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Energy Resources for the Future

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Introduction

Prophecies for the future are dangerous, imaginative, and whimiscal. The pessimistic views are given before the optimistic guesses. The basic needs of energy for society are so great that we will need all of the energy it is possible to convert to human use. Most of the prophecies mean challenges to us as scientists and as humans.

The law of exhaustible resources and the earthly limits of fossil and radioactive fuels are definitely pessimistic. The intensity of exploration is foreboding and pessimistic for future development of oil and gas in the United States. Dependency upon foreign sources of energy resources is not good.

In contrast, if we could use the Middle East as a model, it may be possible to find 12 more Middle Easts all on foreign soil or at sea. Such optimistic view is short in life because that, too, is limited and will face exhaustion. With both optimism and challenge we can look to the future for more efficient electrical conversion and transportation, more efficient transportation use of energy by smaller cars and mass transportation, and to such new systems as breeder fission, nuclear fusion, and solar machines. The development of hydrogen and methanol as feed stocks to energy systems seems far in the future and would, in part, demand some of our present resources. Geothermal, tidal, wind, and

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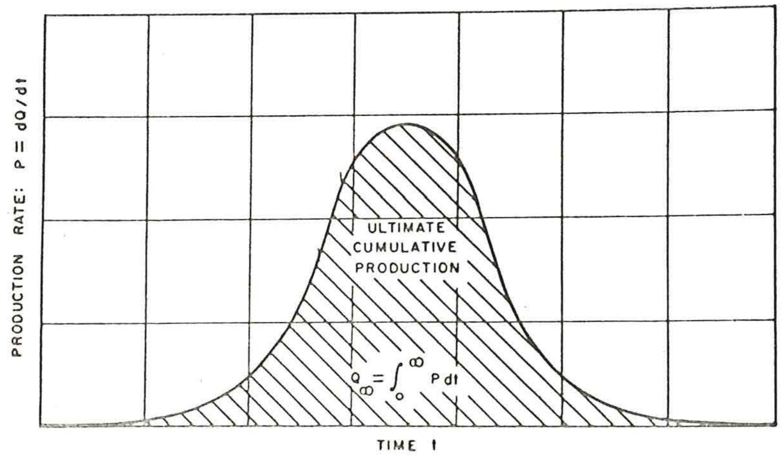
hydropower all appear to be small in comparison to the real needs of the future. The final goal will be to adapt to solar energy systems because at least this, with its shortcomings of weather vagaries, is renewable.

The most important action to take immediately is to reserve all liquid fuels for portable transportation where electricity cannot be satisfactorily used. Natural gas should be reserved only for domestic heating, cooling, and cooking because of its cleanliness and established distribution systems.

The Law of Exhaustible Resources

The pattern of the ultimate cumulative production curves of any exhaustible resource was well depicted by Hubbert in 1962[1] and is shown in Figure 1. This well-known principle has been dormant, suppressed, and ignored by people, economists, geology teachers, researchers, explorationists, and the media. Hubbert demonstrated that definite reserves follow closely the normal symmetrical and asymmetrical distribution types of curves, all of which reach a peak and decline. Exploration activities peak ahead of production, and then decline before actual production reaches a peak and declines.



Production of an Exhaustible Resource

FIGURE 1[2]

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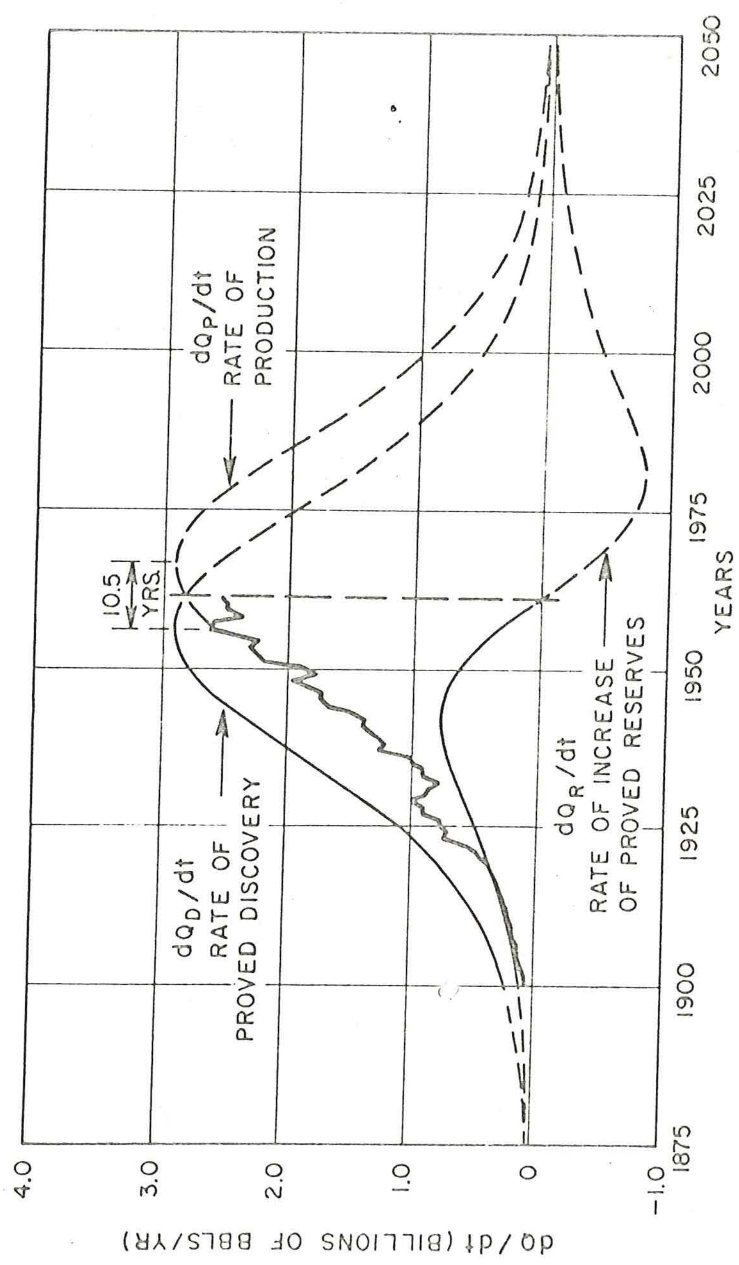
[1] Hubbert, "Energy Resources," *Nat. Acad. Sci-Nat. Res. Counc.* Publ. No. 1000-D (1962).

[2] *Ibid.* (Reprinted with permission by Hubbert, 1962).



Rates of Discovery, Production and Increase of Proved Reserves of U. S. Crude Oil

FIGURE 2[3]

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[3] *Ibid.* (Reprinted with permission by Hubbert, 1962).

