An independent scientist ^analyzes the Gulf oil spill and response

meta

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Freedom of information?

- In the Internet age we have access to more information
- Information isn't free (it takes work to get it)
  - Just a few mega-corporations control much of the media
  - Net neutrality is under attack
  - Information/noise ratio on the Internet is very low
- This talk highlights information about the Gulf oil spill that I found, processed, and tried to communicate to others
  - My analysis suggested a simple alternative to stop the spill
  - At the meta-level, I learned about oil drilling, oil history, physics, and some challenges communicating with the media and Federal Government
  - At the meta-meta level, I explored the metaphysics of innovation -- a methodology to discover and improve solutions to problems
- Science, ethics, and politics
  - The conventional firewall between these domains is unnecessary and counter productive -- it impedes rational understanding in each of these domains

Have you heard of these people?

- Jason Anderson
- Aaron Dale "Bubba" Burkeen
- Donald Clark
- Stephen Curtis
- Gordon Jones
- Roy Wyatt Kemp
- Karl Kleppinger
- Blair Manuel
- Dewey Revette
- Shane Roshto
- Adam Weise

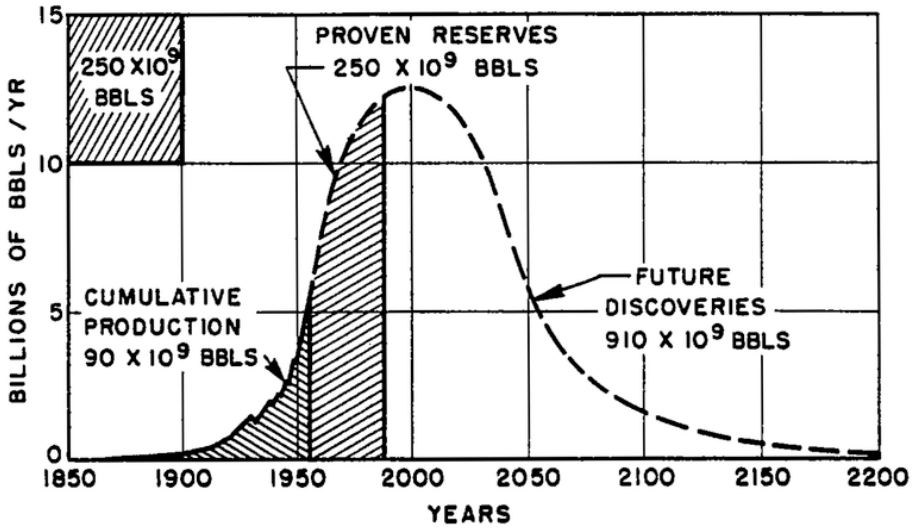
Deepwater Horizon drilling ship

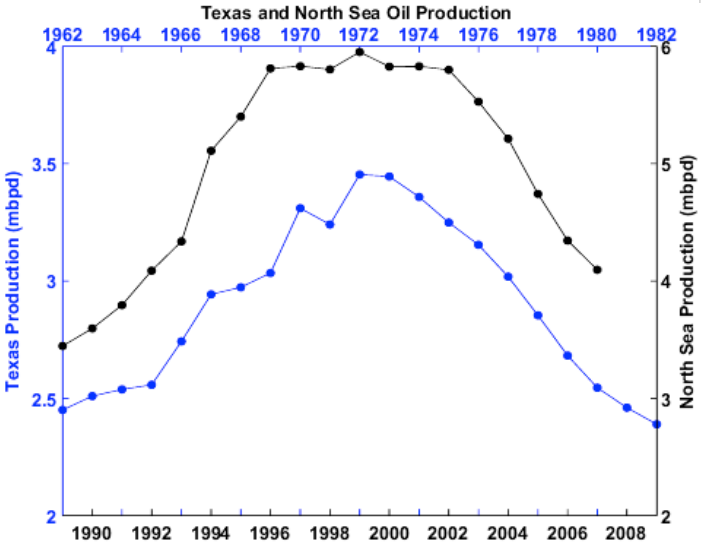
- DH was one of ~200 rigs capable of oil drilling in waters over 5000' deep
- Built in 2001 in South Korea for R&B Falcon, which later became part of Transocean, registered in Marshall Islands, and leased to BP plc for ~$500k/day until 2013
  - ~$270k/day in tax credit
- Drilled the deepest oil well in 2009: 35,055 ft (10,685 m) in 4,132 ft (1,259 m) of water (5000' below its rated depth)
- On April 20, 2010 an explosion on the rig caused by a blowout killed eleven crewmen and created the largest offshore oil spill in United States history
- Sank on April 22, 2010

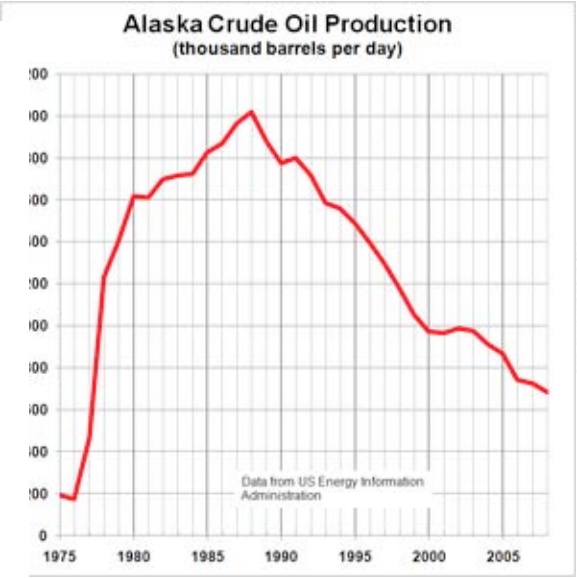
- Question: Why hasn't its wreckage been found, surveyed, salvaged?

