Alternate Energy Research and Technology Challenges in the New Millennium

4th Indo-US Roundtable Meeting
NIAS, Bangalore, India
21-23 Sept, 2010

B. B. Rath, rath@nrl.navy.mil
Naval Research Laboratory
Washington, DC 20375

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
SEP 2010	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Alternate Energy Research and Technology Challenges in the New Millennium	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Research Laboratory Washington, DC 20375**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA560467. Indo-US Science and Technology Round Table Meeting (4th Annual) - Power Energy and Cognitive Science Held in Bangalore, India on September 21-23, 2010. U.S. Government or Federal Purpose Rights License

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**19**	

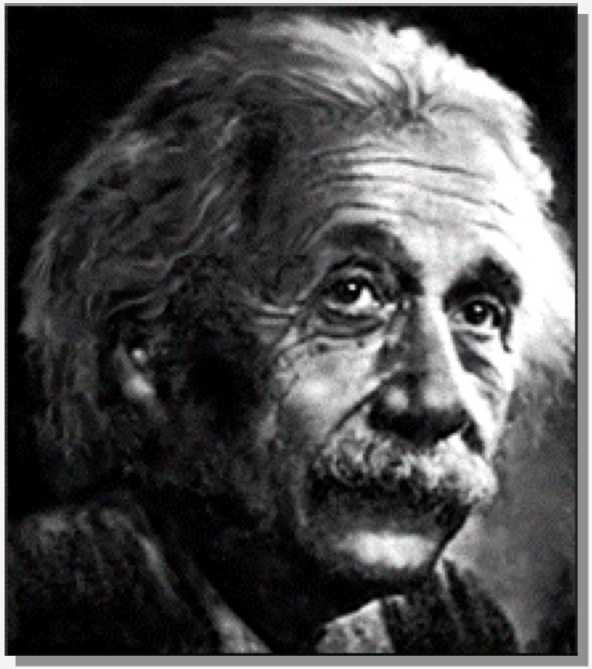
Global Issues

- Energy

- Water
- Environment

When asked shortly after WWII:

"Prof Einstein, what do you see as the greatest threat to mankind?"



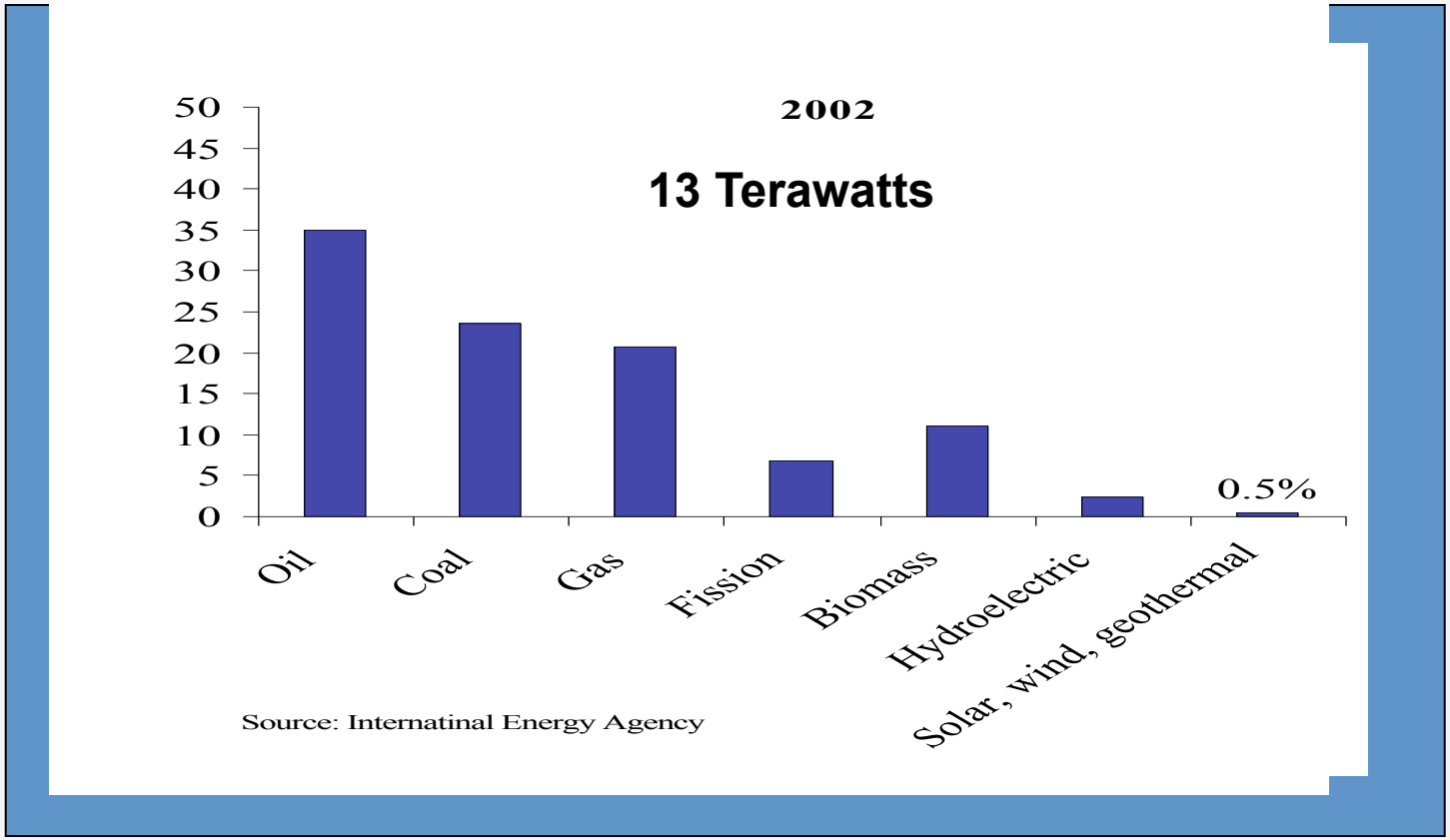
His prompt reply:

