# 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:

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

# 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:

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

# 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 | | | |
| | | | ***conventional*** | | | |
| oil | | | | | | |
| natural gas | | | | | | |
| coal | | | | | | |
| nuclear | | | | | | |

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| primary energy source | energy type | | | physical state | trading units | energy density units |
|---|---|---|---|---|---|---|
| | primary | secondary | tertiary | | | |
| | | | ***conventional*** | | | |
| oil | chemical | radiant | | liquid | bbl, 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 $U_3O_8$ | 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 works 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 -? | $10.4 \times 10^6$ b/d | $6.9 \times 10^6$ b/d |
| How many barrels of oil does - produce each year? | $37.9 \times 10^9$ b | $2.58 \times 10^9$ 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**

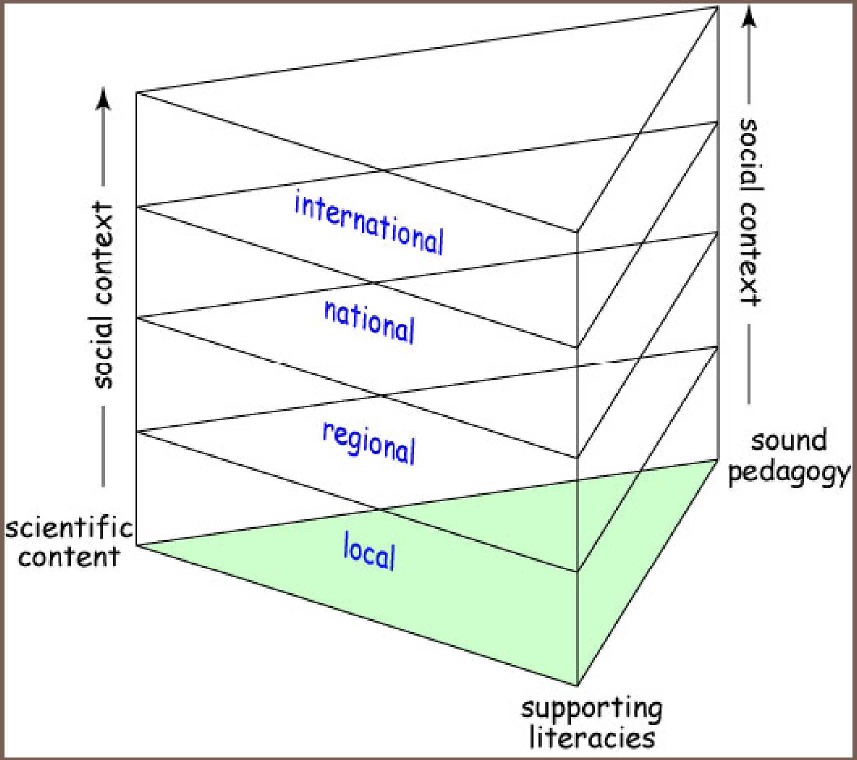