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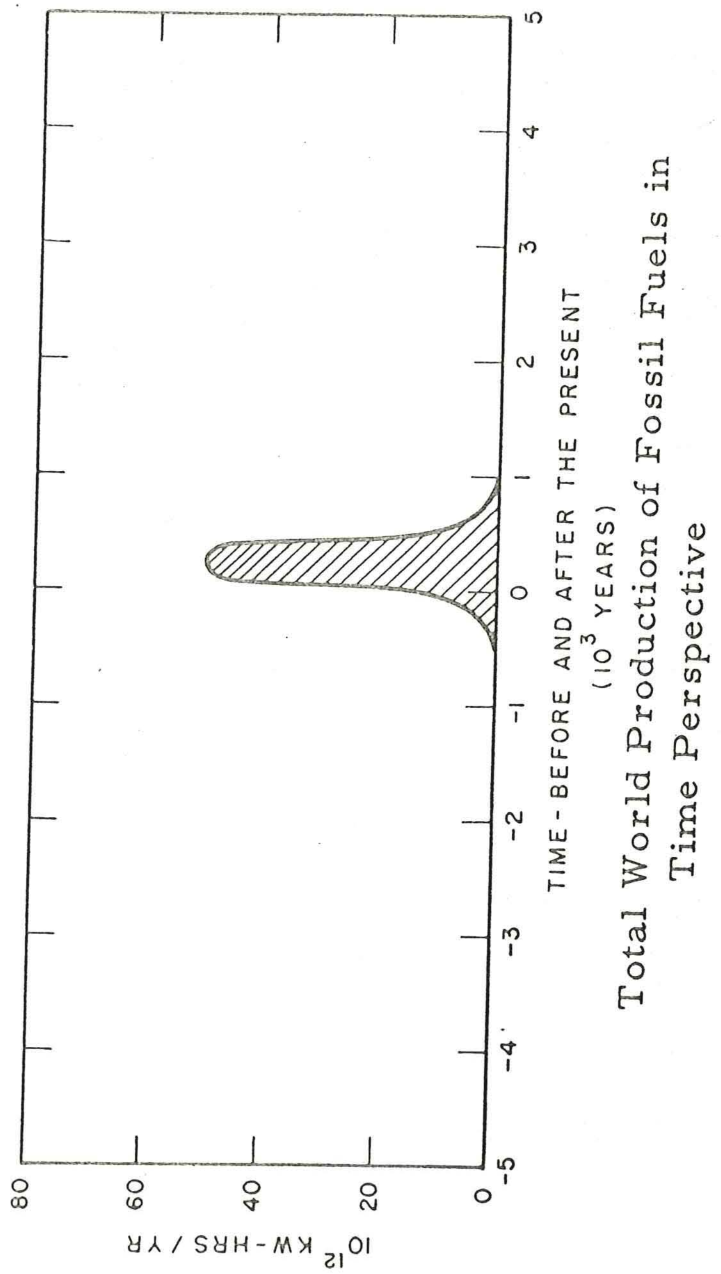

Total World Production of Fossil Fuels in Time Perspective

FIGURE 3[4]

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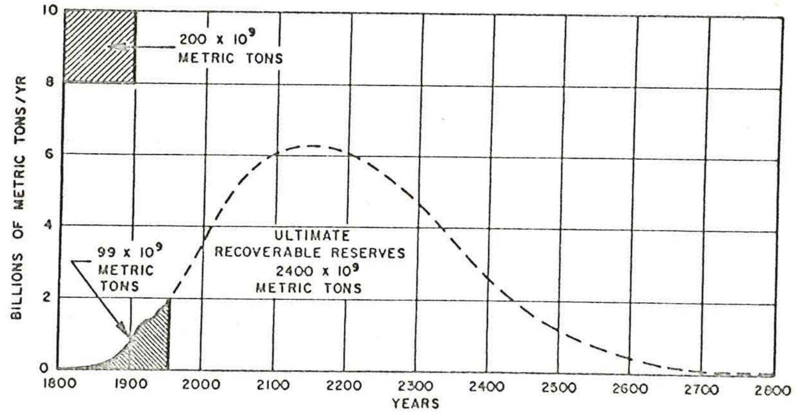
[4] *Ibid.* (Reprinted with permission by Hubbert, 1962).

The Hubbert charts are short-term predictors of production trends. He dealt only with proven reserves, but curves of this sort apply equally well to prospective, probable, and ultimate reserves. The only differences may be in magnitudes. The built-in geological facts of these curves are: Time never reverses; time never stops; there is no vestige that time will end; and the resource is as finite as the earth. Hubbert summarizes his views on total world production of fossil fuels as a steep but time-limited blip in Figure 3. This is depressing and pessimistic. Geologists, engineers, economists, politicians, and people in general must always face the laws of exhaustible resources and meet the challenges that go with this concept.

Kinds of Energy Resources

Material used for energy may be either exhaustible or nonexhaustible. That which is exhaustible is finite, can be used up, and is gone forever. That which is nonexhaustible is renewed, may or may not be limitless but offers optimism for the future. Some materials may be so poorly known that the amounts of future reserves cannot be estimated with assurance. Our known world energy resources that are accessible are:



Ultimate World Coal Production

FIGURE 4[5]

A. Nonrenewable (exhaustible, finite, subject to depletion and laws of exhaustion).

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[5] Ibid. (Reprinted with permission by Hubbert, 1962).

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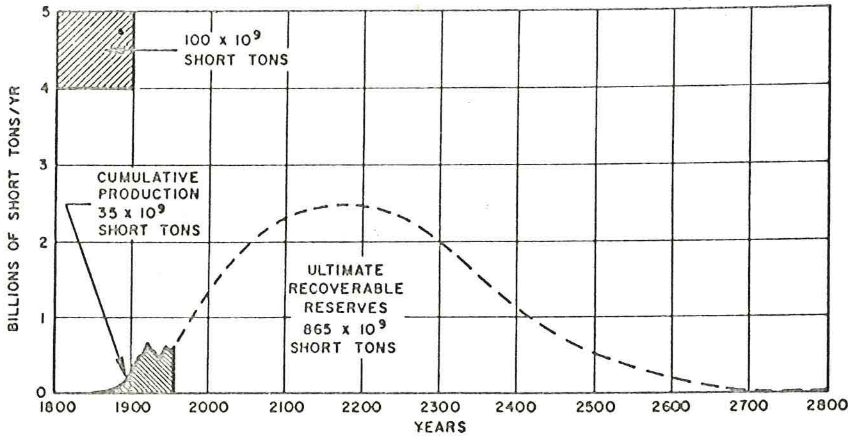
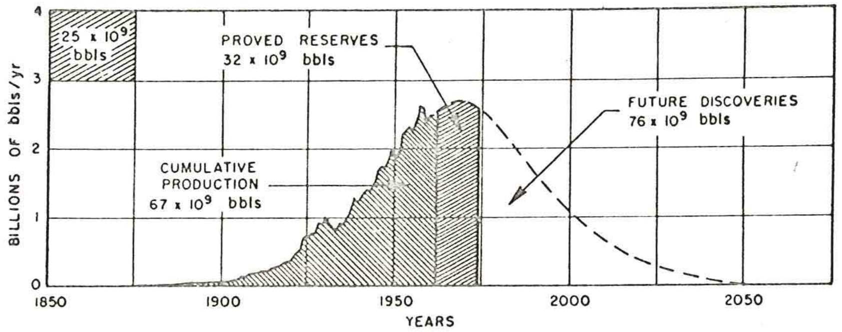
1. *Fossil Fuels* (indirectly stored sunlight via photosynthesis with burial in the rock column).



Ultimate U. S. Coal Production

FIGURE 5[6]



Estimate of Ultimate U. S. Production of Crude Oil

FIGURE 6[7]

a. Coal (from 670×10^{12} watt years equivalent[8] to $6{,}000 \times 10^{15}$ watt hours equivalent[9] stored in rocks and accessible).

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[6] *Ibid.* (Reprinted with permission by Hubbert, 1962).

[7] *Ibid.* (Reprinted with permission by Hubbert, 1962).

[8] Starr, "Energy Resource Planning," *Proc. of Materials Policy Meetings* (Los Angeles, June 1972).

