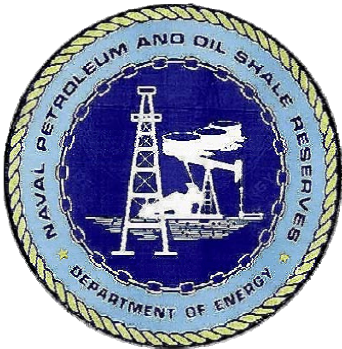


# Energy Cost of Producing Energy – Why Thermodynamics Tell Us It Is Time for Unconventional Fuels from Oil Shale

***27<sup>th</sup> Oil Shale Symposium  
Colorado School of Mines  
October 15-17, 2007***

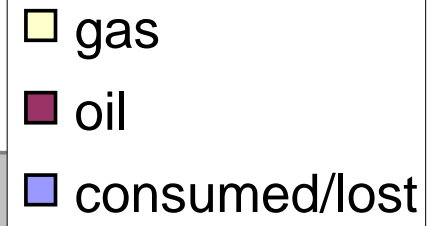


James W. Bungler, JWBA, Inc.  
Anton R. Dammer, Director Naval Petroleum  
and Oil Shale Reserve, USDOE

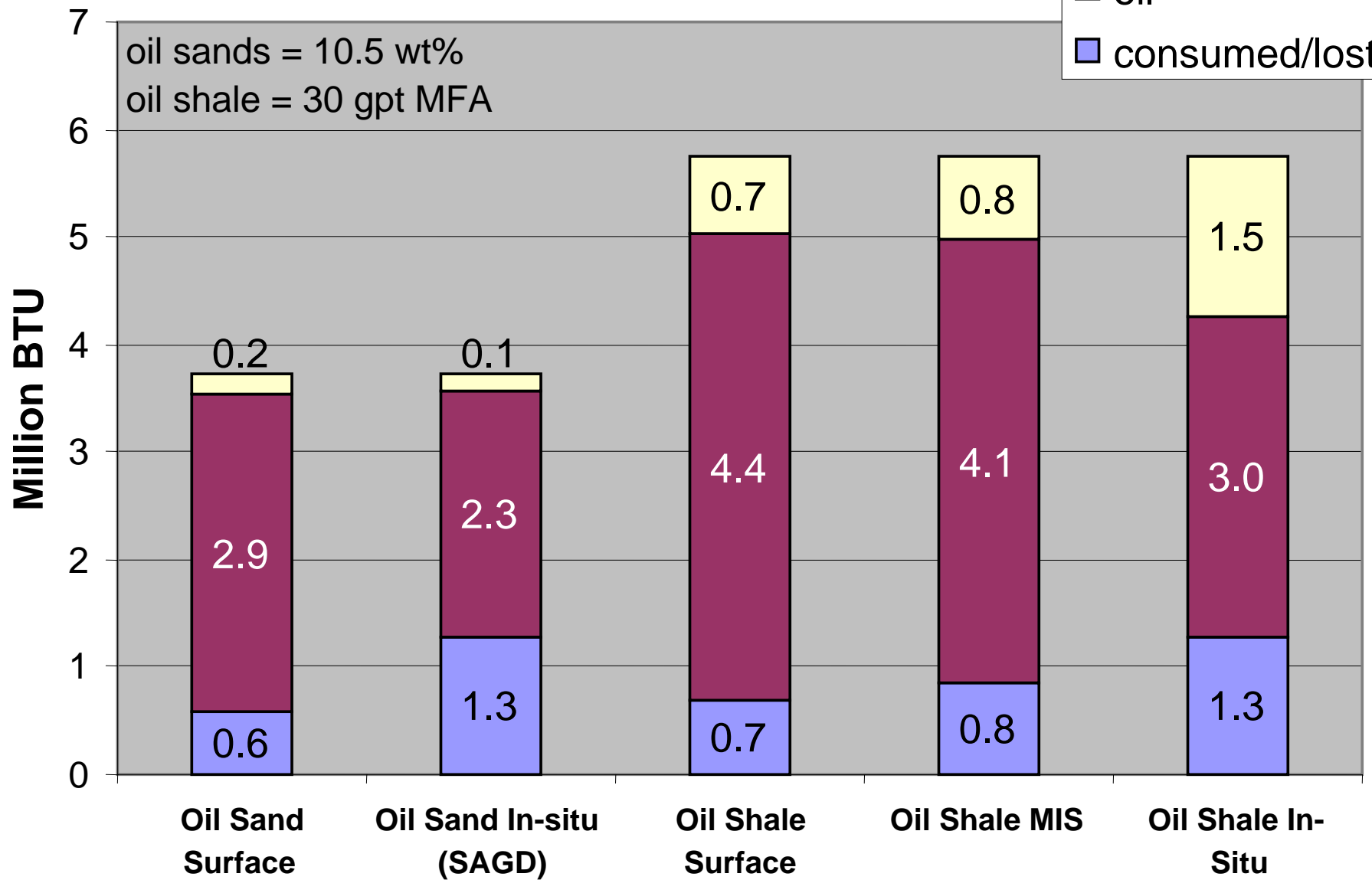
# Unconventional vs. Conventional Oil

- Conventional
  - Significant exploration risk
  - Shrinking availability
  - Subject to decline
  - Well-established markets
  - Variable quality
- Unconventional
  - Little exploration risk
  - Massive and rich resource base
  - High Capital Expenditure (CAPEX)
  - Assured production levels
  - Consistent quality