**Saudi oil production**

# 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:

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

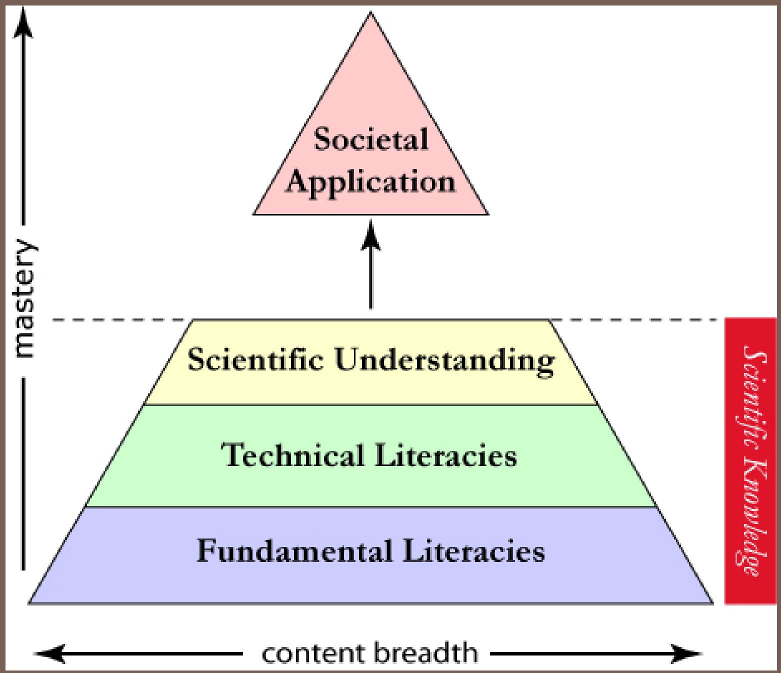
# Energy Instruction: Pedagogy

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

- 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

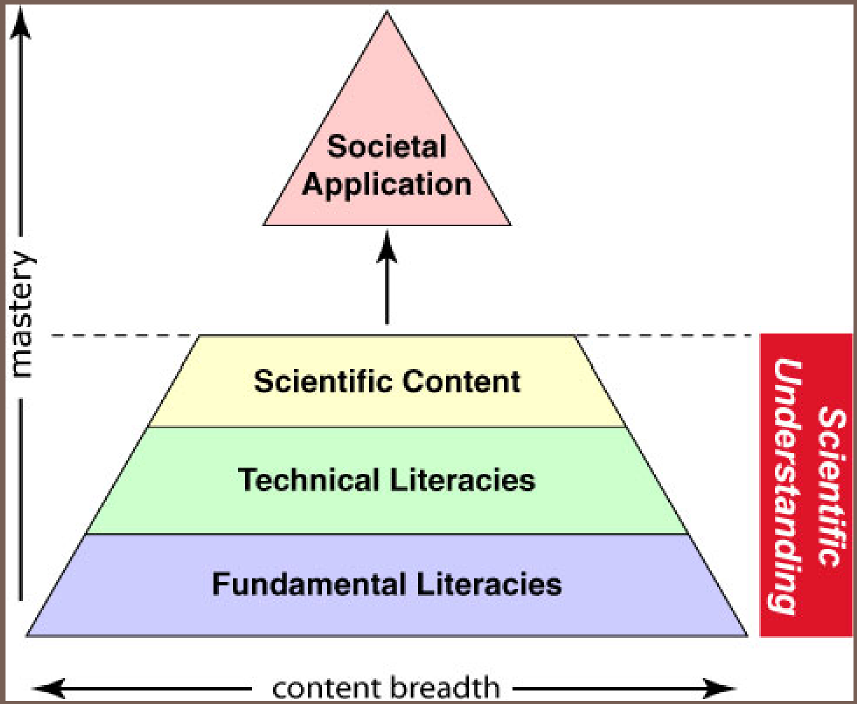
# Literacies: Making Understanding

- *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



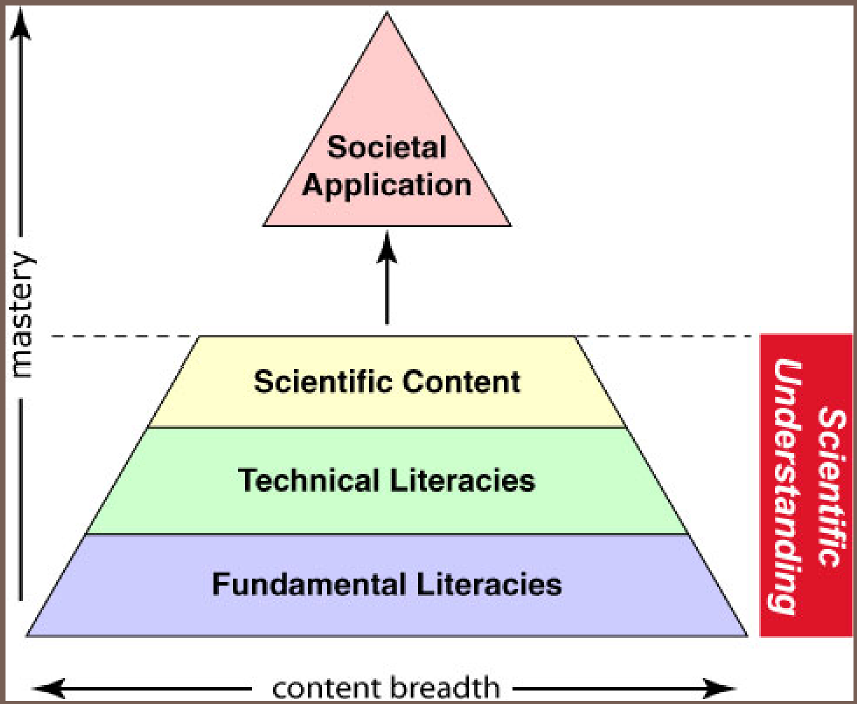
# Literacies: Making Understanding

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



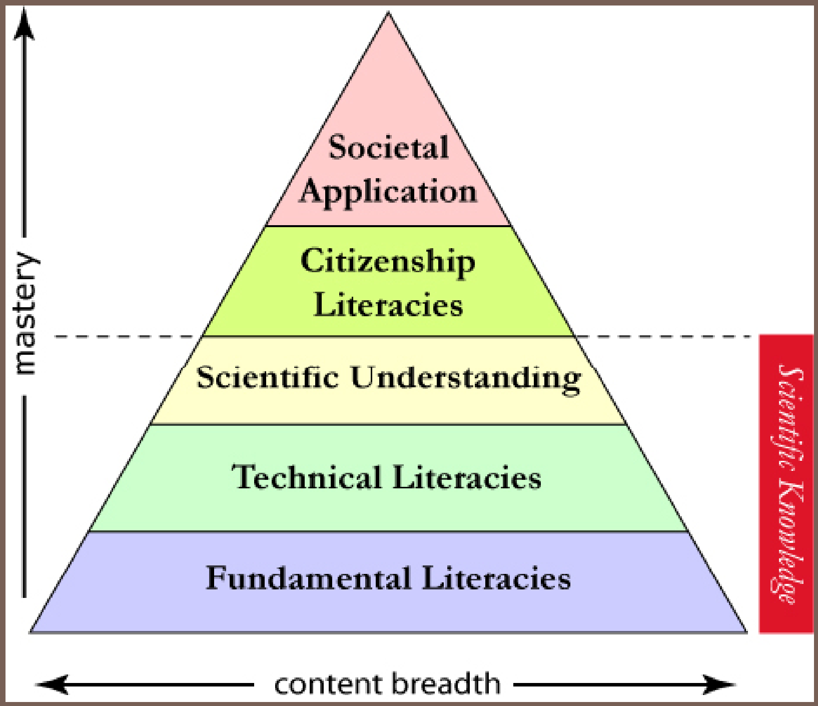
