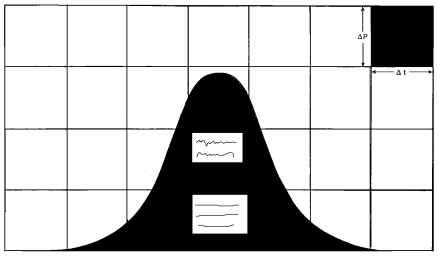
HUBBERT CENTER NEWSLETTER # 97/1



M. KING HUBBERT CENTER FOR PETROLEUM SUPPLY STUDIES

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KING HUBBERT - UPDATED

by
L.F. Ivanhoe

The question is not WHETHER, but WHEN, world crude oil production will start to decline, ushering in the permanent oil shock era. While global information for predicting this "event" is not so straightforward as the data Dr. M. King Hubbert used in creating his famous "Hubbert Curve" that predicted the US (Lower 48 states-US/48) 1970 oil production peak, there are strong indications that most of the world's large exploration targets have now been found, at the same time that the earth's population is exploding along with the oil needs of the developing nations.

This papers reviews Hubbert's original analyses on oil discovery and production curves for the US/48 and projects his proven methodology onto 1992 global oil discoveries and production. The world's oil discovery curve peaked in 1962, and thence declined as a Hubbert Curve predicts. However, global production was restricted after the 1973 Arab oil embargo. Otherwise, world production would have peaked in the mid-1990s. Two graphs show alternate versions of future global oil production.

Idealized Hubbert Curves

Figure 1: (i.e. "Hubbert 1980 Fig. 4: Mathematical relations involved in the complete cycle of production of any exhaustible resource (modified from Hubbert 1956): "Production Rate" (annual barrels/year) vs "Time" (years) produce an idealized "Hubbert Curve" of " Ultimate Cumulative Production."

The total ultimate volume is equal to the area under the curve, at the scale (production rate x years) in the upper right corner. Hubbert's 1956 analysis covered only the Lower 48 states (US/48) onshore and offshore basins. Alaskan oil did not become a significant factor until after 1977.

The Hubbert Curve starts at "zero" (0=production rate & time) and increases for the first years. This smooth "idealized" curve is the mathematical "smoothed average" of the annual production which can oscillate wildly.

Quoting Hubbert:

"The curve does not keep going up, but passes over a hump and then goes back to zero. This is the one future point on the curve that you definitely know and it greatly facilitates the mathematics. The area under the (production) curve is graphically proportional to the amount of development. The area under the curve cannot exceed your estimate. It is a very simple, but very powerful method of analysis."[1] "This

complete cycle has only the following essential properties: The production rate begins at zero, increases exponentially during the early period of development, and then slows down, passes through one or more principal maxima, and finally declines negative exponentially to zero. There is no necessity that the curve P as a function of t, have a single maximum or that it be symmetrical. In fact, the smaller the region, the more irregular in shape is the curve likely to be. On the other hand, for large areas such as the United States or the world, the annual production curve results from the superposition of the production from thousands of separate fields. In such cases, the irregularities of small areas tend to cancel one another and the composite curve becomes a smooth curve with only a single practical maximum. However, there is no theoretical necessity that this curve by symmetrical. Whether it is or is not will have to be determined by the data themselves."[2]

Hubbert wrote virtually nothing about details of the "decline side" of his Hubbert Curve, except to mention that the ultimate shape of the decline side would depend upon the facts and not on any assumptions or formulae. The decline side does not have to be symmetrical to the ascending side of the curve - it is just easier to draw it as such, but no rules apply. The ascending curve depends on the skill/luck of the explorationists while the descending side may fall off more rapidly due to the public's acquired taste for petroleum products - or more slowly due to government controls to reduce consumption.

Figure 2: (ie: "Hubbert 1980, Fig. 29: Annual proved discoveries of US/48 crude oil superimposed upon derivative of logistic equation of 1972.")