"Exponential growth."

Future of Energy After Oil
The Problem

The ENERGY REVOLUTION (The Terawatt Challenge)

Sources of Energy Supply - Worldwide



Source: International Energy Agency

Setting the Stage: A Global Overview

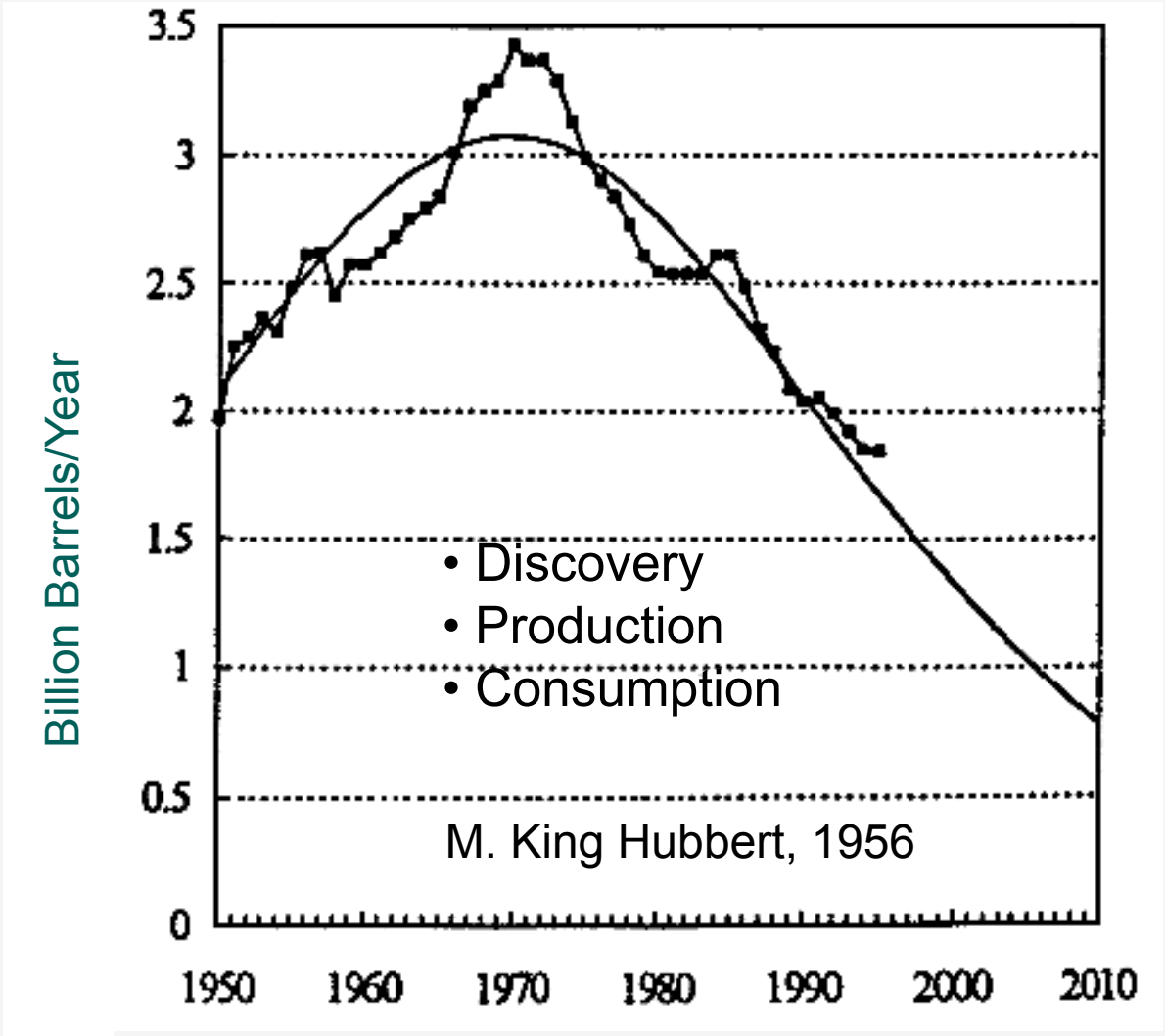
- Consider in 1900 less than 1 million barrels of oil per day vs. today at 85 million barrels per day