# Energy balance\* - BTU/ton-ore

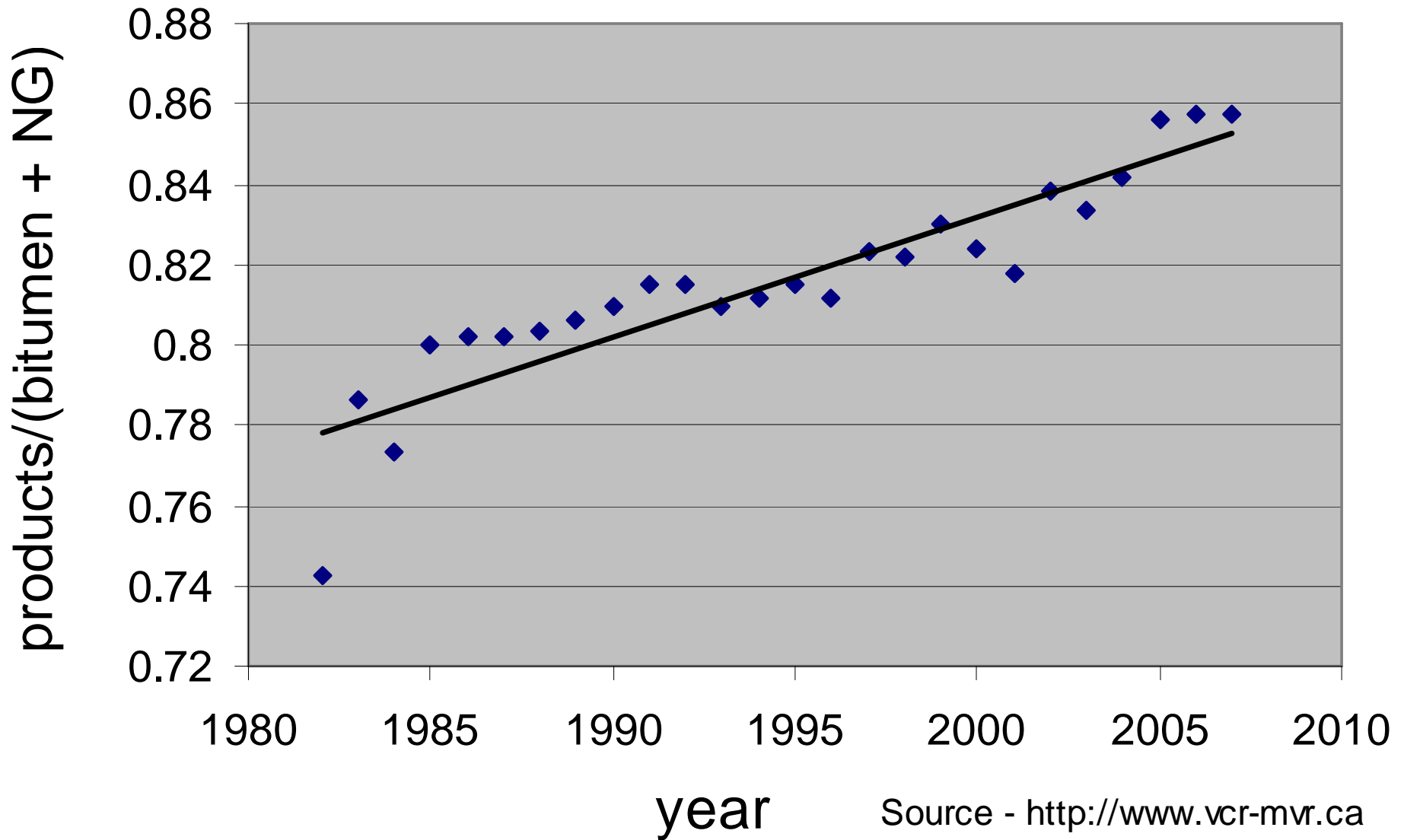


oil sands = 10.5 wt%  
oil shale = 30 gpt MFA



\*preliminary

# 1st Law Efficiency Syncrude, Canada



# Quote

*“...estimates of the ultimate amounts of oil to be recovered [must take] into account the effect of the price of oil.”*

*David Nissen (Exxon) to M. King Hubbert (ca. early 80s) in response to Hubbert's use of Ultimate Recovery as the area under the Hubbert Curve.*