This figure clearly shows how erratic annual discoveries can follow a smooth "idealistic" mathematical curve overall. This curve includes US/48 onshore and offshore areas with the Hubbert US/48 discovery peak at 1958.

Figure 3: (Adapted from Hubbert 1980, Fig. 13, after Hubbert 1962, Fig. 24): Rates of Proved Discoveries and Production during a complete production cycle.

It is commonly overlooked by economists and the general public that crude oil must be discovered before it can be produced. In the idealized example, the PRODUCTION curve is the same shape and area as the DISCOVERY curve, which it follows after a "TIME LAG" peculiar to the region. (Time lag = 11 years for US/48.) Once the Discovery Peak is established, and the Time Lag is known, the Production Peak can be calculated as Hubbert did for the US/48: (= 1958 + 11 = 1969.) US/48 oil production actually peaked in 1970!

Hubbert Curves vs Current Oil Production

Figure 4: US/48 Oil Discoveries & Production.

This graph shows Hubbert's US/48 DISCOVERY curve (after Figs. 2 & 3), plus Hubbert's projected US/48 1972 PRODUCTION curve for ultimate production of 170 billion barrels of oil (Bbo). US/48 oil production peaked in 1970. This resulted in a permanent oil shortage for US/48 crude oil supplies. This was offset by a major increase in imports of crude oil & products and by the completion of the TAPS pipeline in 1977 which brought the supergiant Prudhoe Bay oilfield (discovered in 1968 in arctic Alaska) on production. In 1970, the US/48 supplied 61% of the total USA liquid petroleum consumption, vs only 28% in 1994.[3]

The Production line shows crude oil actually produced in the US/48. This line follows within 10%, the general trend of Hubbert's 1972 decline curve, (thin dashed line). Due to his lack of Production control points for the decline side of his curve, Hubbert simply drew it in as a mirror image of the earlier half of the rising US/48 production curve.

All of the US/48 production is defined here as "unrestricted" because the nation produced virtually all oil that it was capable of. US/48 production was at or near peak capacity since 1972. The heavy dots after 1995 to 2040 project the author's opinion on future US/48 crude oil production, which exceed Hubbert's original 1956 predictions due to improved recovery techniques in recent years.

Figure 5: World Annual Crude Discovery Rate Averaged Over 5-year Periods 1912-1992; Hubbert Curve is Weighted Average of Global Oil Discovered 1915-1992.

This graph summarized the U.S. Geological Survey (USGS) records through 1992. Ivanhoe added the "Hubbert Curve/Discoveries" to the USGS data.[3,4]

Figures 6 & 7: World Oil Discoveries & Production (2 Examples)

These graphs show (on the left) the "Hubbert Curve" for global oil discoveries from Fig 5, as modified by Ivanhoe from C.D. Masters' USGS 1994 paper.[4] The heavy line on the right shows global crude oil PRODUCTION to date. This global production was "unrestricted" until the 1973 Arab oil embargo which caused the "first global oil shock". Since then, global production flattened out, due to worldwide more efficient energy use (insulation, etc.), to a plateau of 20-25 Bbo/year after the "second oil shock" in 1979 (Iran-Iraq War). Global consumption = production has been increasing steadily since 1989.

The DISCOVERY CURVE is well established by long-term USGS records (Fig. 5). The "unrestricted" (pre-1973) portion of the PRODUCTION CURVE (to the right of the discovery curve) tended to parallel the DISCOVERY CURVE as shown in Fig. 3, suggesting that global production would have peaked in the mid-1990s (@ 32 years time lag) if the 1973-1979 oil shocks had not altered the global consumption pattern, leaving area/volume (A) to be produced later. The light dashed line is an "unrestricted production Hubbert curve", and is drawn at the same shape (offset for 32 years time lag) to 2050, as the established discovery curve. Note that the ultimate area under the PRODUCTION curve cannot exceed that under the DISCOVERY curve. It is the date and shape of the post-1994 global production curve that we are trying to establish.