[9] Kristoferson, "Energy in Society," 2 *Ambio* 178-185 (1973).

b. Petroleum (from 100×10^{12} watt years equivalent[10] to $1{,}000 \times 10^{15}$ watt hours equivalent[11] stored in rocks and accessible).

c. Natural Gas (from 70×10^{12} watt years equivalent[12] to 400×10^{15} watt hours equivalent[13] stored in rocks and accessible).

d. Tar Sands, Oil Shales and Bituminous Rocks (from 253×10^{15} watt hours equivalent[14] to $300{,}000 \times 10^{15}$ watt hours equivalent[15] stored in rocks and accessible).

2. *Radioactive Minerals*

a. Uranium and Thorium Minerals (present fission systems from $1{,}500 \times 10^{15}$ watt hours equivalent[16] to $3{,}000 \times 10^{15}$ watt hours equivalent[17] stored in rocks and available for a price of less than $40 per kilogram. Breeder fission systems, not yet operating may have from $300{,}000 \times 10^{15}$ watt hours equivalent[18] to $100{,}000{,}000 \times 10^{15}$ watt hours equivalent[19] stored in rocks and available for a price less than $250 per kilogram).

3. *Geothermal Power* (from 0.006×10^{12} watt hours equivalent[20] to 10×10^{12} watt hours equivalent[21] to be discovered and developed).

B. RENEWABLE (based on sunlight and gravity energies, may be limited and world estimates shown are yearly contributions continuously renewed).

1. *Hydropower* (3×10^{12} watt hours equivalent developed

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[10] See N. 8 *supra*.

[11] See N. 9 *supra*.

[12] See N. 8 *supra*.

[13] See N. 9 *supra*.

[14] See N. 1 *supra*.

[15] See N. 9 *supra*.

[16] *Ibid.*

[17] See N. 8 *supra*.

[18] *Ibid.*

[19] See N. 9 *supra*.

[20] See N. 8 *supra*.

[21] See N. 9 *supra*.

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but 31 × 10^{12} watt hours equivalent available).[22]

   a. Running Water (3 × 10^{12} watt hours equivalent).[23]
   b. Tidal Power (1 × 10^{12} watt hours equivalent).[24]

2. *Atmopower* (from 0.1 × 10^{12} watt hours equivalent[25] to 200 × 10^{12} watt hours equivalent).[26]
3. *Solar Power* (from 3,500 × 10^{15} watt hours equivalent[27] to 28,000 × 10^{12} watt hours equivalent[28] subject to the vagaries of weather).
4. *Wood and Refuse* (from 5 × 10^{12} watt hours equivalent[29] to 50 × 10^{15} watt hours equivalent that might be available but limited by productivity).[30]
5. *Organic Material* (8 × 10^{12} watt hours equivalent[31] but limited by productivity).

C. MISCELLANEOUS (Limited to available source materials, but some are very abundant).

1. *Hydrogen* (made from water by disassociation, no estimation on costs or amounts, as abundant as water).
2. *Deuterium* (heavy hydrogen, obtained from water, no estimates on costs or amounts. It could range up to 300,000,000,000 × 10^{15} watt hours equivalent[32] but fusion reactions not yet operating).
3. *Methanol* (methyl alcohol (CH_3H) may be obtained from any gas, liquid or solid hydrocarbon. Costs and amounts are unknown, but ease of transportation by pipeline may justify it. Sources of materials are ultimately limited).

Coal is the most abundant resource among the fossil fuels, with reserves equivalent above all other fossil fuels. The scarcity of petroleum and natural gas will demand a move to employ more coal. This will also demand higher prices because of the slowness

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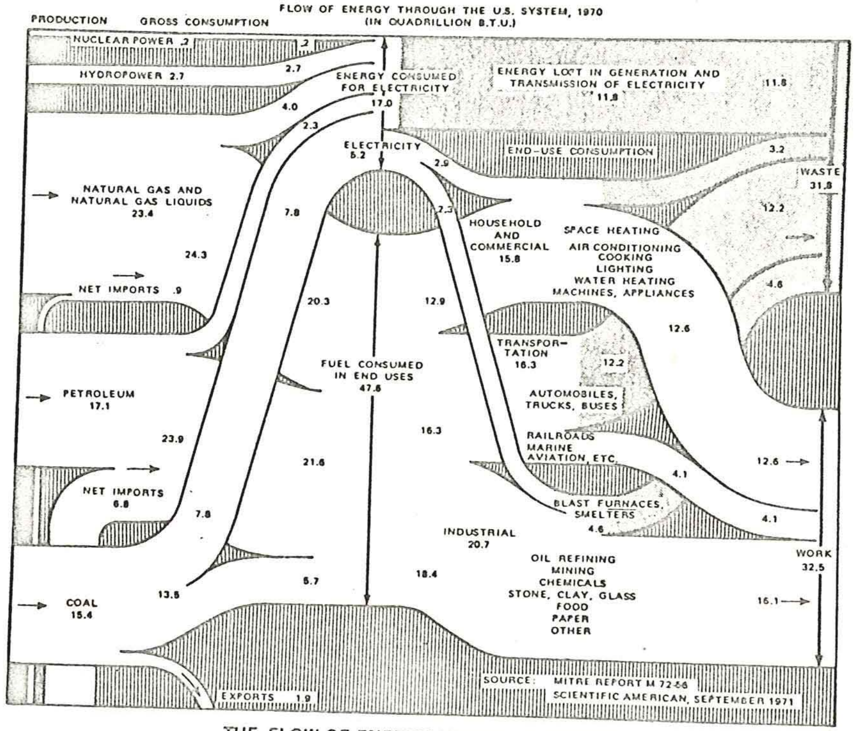
[22] *Ibid.*
[23] See N. 8 *supra.*
[24] *Ibid.*
[25] *Ibid.*
[26] See N. 9 *supra.*
[27] *Ibid.*
[28] See N. 8 *supra.*
[29] *Ibid.*
[30] See N. 9 *supra.*
[31] See N. 8 *supra.*
[32] See N. 9 *supra.*

and costs of extraction. Sulfur in coal may be removed in the processing or in stack gases. This removal will increase the costs of energy.

The obvious ultimate energy resource for the future will be in the nonexhaustible category. Solar energy will become most important in the main low-level domestic heating, cooling, and cooking. Lack of sunlight at night and on cloudy days will require battery storage. Even though the vagaries of weather will plague the system, the future use of solar power seems inevitable.



THE FLOW OF ENERGY IN THE U.S. SYSTEM

FIGURE 7[33]

Provided safety and disposal of dangerous materials are guaranteed, then nuclear fission, breeder fission, and nuclear fusion conversions will become important. Regular nuclear fission as we now know it can last as long as radioactive minerals are available (about 25 years at the present price). Breeder fission will increase

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[33] Reproduced with permission from "The Flow of Energy in an Industrial Society," by Earl Cook, copyright © 1971 by Scientific American, Inc. All rights reserved. This material also appeared in the final report of the National Commission on Materials Policy.

the energy extraction from radioactive minerals by more than 100 times. These two methods may be good stopgaps in our future energy needs.

Nuclear fusion systems, even though not yet perfected, could free the public from dangerous radioactive wastes, and the sources of deuterium seem limitless as the ocean water. Perfection of the system has not yet been accomplished, nor the costs assessed.

Unless exhaustible fuels are rationed and used sparingly, Hubbert's suggested blip on the time chart will take place. To change this blip requires people to change to other possible sources of energy.