# Quote

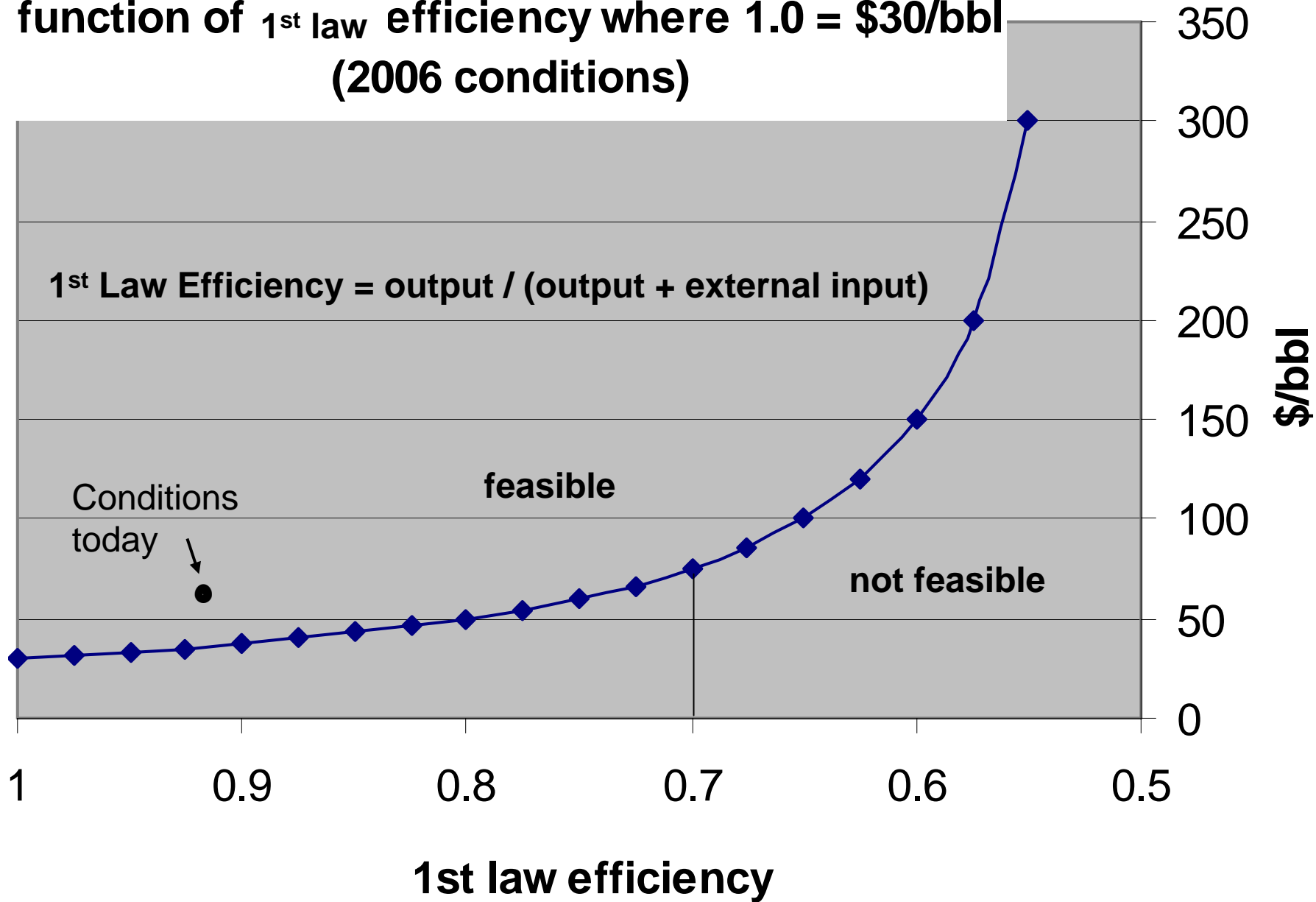
*“Your statement that [price will govern] the fraction of the original oil-in-place that will be recovered is correct, but the [price] effect may easily be exaggerated. ... So long as oil is used as a source of energy, when the energy cost of recovering a barrel of oil becomes greater than the energy content of the oil, production will cease no matter what the monetary price may be.”*