- "Optimistic case for out put of 100 million barrels per day could outstrip supply before 2020"

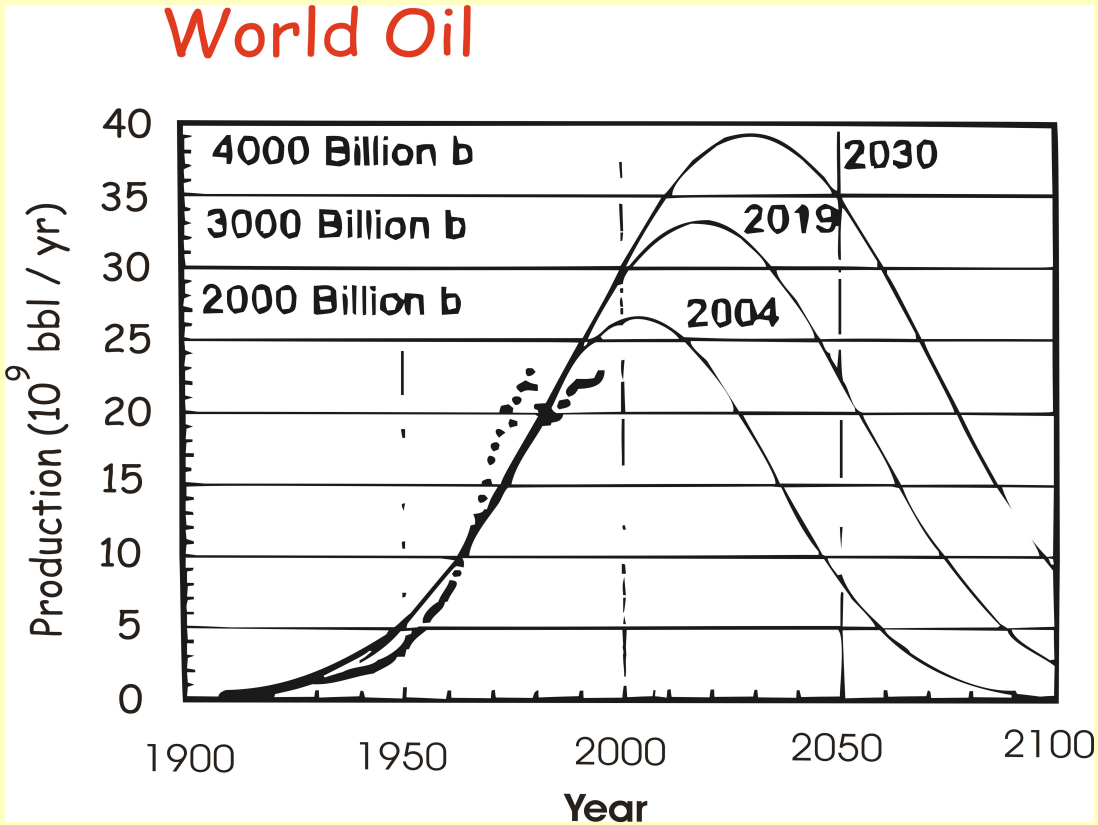
  C. de Margerie, TOTAL
- "By 2010 nearly 40% of the world's daily oil output will have to come from the fields that have not been tapped or even discovered."

