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and Petroleum Engineers (AIME) for their contribution to the program.

Crude Value Enhancement: An Emerging Opportunity for Innovations in E&P?

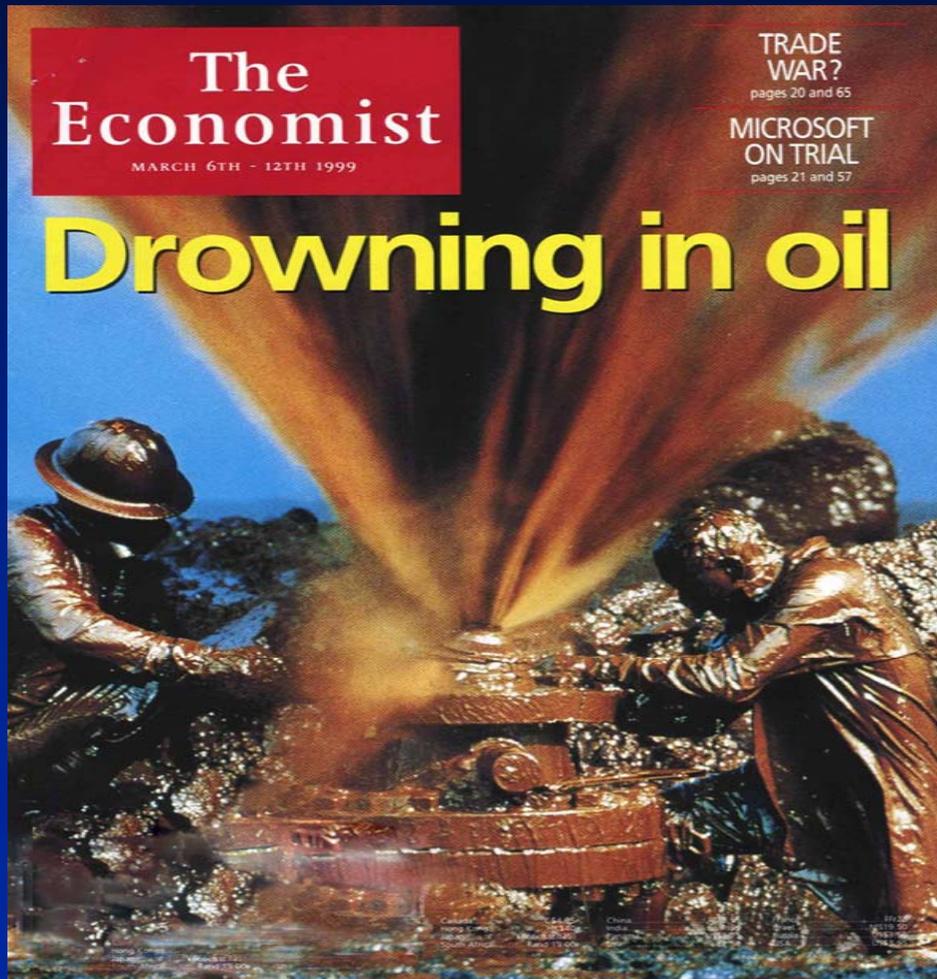
M. Rashid Khan

Rashid.khan.1@aramco.com



Boom and bust: Perception of our mind?

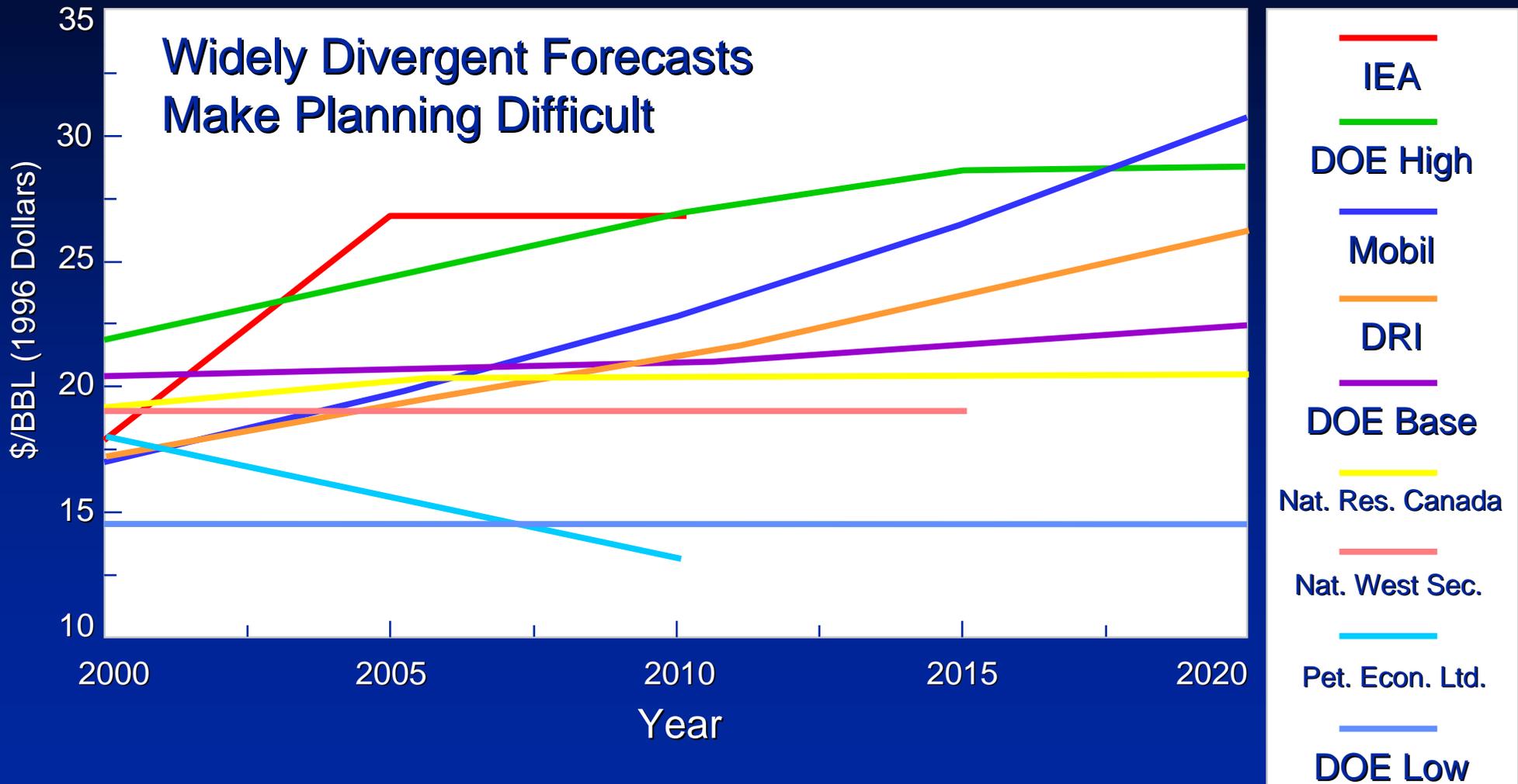
March 1999 \$10/bbl



Oct 2003 \$46/bbl



All major organizations missed Oil price forecasts in 1998



Many books on the topic...

Faults Aug, 2005

The Economist
AUGUST 27TH-SEPTEMBER 2ND 2005

Iraq, the war and the constitution
PAGES 22-24

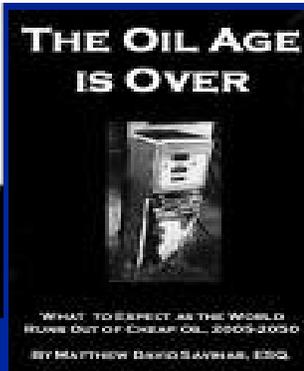
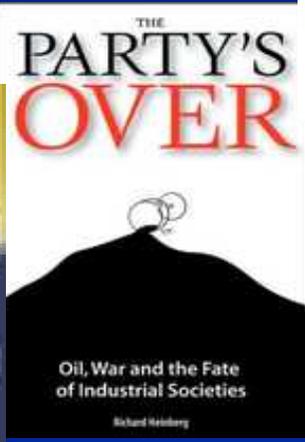
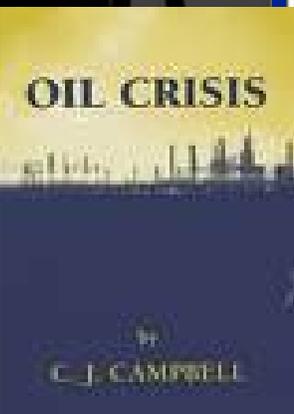
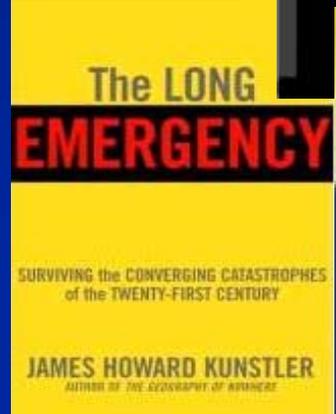
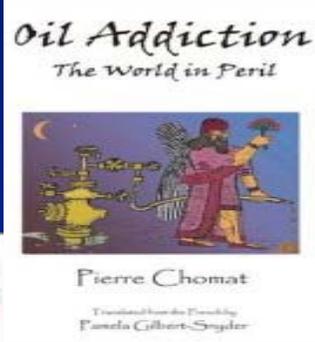
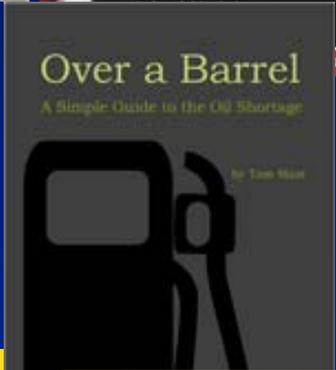
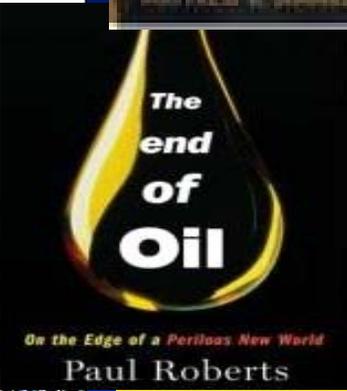
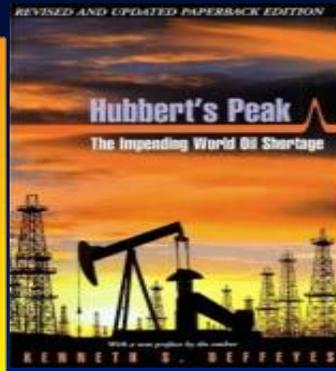
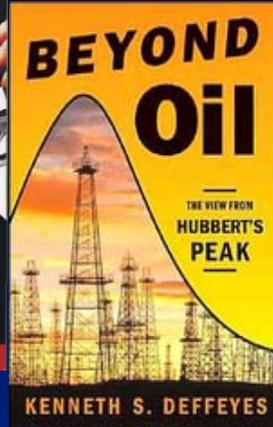
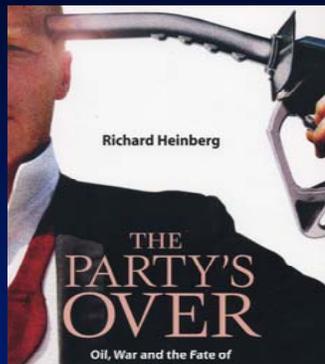
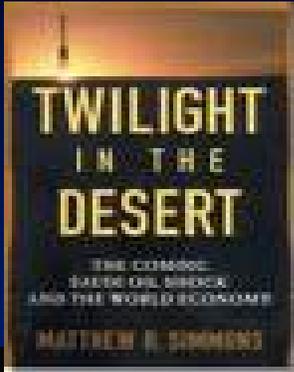
America's unhampered powers
PAGES 13 AND 31

Brother Roger, Taizé's melodic monk
OBITUARY, PAGE 70

Yum! Brands' finger lickin' growth
PAGES 60-62

> \$70

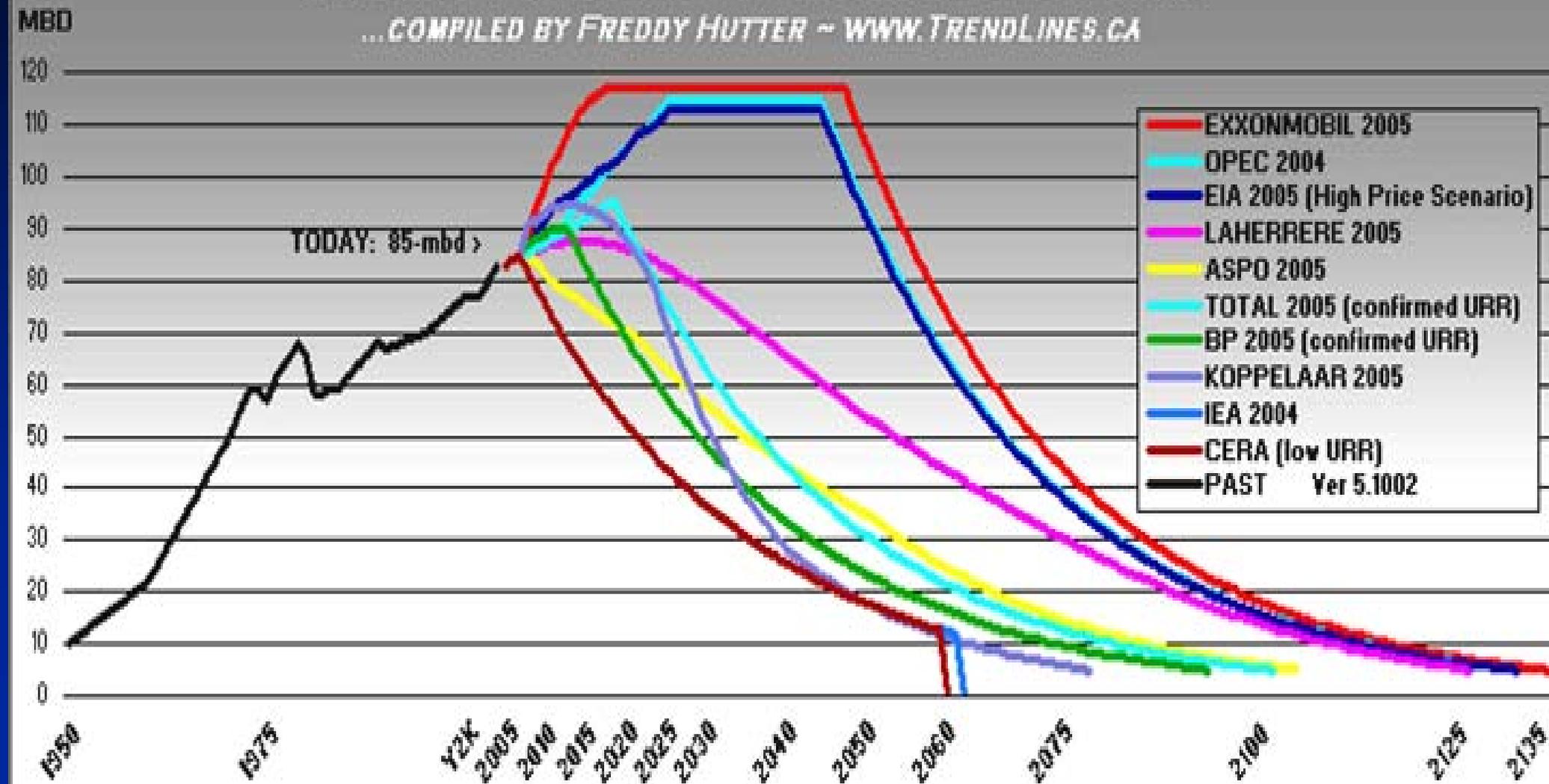
The oiloholics



There are many suggested peaks “Which peak you wish to pick?”