Figure 6: World Oil Discoveries & Production - (Example #1 = R/P)

Figure 6 shows global oil production increasing to more than 25 Bbo/year by 1999. Thereafter a PRODUCTION curve (B), based on the arithmetic Reserve/Production (R/P) ratio would result in a final drop-off 45 years away (year 2040), which is commonly referred to by economists and the general public as "the end of known oil". But such an R/P limit is impossible, because it would require all of the known fields - big or small - to "die" in the year 2040, with all of the world's wells drying up at one time! But oil fields - like human beings - do not die all at once, but gradually as each field (or life) is exhausted. The popularity of this number (R/P=45) is based on the hope that the next oil crisis can be ignored for 45 more years. Unfortunately, the bad news of gradual oil fields' decline/deaths is an unpleasant fact that will not go away just because it is ignored!

Figure 7: World Oil Discoveries & Production - (Example #2 = Hubbert Decline)

This graph shows the same basic data as Figure 6, except that the PRODUCTION curve has been changed after year 1995 to curves (B) and (C). The straight R/P = 45 years (to 2040) of Fig. 6 has been replaced by a more realistic "oil field decline curve" (B) = crosses (+++++) after year 2010. This is similar to the decline of the US/48 oil fields as shown in Fig. 4, and is at the same decline rate for the world shown in Fig. 5.[3]

The critical "Hubbert Peak" year will be close to 2010 (curve B) due to normal oil fields' decline, or a little later depending on post-1992 discoveries. World production will continue for years thereafter at a dwindling rate after the 2010 peak, as indicated by the line of crosses (++++). The post-2006 production of area (B)(=hachured) will eventually equal the delayed production of area (A)(=dotted) for the period 1973-2006. The critical year on decline curve (B) is shown at the year 2010, which is where the world's oil demand will exceed global production (Hubbert Peak) which will initiate the "permanent global oil shortage". Production thereafter will dwindle to about 5 Bbo at year 2050. Thereafter little oil trickles in.

A possible earlier "Hubbert Peak" after the year 2000 (curve C)(=indicated by large dots) may result from unpredictable political problems in Saudi Arabia and the Persian Gulf region.

Figure 8: World Oil Supply

This figure summarizes the data of Figure 7. It shows that production of the USGS global oil discoveries of 1912-1992 (Fig. 5) will peak about year 2010, when the world's demand will exceed global production. Thereafter the gross production will decline steadily as individual oil fields decline and die.

SUMMARY

It is concluded that the critical date per USGS data when global oil demand will exceed the world's production will fall somewhere between 2000-2010, and may occur very suddenly due to unpredictable political events.

This is within the lifetimes of most people now alive. This foreseeable energy crisis will affect everyone on earth.

Governments will have first call on oil supplies during global shortages.