# Literacies: A Missing Ingredient

- 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



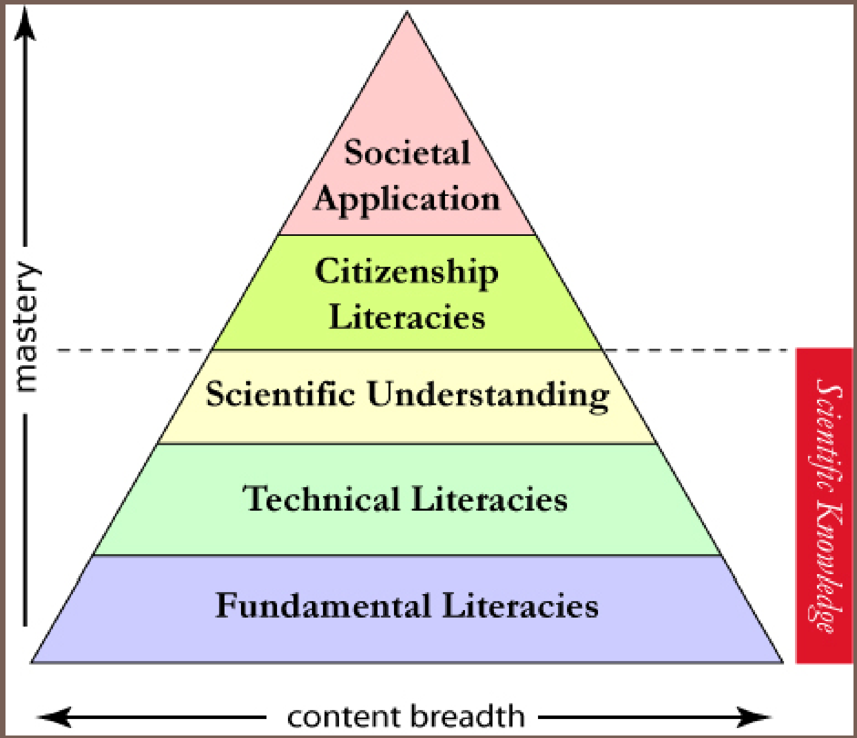
# Literacies: A Missing Ingredient

- 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



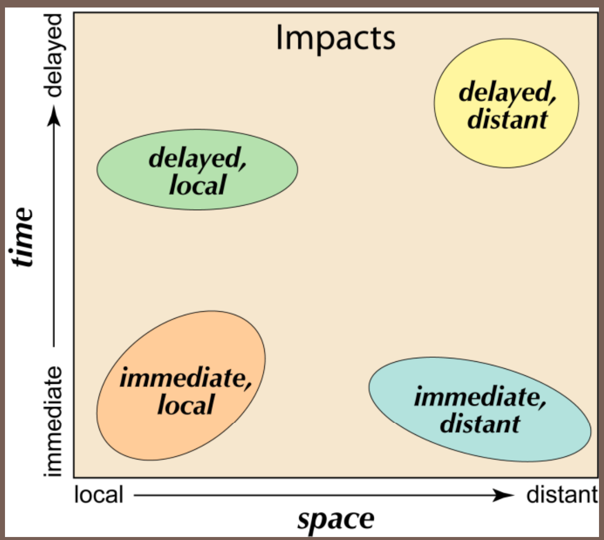
# Literacies: Citizenship

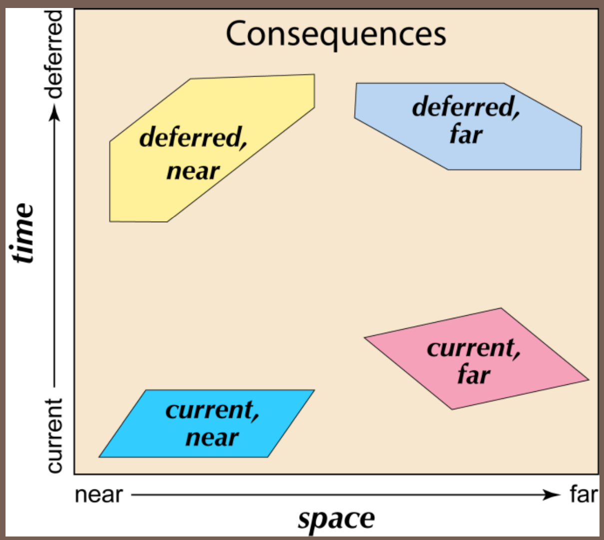
- three classes:
  - critical thinking
  - understanding social context
  - informed engagement
- designed to:
  - help students connect science to real problems in meaningful and effective way
  - enable them to be effective spokespersons