TRENDLINES PEAK OIL DEPLETION SCENARIOS 2005

...COMPILED BY FREDDY HUTTER ~ WWW.TRENDLINES.CA



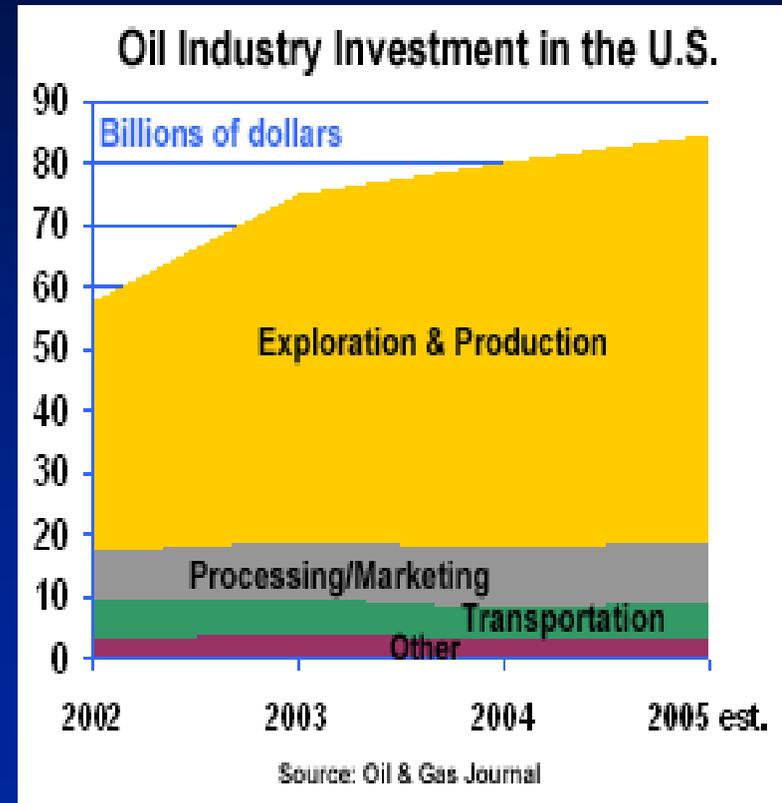
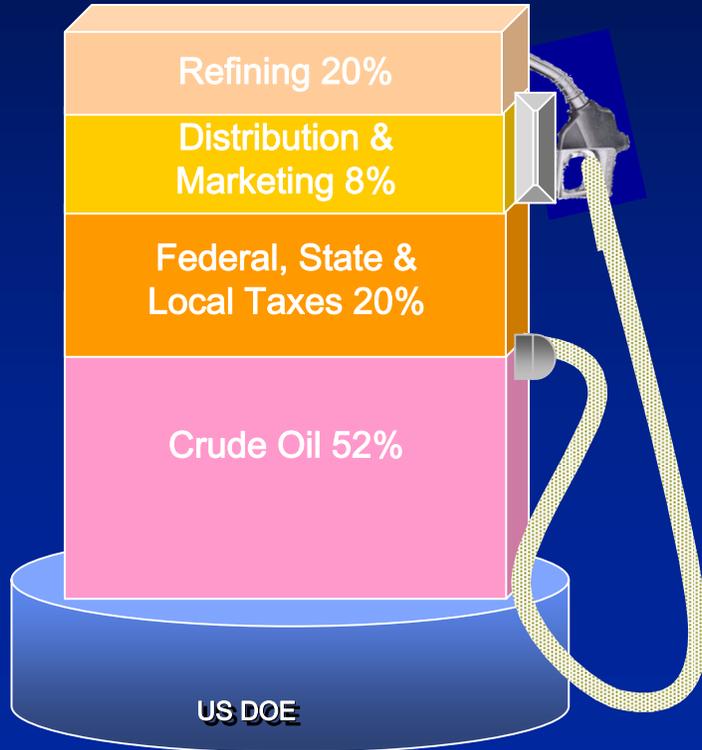
Topics

- Innovation and historical trends in energy usage
- Crude oil quality and its impact on subsequent use
 - “bad actors” or undesirables in crude?
 - human impact on quality? standards of “crude oil”?
- Relation between quality and price
- Traditional upgrading/desulfurization processes?
- Motivation for field upgrading
- Opportunity for innovation

Crude reality

- Is the industry innovative?
- What investment typically goes into production vs. processing?

Where the Gas Dollar Goes?



Is the industry innovative?

Relative R&D performance of Industry leaders for 2003

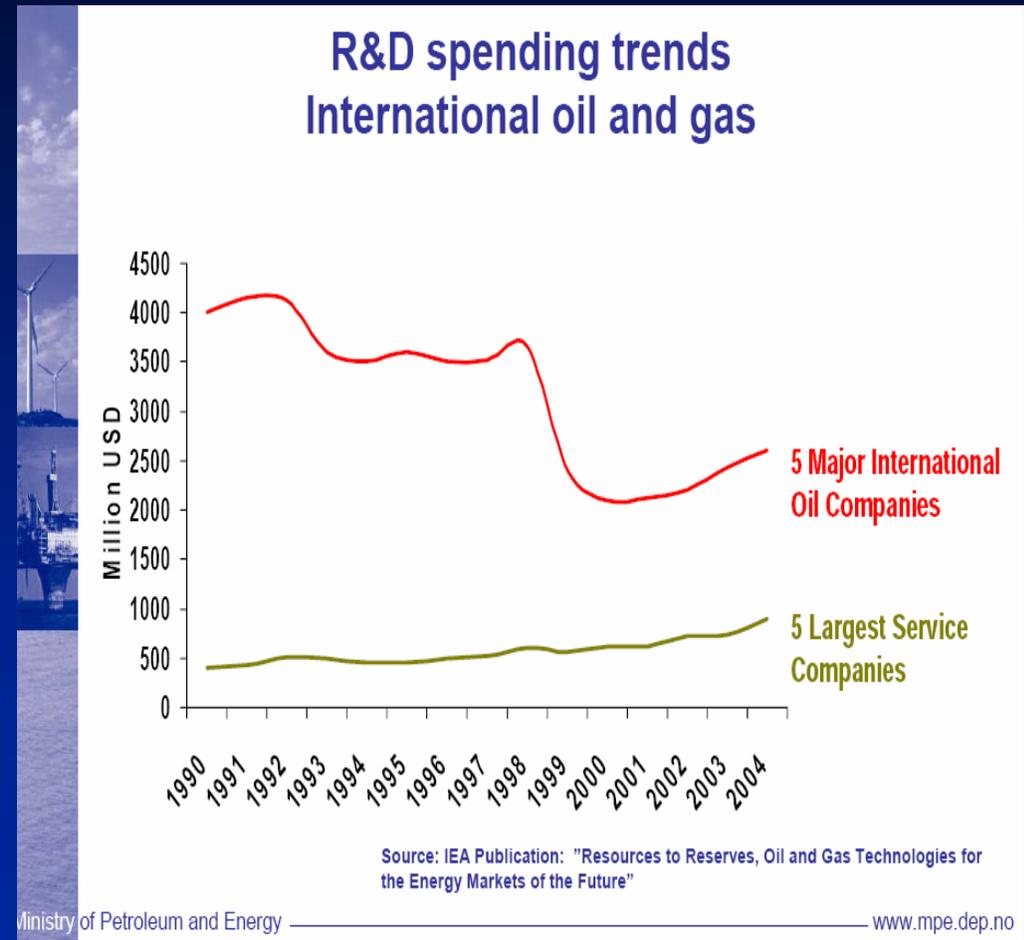
Pharma/biotech*:	\$14 b
Intel & Microsoft:	\$11.5
General Motors:	\$6
Global oil and gas**:	\$3
US Oil & Gas total***:	\$<0.5

*10 Pharma + 3 biotech

**6 Major operators + 5 large service firms

*** US DOE, Fed reporting System 50431-2

Source: Cambridge Energy Research Associates



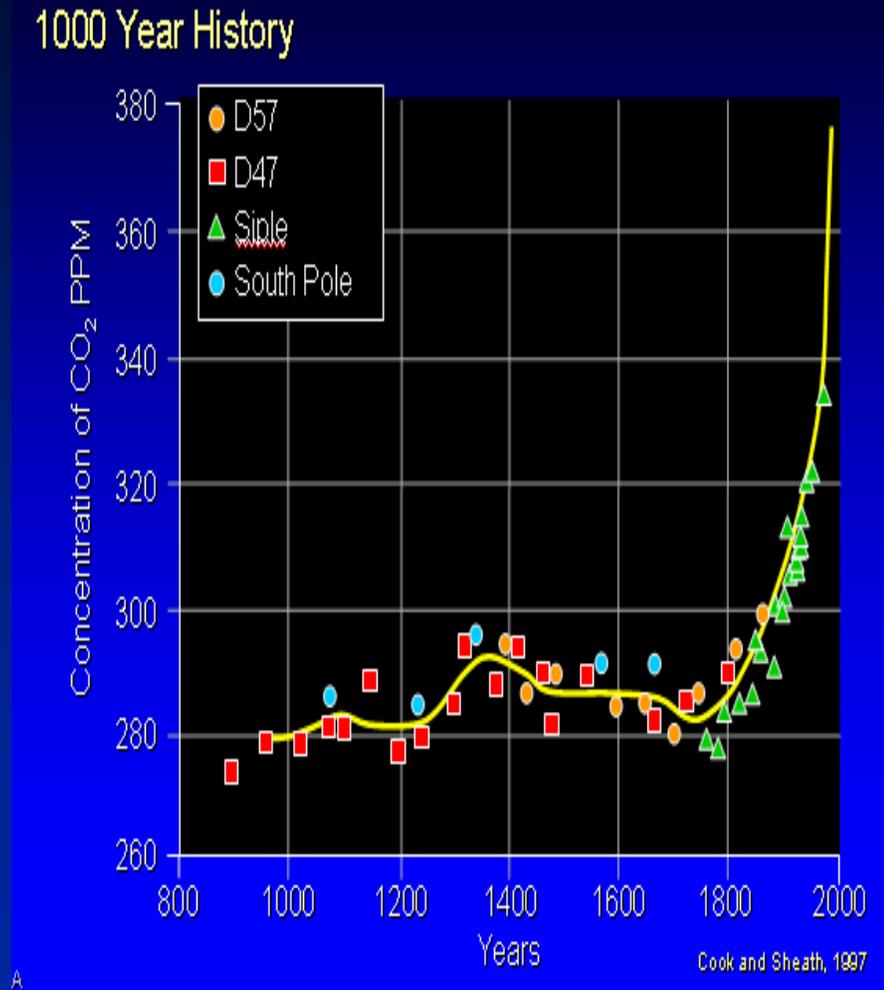
Does crude oil quality matter?

- Crude oil must be converted yet there is “brick wall” when discussing crude quality
- Quality is impacted during or after production
- Sulfur and gravity do NOT adequately define crude quality; other “bad actors” also impacts crude quality



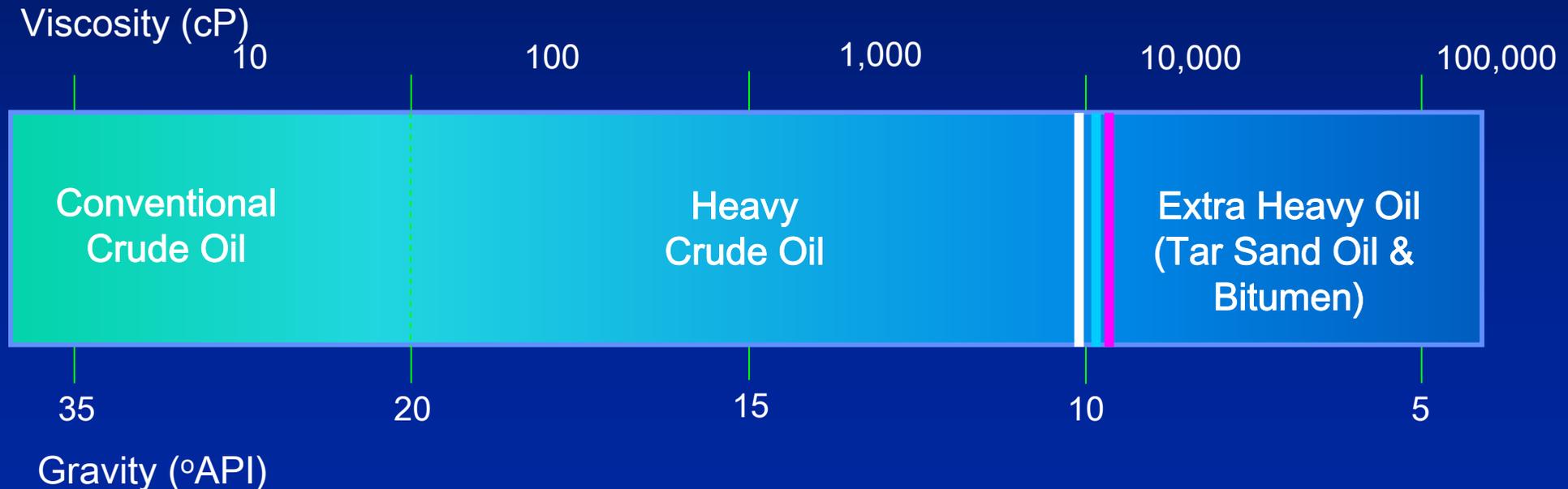
“Bad-actors” – undesirables in crude oil?

