storage tanks and a mile-long pipe rack that is four stories tall.

"We are sometimes criticized for not being more forthcoming about our oil," said Amin Nasser, senior vice president for production and exploration at Aramco, the national oil company, during a slide show presentation in a staff compound here. "But our actions have been louder than our words, despite all the criti-

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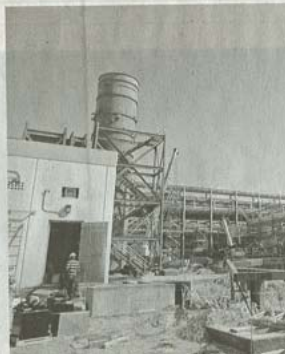
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Harvest The Sun — From Space

By O. Glenn Smith



THE NEW YORK TIMES INTERNATIONAL TUESDAY, JULY 1, 2008



An Asian worker at the Khurais oil field kept his face

hurt oil producers the most. As the former Saudi oil minister, Sheikh Ahmed Zaki Yamani, likes to say, the Stone Age did not end because we ran out of stones. So they have used their dominant position in OPEC to act as the "swing" producer, raising and lowering production as needed to keep prices steady and to ensure that the oil age continues. But lately, their power has been threatened by surging world demand that has eliminated most of the gap between supply and demand. The Khurais field, they hope, will help restore that arrangement.

Mr. Nasser and other Aramco officials described a project



As prices rise, a key producer says it can increase supply.

tions to protect the field include fences and crash barriers, government troops and even dogs. Once it is complete, workers at the complex will live in a nearby

Sports Wednesday, C13-16

Uprising Against the Ethanol Mandate

By DAVID STREITFELD

The ethanol industry, until recently a golden child that got favorable treatment from Washington, is facing a critical decision on its future.

Gov. Rick Perry of Texas is asking the Environmental Protection Agency to temporarily waive regulations requiring the oil industry to blend ever-increasing amounts of ethanol into gasoline. A decision is expected in the next few weeks.

Mr. Perry says the billions of bushels of corn being used to produce all that mandated ethanol would be better suited as livestock feed than as fuel.

Feed prices have soared in the last two years as fuel has begun competing with food for cropland.

"When you find yourself in a hole, you have to quit digging," Mr. Perry said in an interview. "And we are in a hole."

His request for an emergency waiver cutting the ethanol mandate to 4.5 billion gallons, from the 9 billion gallons required this year and

the 10.5 billion required in 2009, is backed by a coalition of food, livestock and environmental groups.

Farmers and ethanol and other biofuel producers are lobbying to keep the existing mandates.

"This is a critically important decision that will determine the future of biofuels in this country," said Brent Erickson, a lobbyist at the Biotechnology Industry Organization, which supports the ethanol mandates. "There will be a dramatic reaction from whoever loses."

The E.P.A. received 15,000 public comments on the Texas proposal, roughly split between those in favor and those against.

LHT Inc., an infrastructure company, said it never would have spent tens of millions of dollars developing delivery pipes for ethanol without the mandated increases. "How do we get our money back?" an executive asked.

O.K. Industries, a poultry company in Arkansas upset about rising feed costs, said this was the first year since the company was

Continued on Page 5

THE NEW YORK TIMES OP-ED THURSDAY, JUN



By Thomas W. Evans

THE president of the United States has the power to attack, and perhaps destroy, the Organization of the Petroleum Exporting Countries, the illegal cartel that has driven the price of oil over \$100 per barrel. This can be accomplished without invasion or bombing. No special legislation is needed. The presi-

dent refers to the "act of state doctrine," which was first enunciated by the Supreme Court in 1887 with the following words: "Every sovereign state is bound to respect the independence of every other sovereign state, and the courts of one country will not sit in judgment on the acts of the government of another, done within its own territory." The doctrine was seldom used, but new life was breathed into it in 1964, when the Supreme Court denied relief to Americans

Austria that directs 13 nations to sell their product at inflated prices to customers outside their boundaries. If the states won the case, the court could recover substantial damages based on assets and commercial activities of OPEC member nations in the United States.