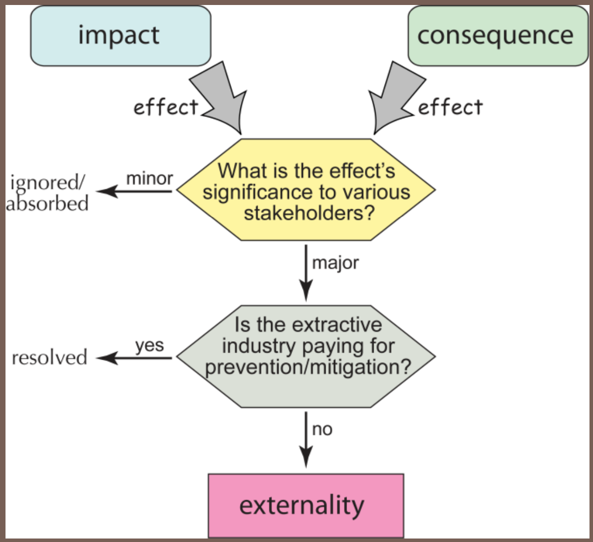


# Citizenship Literacies

- **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)

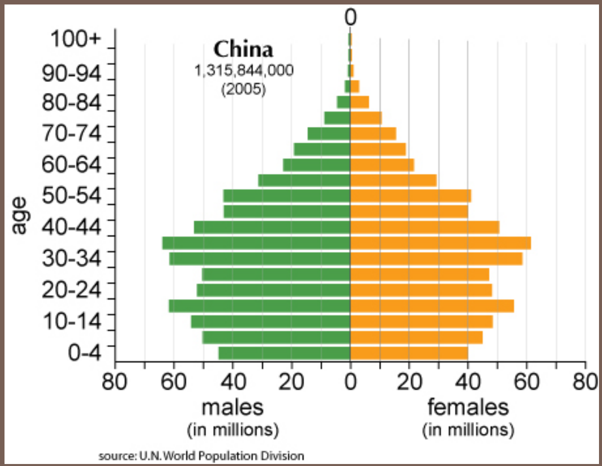


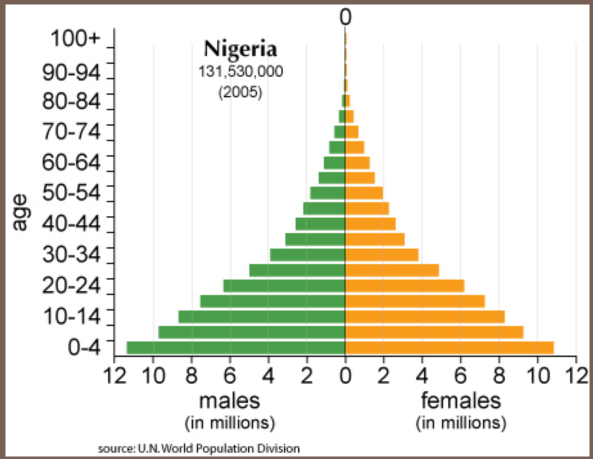



# Citizenship Literacies

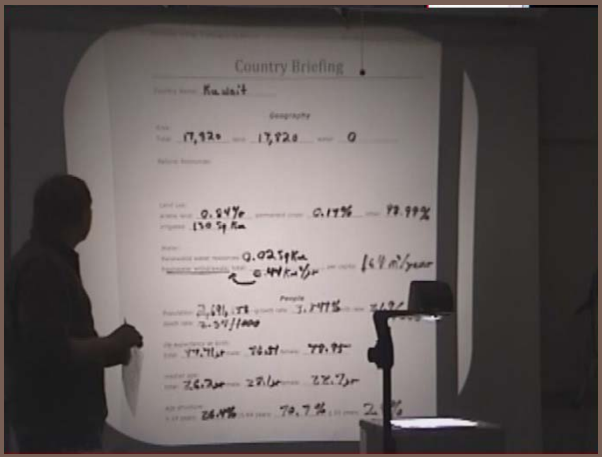
- **understanding social context**: skills useful for understanding cultures and societies affected by geologically influenced "problems"
  - appreciating historical background and significance
  - understanding population demographics
  - acknowledging economic extent
  - recognizing different cultural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