- Sulfur, Density (API Gravity)
- Total Acids (TAN)
- Nitrogen, BSW (bottom, sediment, water)
- Viscosity, Boiling Point
- Carbon residue, metals
- Dissolved H₂S or elemental S
- Contaminants introduced
- Precursor for green-house gas (more later)
- Every crude oil is unique



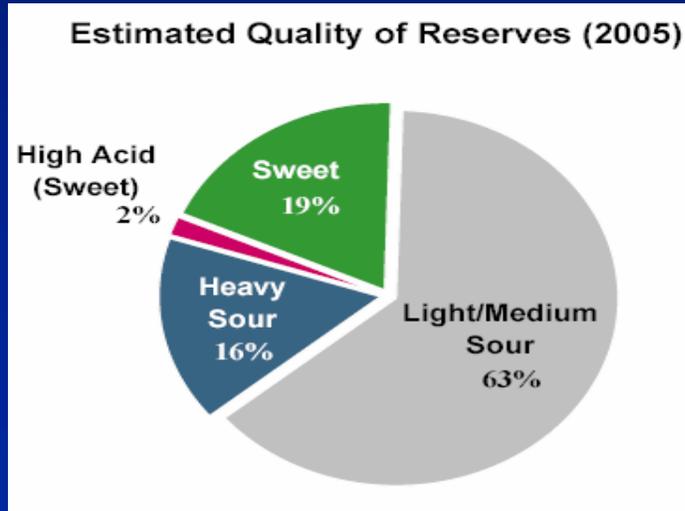
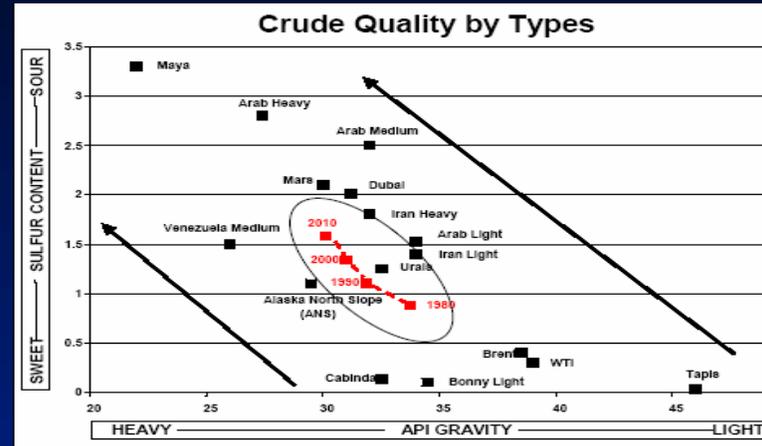
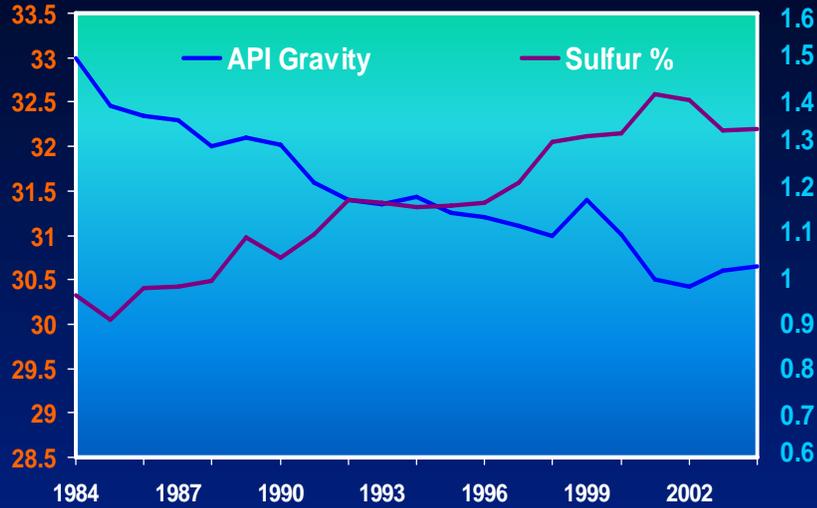
Definitions and impact

- Sulfur: Less than 0.7% S = sweet; >0.7 %S = sour, require more processing
- Acid: Acidic Crudes (>TAN 1) are highly corrosive at various areas
- Density (API gravity): Light crudes are easier to process

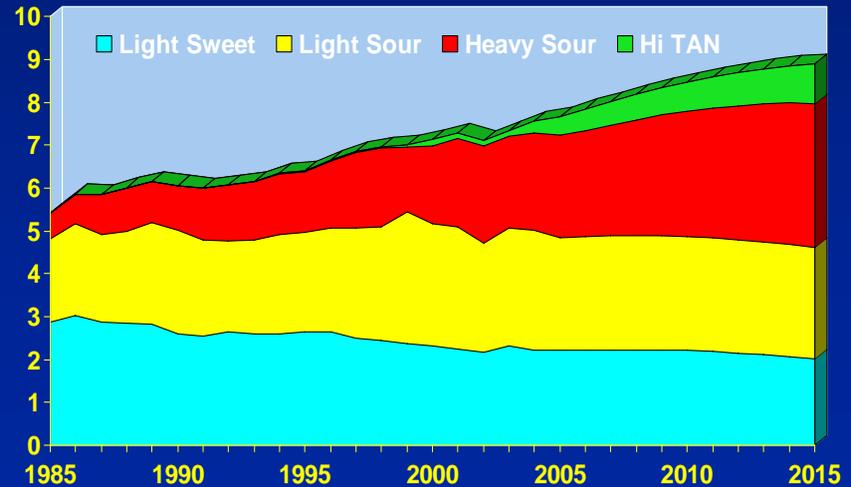


Quest for quality

All data show that most new global capacity is sour and heavy

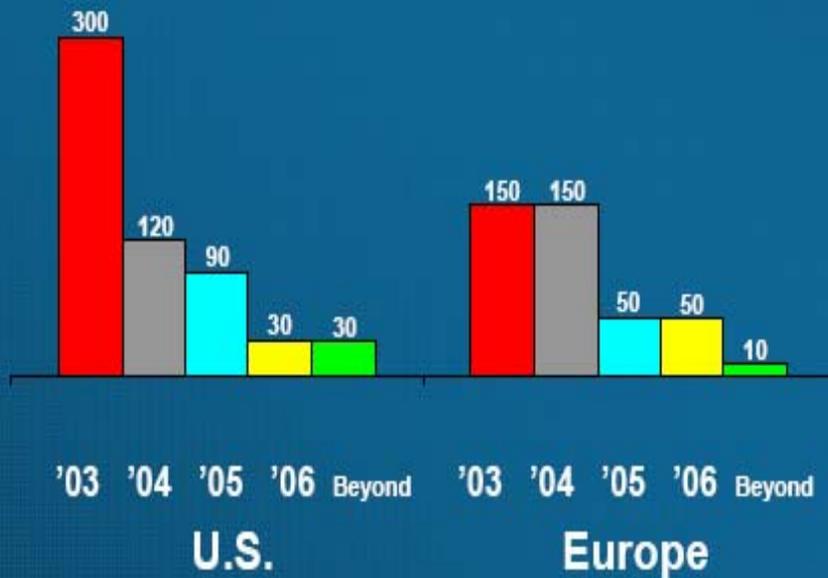


USGC million bbl/day

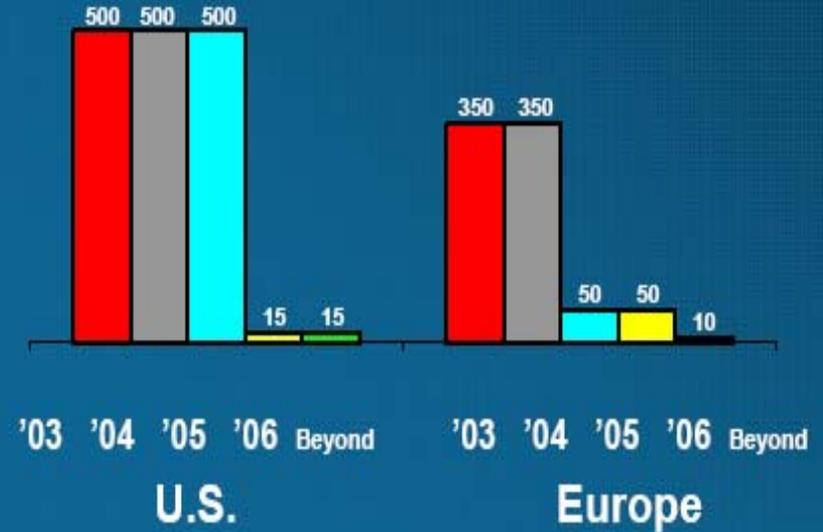


Quest for “ultra clean” fuels diverted capital

Maximum Gasoline Sulfur Content (PPM)



Maximum Diesel Sulfur Content (PPM)



Factors impacting crude price

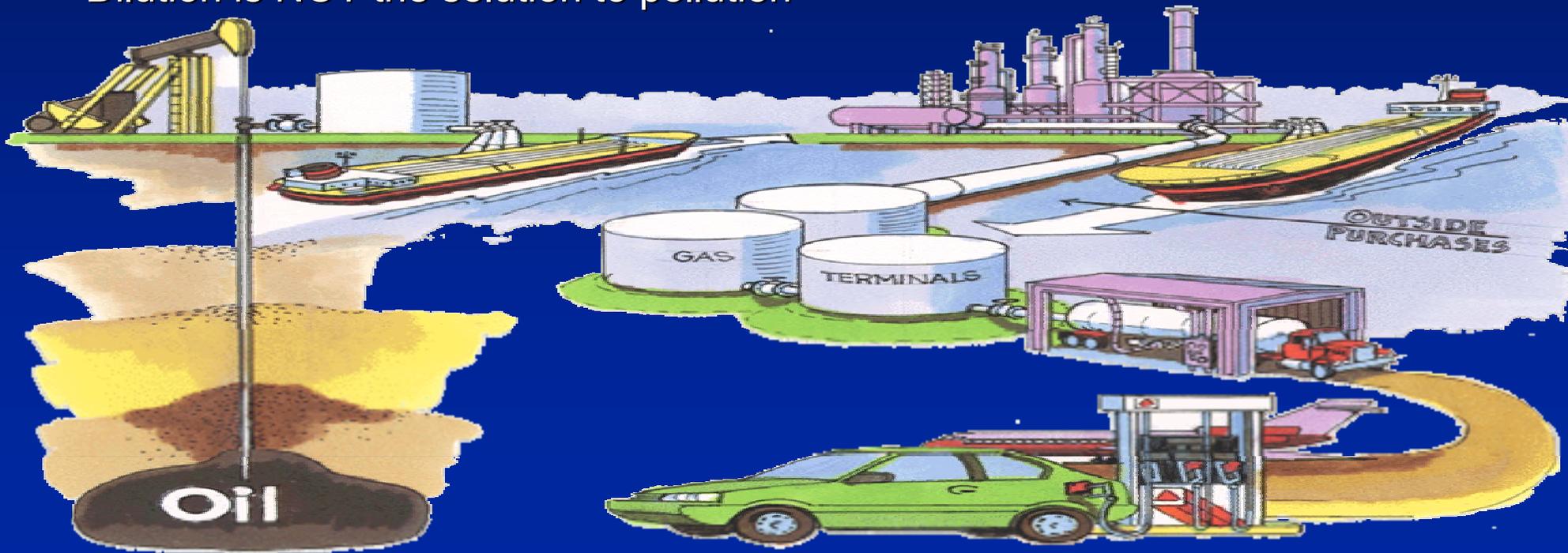
- Declining crude quality
- Changes in product quality specifications
- Little spare crude oil processing capacity
- Investment constraints
- Demand outpacing supply



From production to refinery

Human factors impacting quality: “dilution is the solution to pollution”

- “Crude oil” does not have strict “quality standards”
- Contamination: Cleaning waste, chlorinated solvents, NG liquids
- Alternation: Completion & drilling fluids, production chemicals, additives, etc.
- Blending: Some are not transparent.
- “Dilution is NOT the solution to pollution”



Comments from Crude Quality group

“We are concerned with the increased blending crude with foreign Sour to sulfur and gravity limits and representing them as neat domestic barrels. We are hoping to come to an agreement to push the entire industry to report on a routine basis on all barrels traded. We hope the traders will no longer merely trade on gravity and sulfur.....”

Dr Khan I would be interested to know the E&P feedback to the downstream on what additives are present in crude oils and ...evaluate impacts of existing and new chemical additives....

Dr. Khan,... the industry has yet to develop a full understanding of the performance of crude oil after it has been significantly changed by the production process.