*M. King Hubbert (Shell) to Nissen*

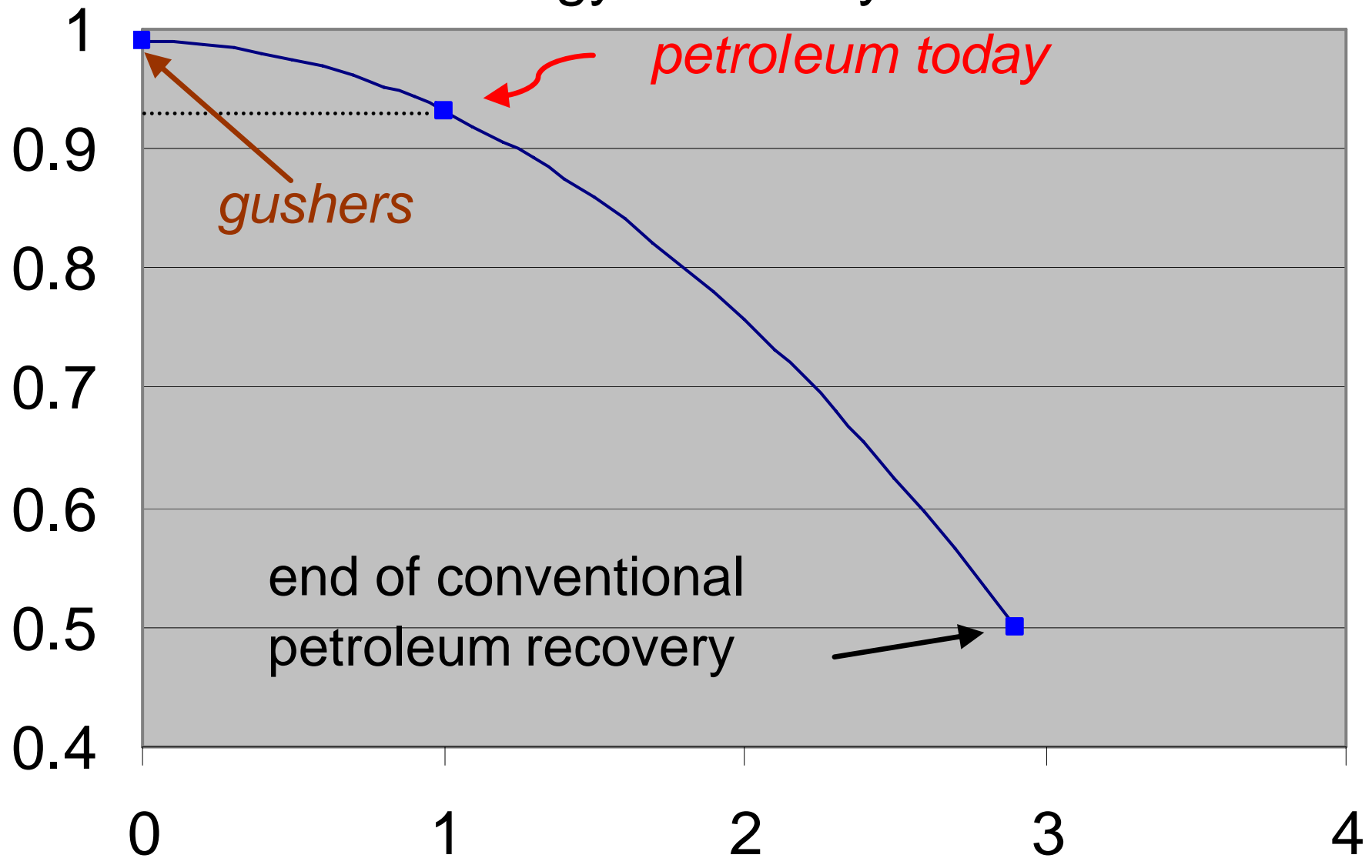
(as Referenced by Ivanhoe, 1982).