# Citizenship Literacies

- informed engagement: ability to use scientific understanding, critical thinking skills and social contextual understanding in public discourse
  - devising alternative strategies
  - achieving common ground



# Our Case-study Library: Energy

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

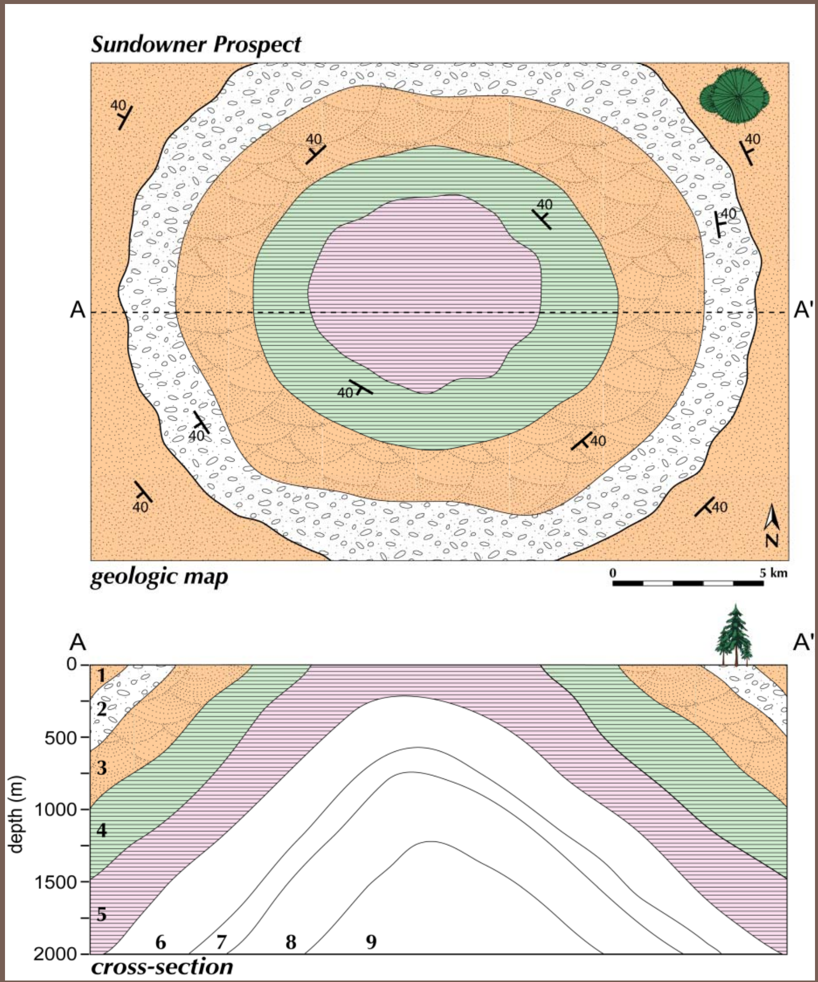
# Our Case-study Library: Energy

| Resource | Country | Case Study | Modules |
|---|---|---|---|
| nuclear power | Iran | Power, Weapons & Iran | I. Designing a Uranium Mine<br>II. Choosing a Reactor Design and Fuel Cycle<br>III. Iran, the West and Nuclear Non-proliferation |
| biofuels | Brazil | The Future of Global Energy? | I. The Production of Biofuels<br>II. Economic Reality: Biofuels vs. Petroleum<br>III. Food vs. Fuel: The Global Implications of Biofuels |