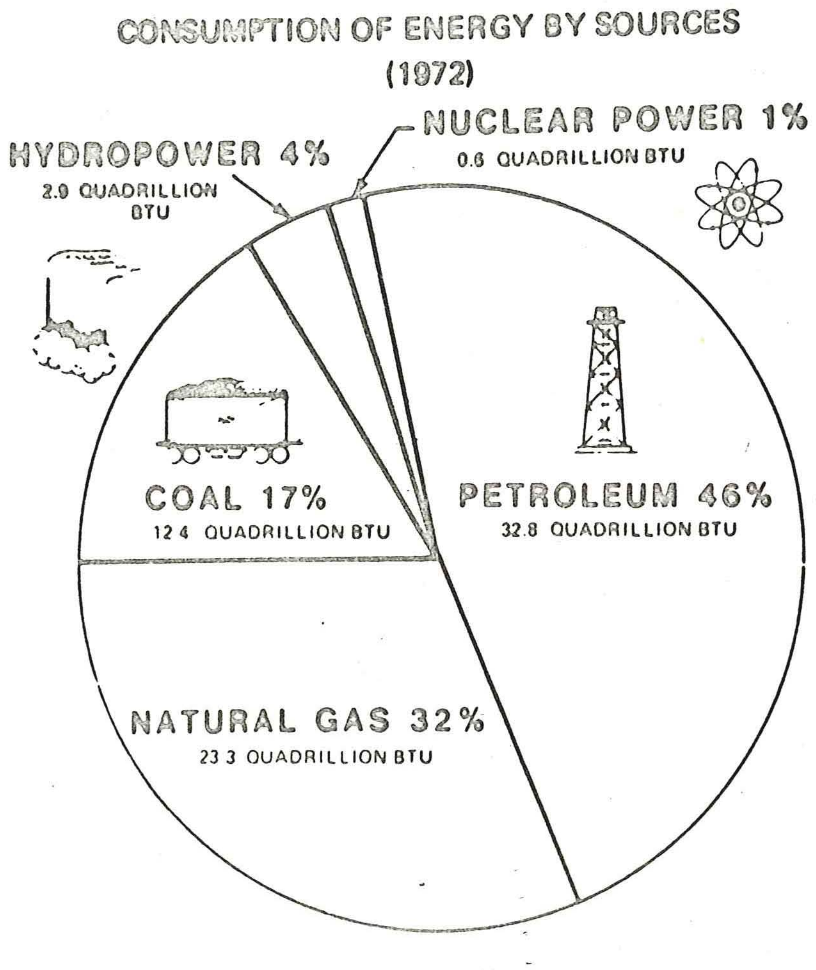

FIGURE 8[34]

The United States is completely dependent upon fossil fuels for energy at this time. Fully one-third of the electricity is made from oil and gas. Two-thirds of the energy put into the making of electricity is lost on conversion and distribution. This lost energy never reaches the user-customer. Transportation has one of the most inefficient conversion systems, where more than 70 percent of the energy put in the system is lost. We as people, scientists, and engineers ought to be working hard to reduce these losses in electrical conversion and in transportation uses.

Since all portable transportation, except electrified mass transit systems, are dependent upon the handy can of gasoline, kerosene or diesel fuel, it is proposed that all liquid petroleum be reserved for portable transportation where electricity or coal cannot be used. It is also proposed that all clean natural gas be reserved for domestic heating, cooling, and cooking because the cleaning and distribution systems are already established. It also keeps the environment cleaner. This denies these easily handled but limited commodities to the electrical generators and forces them to use coal, nuclear, or solar power.

Predictions for the future by the National Petroleum Council[35] in Figure 9 show how the United States will become very dependent upon foreign sources of petroleum and natural gas. There will be enormous increases in coal and nuclear power plants. The contributions to be furnished by geothermal and hydropower sources are small. The part to be played by using hydrogen, deuturium, and methanol are not shown because they would be guesses.

If the United States becomes more and more dependent upon foreign sources for petroleum and natural gas, then the Government must establish a far-reaching and definite policy to remain absolutely friendly to all foreign nations, especially those with oil and gas resources. Dependency on foreign countries further obligates the United States to have manufactured goods, food, technical services, training services, and other desired commodities that can be traded for energy resources. Sending the United States currency to foreigners to pay for oil and gas destroys the balance of payments and erodes the values of the currency. A worsening

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[34] National Comm'n on Materials Policy, Materials Needs and the Environment, *Today and Tomorrow* (June 1973).

[35] Modified from National Petroleum Council, 1 *United States Energy Outlook—an Interim Report*, p. xxv, Fig. 1 (1972).

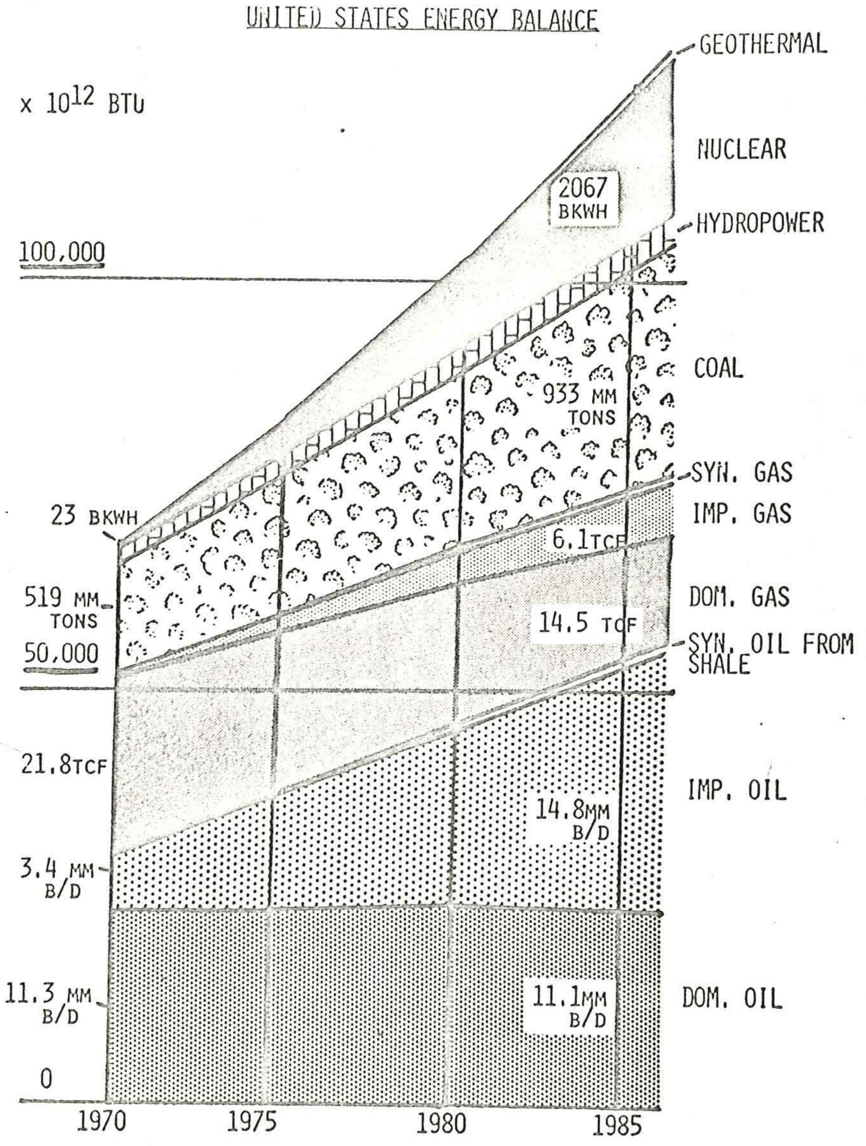

FIGURE 9[36]

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[36] Modified from National Petroleum Council, 1 *United States Energy Outlook—an Interim Report*, p. xxv, Fig. 1 (1972).