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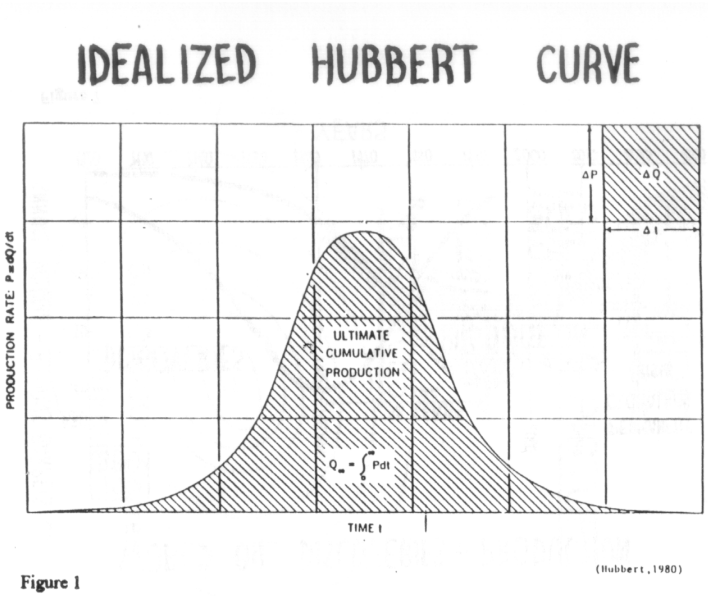
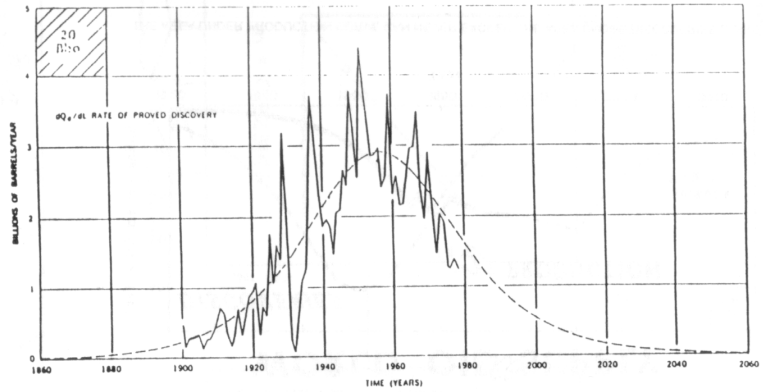


Figure 1



LOWER US(48) OIL DISCOVERIES/YEAR SUPERIMPOSED ON HUBBERT'S 1972 IDEALIZED DISCOVERY CURVE.