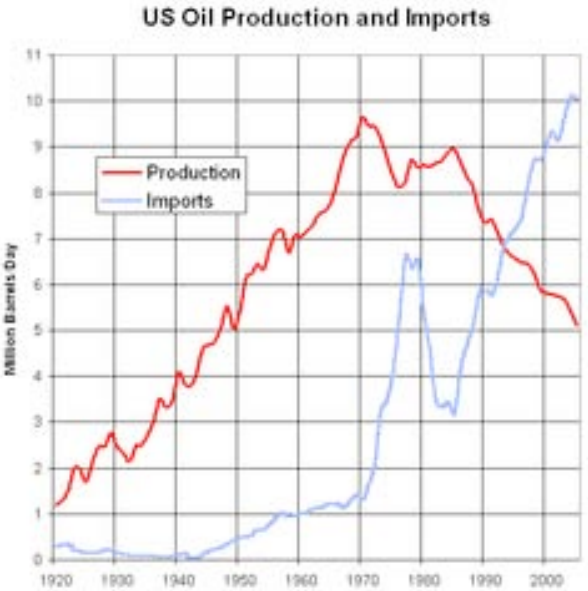
Peak oil

- The Hubbert curve (1956)
- Various events have perturbed the curve but exponential growth of demand eventually will collide with finite supply
- The easily accessed oil was used first