Crude quality may have many implications

- Corrosion: main cause of pipeline failures
- Case study: costs of pipeline corrosion: \$5 -9 b/y
- In one pipeline alone in USA required > \$1b



Options for crude upgrading

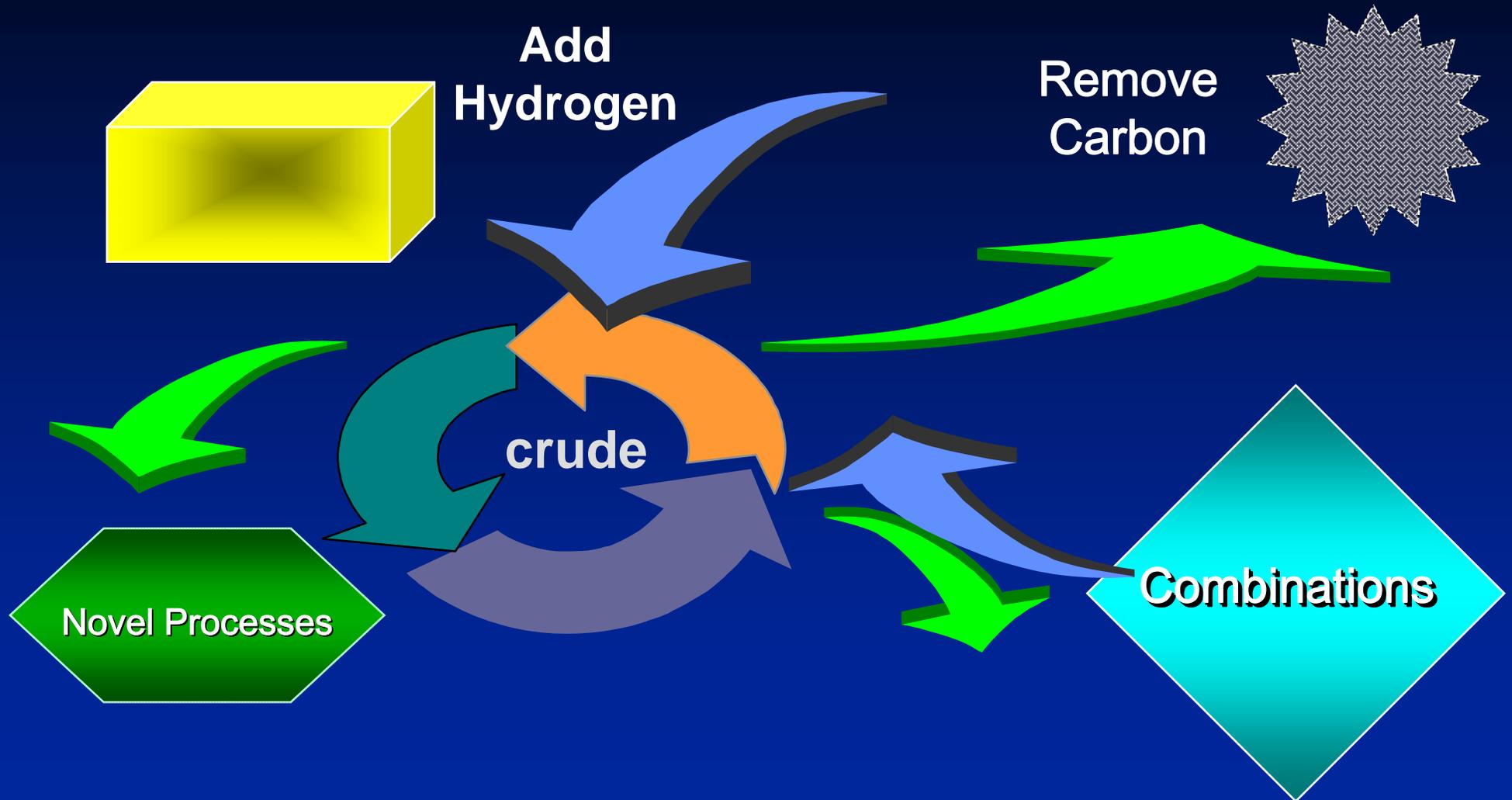
1. In refinery (current) “in your backyard.”
2. Field upgrading
3. In-situ, down hole

More field upgrading, less refining

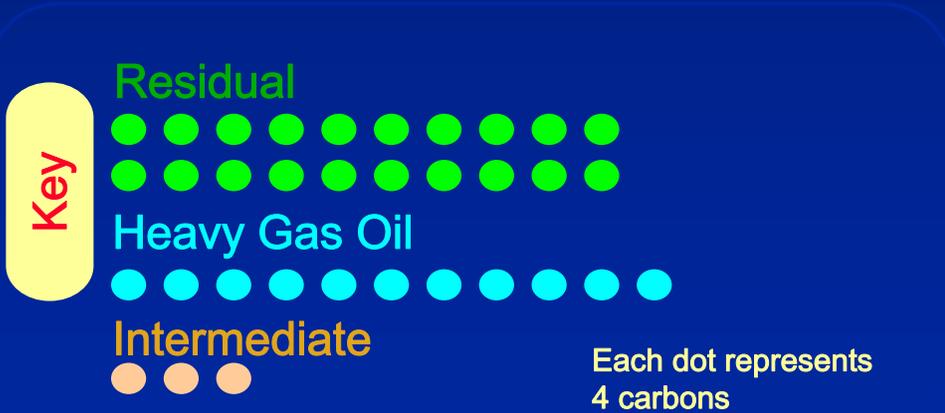
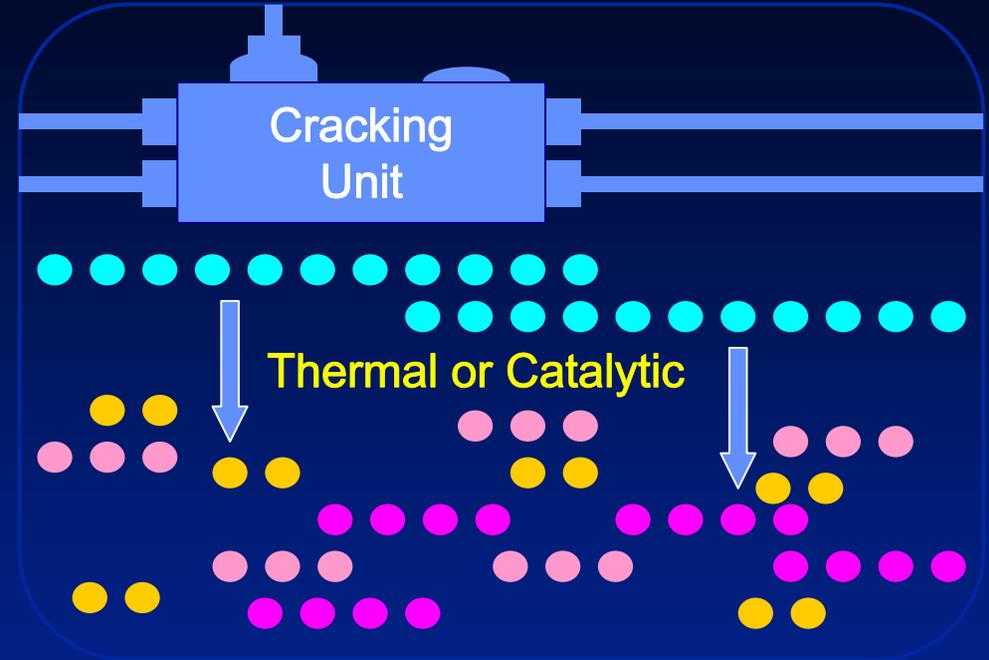
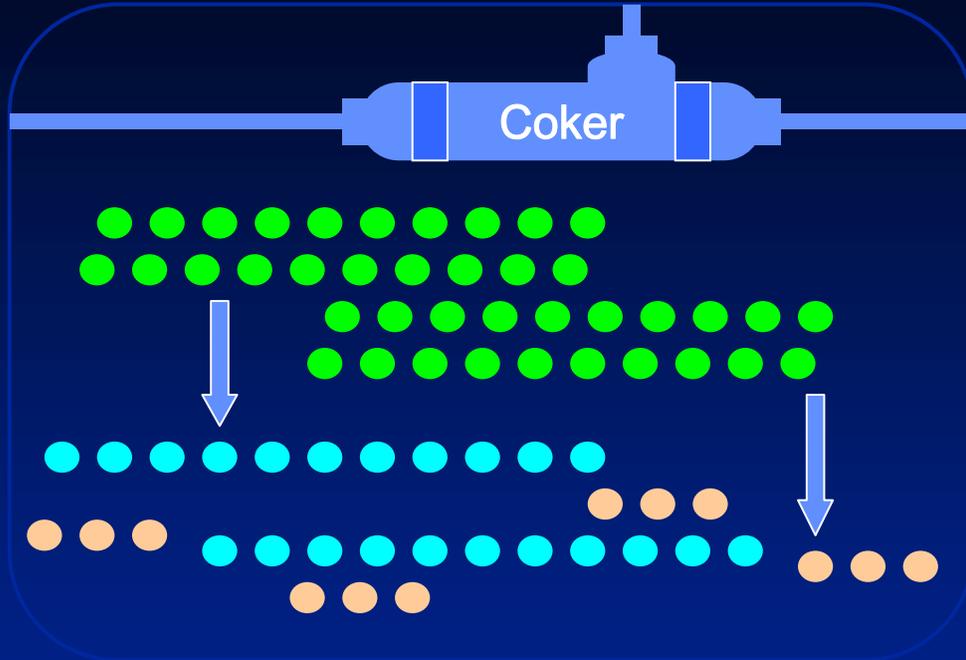
- Crude is generally converted near the population centers.
- **Integration with production may provide synergy, be less energy intensive and be cleaner.**
- **Leave “bad-actors” at the source.**



Science for crude upgrading



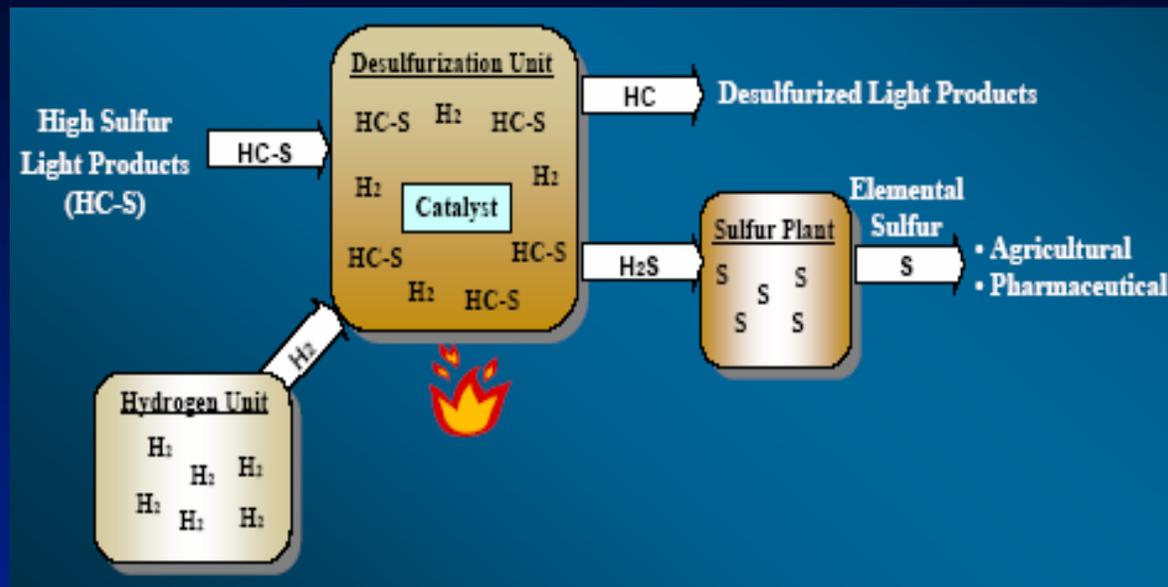
Fundamentals of carbon rejection



Processes: Visbreaking, Steam cracking, Fluid Cracking, Coking

Fundamentals of hydrogen addition

- Cracking in the presence and H_2
- Reactions catalyzed by metal sulfides



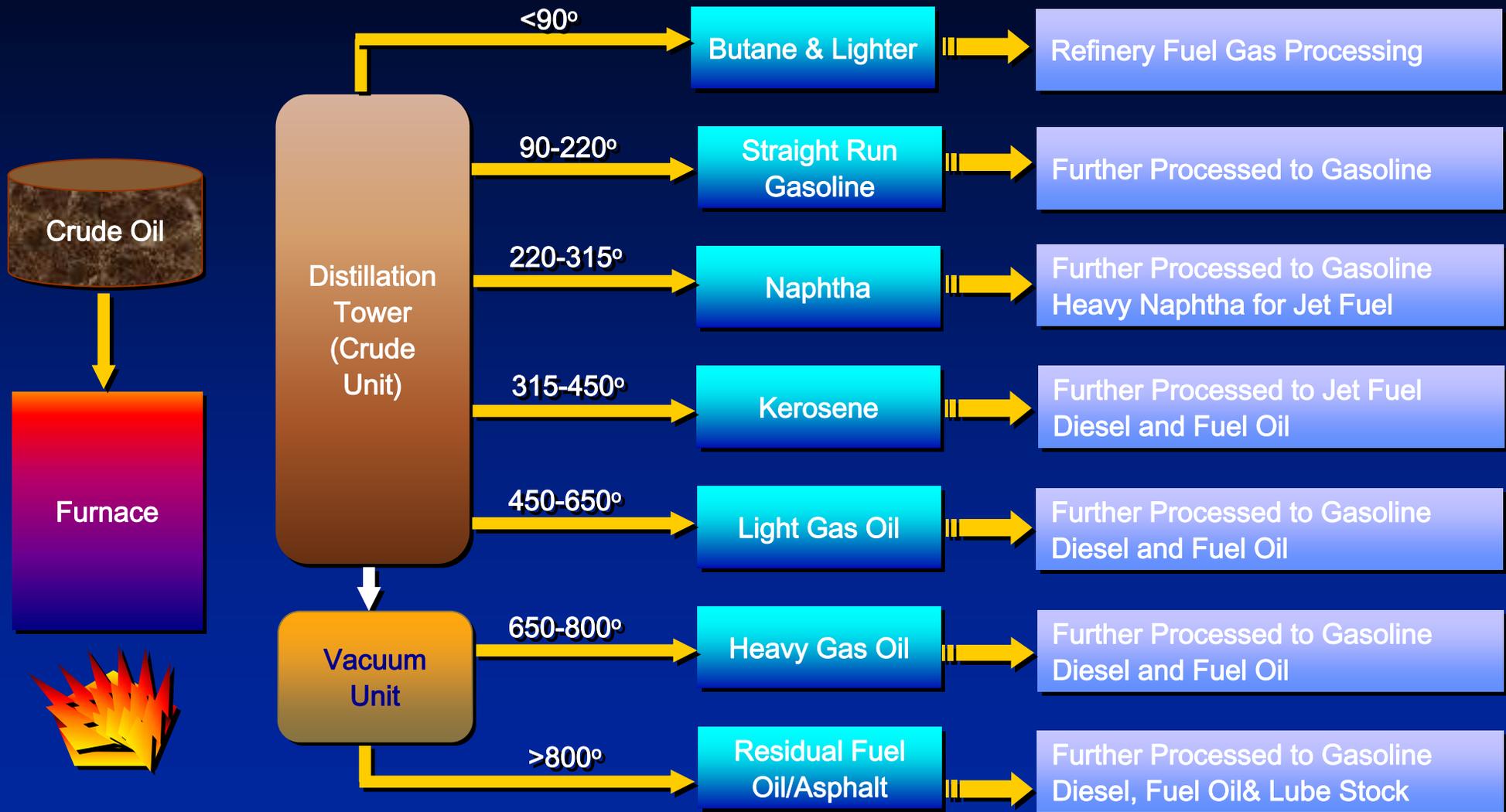
Organic Sulfides



Processes

Hydrocracking, Hydrovisbreaking

Defining refining



Crude types vs products

Crude Types

Characteristics

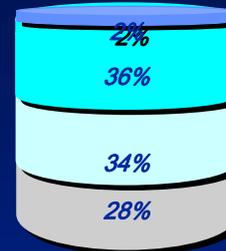
Yields

2004 U.S. Refinery Production

Sweet Crude

(e.g., WTI, Brent)

