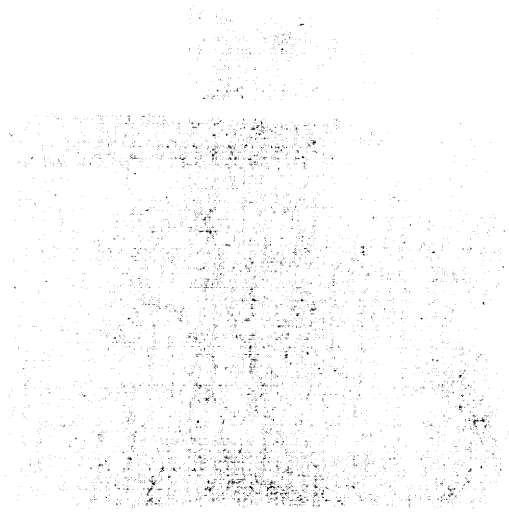
IL An Assessment of the Potential of Enhanced Oil Recovery



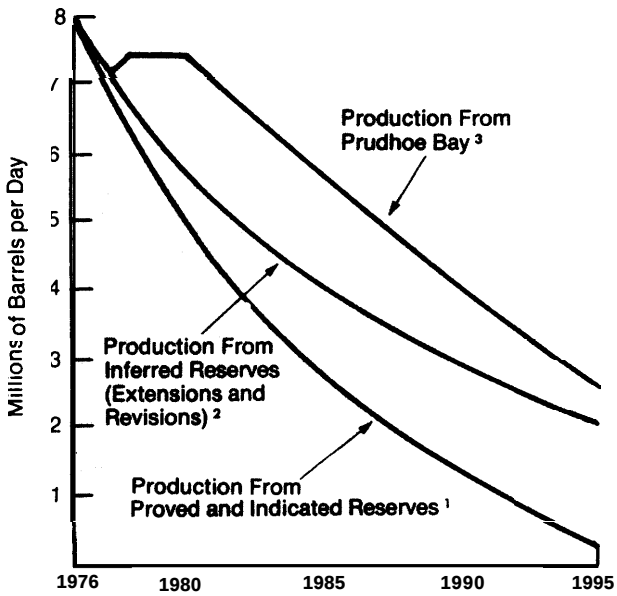
II. An Assessment of the Potential of Enhanced Oil Recovery

The United States must have reliable sources of energy to maintain stability. in its energy-intensive economic base—a fact dramatically emphasized in October 1973, when Arab oil producers imposed a 5-month embargo on oil shipments to the United States, and again in the record-cold winter of 1976-77, when natural gas supplies fell short of demand. Until the oil embargo, most Americans took it for granted that their energy needs would be met despite declining domestic production of oil and gas, which together provide 75 percent of the Nation's energy. The embargo and curtailments of natural gas supplies have made it clear that steady flows of energy cannot be taken for granted and have driven policy makers to a search for a national policy which will make the United States less reliant on foreign energy sources.

Because of congressional concerns over declining domestic supplies of oil and natural gas, and the possibility that new technologies can increase the Nation's oil and gas reserves, the Office of Technology Assessment (OTA) was asked to assess the potential of the technology associated with enhanced oil recovery (EOR). This report is in response to that request.

Proved reserves of crude oil (recoverable with current technology under current economics) in the United States increased from 20 billion barrels in 1946 to 30 billion barrels in 1959. Additions to reserves about equalled withdrawals from domestic reservoirs between 1959 and 1970. The discovery of oil in Alaska increased the proved U.S. oil reserve to 39 billion barrels in 1970. However, since 1970, the domestic proved oil reserve has declined at a 2- to 5-percent annual rate (table 2), annual production from old oilfields has fallen each year, and the United States has become increasingly dependent on imported oil (table 3). Unless these trends can be reversed, the gap between supplies of domestic oil and U.S. demand will widen within the next 10 to 15 years (figure 1). There are two approaches to increasing proved reserves of oil: (1) find additional oil through increased exploration; and (2) use more efficient methods to recover oil from known reservoirs. Enhanced oil recovery processes fall into the second category.

Figure 1. Projected Oil Production by Conventional Methods From Known U.S. Reservoirs, 1976-95



NOTE: The Decline Curves for Proved and Indicated Reserves, and Inferred Reserves Do Not Include Enhanced Oil Recoveries Recorded within these Categories.

SOURCES: 1 American Petroleum Institute, Reserves *of* Crude *Oil,* Natural Gas Liquids, and Natural Gas m the U.S. and Canada as of December 30, 1975: Lewin & Associates, Inc. for Federal Energy Administration, Dee/me Curve *Analysis,* 1976.
2 U. S. Geological Survey, *Circular* 725, 1975.
3 Federal Energy Administration, *National* Energy *Outlook,* 1976.