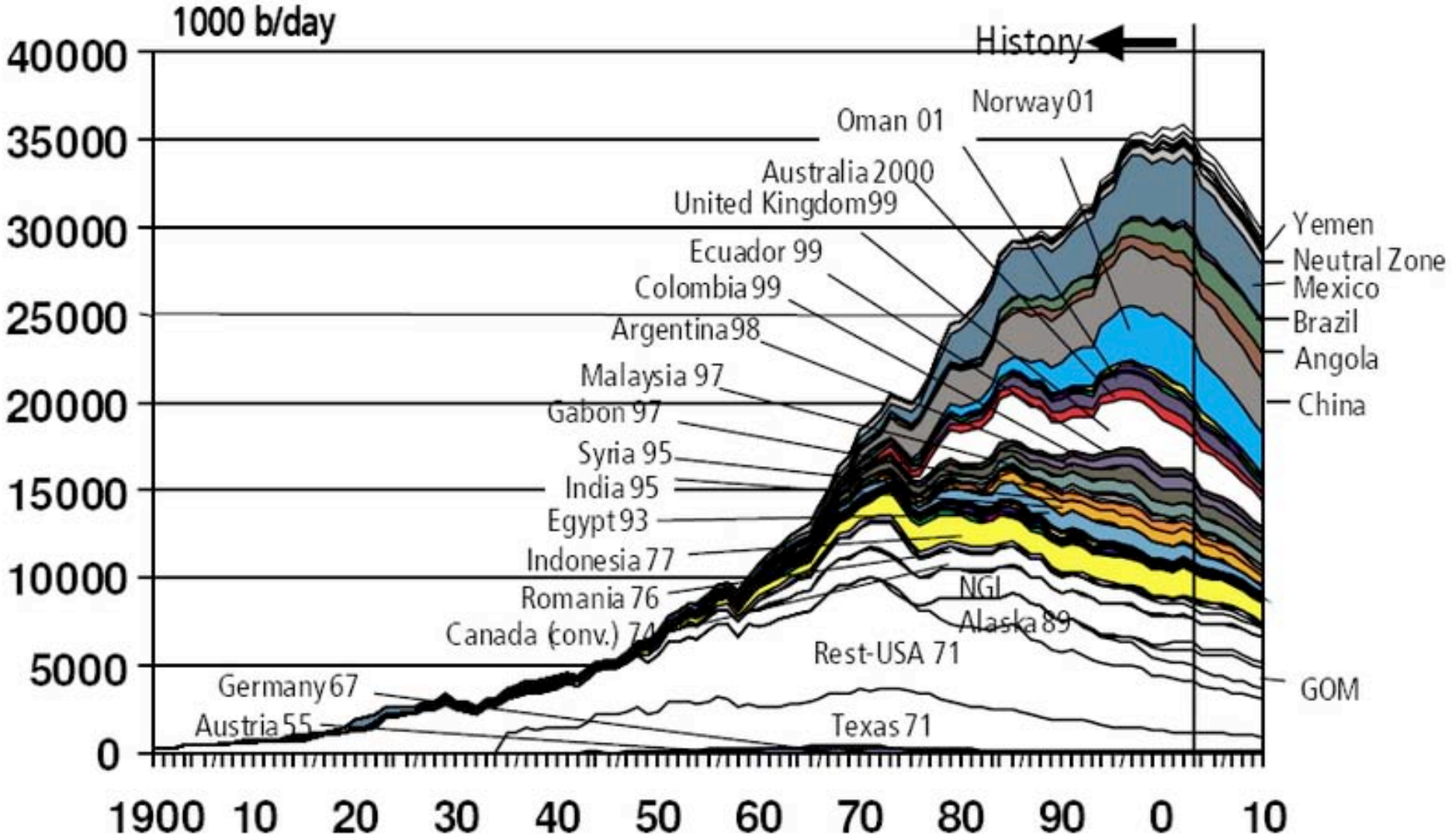






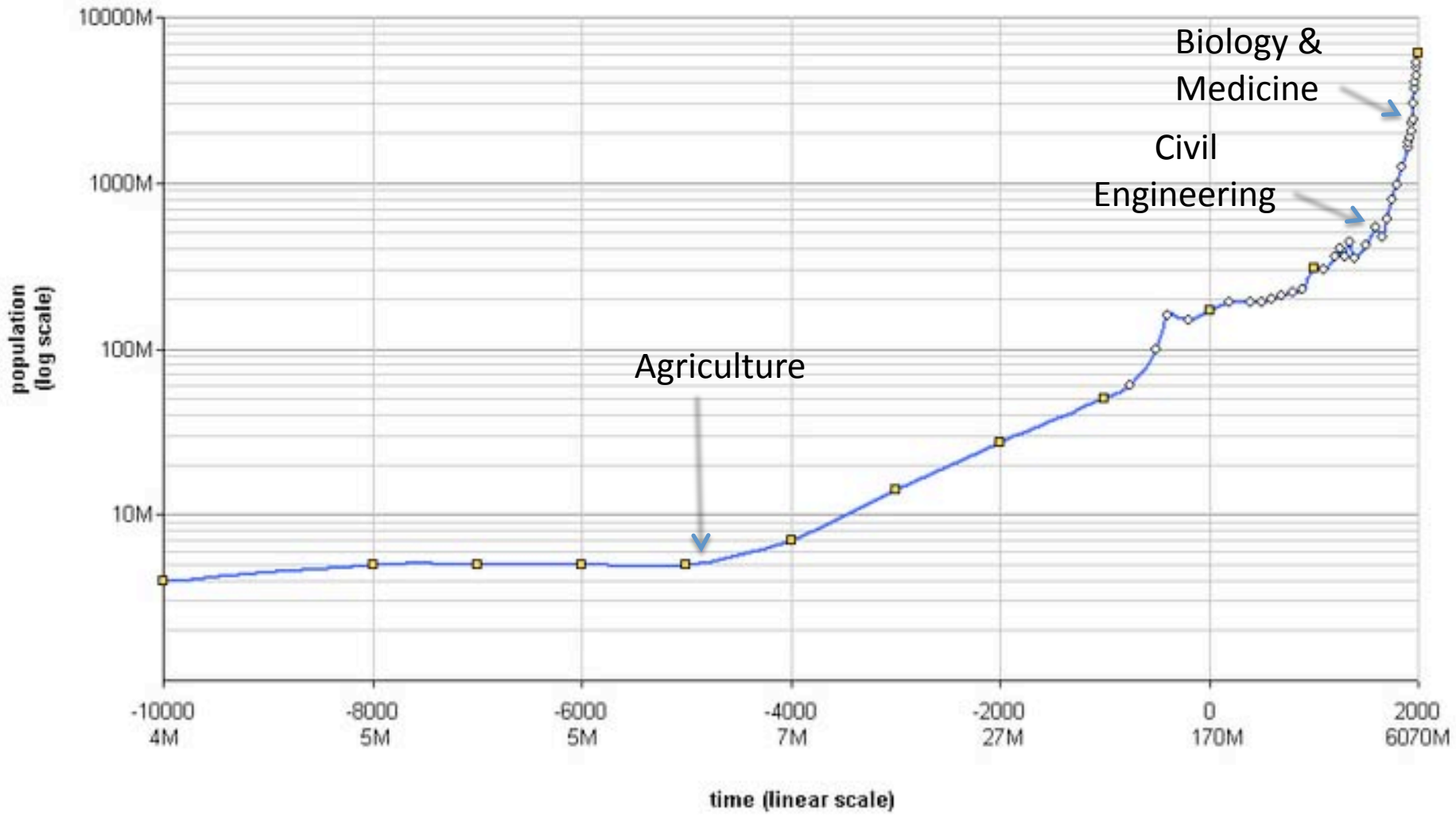


World oil production



Source: Industry database, 2003 (IHS 2003)
OGJ, 9 Feb 2004 (Jan-Nov 2003)

World population



Exponential growth in a finite environment

Consider a strain of bacteria with a 1 minute division time.

The number of bacteria thus grows exponentially with a doubling time of 1 minute, mathematically equivalent to our exponentially growing consumption of oil.

One bacterium is put in a bottle at 11:00 a.m. and it is observed that the bottle is full of bacteria at 12:00 noon.

Questions:

1) When was the bottle half-full?
2) At what time might a hypothetically intelligent bacterium realize that they were running out of space?
3) How long can the bacterial growth continue if the total space resources are quadrupled (e.g., 3 more bottles are found)?