Country	Areas 10³ Sq. Mi. Total	Expl.	Wells 10³ Prod. 1973	All 1973	Prod. per Sq. Mi. Total	Prod. per Sq. Mi. Expl.	All per Sq. Mi. Total	All per Sq. Mi Expl.
Texas	267°	233†	174°°	563‡	0.6524	0.7476	2.1087	2.4163
United States (Incl. Alaska)	4,200°	2,019††	517°°	1,738‡	0.1230	0.2560	0.4138	0.8608
Canada	3,851°	570†	23°°	–	0.0059	0.0403	–	–
Venezuela	352°	212†	12°°	–	0.0341	0.0566	–	–
North Africa	2,219°	1,586†	1.8°°	–	0.0008	0.0011	–	–
Middle East	2,229°	750†	3.2°°	–	0.0014	0.0042	–	–
Upper Amazon	–	750†	0.2°°	–	–	0.0002	–	–

° World Book Encyclopedia, 1970[37]
† Ellison's calculations
°° Oil and Gas Journal, 1973[38]
†† Cram, 1971[39]
‡ Twentieth Century Petroleum Statistics, 1972[40]

FIGURE 10

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[37] *The World Book Encyclopedia for 1970* (Field Enterprises 1970).

[38] Gardner, "The Year of Major Changes in Worldwide Oil," 71 *Oil & Gas J.* No. 53, pp. 35-136 (1973).

[39] Cram, "Future Petroleum Reserves of the United States—Their Geology and Potential," *A.A.P.G. Memoirs* 15 (2 vols. 1971).

[40] DeGolyer and MacNaughton, *Twentieth Century Petroleum Statistics* (June 15, 1972).

balance of payments means lower standards of living in the United States.

Pessimistic and realistic views deepen further for United States if consideration is given to the density of exploration and the density of production of petroleum and natural gas. The United States is the most densely explored area of the world for these products. Combining the best figures available, the exploration area of the United States has an exploration index of 0.86 wells per square mile, and Texas is almost three times as dense.

Unfortunately, exploration wells for other major producing countries of the world are not available. Usually, there are only a few nonproductive wells in foreign areas. A comparison of the density of producing wells can be made for some of the major oil and gas producing areas of the world. The Middle East, North Africa, and Venezuela are quite small as compared to the United States if the productive index is used. The success of exploration and productivity is bound to be greater in foreign areas. Sea-floor data are so scarce that comparisons cannot yet be made. This parameter of well index ought to be in every oil and gas searchers double-check system. These same data ought to be in the hands of the layman so he can understand our need to go foreign or to sea for exploration activities.

The Middle East as a Model

It takes time to switch to different methods of manipulating energy resources. Even though nuclear energy is in sight and solar energy will become the ultimate source, interim needs must be met. To command attention, the importance of the Middle East as a petroleum and natural gas producing area is shown in Figure 11.

The Middle East has 55.8 percent of the world's proven reserves of petroleum and 20.3 percent of the proven gas reserves. In contrast, the United States has 5.5 percent of the proven oil and 12 percent of the proven gas reserves. The United States has produced 36 percent of the accumulated world production of petroleum, but the Middle East, with vastly greater reserves, has produced only 23.4 percent of the accumulated oil production. That such a vast reserve is known in the Middle East is enough to demand that we understand the geological occurrences of the hydrocarbons in that area. Using the Middle East as a model, hopefully, the interim needs of energy can be partially filled if we can find more Middle Easts. Based on the exploration and productivity densities, such additional areas are not likely to be within the United States, but rather at sea or in foreign lands.

Jan. 1, 1974	*Middle East*	*U.S.*	*Can.*	*Communist (Inc. USSR)*	*World*
Oil [$\times 10^9$ b]					
Reserves (Proven)	350 (55.8%)	34.7 (5.5%)	9.4 (1.6%)	103.0 (16.4%)	627.8
Accum. Prod.	69 (23.4%)	109.5 (36.0%)	5.8 (2.0%)	31.6 (10.0%)	295.9
1973 Prod.	7.8 (38.8%)	3.0 (16.0%)	0.6 (3.0%)	2.7 (16.1%)	20.1
Gas [$\times 10^{12}$ c.f.]					
Reserves (Proven)	413.3 (20.3%)	247.0 (12.0%)	50.2 (2.4%)	735.4 (36.0%)	2,033.3

FIGURE 11[41]

The geological occurrences of oil and gas in the Middle East are in an elongate Cenozoic-Mesozoic asymmetrical basin along the northeastern edge of the Arabian pre-Cambrian plate. The Jurassic to late Tertiary rocks dipping into the basin have been gently deformed into anticlines along the southwestern part of this basin. In contrast, tightly folded disharmonic anticlines are in the folded belt of the Zagros-Taurus Mountains to the northeast. The tightly folded areas are also intensely fractured, especially along the crests of folds. The carbonate oil and gas reservoirs are fractured deeply into Mesozoic rocks. At the northern end of the Gulf of Arabia, gently folded Cretaceous sand bodies form reservoirs that are considered among the largest bodies of oil and gas in the World. Southward, both Cretaceous and Jurassic carbonate reservoirs in gently folded anticlines are dominant.

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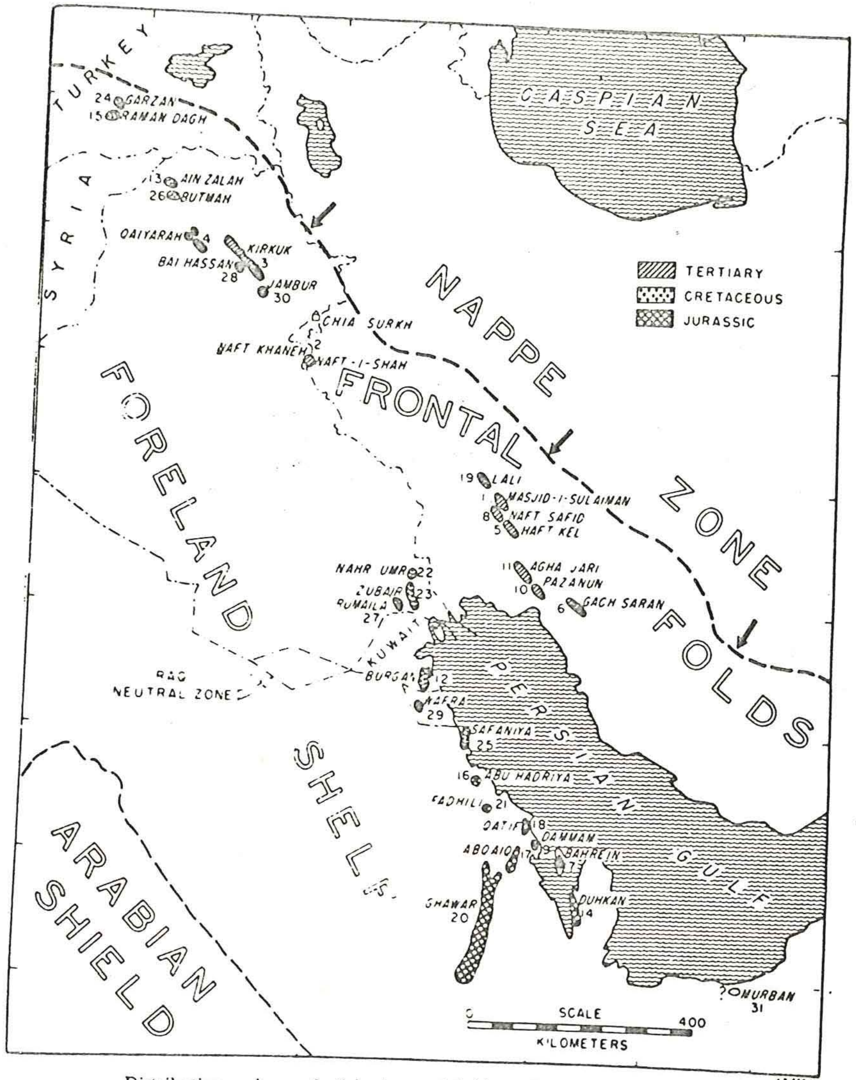
[41] See N. 38 *supra.*