Traditional methods of oil production (natural flow and flushing the oil reservoir with water) recover on average only about one-third of the oil present in a producing formation. Methods

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Table 2
Proved Reserves of Crude Oil in the United States, 1959-76
(Billions of Barrels of 42 U.S. Gallcms)

Year	Proved reserves at beginning of year	Proved reserves at end of year	Net change from previous year
1959 ..., , ...	30.5	31.7	+1.2
1960 . . . . . , ...	31.7	31.6	-0.1
1961	31.6	31.8	+0.2
1962	31.8	31.4	-0.4
1963	31.4	31.0	-0.4
1964	31.0	31.0	+0.0
1965	31.0	31.4	+0.4
1966 . . . .,,,	31.4	31.5	+0.1
1967	31.5	31.4	-0.1
1968	31.4	30.7	-0.7
1969	30.7	29.6	–1,1
1970	29.6	39,0	+9,4
1971	39.0	38.1	-0.9
1972	38.1	36.3	–1.7
1973	36.3	35.3	–1.0
1974	35.3	34.3	–1.1
1975	34.3	32.7	–1.6
1976	32.7	30,9	–1.7

Note: 1970 figures reflect the addition of Prudhoe Bay Alaska reserves.

Source: Reserves *of Crude Oil* Natural Gas Liquids, and Natural Gas in the United States and Canada as of December *31,* 7975, Joint publication by the American Gas Association, American Petroleum Institute, and Canadian Petroleum Association, Vol. 30, May 1976,

Table3
U.S. Domestic Production and Imports of Oil, 1959-76
(Barrels of 42 U.S. Gallons)

Year	Production		Imports	
	Annual (billions of barrels)	Daily (millions of barrels)	Annual (billions of barrels)	Daily (millions of barrels)
1959	2.6	7.1	0.7	1.8
1960	2.6	7.5	0.7	1.8
1961	2.6	7.2	0$7	1.9
1962	2.7	7.3	0.8	2.1
1963	2.8	7.5	0.8	2.1
1964	2.8	7.6	0.8	2.3
1965	2.8	7.8	0.9	2.5
1966	3.0	8.3	0.9	2.6
1967	3.2	8,8	0.9	2.5
1968	3.3	9.1	1,0	2.8
1969	3.4	9.2	1.2	3.2
1970	3.5	9.6	1.2	3.4
1971	3.5	9,5	1.4	3.9
1972	3.5	9.5	1.7	4.7
1973	3.4	9.2	2.3	6.2
1974 .....,..	3.2	8.8	2.2	6.1
1975	3.1	8.4	2.2	6.0
1976	3.0	8.1	2.7	7.3

Source: U.S. Bureau of Mines.

which increase the amount of oil that can be recovered from a reservoir increase the proved reserves of that reservoir. Recent studies using differing assumptions indicate that our oil reserves could be increased by as much as 76 billion barrels (table 4) by application of EOR methods. Large disparities not only of total future production but of daily production rates from EOR projects exist in these estimates.

This report assesses the magnitude of the increased oil reserves which may result from use of EOR in an effort to reduce the uncertainties posed by earlier studies, and determines reasonable limits of ultimate recovery and production rates under different sets of assumptions about technology, price, and investment climate. An assessment also has been made of the impact on EOR activity of various policies that could be implemented by Congress to increase total recovery and/or accelerate oil production.

Table 4
Estimates of Enhanced Oil Recovery Potential

Source	Potential EOR recover) (billions of barrels)	Production in 1985 (millions of barrels/day)
NPC Study[a]		
------ $ 5	2.2	0.3
------ $10	7.2	0.4
------ $15 (1 976 dollars)	13.2	0.9
------ $20	20.5	1.5
------ $25	24.0	1.7
GURC[b]		
------ $10 (1 974 dollars)	18-36	1.1
------ $15	51-76	—
FEA/PIR[d]		
------ business as usual, $11	—	1.8
------ accelerated development, $11	—	2.3
EPA"		
------ $ 8-12 (1975 dollars)	7	—
------ $12-16	16	—
FEA/Energy Outlook'		
------ $12	—	0.9
FEA (3 States)[g]		
------ upper bound, $11.28 (1975 dollars)	30.5[h]	2
------ lower bound, $11,28	15.6'	1

[a] Total U. S.; base case performance and costs; minimum DCFROR requirement of 10 percent; moderate tax case.

[b] *Planning Criteria Relative to a National* RDT & *D Program to the Enhanced Recovery of Crude Oil and Natural Gas,* Gulf Universities Research Consortium Report Number 130, November 1973.

[c] *Preliminary Field Test Recommendations and Prospective Crude 01/ Fields or Reservoirs for High Priority Testing,* Gulf Universities Research Consortium Report Number 148, Feb. 28, 1976.

[d] *Project Independence Report,* Federal Energy Administration, November 1974.

[e] *The Estimated Recovery Potent/a/ of Convention/ Source Domestic Crude 011,* Mathematical, Inc., for the US. Environmental Protection Agency, May 1975.

[f] *1976 National Energy Outlook,* Federal Energy Administration.

[g] Th, *Potential* and Economics of Enhanced 01/ *Recovery,* Lewin & Associates, Inc. for the Federal Energy Administration, April 1976.

[h] Reserves added b, th, year 2000 if projects return DCFROR of 8 percent or greater.

[i] Reserves added by the year 2000 if projects return DCFROR of 20 percent or greater.