[http://www.hubbertpeak.com/hubbert/to\\_nissen.htm](http://www.hubbertpeak.com/hubbert/to_nissen.htm)

# Minimum price of unsubsidized energy as a function of 1<sup>st</sup> law efficiency where 1.0 = \$30/bbl (2006 conditions)

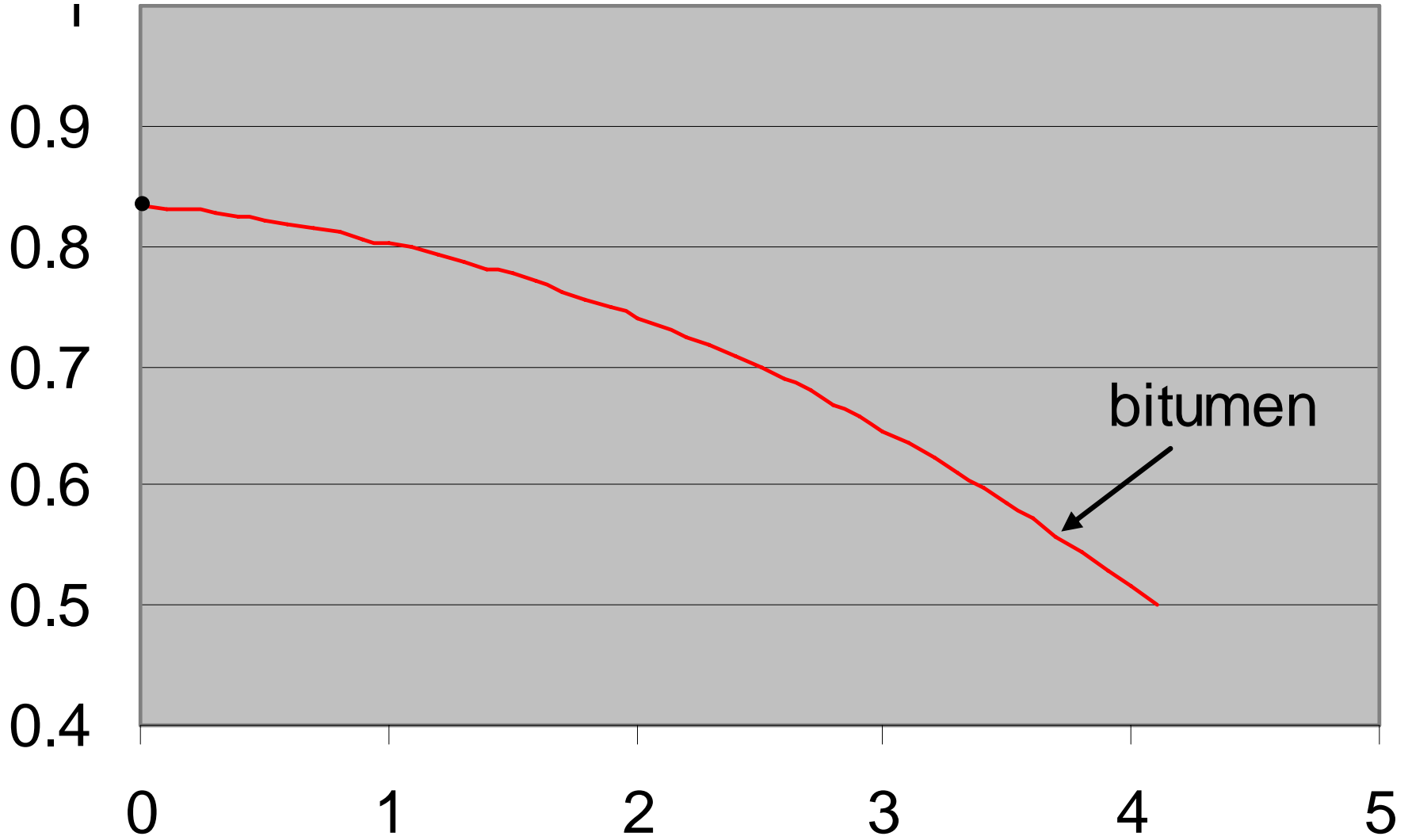