Figure 2

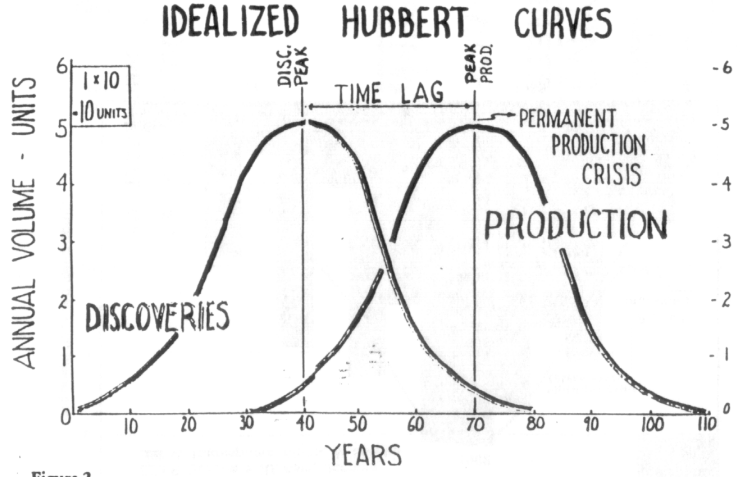


Figure 3

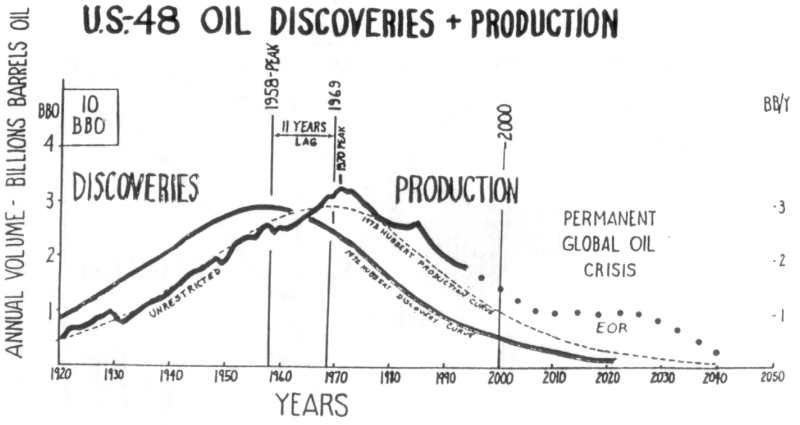


Figure 4

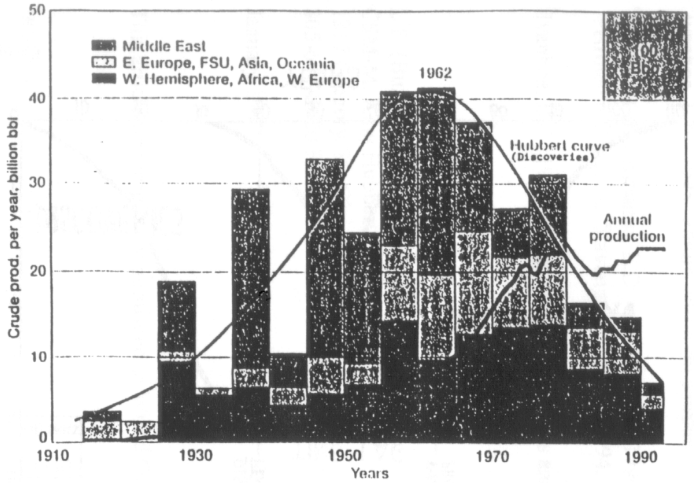


Figure 5

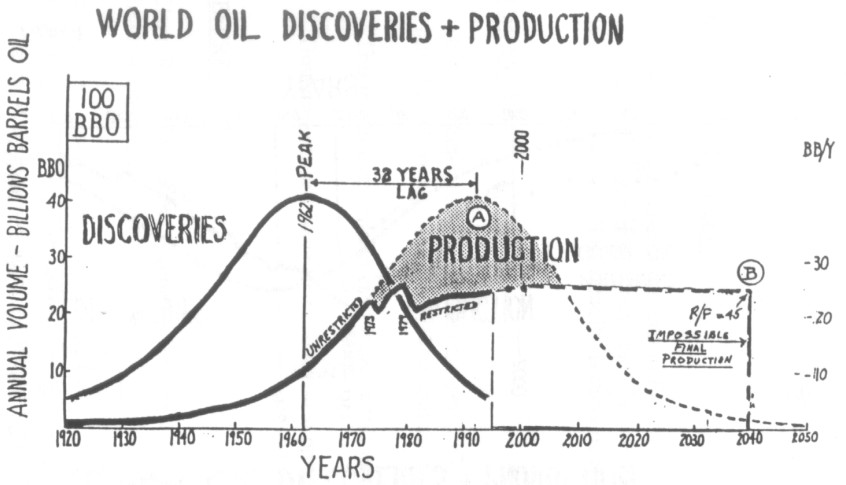


Figure 6

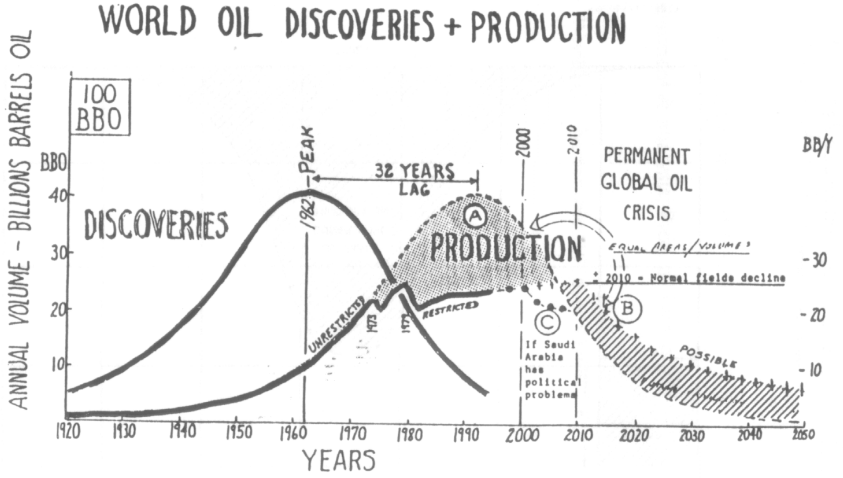
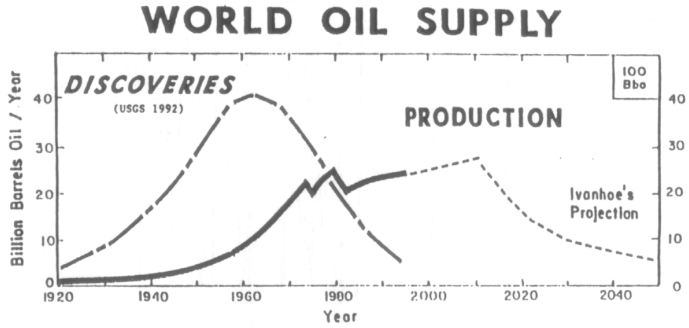