—Distribution and age of oil horizons of fields in the Middle East. Numbers indicate the order in which fields were discovered, except in three instances where groups of fields have been assigned the number of the first discovery, e.g., Qaiyarah, Najmah, Jawan, and Qasab.

FIGURE 12[42]

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[42] Greig, "Oil Horizons in the Middle East," Special Publication *Habitat of Oil* (A.A.P.G. 1958). (Reprinted with permission from the AAPG and Greig).

FIGURE 13[43]

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[43] Baker and Henson, "Geological Conditions of Oil Occurrence in Middle East Fields," 36 A.A.P.G. Bull. 1885-1901 (1952). (Reprinted with permission from the AAPG and Baker and Hensen).

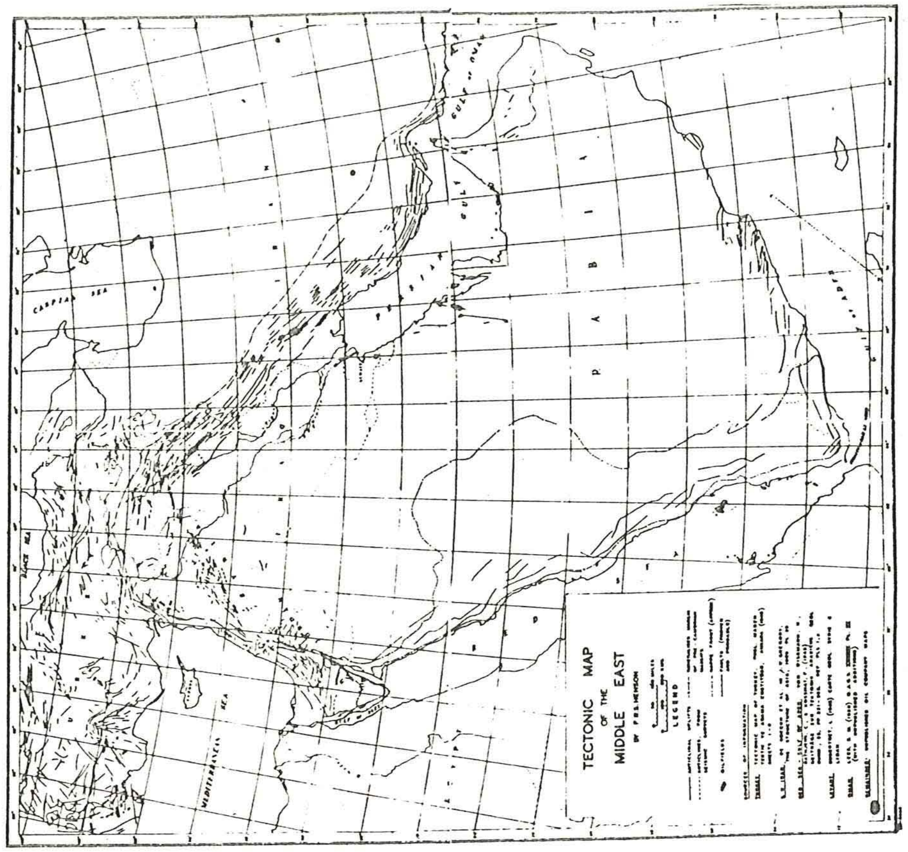

FIGURE 14[44]

Salt plugs and anticlines are in the southern part of the Gulf of Arabia and the southern Zagros Mountains. The salt is thought to be Cambrian. The elongate basin is definitely Jurassic, Cretaceous, and Tertiary. Paleozoic rocks, although present, are not in a sharp elongate basin configuration prior to the present basin folding.

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[44] *Ibid.* (Reprinted with permission from the AAPG and Baker and Hensen.)

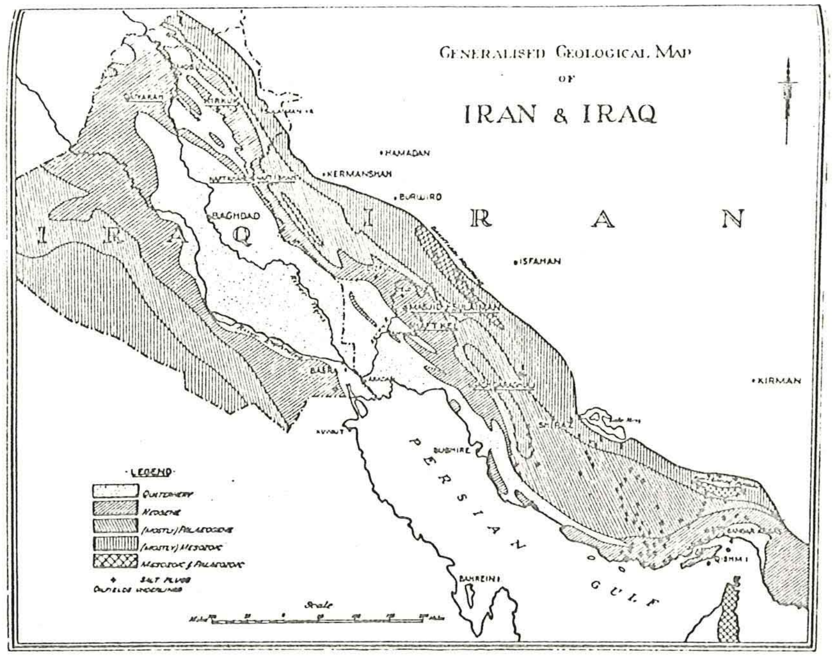

FIGURE 15[45]

Much detail is known about the geology of the Middle East and the surrounding areas. A few choice bits of information are: the 1,200 feet of oil column in the clean Cretaceous sands in the Burgan field, Kuwait; the extraordinary lateral fluid connections in the Ghawar field, Saudi Arabia, where wells produced at the northern end will cause pressure drops in wells 160 miles away to the south; the immense offshore field called Safaniya, Saudi Arabia, vying for the largest offshore production in the world; and the remarkable disharmonic folding in Iran and Iraq in the Zagros Mountain belt.

Additionally, facies changes control production in the Kirkuk field, Iraq; much of the porosity and permeability of the Asmara limestone, Tertiary, in the fold belt is due to vertical fractures; Cretaceous oil migrates through fractures upward into Tertiary limestones in the fold belt; and the salt intrusions of southern Iran

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[45] Lees, "The Middle East," 4 *The Sciences of Petroleum*, No. 1, pp. 66-72 (1953).