Adapted from Al Bartlett, "Forgotten Fundamentals of the Energy Crisis"

Exponential growth cannot be sustained

- On April 18, 1977 President Carter told the American people, "And in each of these decades (the 1950s and 1960s), more oil was consumed than in all of man's previous history combined."
  - Response to his "limits" speech were immediate and vitriolic
- President Reagan offered Americans a much more optimistic future
  - While gutting Carter's energy policies and encouraging globalization

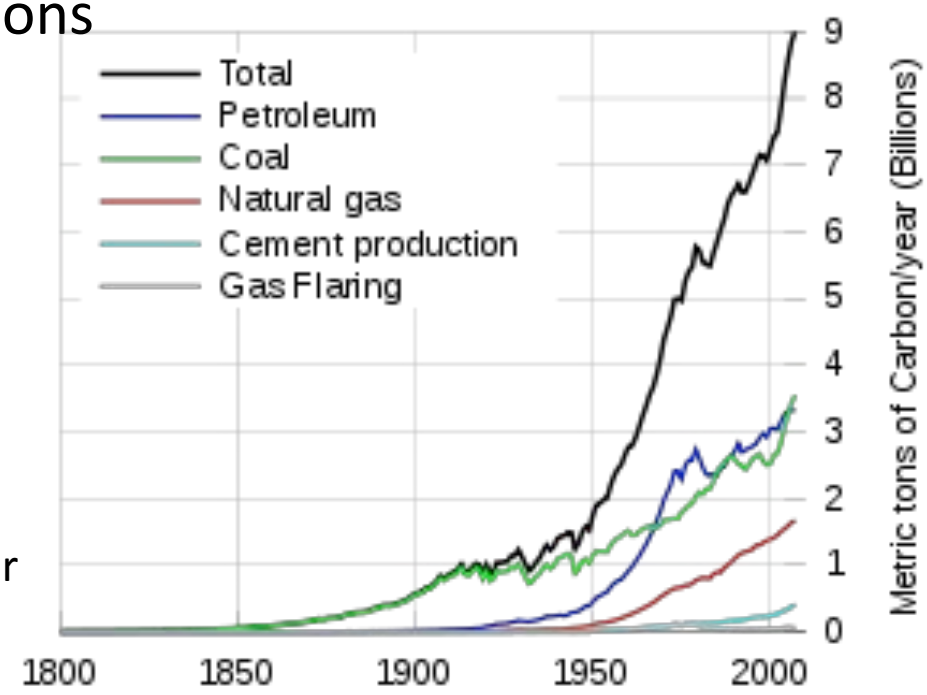
- China & India have rapidly growing oil demands
- Global demand *growth* has slowed with the recession
- A collision of exponential demand with finite supply is inevitable

The Hirsch Report (2005)

1. World oil peaking is going to happen - within a decade or soon thereafter.
2. Oil peaking could cost economies dearly – particularly the U.S.
3. Oil peaking will be abrupt and revolutionary.
4. A major problem is liquid fuels for transportation have no ready alternative.
5. Mitigation efforts will require substantial time and intense effort over decades.
6. Both supply and demand will require attention - higher efficiency can reduce demand, but large amounts of substitute fuels must be produced.
7. It is a matter of risk management - early mitigation will be less damaging than delayed mitigation.
8. Government intervention will be required - otherwise the economic and social implications would be chaotic.
9. Economic upheaval is not inevitable - without mitigation, peaking will cause major upheaval, but given enough lead-time, the problems are soluble.
10. More information is needed - effective action requires better understanding of a number of issues.

Global problem

- Oil is 1/3 of global CO_2 emissions
- Larger contribution to global warming
- Larger environmental (and economic) effects
  - Oil spills
  - Wars
  - Concentration of wealth and power



Faster, ~~better~~, cheaper

- Oil is becoming harder and more expensive to find
- Oil companies are driven to maximize profits
- Investments in proactive safety generally hurt the next quarterly statement
- Long-term safety investments are rarely explicitly rewarded

- Driven by metrics of short-term performance, quality (and safety) will tend to be sacrificed in favor of working faster and cheaper

- Large corporations have learned to effectively manage the human and environmental costs of disasters
  - That disasters happen is fully expected
  - Only the details can't be anticipated

Macondo Prospect (Block 252)

- BP purchased mineral lease from MMS in March 2008
- MMS issued permit to drill in March 2009
- Drilling began Oct 2009, stopped in Nov due to Hurricane Ida
- DH resumed drilling February 2010

- Under 5000' of ocean, the sea floor is fine mud – millions of years of sediment from the Mississippi river
- *There is no solid ocean floor there* – a slight complication …