  J. Mulva, ConocoPhillips
- "By 2015 we need to find, develop and produce new oil that is equal to 8 out of 10 bbl being produced today." President Exxon Mobil 2003

Tapped Out, Paul Roberts, National Geographic, June 2008

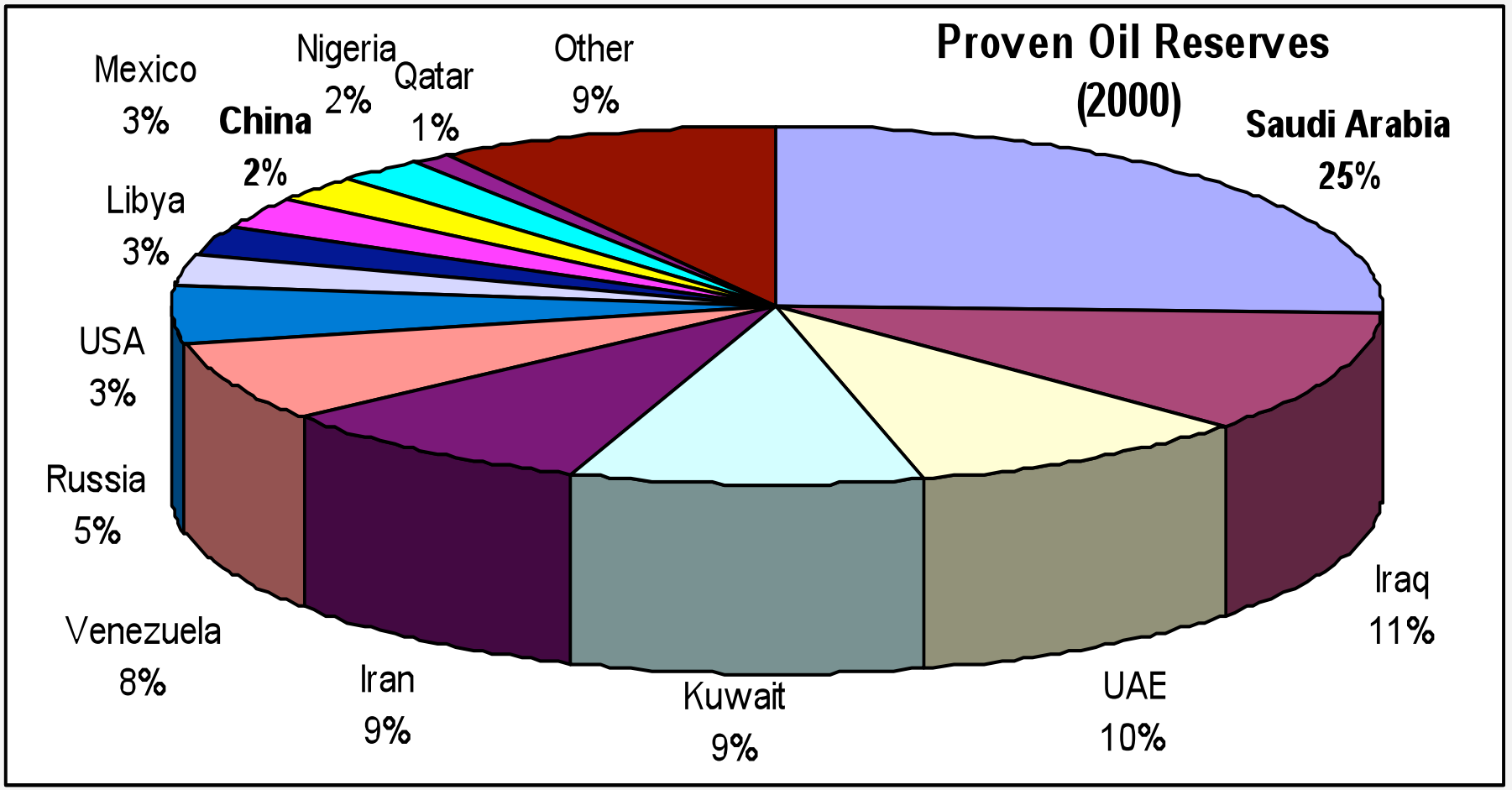
Crude Oil Production in the Lower 48



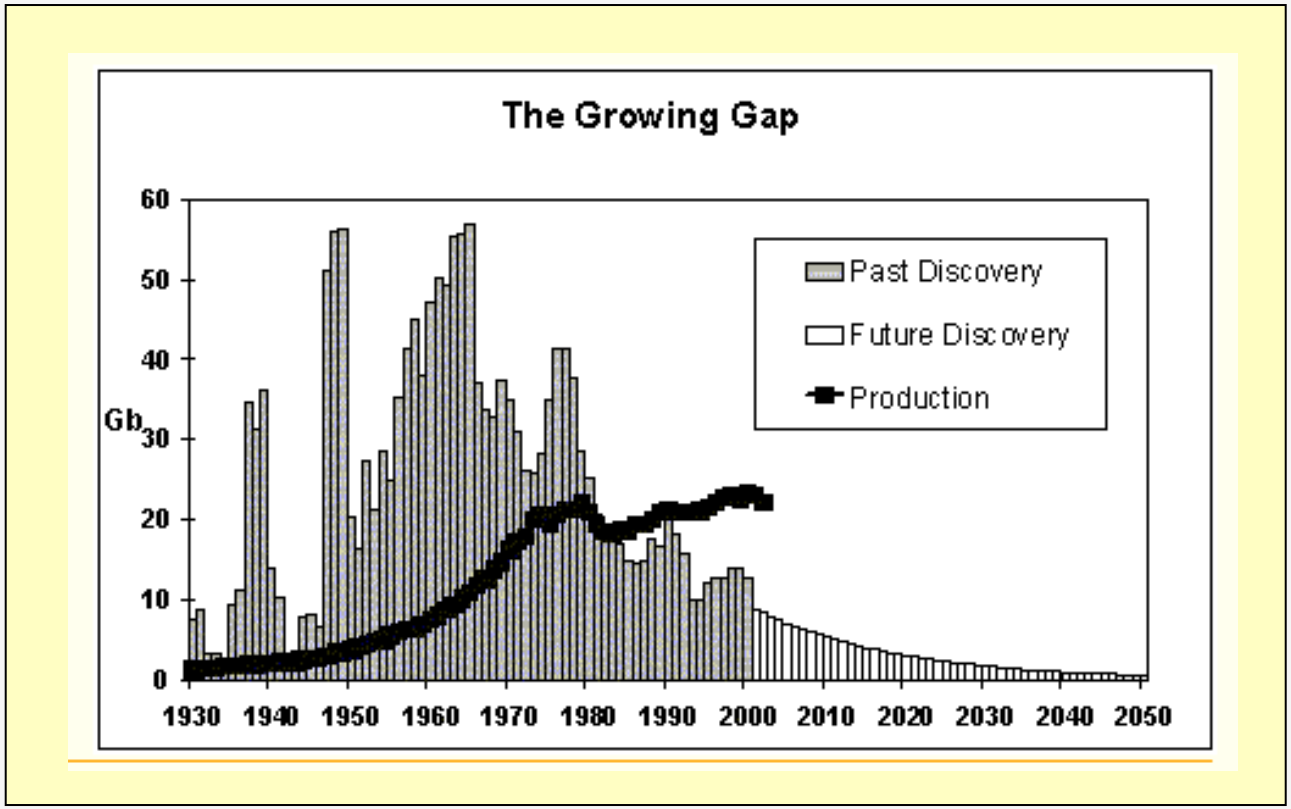


Deffeyes, Hubbert's Peak, 2001

World Proven Oil Reserves



Depletion of Oil Reserves



World oil reserves accumulated since 1930 are now being depleted. Industrial growth in Asia will accelerate the depletion

The Coming Oil Crisis, Colin J. Campbell

Alternatives (Renewables and nonrenewables)

- Conservation / Efficiency -- not enough

Renewables

- Biomass -- large land mass, cost?, aviation?
- Hydrogen -- cost? safety? Beyond horizon for large scale use
- Wind -- commercial, not enough