*34+ API Gravity
<0.7% Sulfur
Most Expensive*



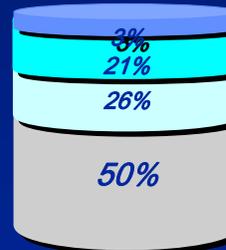
8%

Propane/
Butane

Medium Sour Crude

(Mars, Arab Light,
Arab Medium)

*24-34 API Gravity
>0.7% Sulfur
Less Expensive*



49%

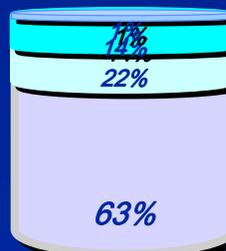
Gasoline
RFG
Premium



Heavy Sour Crude

(e.g., Maya)

*<24 API Gravity
>0.7% Sulfur
Least Expensive*



32%

Distillate
Jet Fuel
Diesel
Heating Oil



11%

Heavy
Fuel Oil
& Others

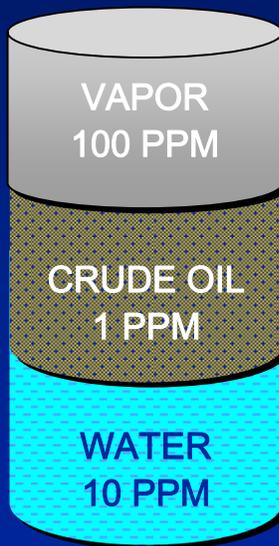
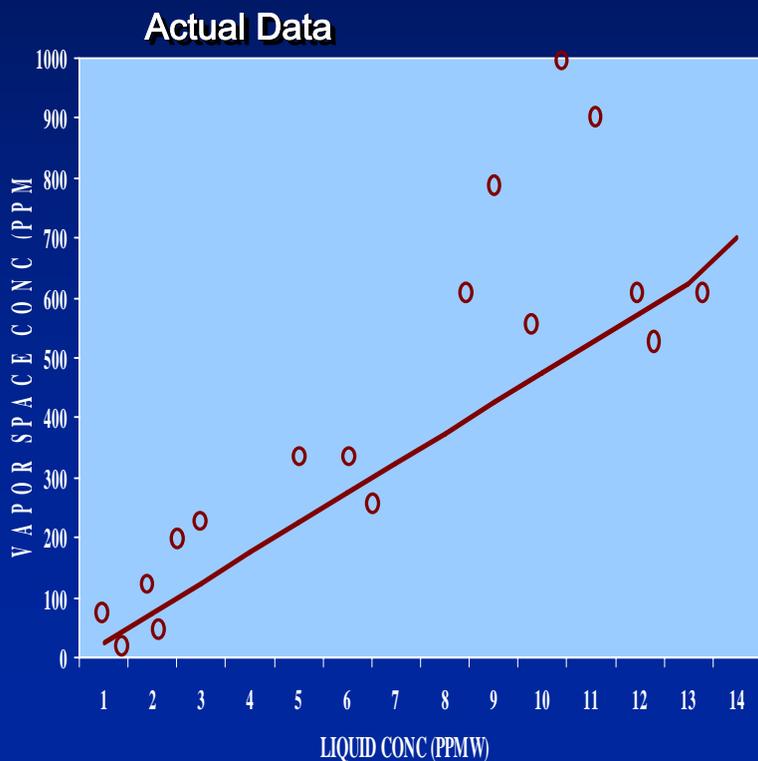


Many field treatment are already viable

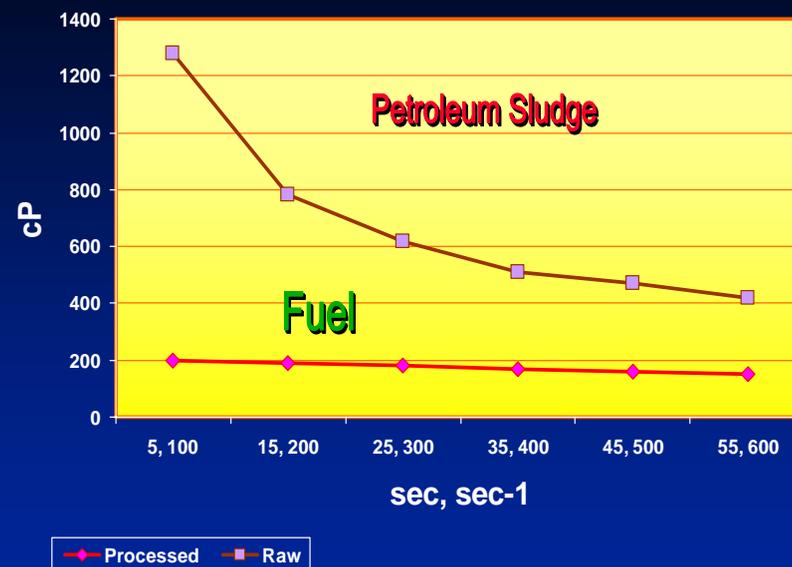
Remove H₂S in crude oil in the field; viscosity reduction

- Sour crude have high elemental S (>0.5%), dissolved H₂S
- Maya, Qatar, W. Texas: 200 -350 ppmw
- H₂S is removed in the field strippers, desalters or holding tanks, but elemental S may remain; the easiest way to remove is by upgrading (T, t, catalysts).

H₂S Concentration

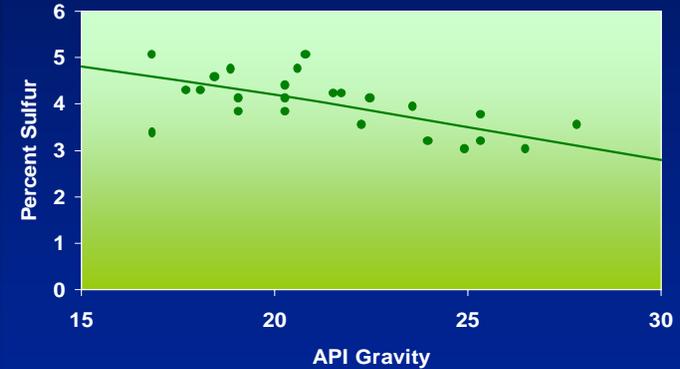
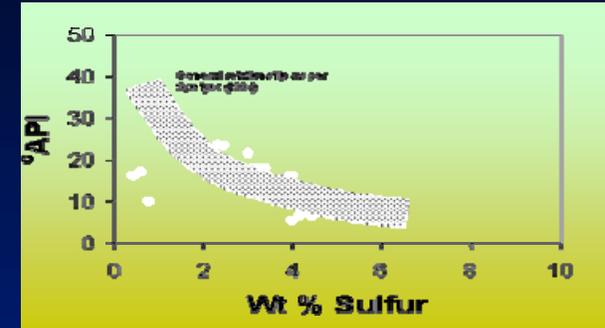
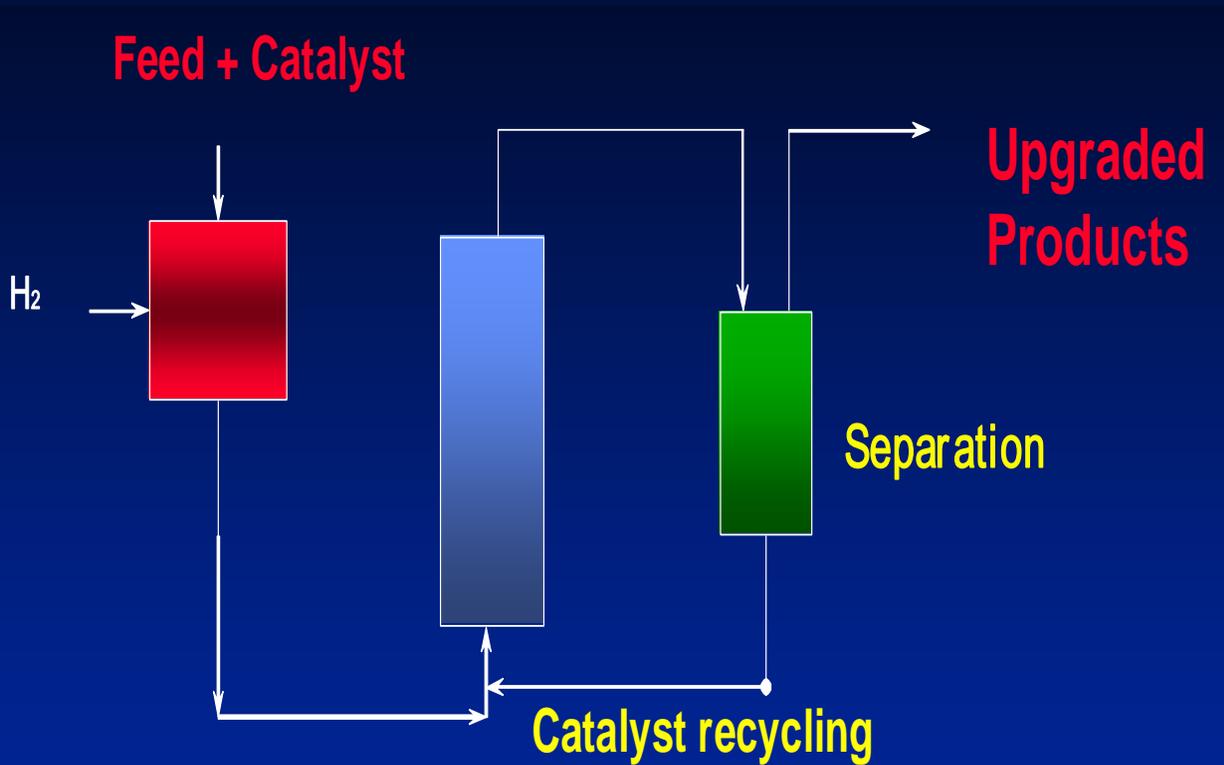


Lowering crude viscosity in field?



Physical treatment eased transport

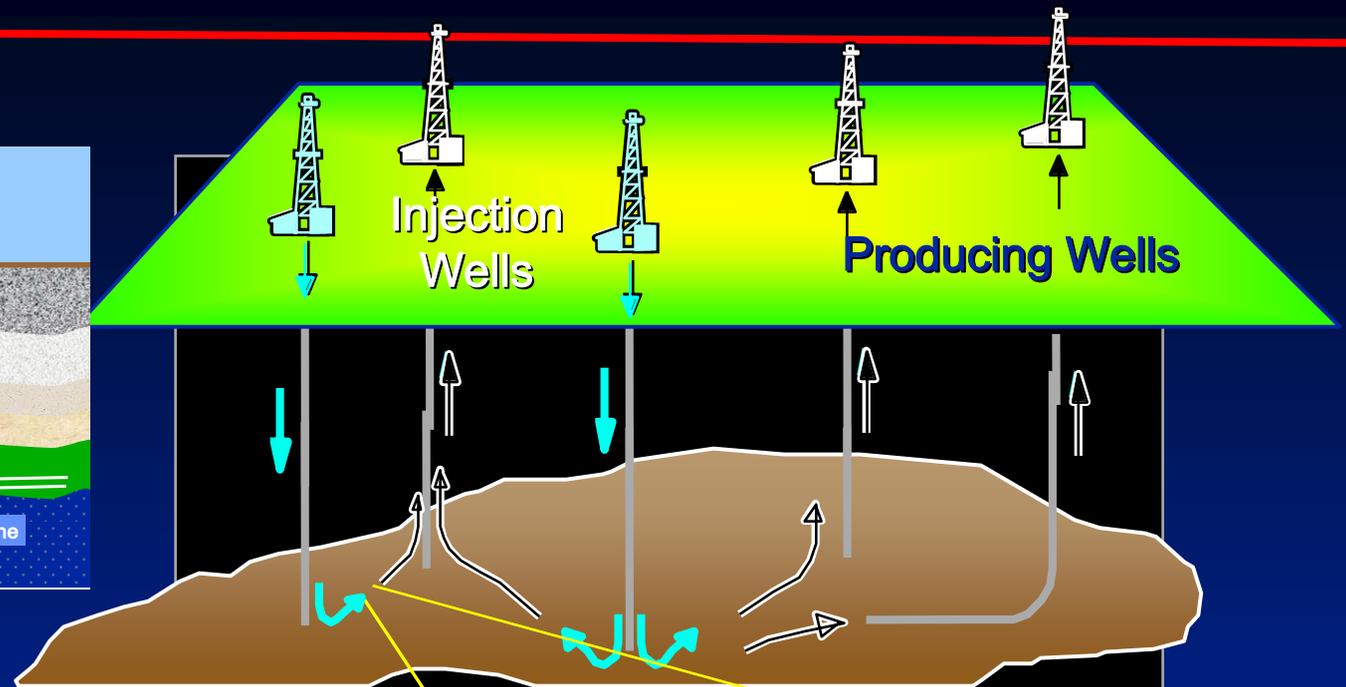
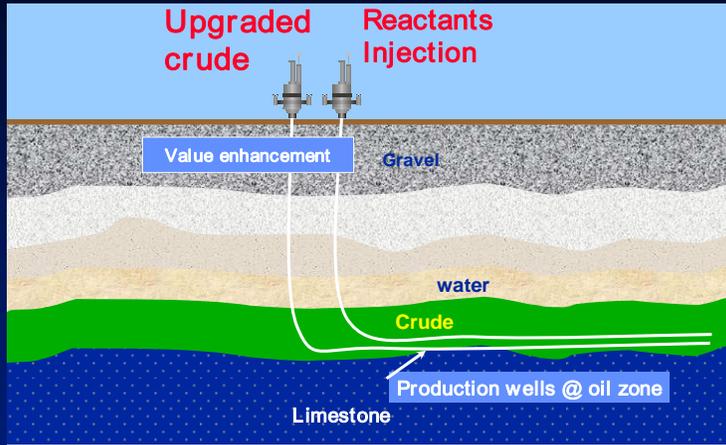
Basic field upgrading to syncrude



Gravity & sulfur during upgrading

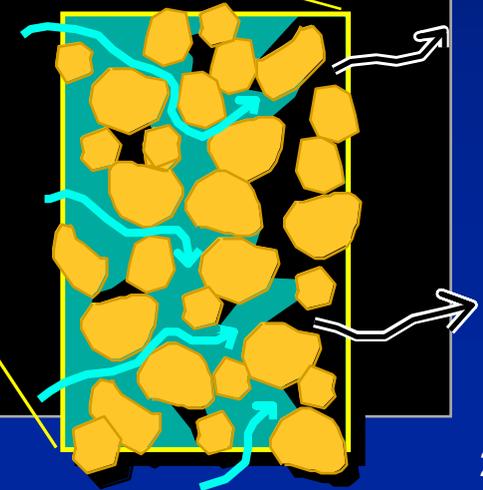
In-situ upgrading & recovery of 60% remaining oil

Pipe dream?