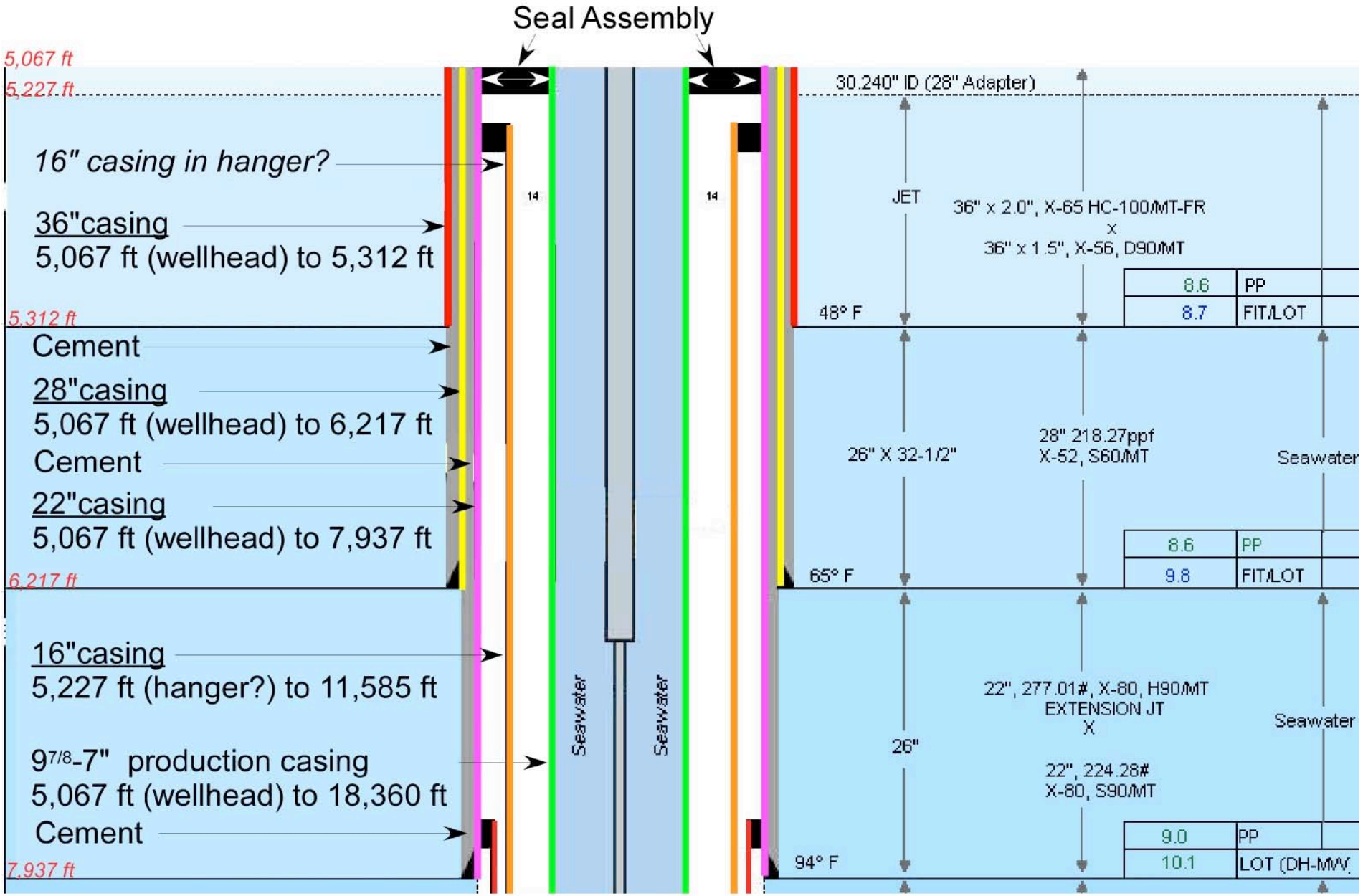
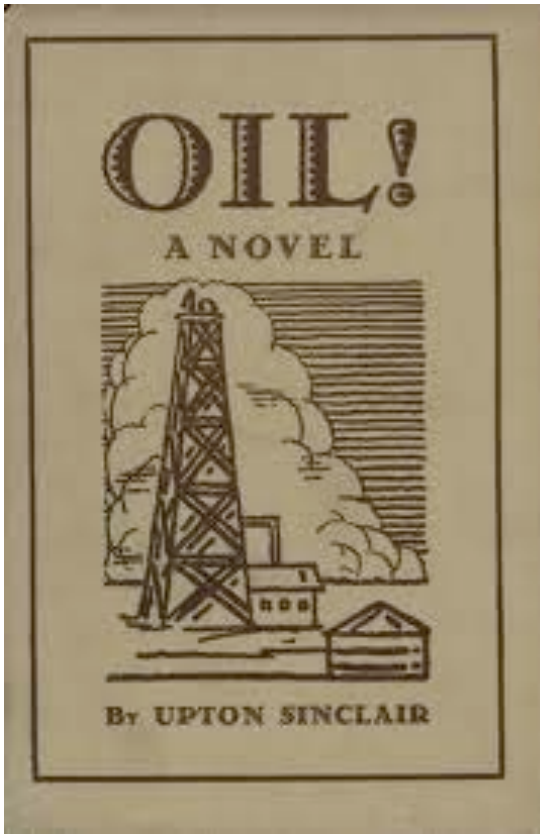


Figure 1a. Upper portion of Department of Energy well configuration diagram.
Modified from http://www.energy.gov/open/documents/3.1_Item_2_Macondo_Well_07_Jun_1900.pdf

Drilling a well

- The process
  - A good description is in Upton Sinclair's classic *Oil!*
  - Little has changed in 100 years

- Much oil exploration work is outsourced
  - Transocean ran the rig
  - Halliburton did cementing
  - Schlumberger tested the cement
  - Contractors save money by externalizing costs
  - Tax credits and shelters subsidize outsourcing



(1927)

The early days of the spill

- Very sparse information was forthcoming
- In Physics 106, “Applied physics and modern society”, I explored what applied physics can tell us

Hagen–Poiseuille equation

- The flow rate in a long straight pipe:

$$\Phi = \frac{\pi D^4 \Delta P}{128 \eta L}$$

where:

Φ = flow rate

D = well bore diameter ~4" ~.1 meter

ΔP = static pressure of the well ~10000PSI ~6.7×10^7 Pascal

η = viscosity of light crude oil ~ 1 Pascal•seconds

L = well length ~10,000 ft ~ 3000 meters

gives a flow rate of 0.05 cubic meters/second = 30,000 barrels/day

1. Where did this information come from?
2. Was the result credible?
3. Why is it so close (within a factor ~2) to public estimates that came out much later?