Figure 7

Axiom: One cannot produce more oil than has been discovered.

Oil Production volume/(area under the Production Curve)
cannot exceed Discoveries volume / (Area under Discoveries Curve);
(per M. King Hubbert, 1956.)

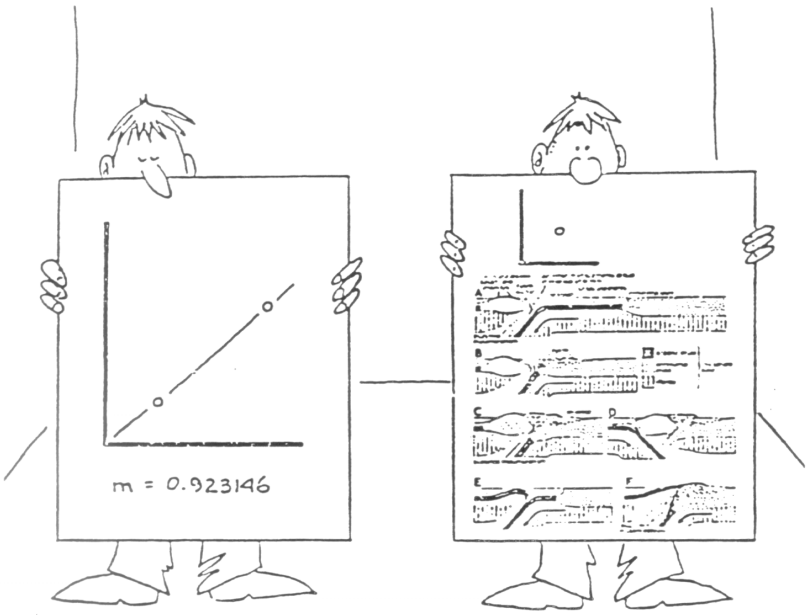
Discoveries Curve adapted from USGS/Masters,1994.
Production Curve extrapolated to match Discoveries volume/(area).



THE AREA UNDER PRODUCTION CURVE CAN NEVER EXCEED THE AREA UNDER DISCOVERIES CURVE.

Figure 8

FRIVOLITY



"It's easy to tell them apart — the **Engineer** *is the one with two data points and a trend calculated to 6 places — and the* **Geologist** *is the one with one data point and 6 working hypotheses."*

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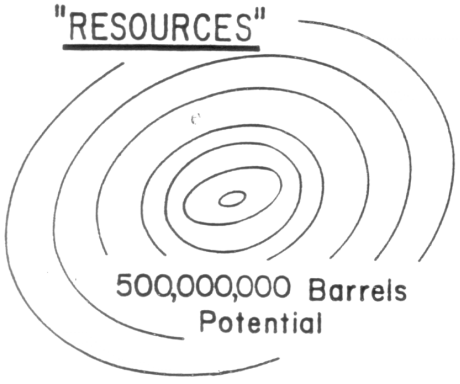
OIL PROSPECTS - SIZE