# Saudi Arabia, OPEC & Global Oil

## I. Tapping the World's Largest Oil Fields

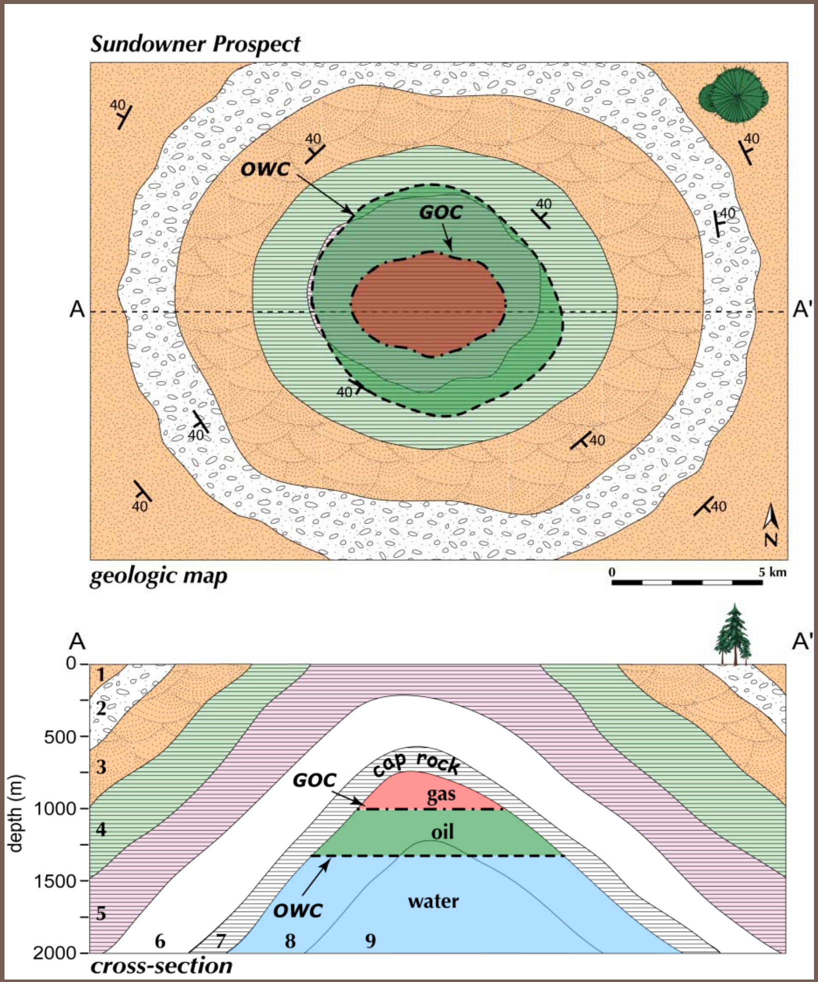
- use geologic principles to devise exploration program
  - where to drill
  - how deep to drill
  - what logs to run
- interpret results
  - locate hydrocarbons
  - determine types present
- present findings orally and in writing
  - make recommendation which leases to evaluate and which to abandon