Reynolds Number

- Onset of turbulence at Re >~2000

$$R_e = \frac{\rho V L}{\mu}$$

where:

ρ = oil density ~ 1g/cm^3 ~ 10^3 kg/m^3
V = fluid velocity, see below
L = characteristic length ~ well diameter ~ 0.1m
μ = dynamic viscosity of oil ~ 1 Pa-sec

- V = flow rate / well cross-sectional-area

  = (.05 m^3/sec) / (pi * (.05m)^2) = 7 meters/sec

→ R_e ~700 = 2000 (to our degree of uncertainty)

- Turbulence reduces Poisuille flow

→ *The computed flow rate is consistent with an unobstructed well pipe and a self-limiting flow at the onset of turbulence*

→ Could that be just coincidence or circular reasoning??

$$R_e = \left(\frac{\rho}{128\mu^2}\right) D^2 P$$

The Law of Large Numbers

- The sample average converges to the expected value as the number of samples approaches infinity:

  For $\overline{X}_n = \frac{1}{n}(X_1 + \cdots + X_n)$, $\overline{X}_n \to \mu$ for $n \to \infty$

  where X_1, X_2, ... is a sequence of *independent and identically distributed* random variables with finite expected value $E(X_1) = E(X_2) = \ldots = \mu < \infty$.
- The LLN is why scientists often repeat measurements – the uncertainty of the mean is $1/\sqrt{n}$ less than the uncertainty of individual measurements
- Propagation of uncertainty says the relative uncertainty of the flow rate increases (in quadrature) with each term:

$$\Phi = \frac{\pi D^4 P}{128 \eta L}$$

$$\frac{\Delta\Phi}{\Phi} = \sqrt{4\left(\frac{\Delta D}{D}\right)^2 + \left(\frac{\Delta P}{P}\right)^2 + \left(\frac{\Delta \eta}{\eta}\right)^2 + \left(\frac{\Delta L}{L}\right)^2}$$

→ Accuracy was just luck!

Measuring flow rate

- Measuring flows is **key** to the oil business
- From BP's "Frontiers" periodical, August, 2008:
  - "... BP has identified that by combining sonar flow measurement with additional measured parameters, such as pressure drop in a flow line, both the liquid rate and the gas rate on a wet gas flow line can be determined. BP has proven this additional breakthrough in practice and expects to deploy the technique in the field by the end of this year."*
- BP has taken exceptional effort to *not* measure the flow rate
  - Censored data and video feeds
  - Prohibited independent ROVs
  - Deployed equipment lacking the necessary combinations of sensors
- Fines are proportional to quantity of oil and gas spilled

➔ *If you don't measure it, then it didn't happen?*

*www.bp.com/liveassets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/frontiers/STAGING/local_assets/pdf/bpf22_34-38_sonarflow.pdf

BP's options to stop the spill

- The 3 publicly stated alternatives to stop the oil spill
  1. shut the broken valves on the BOP
  2. drill a tangential well to relieve the pressure
  3. capture the leaking oil in a funnel and pipe it to the surface

- Was there another agenda?
  - Note that all of these options preserve the ability to collect and sell the oil in the future -- in fact two of these approaches will *require* the oil to be captured until the field is depleted

- Was there another *paradigm* to stopping the well that wasn't being pursued?
  - *How can you stop a runaway train?*

Imploding the well

- Can the well be imploded by explosives?
- Explosives create seismic and shock waves -- propagating energy -- that generate huge shear forces where the speed of sound changes, e.g., at the interface between dirt and metal and oil at the edge of the well bore.
  - The principle behind the military's "bunker-busting" bombs
  - An underground detonation creates a spherical shock wave
  - Will compress inelastic casing and pipe
  - Debris would likely rain down sealing voids
  - Seismic waves would assist settling, and the enormous weight of material could hold back the pressure.

- ***Detonating a deep underground explosive near the well can collapse the well*** *and stop the spill*
  - This doesn't require the precision nor depth of a "pressure relief well"
  - Can be done in a fraction of the time

- Might BP reject this proposal because it offers them no benefit?
  - If they maximized their liability, shutting the well just kills their future up-side

“Blow up the well!!”