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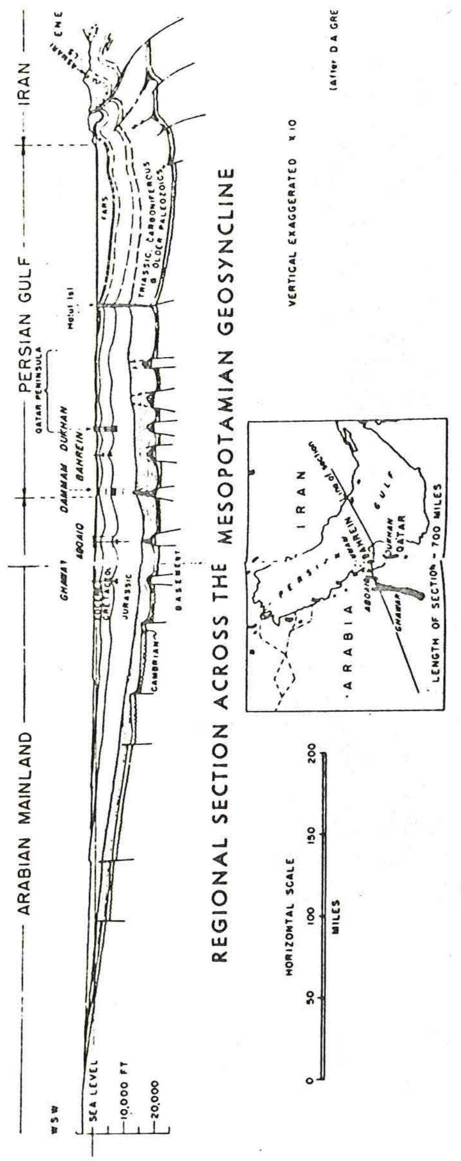

FIGURE 16[46]

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[46] See N. 42 *supra.* (Reprinted with permission from the AAPG and Greig.)

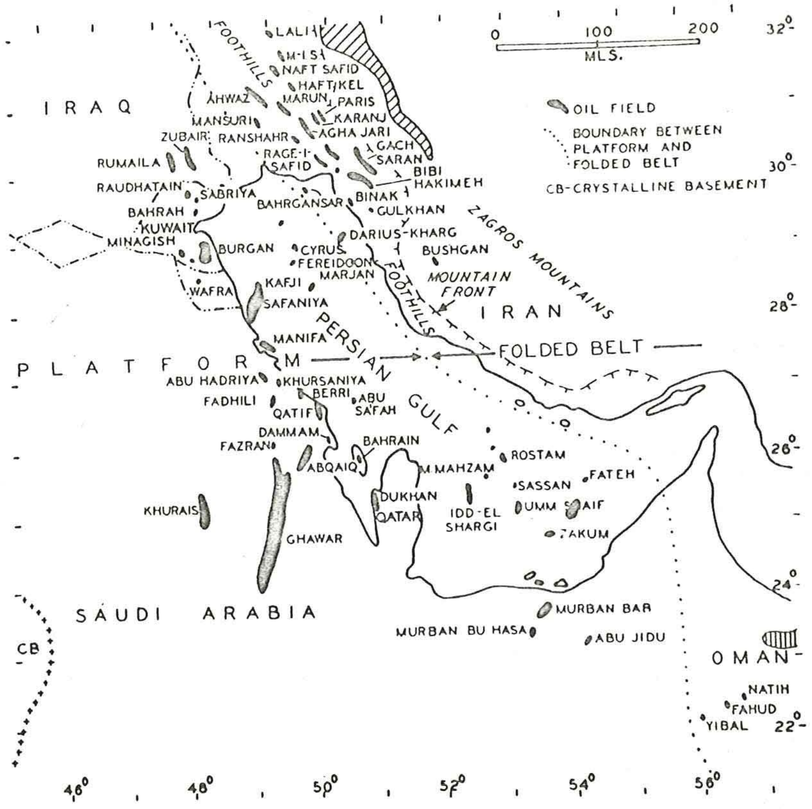

FIGURE 17[47]

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[47] Kamen-Kaye, "Geology and Productivity of Persian Gulf Synclinorium," 54 A.A.P.G. Bull. 2371-2394 (1970). (Reprinted with permission from the AAPG and Kamen-Kaye.)

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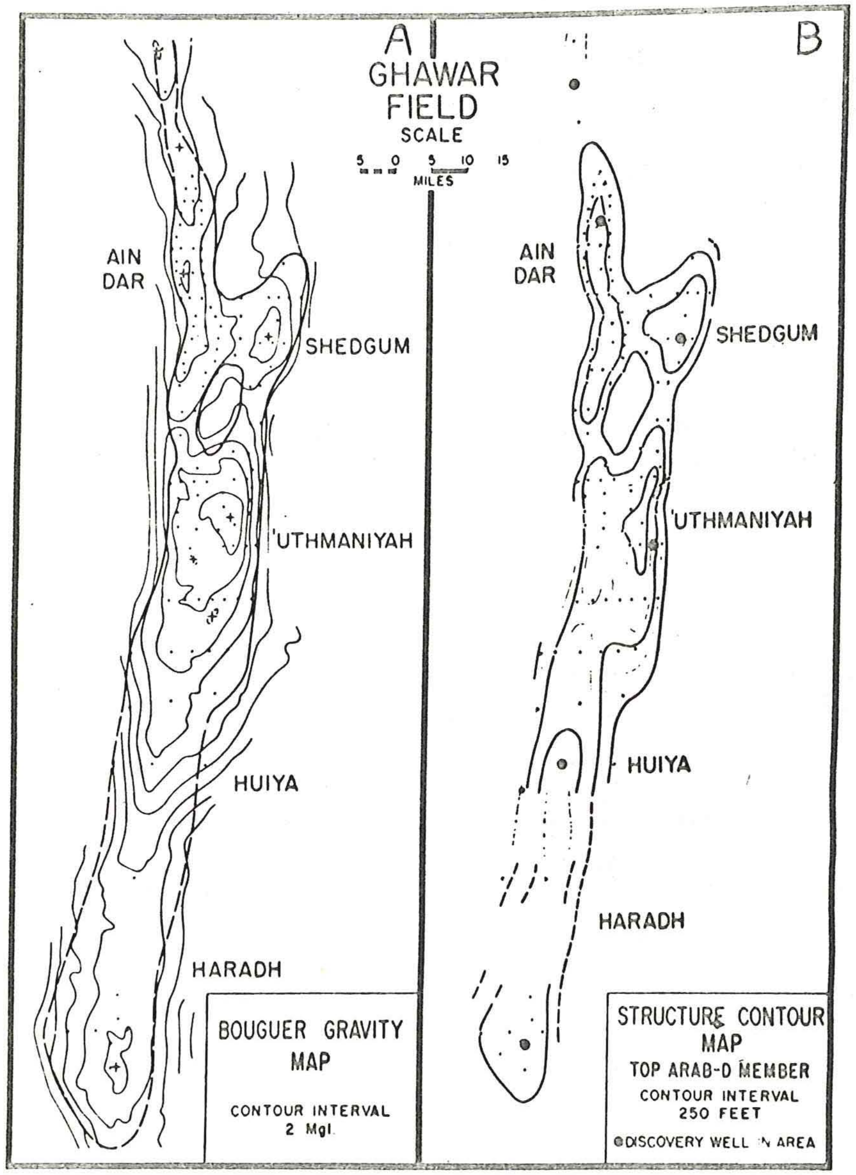