BEFORE	AFTER
SELLING PICTURE	BUYING PICTURE
GEOLOGIST	ENGINEER
YOUR MONEY	*MY MONEY*
"RESOURCES"	"RESERVES"



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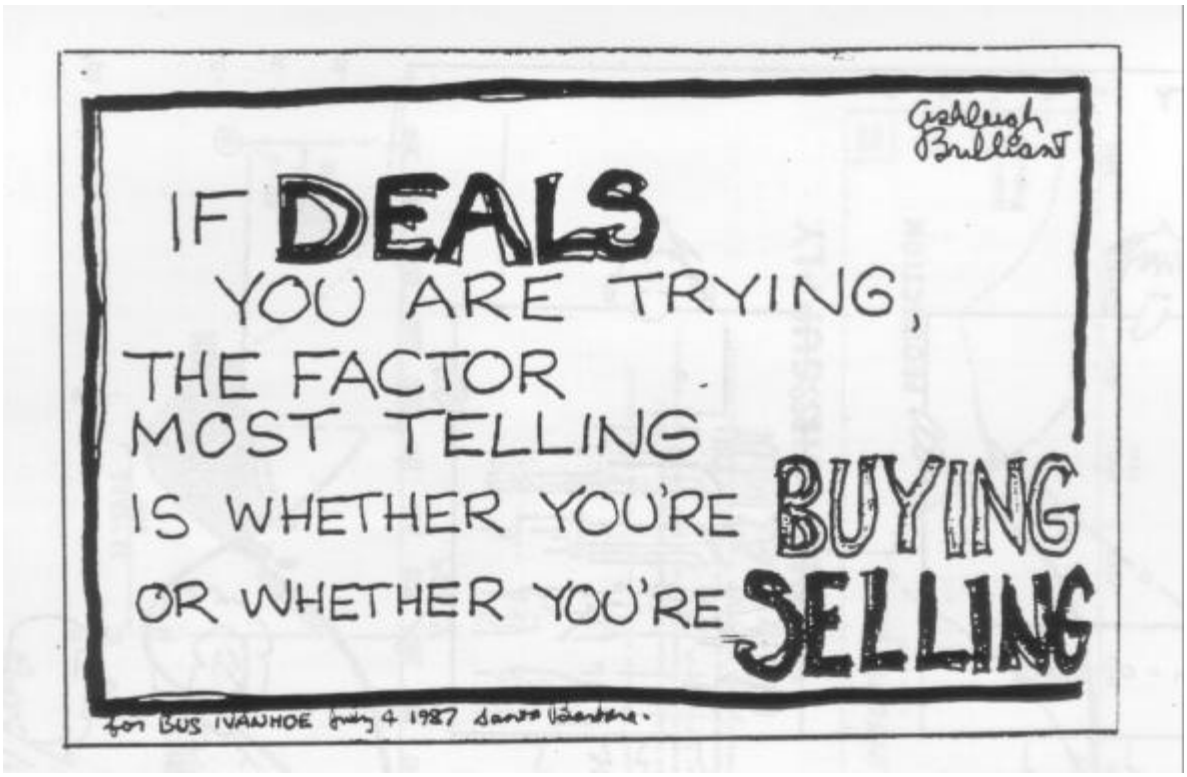

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H.C. NEWSLETTER

The M. KING HUBBERT CENTER FOR PETROLEUM SUPPLY STUDIES
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Colorado School of Mines
Golden, Colorado

The Hubbert Center has been established as a non-profit organization for the purpose of assembling and studying data concerning global petroleum supplies and disseminating such information to the public.

The question of WHEN worldwide oil demand will exceed global oil supply is stubbornly ignored. The world's oil problems, timing and ramifications can be debated and realistic plans made only if the question is publicly addressed. A growing number of informed US and European evaluations put this crisis as close as the years 2000 - 2014. The formation of this center is to encourage a multi-field research approach to this subject.

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