# 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



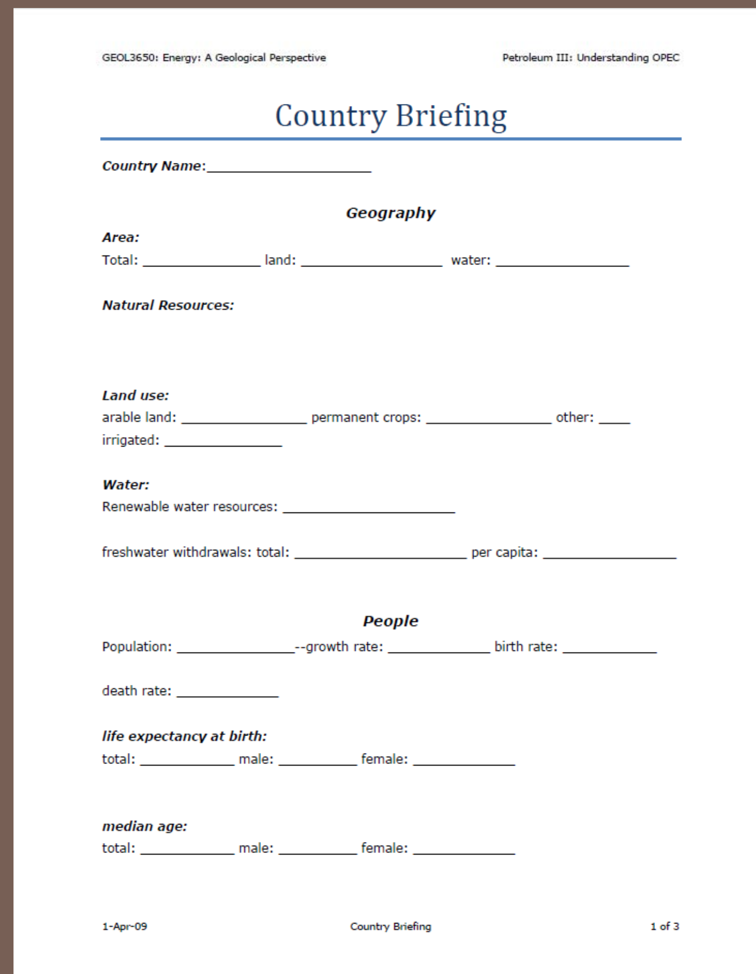
# Saudi Arabia, OPEC & Global Oil

## The U.S. View

# 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 Reponses

- 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 Reponses

- 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 Reponses

- 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 the 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/

# References


- Hilbert, D., 1901, Mathematische problem: Archive der Mathematik und Physik, vol. 3, pp. 44-63, 213-237.
- DePaolo, D. and Orr, F., 2007, Basic Research Needs for Geosciences Workshop, Office of Basic Energy Sciences, 287 pp., http://www.sc.doe.gov/bes/reports/files/GEO_rpt.pdf.
- Myers, J.D., and G. Massey, 2008, Earth Resources: What's Sociology Got to Do with It?: *in* Hartman, H. (ed.), *Integrating the Sciences and Society: Challenges, Practices, and Potentials*, Research in Social Problems and Public Policy, vol. 16, pp. 76-98.
- National Academy of Engineering, 2008, *Grand Challenges for Engineering*, 56 pp. http://www.engineeringchallenges.org/?ID=11574, (December, 2008)
- National Research Council, 2001, *Grand Challenges in Environmental Sciences*: National Academy of Sciences, Washington, D.C., 106 pp., http://www.nap.edu/books/0309072549/html/index.html, (December, 2008).
- National Research Council, 2005b, *Sustainability in the Chemical Industry: Grand Challenges and Research Needs*: National Academy of Sciences, Washington, D.C., 206 pp., http://www.nap.edu/catalog.php?record_id=11437, (December, 2008).
- National Research Council, 2005c, *Creating a Disaster Resilient America: Grand Challenges in Science and Technology*: National Academy of Sciences, Washington, D.C., 19 pp, http://www.nap.edu/catalog.php?record_id=11274.

# References (con)


- Omenn, G.S., 2006, Grand challenges and great opportunities in science, technology, and public policy: Science, vol. 314, pp. 1696-1704.
- Robbins, A., 1996, Transfer in Cognition: Connection Science, vol. 8, no. 2, pp. 185-203.
- Schellnhuber, H.J. , and D. Sahagian, 2002, The twenty-three GAIM questions: Global Change Newsl., vol. 29, 20-21.
- Steffen, W., A. Sanderson, P.D. Tyson et al. (eds.), 2004, *Global Change and the Earth System: A Planet Under Pressure*: The IGBP Book Series, Springer, Berlin.
- Varmus, H., R. Klausner, E.Zerhouni, T. Acharya, A. S. Daar, and P. A. Singer, 2003, Grand Challenges in Global Health: Science, vol. 302, pp, 398.
- Zoback, M.L., 2001, Grand Challenges in Earth and environmental sciences: Science, stewardship, and service for the twenty-first century: GSA Today, December, pp. 41-47.