# 1st law energy efficiency vs. trillion bbl

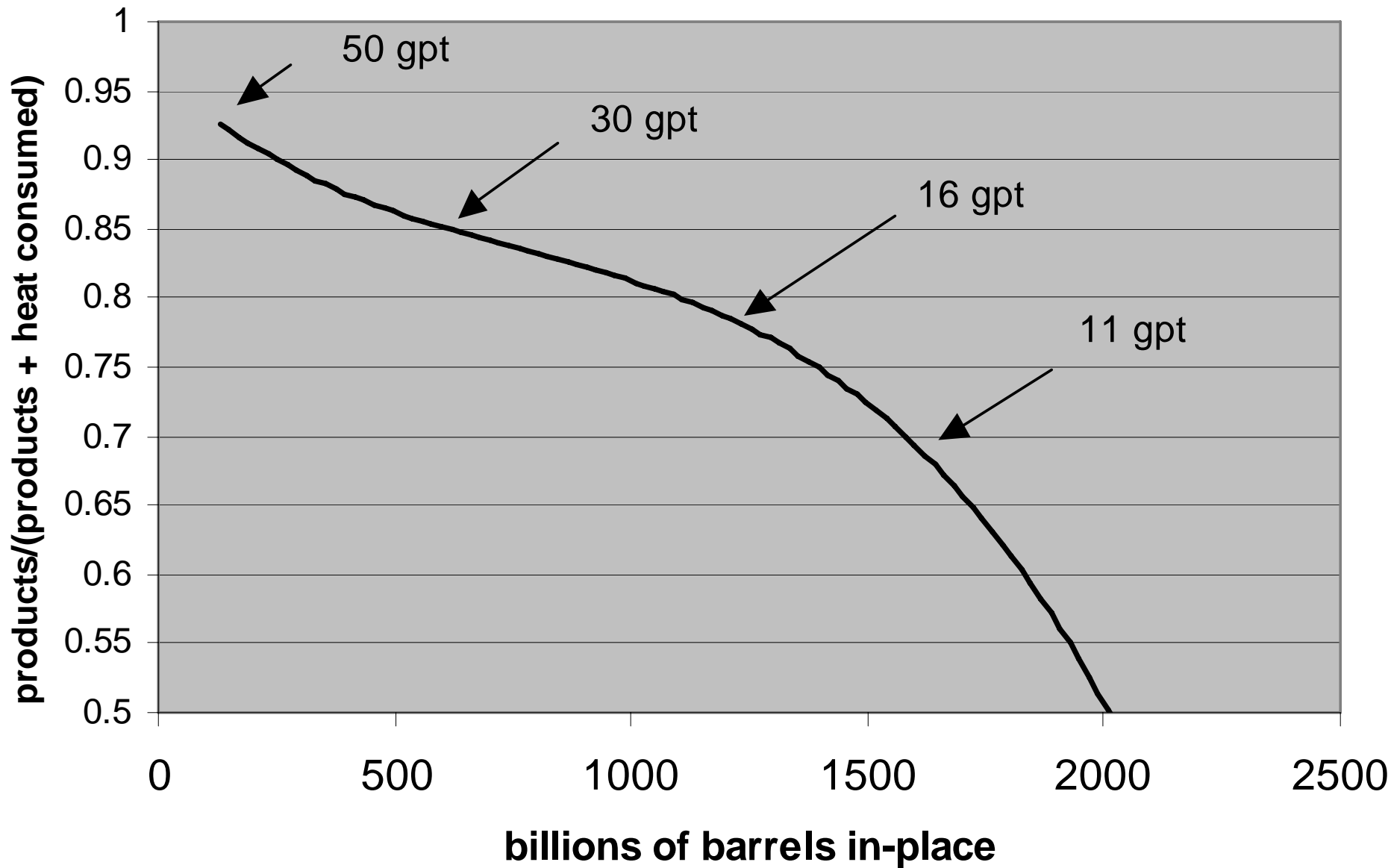




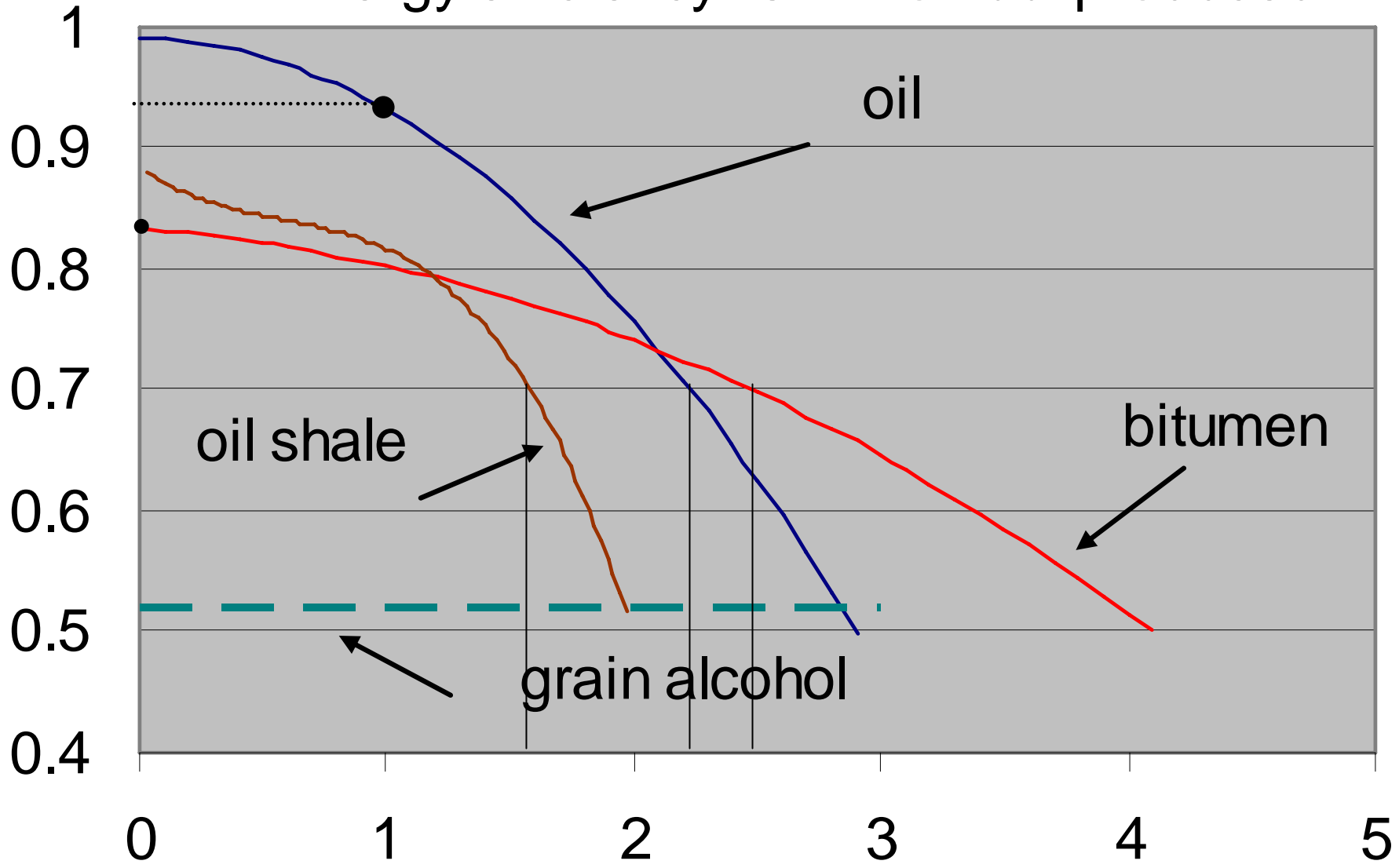
# Energy efficiency vs. trillion bbl bitumen produced



# Cumulative US Oil Shale Resource vs 1st law Retort Efficiency



# Energy efficiency vs. trillion bbl produced



# Implied Remaining reserves within 70% 1<sup>st</sup> law efficiency

(Remaining = Ultimate less economic and thermodynamic limitations)