- Verified the idea with many colleagues
- Who to contact?
  - Knew BP’s ex-CTO in grad school; now under secretary of science in DOE

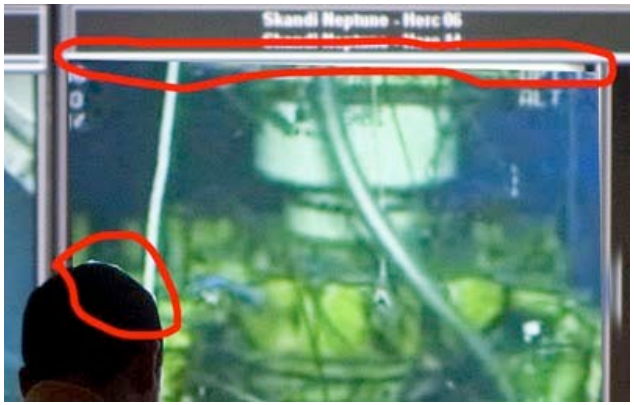
    “Brian: I'm constrained by ethics rules from any direct involvement in the current Gulf situation. But I believe approaches of this sort are being considered by the engineering response team. I will, in any event, forward your note on to someone more directly involved and expect they'll get in touch as they see fit. Steve Koonin
  - Congresspersons on energy/environment committees (many House members only accept email from addresses in their district)
  - Reporters: MSNBC (Maddow, Olbermann) have blogs and Facebook/Twitter, NYTimes (Andrew Revkin), Mother Jones, …
  - Academics: Dan Kammen, Bob Bea, …
  - Comedians: Bill Maher, Jon Stewart
    - “just blow up the f*cking well”
- How to contact?
  - Sent many emails to Gov’t officials advocating blowing up the oil well … (and I’m still here)
  - Several responses suggested submitting the idea to BP’s website

Rotting flesh brings the flies

- The lack of independent, real, regulation by government and lack of self-regulation as corporations maximize short-term profits led to this crisis
- MMS lacks the resources and infrastructure to implement decisions in the best interests of society
  - The spill threatened 1/3 of the Nation's wetlands and ¼ of its fisheries
  - Very cautious of impeding BP, else they "own" the problem
- BP acts in their own self-interest to shareholders
- Conspiracy theories abound in such an environment of distrust and chaos
- Independent intellectuals from all over suddenly become "experts" offering advice, and add to the noise

BP's responses

- Ruled out explosions
  - "Nuclear explosions on the sea floor are a very bad idea"
- Can't cap the well because it won't sustain the static pressure
  - Pressure at the well bottom is ~13,000 psi relative to the BOP
- … until they capped the well…
- Manipulated data, images, and video



Capping the well

- Many proposals for plugging the well -- sinking a ship on it, dumping debris, or lowering a big heavy tapered cone, etc. -- were rejected for fear of blowing out the casing
  - Stopping the flow would result in the reservoir static pressure appearing on the cap
- Even the Coast Guard was surprised and stopped BP when they started shutting off valves on the cap, because of this concern
- What changed to make this possible on July 18, day 86?
- Pressure on the cap was holding at 7000psi
  - The static pressure of the reservoir is thus 7000psi + the pressure of the weight of the oil (did experts forget this later term?):

$$P_{oil} = \rho_{oil} g h \approx \left(1000 \frac{kg}{m^3}\right)\left(10 \frac{m}{s^2}\right)(4000m) = 4x10^7 Pascal\left(\frac{1psi}{7000Pa}\right) \approx 6000\,psi$$

  - 13,000 psi = earlier estimates of reservoir static pressure, suggesting the cap is holding
  - Note: scuba tanks and welding tanks are typically filled to ~3000-4000 psi. Small rifles withstand >50,000 psi when fired

Externalities

- All things have direct costs, as well as indirect or external costs
- The consumer pays just direct costs
  - The costs of pollution are distributed through society
  - External costs unfairly burden people who often get no benefit from them
  - External costs are thus subsidies, which distort "free markets"
- External costs of oil include wars, pollution, and global warming
  - We pay a fraction of these in taxes, health care, and premature death
  - Much of it is paid by the labor and suffering of billions of poor foreigners
  - Estimates of the external costs are many dollars/gallon
    - $6 - $15/gal for gasoline from http://www.icta.org/
- Oil also benefits from sunk or amortized costs
  - Extensive infrastructure to facilitate its production and sale paid for long ago
  - Network of ports, pipelines, tankers, refineries, pollution credits, gas stations, …
  - Alternative energy sources without comparable infrastructure are disadvantaged

Externalities

- The oil industry generally opposes new government energy subsidies, because they already got theirs
- Nuclear energy isn't viable without government subsidies for at least liability insurance and waste disposal
- Conservation and "green" energy, especially decentralized energy production, generally are much more expensive than the already subsidized oil (and coal and electricity) systems, but have much lower externalities

- BP's accident may increase the cost of future oil drilling
  - If government responds with increased regulation and internalizes more existing externalities
  - Conservative politics strongly opposes such changes
- The externalities for oil are the poor subsidizing the rich
  - They has enriched the oil companies, who in turn have lobbied and corrupted government to perpetuate this status quo

Why did the government (MMS) fail so badly?