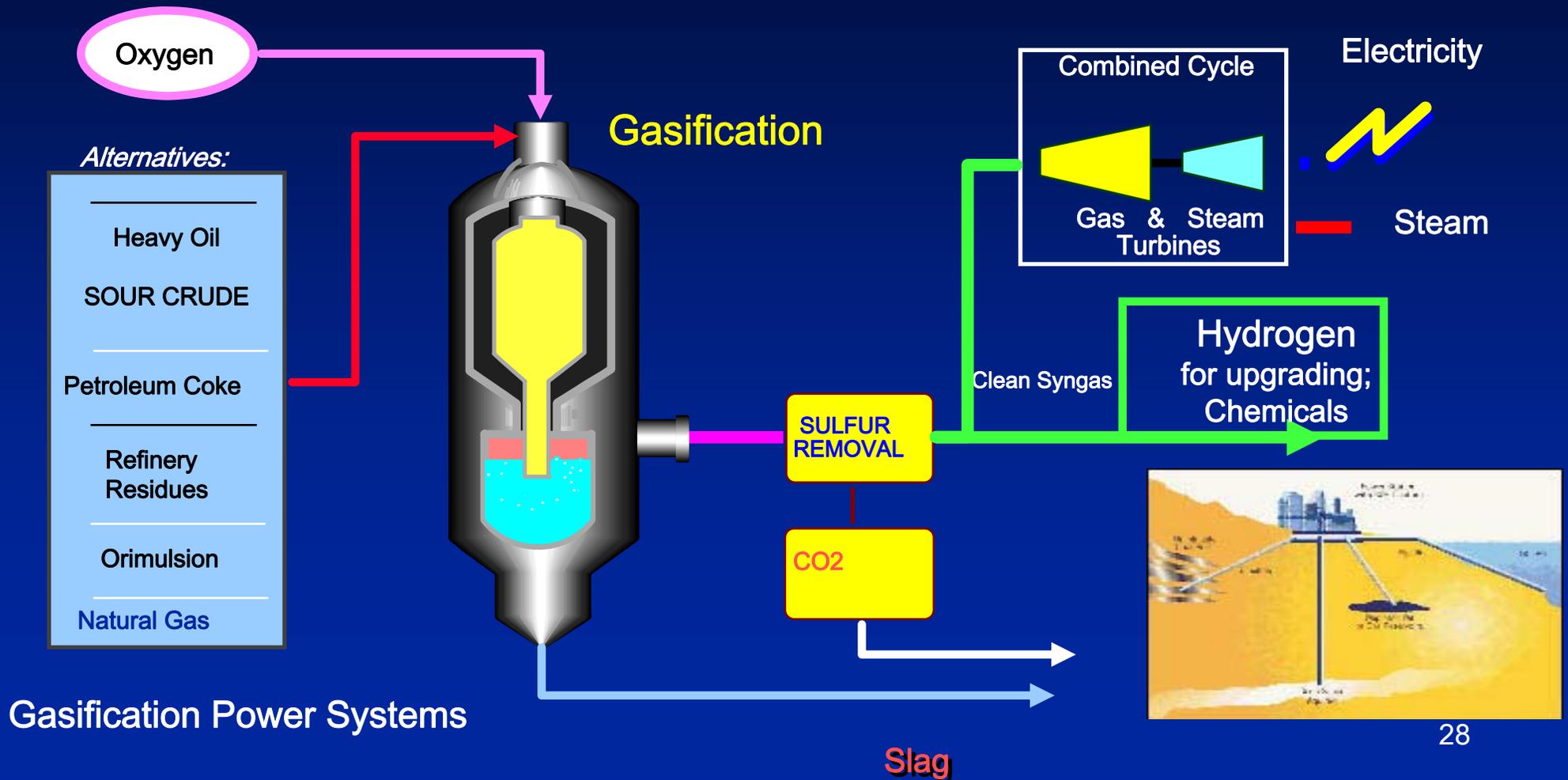
- CO₂
- Water
- Gas
- Steam
- Chemicals
- Oxygen

Inject into the reservoir to force additional crude out of the pores in the reservoir rock. Some additives may change asphaltene improving quality and yield.



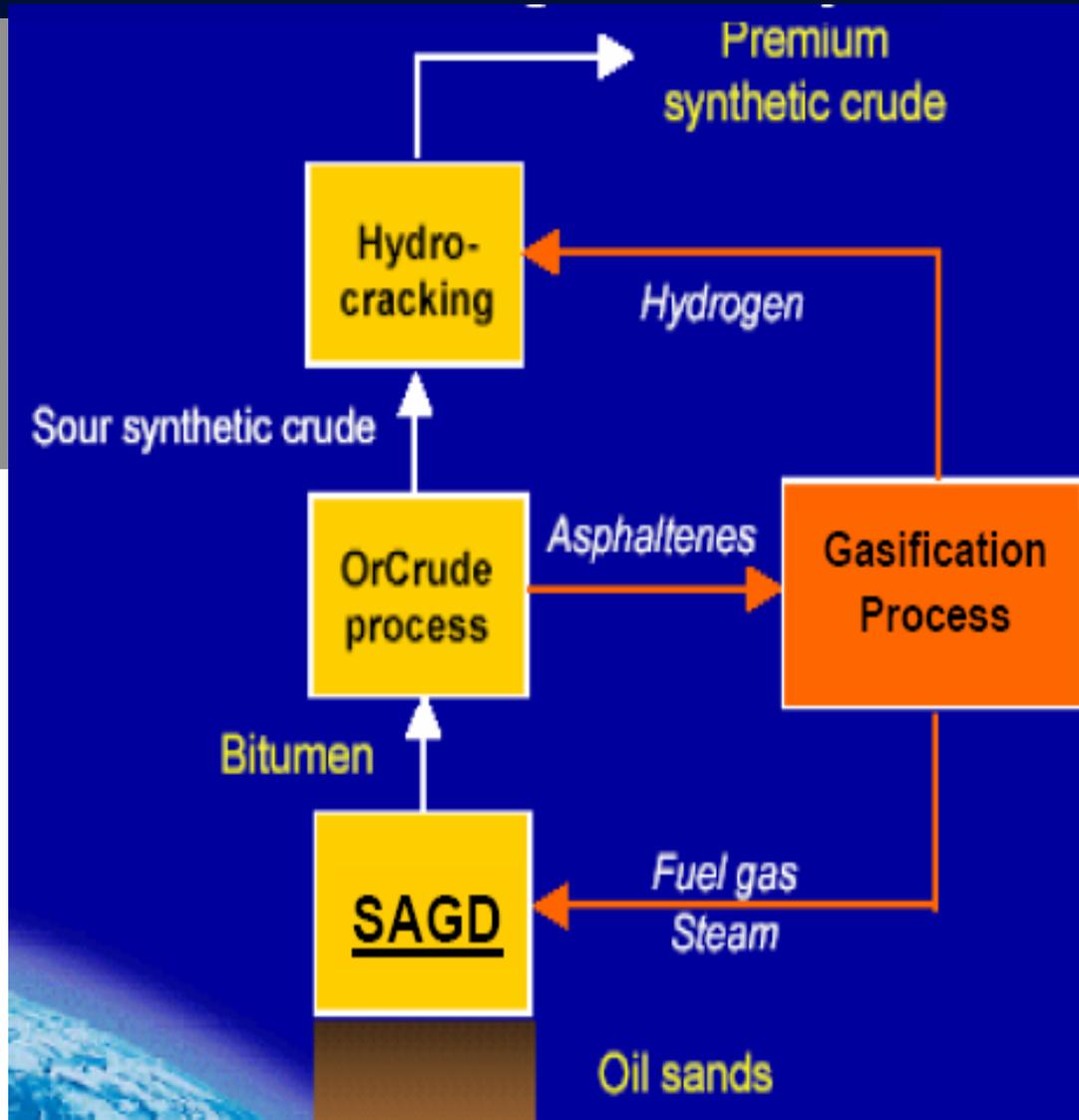
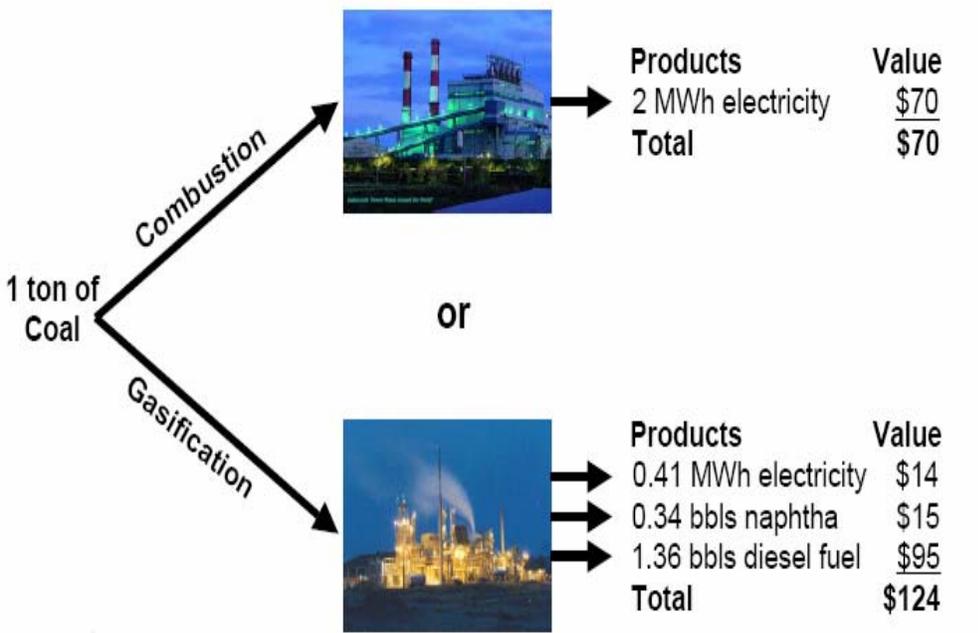
Integrated gasification: innovative bridge to the future

Sweet crude, chemical, power without GHG emission possible today



Field or "mine mouth" conversion of fuel

Opportunity for CO₂ sequestration while making a sweet crude

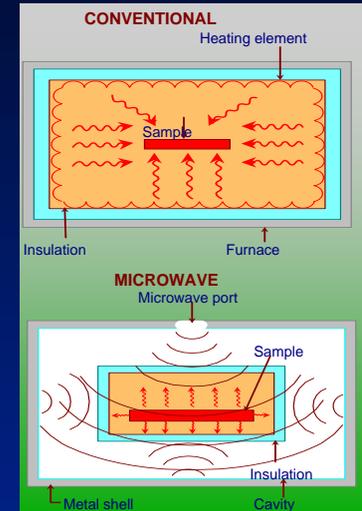


Growing inventions on upgrading

some of which may be useful near production site or in-situ

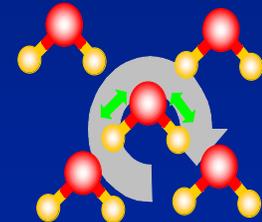
131 patents
'downhole &
upgrading';
181 patent
applications

24 patents on
'ultrasound+
desulfurization';
21 applications



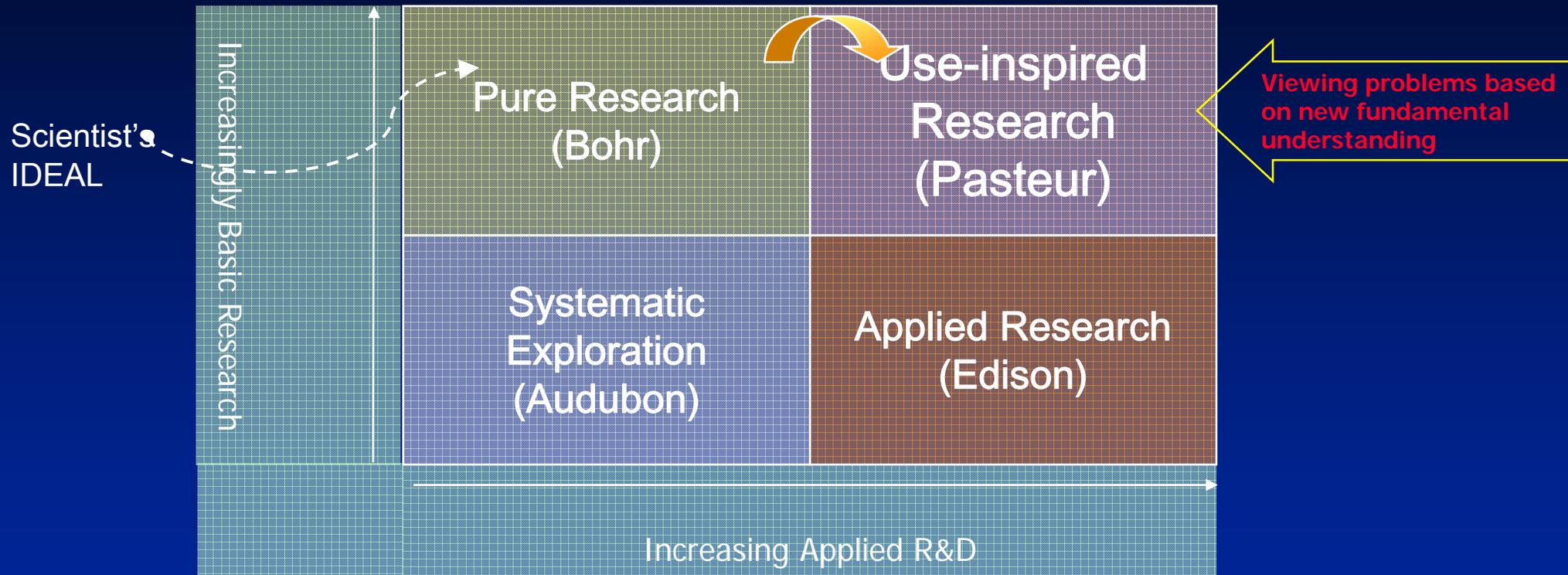
145 patents
'downhole &
desulfurization';
106 applications