- Petroleum = 1.5
- Bitumen = 1.6
- Oil shale = 1.1

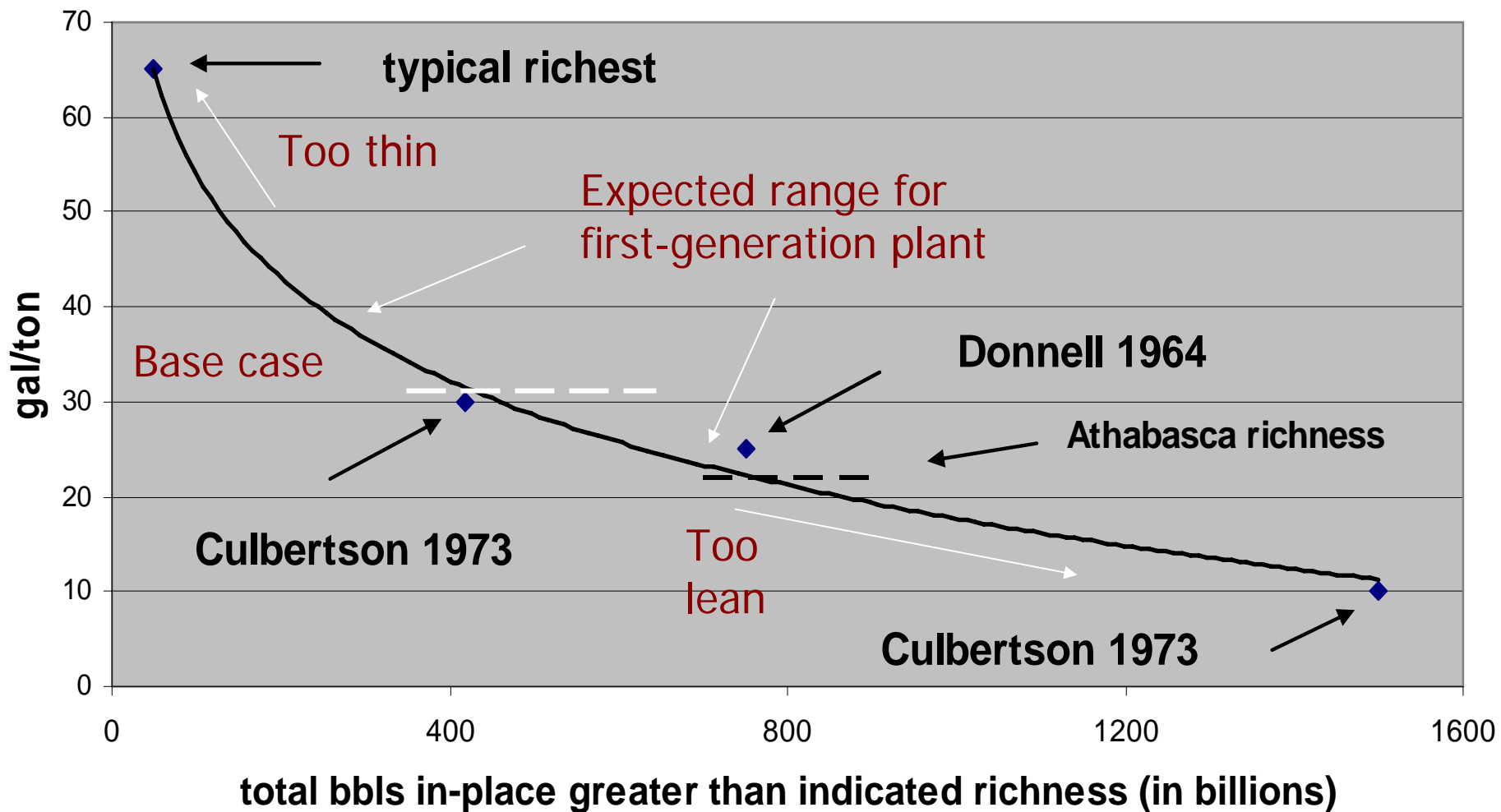
Net Total (not including coal or NG) = 4.2 trillion bbl

Percentage in North and Latin America > 50%

Should be the target for proving reserves

# Green River Formation Oil Shale

## Richness vs Total Resource



# Goals

- Provide access to resource
- Demonstrate technologies for:
  - Surface recovery
  - Modified in-situ
  - True in-situ
- Achieve reclassification of resource to proven reserves of at least 400 billion bbls.

Thank You

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