- MMS's budget history
  - Oil and gas royalties are the largest gov't income source after taxes
  - In 2001, VP Cheney approved a change in payments to "Royalties in Kind"
  - From 2003-2008, the GAO consistently challenged the legitimacy and justification of the RIK program
  - In 2008, MMS got $2.4B in oil, $4.2B in gas, and $5.4B in cash
  - Interior Secretary Salazar shut it down in Sept 2009, lost $billions of revenue (another effective subsidy to oil companies)
- Who should pay for MMS?
  - Top Republican on the House Committee on Oversight and Government Reform says there *may be* a conflict of interest for the MMS to collect revenue and also oversee safety
- You get what you pay for …
- "We have the best government money can buy"

- Should students pay more for their education? These questions maybe decided in the Nov. 2 election…

The well is dead

Update: Sunday, 19 Sept 2010, 11:40am: The well is effectively dead, according to Coast Guard Admiral Allen. The official statement is as follows:

After months of extensive operations planning and execution under the direction and authority of the U.S. government science and engineering teams, BP has successfully completed the relief well by intersecting and cementing the well nearly 18,000 feet below the surface. With this development, which has been confirmed by the Department of the Interior's Bureau of Ocean Energy Management, we can finally announce that the Macondo 252 well is effectively dead. Additional regulatory steps will be undertaken but we can now state, definitively, that the Macondo well poses no continuing threat to the Gulf of Mexico. From the beginning, this response has been driven by the best science and engineering available. We insisted that BP develop robust redundancy measures to ensure that each step was part of a deliberate plan, driven by science, minimizing risk to ensure we did not inflict additional harm in our efforts to kill the well. I commend the response personnel, both from the government and private sectors, for seeing this vital procedure through to the end. And although the well is now dead, we remain committed to continue aggressive efforts to clean up any additional oil we may see going forward.

Metaphysics of Innovation

- What cognitive processes foster learning and discovering new ideas?
  - Aristotle established "classical" processes like reductionism and the scientific method as powerful for *validating* theories
  - However, many scientists describe their discovery/invention of theories in very romantic, holistic, intuitive terms
  - There is voluminous literature about the classical/romantic dichotomy
- Broad literature exists about managing innovation in business
  - Many successful companies that develop economies of scale for production lose their abilities to innovate
  - Processes for improving existing products are very different than processes for discovering new products
- Teaching innovation is much harder than teaching validation
  - We don't understand romantic processes and tools nearly as well as classical ones
  - Romantic processes aren't very amenable to classical analysis
- How did classical and romantic methods help me learn about the oil spill?

Metaphysics of Innovation

- The classical, reductionist approach to the oil spill
  - Isolate the problem
    - Identify the malfunction(s) in the BOP
    - Locate the leaks
    - Add dispersants to keep the oil from the surface
  - This approach rigorously explores solutions "within the box"
- The romantic approach to the oil spill
  - Generalize and abstract; see it as part of a bigger whole
    - This oil well is a *complex system that has gotten out of control* …
    - We have an energy consumption/population problem …
  - This approach enables the discovery of "outside the box" solutions
- Evaluate the new landscape classically
  - Reduce the class of problems to principles, e.g., complex systems can be fragile
  - Examples: A runaway freight train can be stopped by destroying the tracks
- D*estroying* the well is a new *class* of solutions

➔ What would happen if we blew up the well?

➔Answer the question with reductionism and generalization (e.g., bunker busters)

Alternating classic and romantic viewpoints

- Alternating reductionism and generalization+abstraction can reveal a broader range of potential solutions
- These two methods are analogous to pushing and pulling a pry bar – after each successive push or pull, the bar penetrates deeper and the leverage increases for the next cycle
- Classical methods can find and compare solutions within a pre-defined domain (the “box”)
- Romantic methods can expand the box, but they are poor at comparing and optimizing potential solutions

A recipe for problem solving?

- Find what choices are there (Romantic view)
  - Big picture
  - Abstract
  - Intuition and inspiration
  - Brainstorm
- Identify which choice is best (Classical view)
  - Reduce them to similarities and differences
  - Explore their consequences
  - Compare
  - Analyze

Dichotomy of processes

- Discovering solutions and comparing solutions are very different processes
  - You discover solutions by
    - Exploring different (*distant*) domains
    - Using different recognition criteria
    - (You won't find anything new looking in the same way at the same place)
  - You compare solutions by
    - Placing them *close* to each other
    - Using the same criteria to measure their Quality

- Successful problem solvers act romantically *and* classically
  - Finding the best solutions will reveal many lesser candidates
  - Comparing these candidate solutions to find the optimum
  - Fundamentally different approaches dominate each of these activities

Consequences of Classical dominance

- Lack of corporate investment in romantic activities is a major cause of failing innovation
  - Management
- Lack of software tools for romantic activities is a major cause of the failure of artificial intelligence
  - Computers and their software are extremely classical
  - Exceptions are content-addressable memories, neural nets, etc.
- Lack … education

Summary

1. Basic physics immediately revealed the oil well as uncontrolled
2. The spill could have been stopped months earlier by capping or imploding
3. The problem wasn't just BP's mistakes. We've run out of easier and safer oil.

   With 200 rigs drilling below a mile of ocean under enormous pressure to succeed, with little independent regulation or scrutiny, accidents like this are bound to happen.
4. Soon we'll even run out of more expensive and dangerous oil.
   - The impending crisis will create profound social and economic change
   - The longer we defer investing in radical conservation and alternative fuels (especially for transportation), the deeper and uglier the crash will be
5. Government intervention
   A. Should enforce and verify safety – or it won't happen
   B. Should internalize costs and at least level the playing field for newer energy technologies
   C. Should defend the public interests, which is not the mandate of companies
   D. Could increase transparency and credibility, reducing speculation, scapegoating, and radicalism
   E. Is strongly opposed by the oil industry, who now pay few taxes and receive tax credits
6. Alternating romantic and classical approaches can assist in discovering "out of the box" solutions
   – Reframing these problems is critical to finding solutions

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