- Nuclear Fusion -- technology challenges, cost? Beyond horizon
- Solar terrestrial -- commercial, large land mass, cost?
- Geothermal -- not enough
- Wave -- not enough, coastal issues
- Ocean thermal -- confined to tropical / equatorial regions, cost?
- Hydroelectric -- not enough
- Synthetic fuel -- technology challenges

Non Renewables

- Clean Coal / CTL -- sequestration?, cost?
- Nuclear Fission -- radioactive waste?, cost??
- Natural Gas -- resource and usage limits
- Oil shale -- Technology? Environment? Cost?
- High energy density fuel -- research challenges
- Methane Hydrates -- clean and in abundance

(• Potential candidates for Navy / DOD)

Biomass:
A Potential Renewable Energy Source

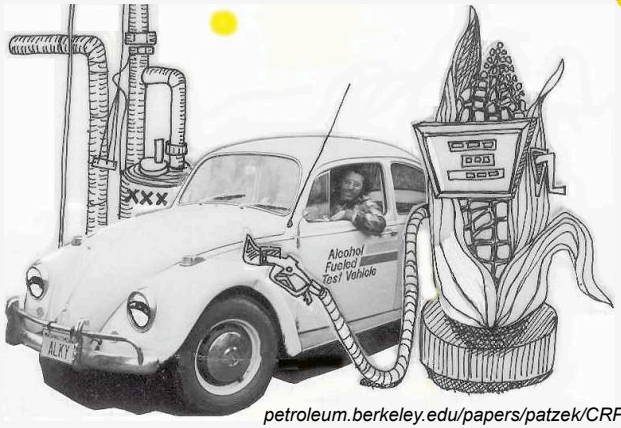
Biomass: A Potential Energy Resource

- The oldest known energy source since the discovery of fire
- World's 4th largest energy source (47 quads/year; 13.6×10^{15} watt hr; 47×10^{15} BTU)
- Domestic Biomass Source for Energy
  - Agricultural Waste
  - Forestry Waste
  - Municipal Solid and Industrial Waste
  - Energy Crops (Grown for Fuel)
- Goals for Energy Contribution from Biomass by 2020 (NREL/DOE)
  - 10% Transportation Fuels
  - 5% Electric Power Production
  - 18% Chemicals and Materials

Robert Armstrong, NDU Report

Range in Biofuel Production

Feed Stock	~ Gal Oil / Acre / Yr
Corn	350
Soybeans	48
Safflower	83
Sunflower	102
Rapeseed	127
Oil Palm	635 (2 crops)
Sugar Cane	662 (2 crops)
Cassava	410
Sweet Sorghum	374
Algae*	1000-5000**
Camelina*	75-100
Cyanobacteria*	700?
Jatropha*	125
Switchgrass*	Low?



petroleum.berkeley.edu/papers/patzek/CRPS416-Patzek-Web.pdf -

http://oakhavenpc.org/cultivating_algae.htm

A comprehensive study is needed to evaluate investment, production, cost and future implications