133 patents on
'in-situ &
gasification';
179 patent
applications



Quest for disruptive or radical innovation

in energy development



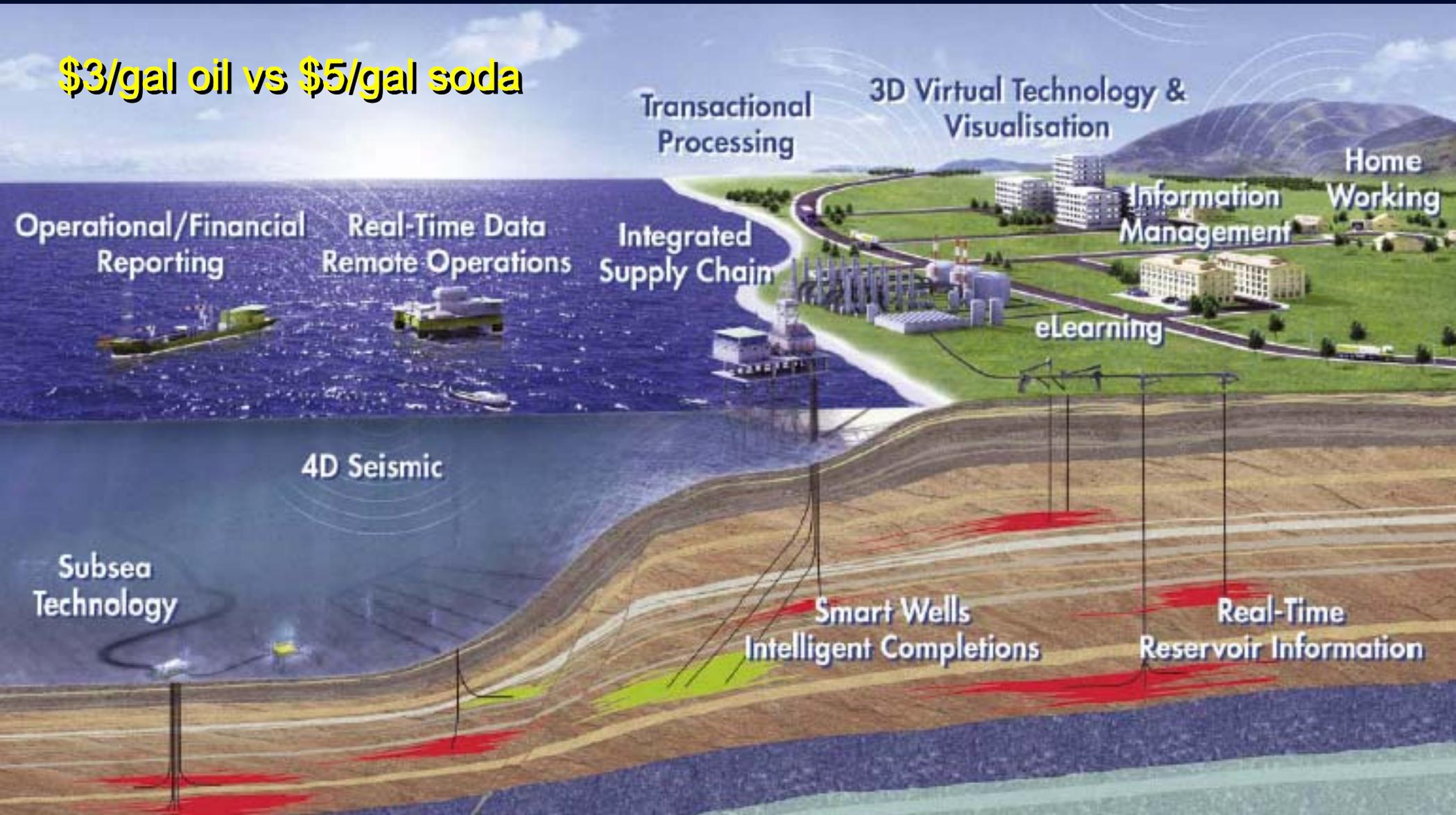
Contribution of technology to economic growth >50%. but this is primarily from

PASTEUR QUADRA; Ref: Modified from Donald Stokes, "Pasteur's Quadrant"

IT innovation made oil field into a digital factory

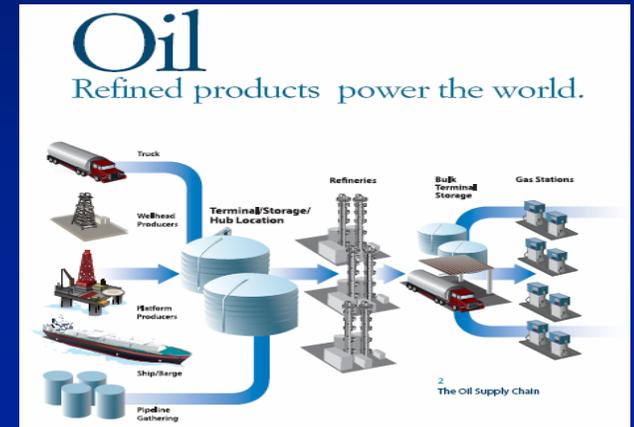
Much of today's oil is "smart oil."

\$3/gal oil vs \$5/gal soda



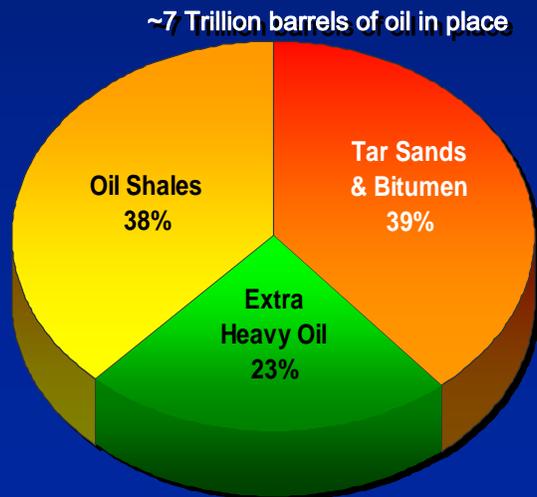
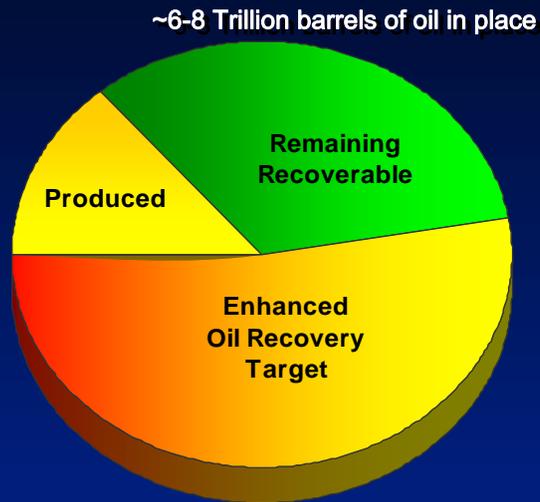
Finding and supplying crude oil is challenging

Many innovative successes by E&P, but future successes may be different



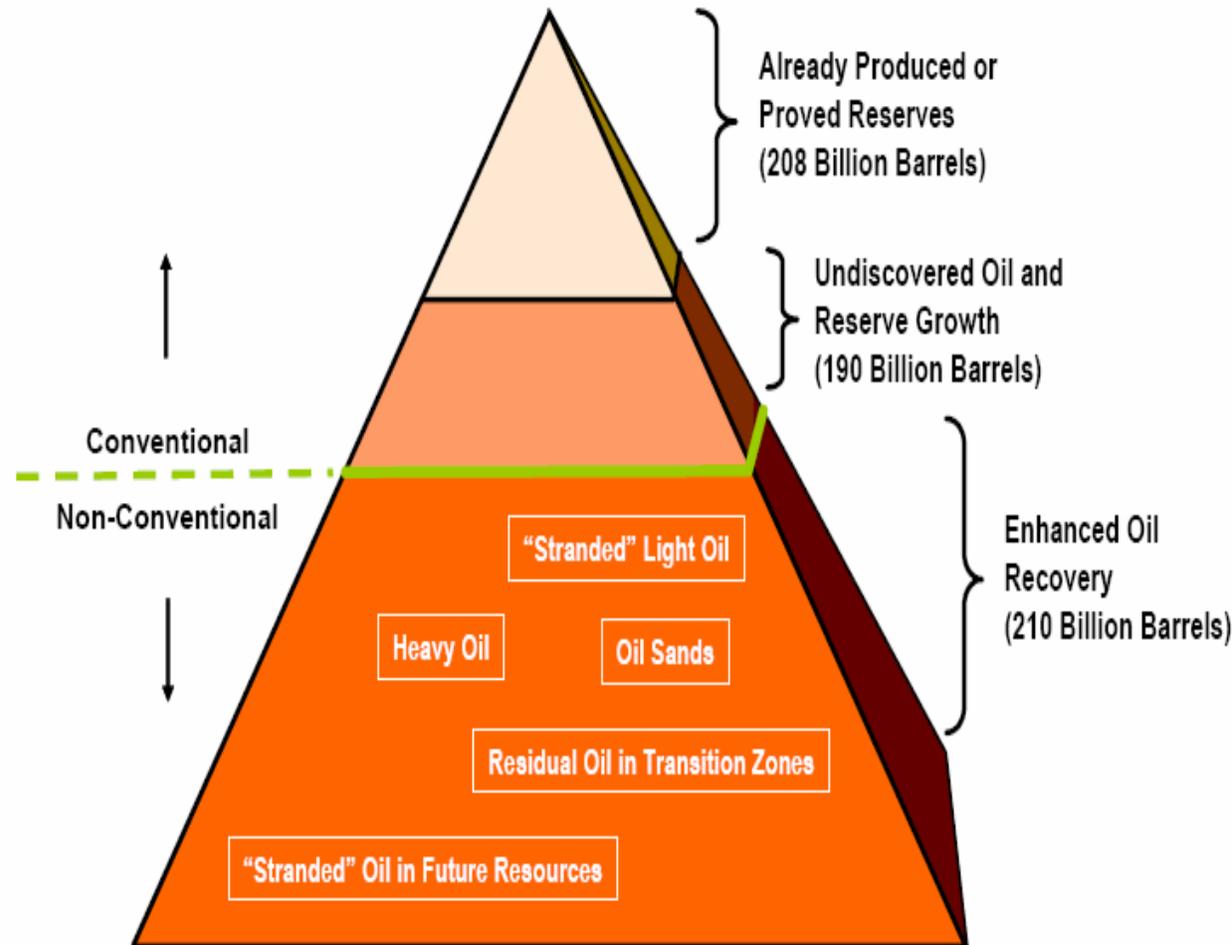
Huge conventional & non-conventional oil sources exist:

Opportunity for E&P innovation in heavy &/or sour resources



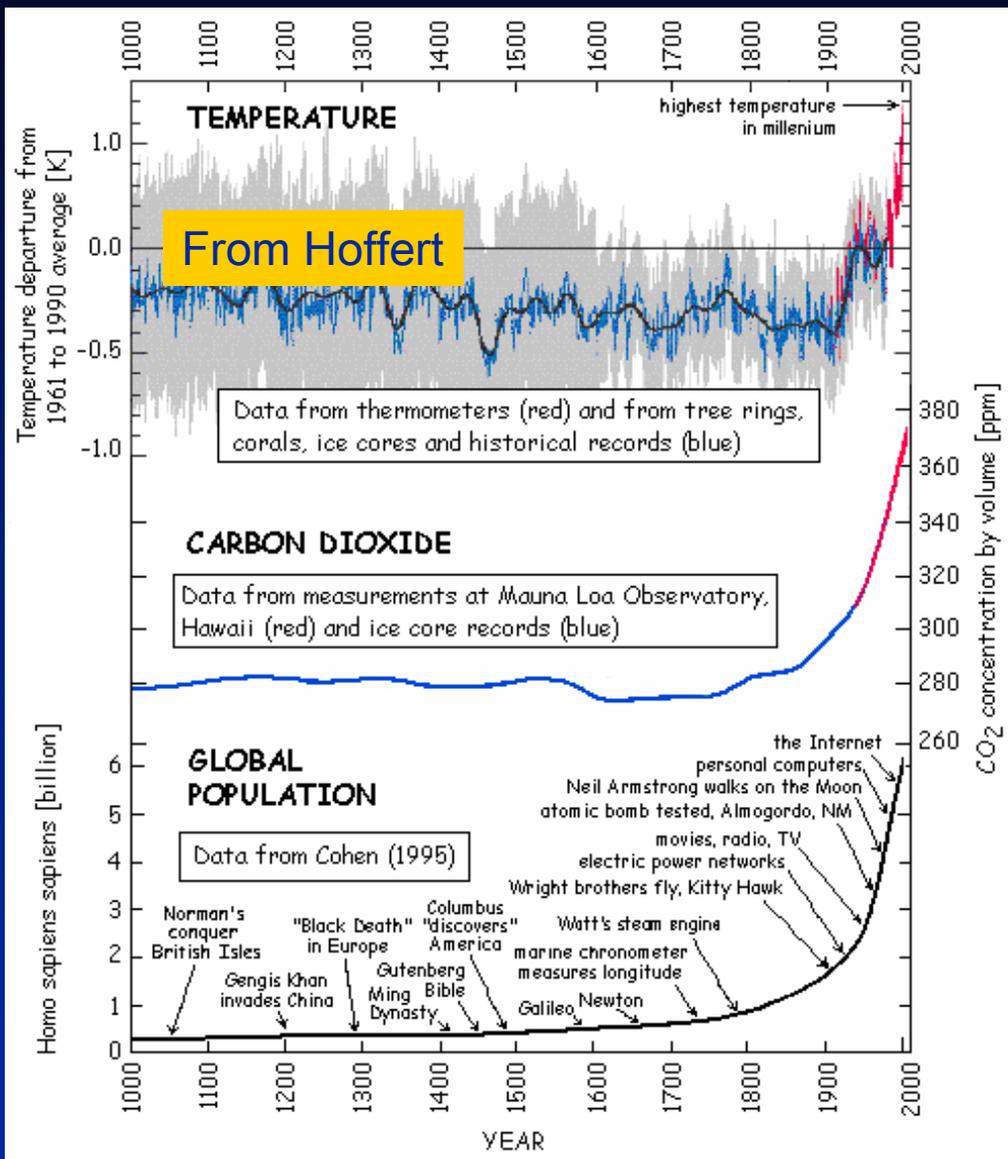
Source: IEA World Energy 2004

Original Oil Resource In-Place: 1,332 Billion Barrels
Remaining Undeveloped Oil Resource In-Place: 1,124 Billion Barrels



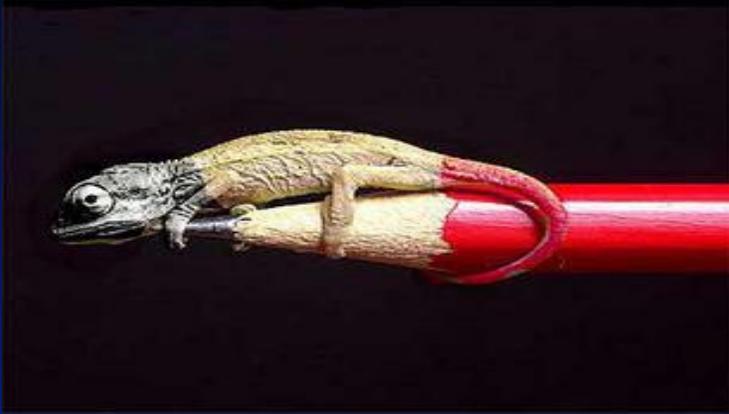
Source: Advanced Resources

A major problem for all fossil fuels is green house gas



- Climate changes threaten the world
- Our energy policy must account for it by innovations for CO₂ capture, sequestration
- A major need is to separate the energy content from carbon present in fossil fuels.
- World needs “disruptive innovations” to face the challenges.