Still, even though the states are allowed to sue OPEC in the Supreme Court, they might not prevail. There are significant separation of powers issues. The court might determine that OPEC's ille-

gality was remedied only by the legislature — whether his successor — the Court decided of the political would ask the president permitting the or at least assure interview to end established in a gress in the wake of American sug-

decision in this suit OPEC's destruc- tion from which- identified as hav- against the cartel. decision would de- onal path to re-

ed with the likeli- and restraint of its - or some of its a settlement estab- lish that would pre- actual costs. The be price of heating mp might exceed rent federal stimu-

ward the states to a would undoubt- dlers to the 2008, need for diplomatic a fallout. But how

Kevin Muloney for the New York Times



A shipment of milo, a sorghum grain, being unloaded at the Reeve Agri-Energy ethanol plant near Garden City, Kan.

Saudi Arabia, OPEC & Global Oil

III. Energy Independence: An OPEC Perspective

- *premise:* OPEC meeting to vote on 6 million bbl/d cut in production
 - member cut assigned based on proven reserves
- *roles:* Saudi Arabia, Iran, Venezuela, Kuwait or Nigeria
- *tasks:*
 - prepare country brief
 - calculate their nation's share of the proposed production cut
 - evaluate likely economic impact of the cut
 - vote for/against the cut

GEOL3650: Energy: A Geological Perspective Petroleum III: Understanding OPEC

Country Briefing

Country Name: _____

Geography

Area:
Total: _____ land: _____ water: _____

Natural Resources:

Land use:
arable land: _____ permanent crops: _____ other: _____
irrigated: _____

Water:
Renewable water resources: _____
freshwater withdrawals: total: _____ per capita: _____

People

Population: _____ --growth rate: _____ birth rate: _____
death rate: _____

life expectancy at birth:
total: _____ male: _____ female: _____

median age:
total: _____ male: _____ female: _____

1-Apr-09 Country Briefing 1 of 3

Assessment

- three basic mechanisms
 - pre- and post-course literacy surveys
 - fundamental & technical, citizenships
 - knowledge surveys
 - focus groups
 - individual case studies
 - overall lab structure
- results from:
 - Earth Resources
 - Physical Geology
 - Earth & Mineral Resources
 - Energy: A Geological Perspective

Student Responses

- case studies: “...the real world of the case study made it more interesting.... The types of information were the same, but the way I learned them was different. That makes it a plus for me.”
- group learning: “My group was a mix; all three of us were in different majors, so we all three had different ways of looking at the problem.”
- peer instruction: “...we [geology majors] were able to help other students with that.”

Student Responses

- problem-based learning: “There were a lot of lectures about oil drilling and it wasn’t sinking in. Then we did the labs and it made sense because we were actually taking it and applying it and using [it to figure something out].”
- oral presentations: “When you have to get up and talk about it, that means you have to kind of remember and understand what you were talking about... You actually have to process the information.”

Student Responses

- written reports: “They [the non-geology majors] weren’t used to writing lab reports. So I found, from my background, I was trying to explain to them.”
- discussion: “[I learned] how to deal with other people. Like the last one, we had to deal with the government, the company, and the union. We had to deal with different groups, different factions of people. They had a different agenda than we did. You learned to deal with people, how to talk to them, how to negotiate.”

Conclusions

- in the future, U.S. citizens will increasingly face energy questions
 - surveys show they are ill-prepared for these debates
- we can prepare them better, but not by teaching only energy content
- preparation requires addressing:
 - energy science
 - technology
 - energy context
 - multiple perspectives, e.g. economic, political, legal, etc.
 - established by energy's social context

Conclusions (con.)

- instruction must also explicitly address the underlying fundamental skills, i.e. literacies, of energy
 - *fundamental literacies*: ability to read & interpret data and make computations
 - *technical literacies*: skills specific to a scientific discipline
 - *citizenship literacies*: skills necessary to apply scientific understanding and knowledge to a variety of complex societal problems
- a successful transition to the future's new energy era requires, in part, a rethinking of instruction at all educational levels

Questions & Comments?

- email: magma@uwyo.edu
- class Web sites:
 - Energy: A Geological Perspective: <http://www.gg.uwyo.edu/geol3650>
 - Global Sustainability: Managing the Earth's Resources: <http://www.gg.uwyo.edu/geol1600>
- seminar Web sites:
 - Carbon Sequestration: <http://www.gg.uwyo.edu/geol4200-4>
 - Climate Change: What is the Science?: <http://www.gg.uwyo.edu/geol4200-5>
 - Peak Oil: Resource Exhaustion?: <http://www.gg.uwyo.edu/geol4200-6>
- resource Web site:
 - The Magma Foundry: <http://tmf.gg.uwyo.edu/>

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