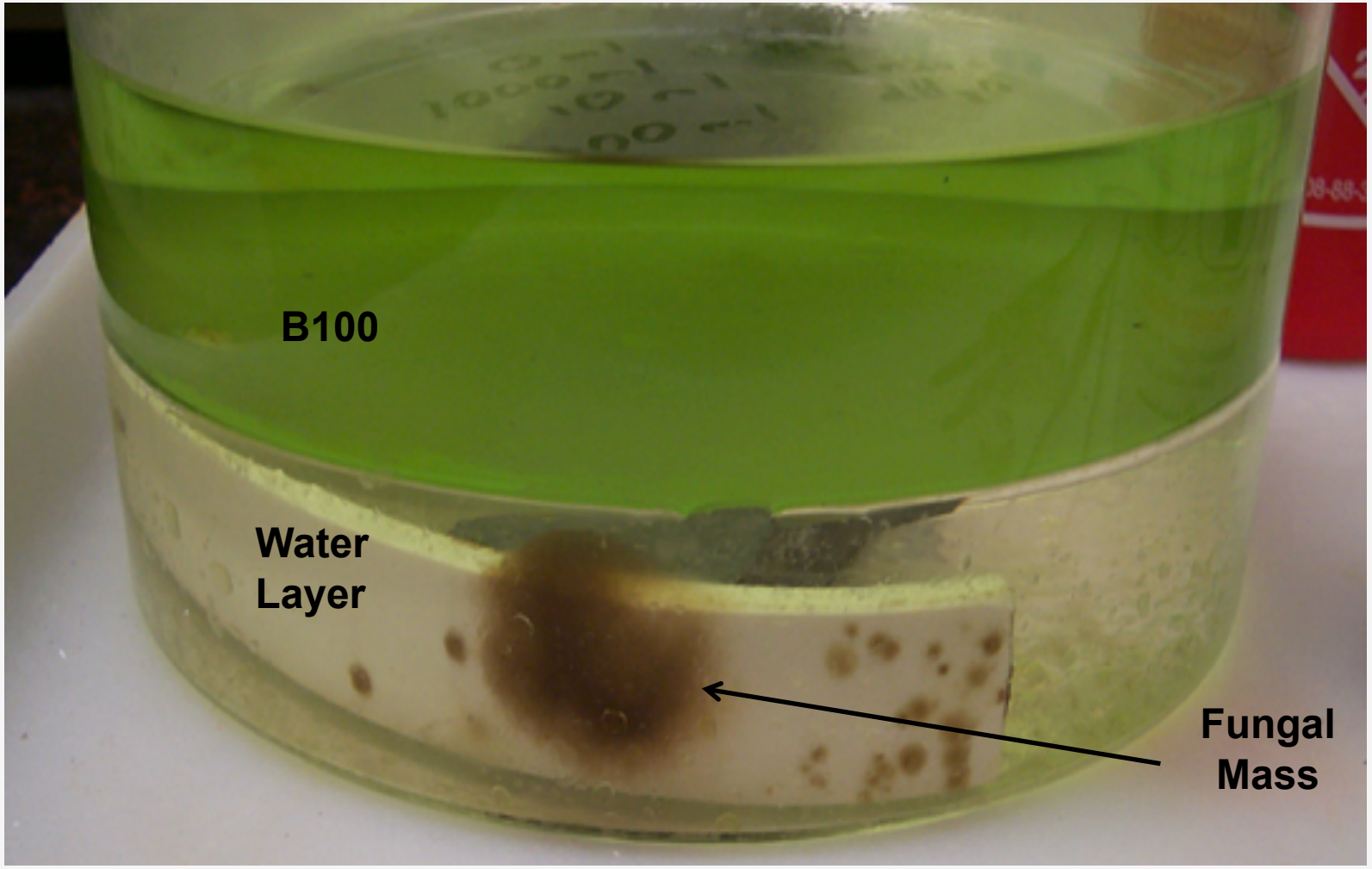
*Non food crops

** requires massive CO_2 injection for higher gallon number

Alternate renewable fuels From biomass (diesels & alcohols)