To survive we have to adapt and innovate



"It is not the strongest of the species that survives, nor the most intelligent; it is the one that is most adaptable to change."

-- *Darwin (1809-82)*

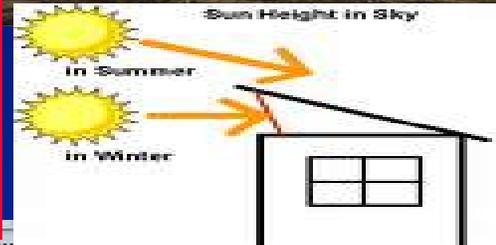
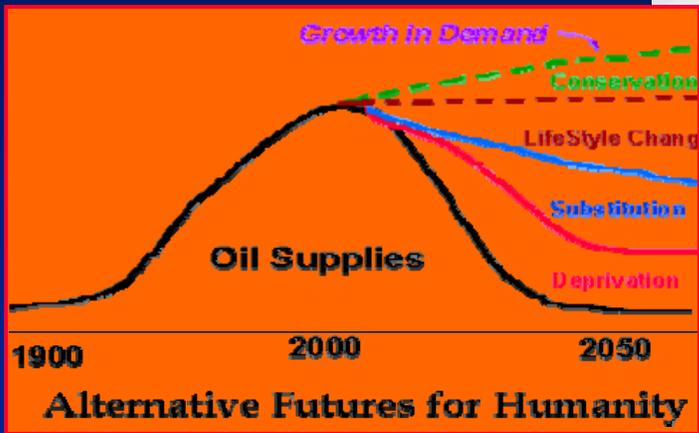


Mother earth is getting sick

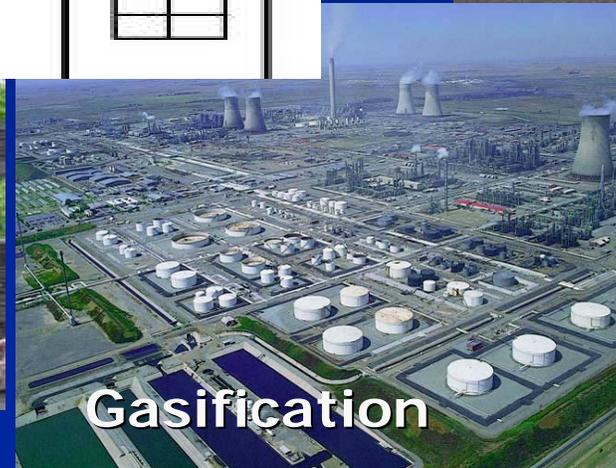
Responsible energy alternatives and energy conservation



OIL SANDS



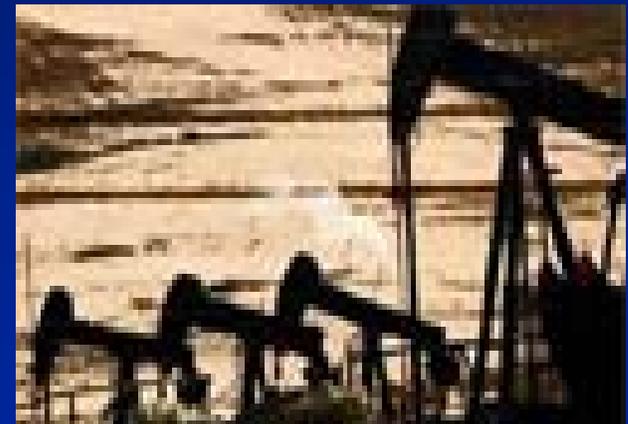
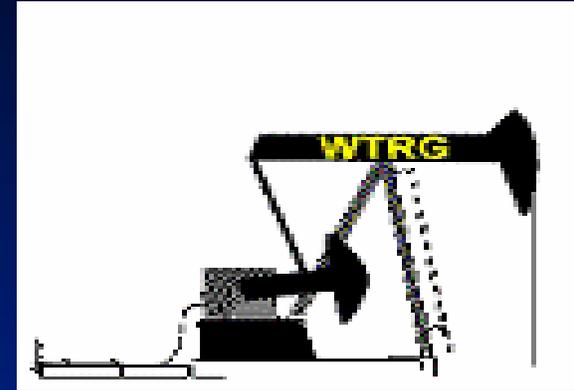
ethanol
0.8 b/d)



Innovation in oil discovery: lessons from wildcatters

“While people think big oil finds big oil, over the years about 80% of the oil found in the US has been brought in by wildcatters.”

WSJ, “Wildcat Producer Sparks Oil Boom in Montana,” 4, 2006



Innovation in oil industry did “miracles”

Lessons from Kern River: discovered in 1899

- Kern River, after 43 years of operation had “remaining reserve” of 54 million bbl.
- In the next 43 years of life, it produced, not 54 but 730 million bbls.
- In 1986, it had “remaining reserves” of about 900 million bbls.
- **Innovation will bring surprises to crude quality and reserves.**

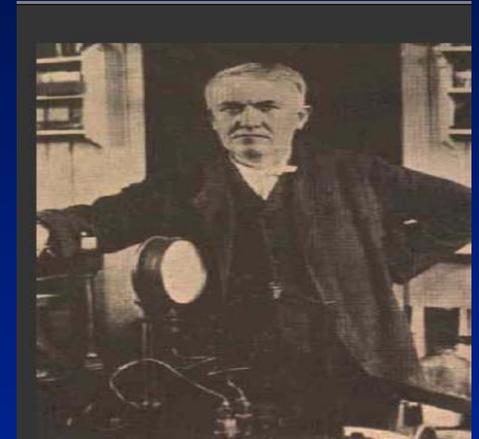


Innovation with optimism is the solution

“Everything that can be invented, has been invented.”

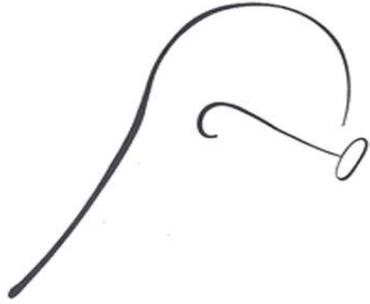
-Charles Duell, Head, US Patent, 1899

- Edison 1888: Genius is 99% perspiration
- Prof Dickey 1958: “We usually find oil in a new place with old ideas. Sometimes, we find oil in an old place with a new idea, BUT we seldom find much oil in an old place with an old idea. **Several times in the past we thought we were running out of oil, whereas actually we were running out of ideas.**”



Concluding remarks

- Society quests for cleaner environment & cleaner fuels
- Crude must be converted to clean fuels, but there is no clear standards on crude quality.
- Human factors impact crude oil quality.
- Concerns are on yield and not on quality; refiners are challenged by supply & capacity constraints.
- The challenge: make cleaner products from poorer feeds.
- Opportunities exist to synergize quality issues while addressing production.
- Disruptive innovation is needed to provide cleaner energy & address carbon & quality aspects of fuels.



Be the change you want to see in the world

Thank you



You are invited to the spectacular natural wonders of Arabian gulf

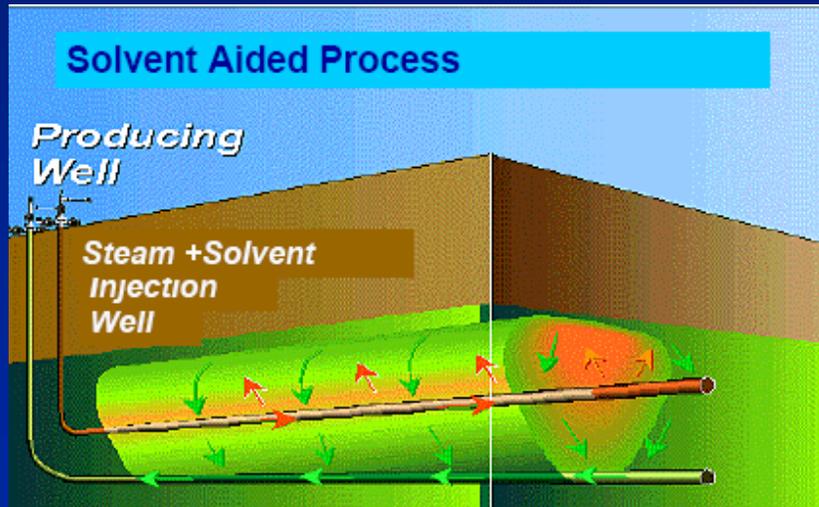
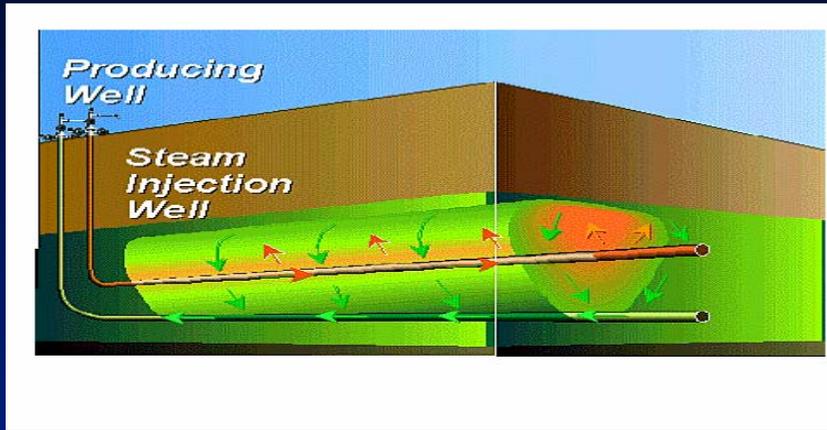
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Please send any comments or feedback

Q. How human impacts quality during production?

- There are a number of steps involved before a crude is shipped to the refinery: GOSP followed by pipeline, shipping tank, storage etc.
- Contamination: Tank cleaning solvents, cleaning waste, chlorinated solvents, NG liquids. The cleaning solvent with HCl is very damaging to refinery
- Alternation: Completion fluid containing salt water, production chemical containing acids , drilling fluids, drag reducers, additives, antifoam, etc.
- Blending: Well head, refinery charge etc, but some are not transparent (separation of asphaltenes is one of the concerns).

Steam/Solvent assisted processes

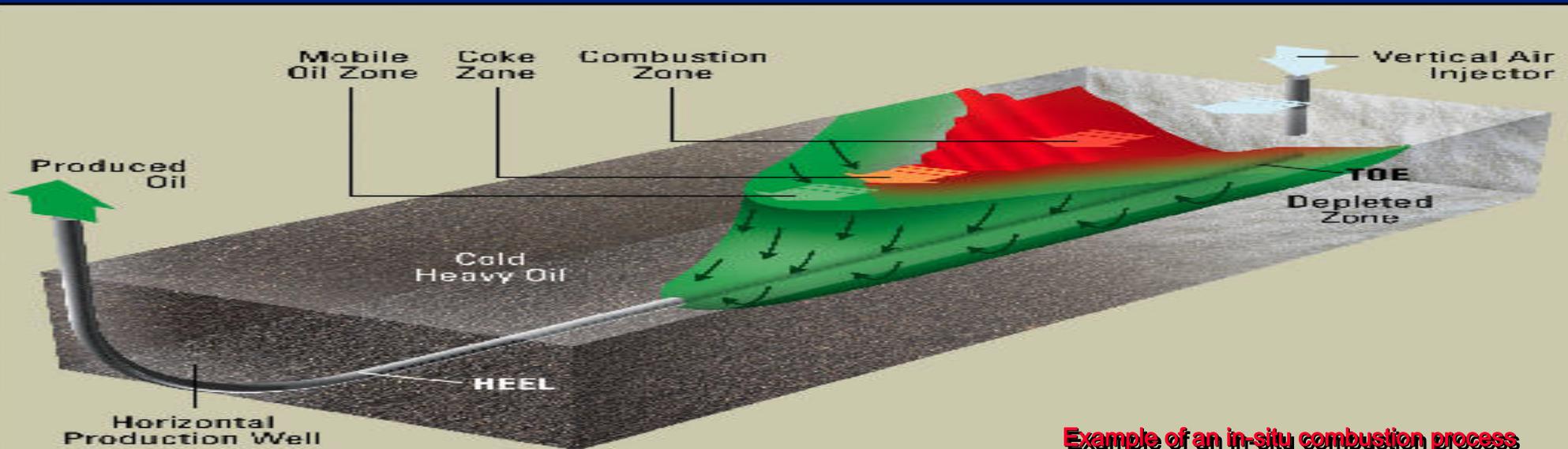


1. Steam-Assisted Gravity Drainage and variations
2. Vapor-Assisted Petroleum Extraction, VAPEX and variations. Advantages of solvent aided over steam only:
 - Lower capital needs
 - Lower emission
 - Lower water usage
 - Some quality improvement

Ref: S. Gupta, EnCana Corp.

Q. Examples of current EOR and in-situ upgrading options

- THAI process converts 10 API oil to 20.6 API; converts asphaltene in the oil.
- CHOPS (Cold Heavy Oil Production with Sand) produces oil along with sand.
- PPT (Pressure Pulsing Technique) increases oil rates of the original oil.
- IGI (Inert Gas Injection) injects inert gas with gravity drainage for pressure maintenance'
- SAGD (Steam Assisted Gravity Drainage) heats the oil to reduce the temperature for vertical drainage, producing the original oil.
- VAPEX (Vapor Assisted Petroleum Extraction): Can provide upgrading by leaving some of the heavier components in the reservoir.



Example of an in-situ combustion process