Feedstocks	Processes	Products	Problems
Algae Vegetable Oils 	Esterification (methanol, Strong Base) $CH_3OH + NaOH$	Biodiesel Fatty Acid Methyl Ester (FAME)	Stability (microbial, emulsions, solvation)
 Animal Fat (Conoco Philips and Tyson Foods) (Neste Oil)	Hydro-treating (Hydrogen)	Green diesel	Stability (Meet Navy Specifications??)
Multiple Biomass (Municipal Waste)	Biomass to Liquid (BTL Gasification) (formation of syngas)	Fischer-Tropsch (FT) diesel	Navy Specification Testing
Corn / Sugar Cane	Hydrolysis/ Fermentation	Ethanol/C2+ Alcohols	Navy Specifications (Flashpoint, Energy Density)

Demonstration of Biofouling in a Diesel Fuel /Water Mixture



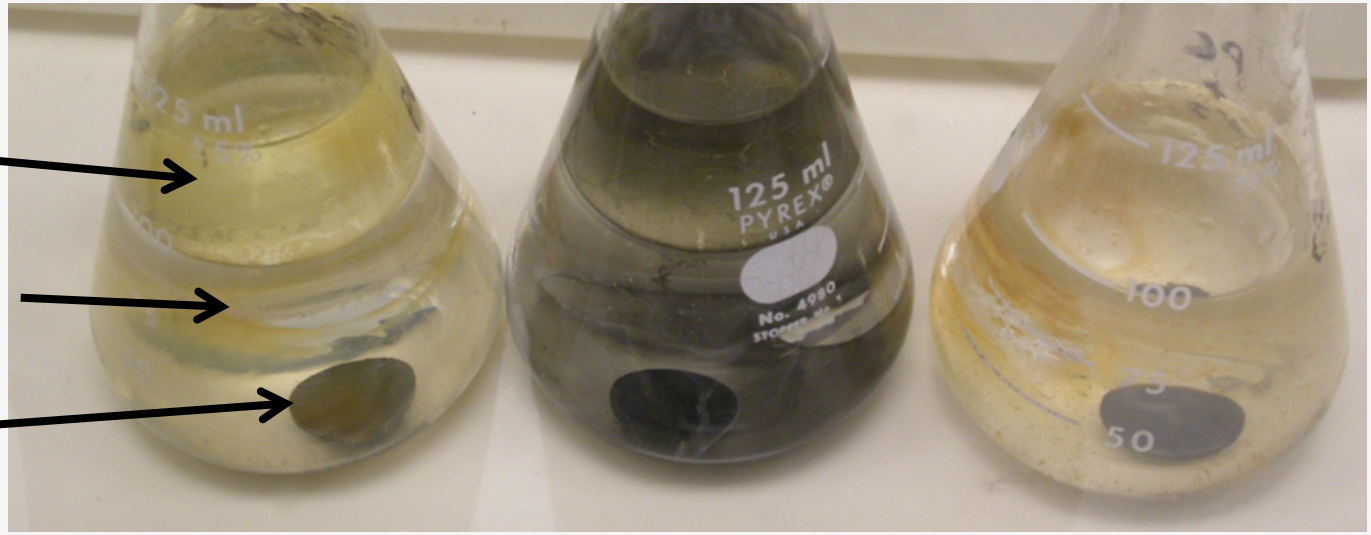
Biodiesel provides carbon source for microbial growth resulting in sulfide production and corrosion

No Sulfide Production | Sulfide Production | No Sulfide Production

Biodiesel

Persian Gulf SW

Carbon Steel Coupon



Sterilized Persian Gulf Seawater + Biodiesel | Natural Persian Gulf Seawater + Biodiesel | Natural Persian Gulf Seawater

Hydrocarbon Yields from Corn / Sugar cane

Gasoline Gallon Equivalent

Fuel Type	BTUs/gal	Gal. Equivalent
Gasoline, regular unleaded	114,100	1.00
Diesel (typical)	129,800	0.88
Methanol	56,800	2.01
Ethanol	76,100	1.50

- Low energy density
- Low flash point
- Hygroscopic
- Energy Input exceeds output
- Unsuitable for naval use

Switchgrass to Ethanol

- A perennial grass native to the Great Plains
- Grows in marginal land
- Needs seeding once / decade
- Cultivation requires fertilizers (~ 100 lbs N / acre) and irrigation
- Low yield in marginal land
- Needs higher cost enzymes for bioreactors, cost / gal about that for corn