FIGURE 20[50]

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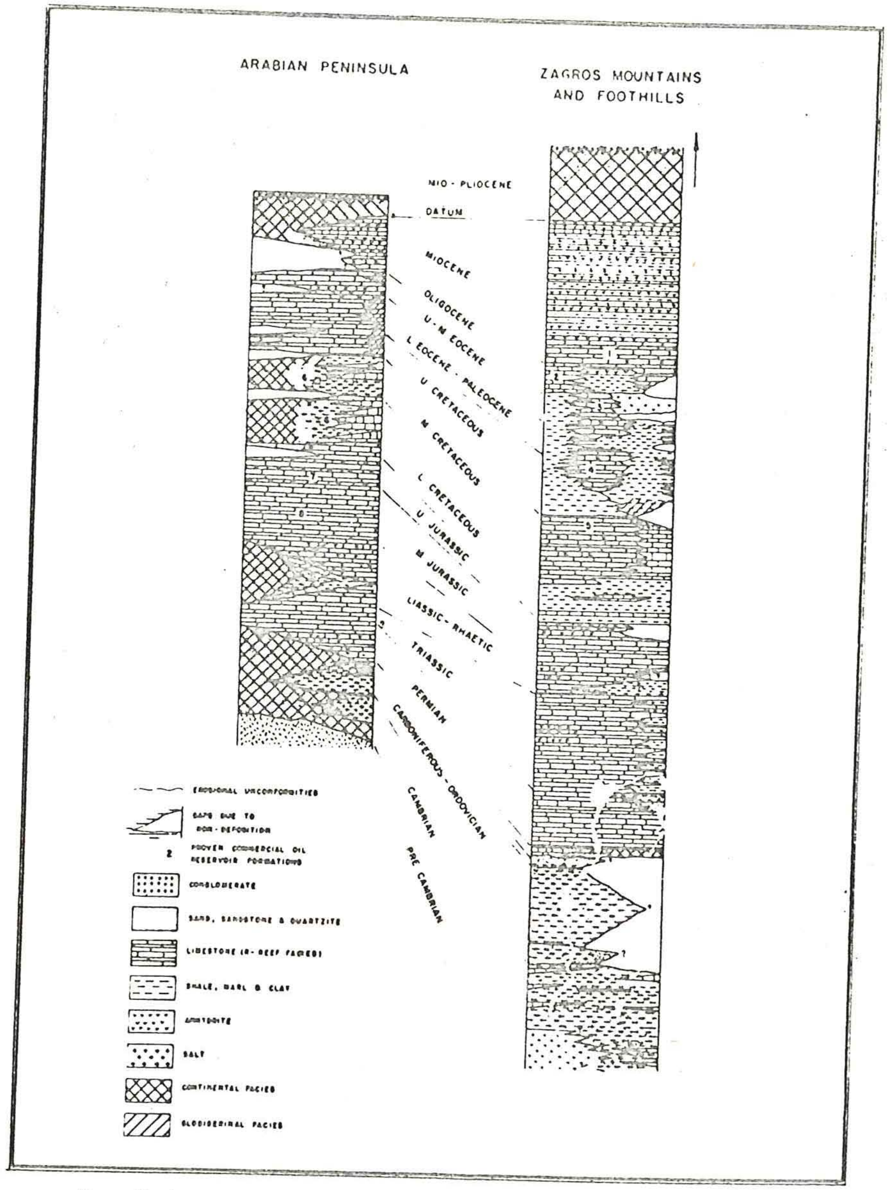
[50] Arabian American Oil Co. Staff, "Ghawar Oil Field, Saudi Arabia," 43 A.A.P.G. Bull. 434-445 (1959). (Reprinted with permission from AAPG and the Arabian American Oil Co. Staff.)



-Generalized stratigraphic sections southwest and northeast of Persian Gulf,

FIGURE 21[51]

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[51] Law, "Reasons for Persian Gulf Oil Abundance," 41 A.A.P.G. Bull. 51-59 (1957). (Reprinted with permission of the AAPG and Law.)

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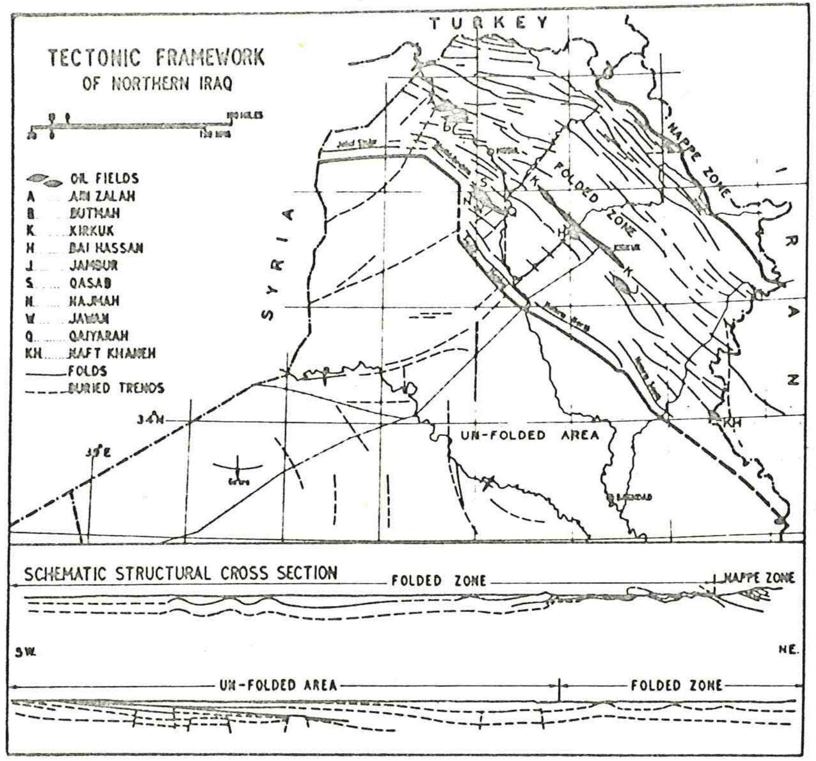

FIGURE 23[56]

Search Areas Elsewhere

Geologists may take flights of fantasy and borrow from unproven theories. Assume that some of what we know about plate tectonics is real. Plates of two continents may push together to form basins and mountains. Similarly, plates of two continents may pull apart to form trenches and grabens. Further, a continental plate may ram against and ride over ocean floor plates. Subduction and an arc-shaped trench may form. Landward from the arc will be a basin, partially cut-off from the ocean, and it may contain reefs and deltas. Deposition within the basins are likely places for the accumulation of organic material in the sediments. Deposition in grabens may have similar possibilities. Deposition by rivers in deltas along the trailing edge of a plate may be rapid enough to maintain an excess of organic materials for the sediments. All of these could be sites for potential oil and gas bearing strata.

We know the Middle East is in a push-together zone. It has at least 55.8 percent of the world proven oil reserves. Our first effort should be to find other Middle Easts.

Potential search areas are outlined as follows:

(1) Ganges Basin, India, West Pakistan, East Pakistan, Nepal and Bhutan (compression between continental plates, deltas, reefs, elongate, Mesozoic-Cenozoic).

(2) Adaman Sea, Sumatra, Java, Java Sea, and Sunda Sea (compression between a continental plate and an ocean floor plate, elongate, deltas, Mesozoic-Cenozoic, Sumatra and Java already productive).

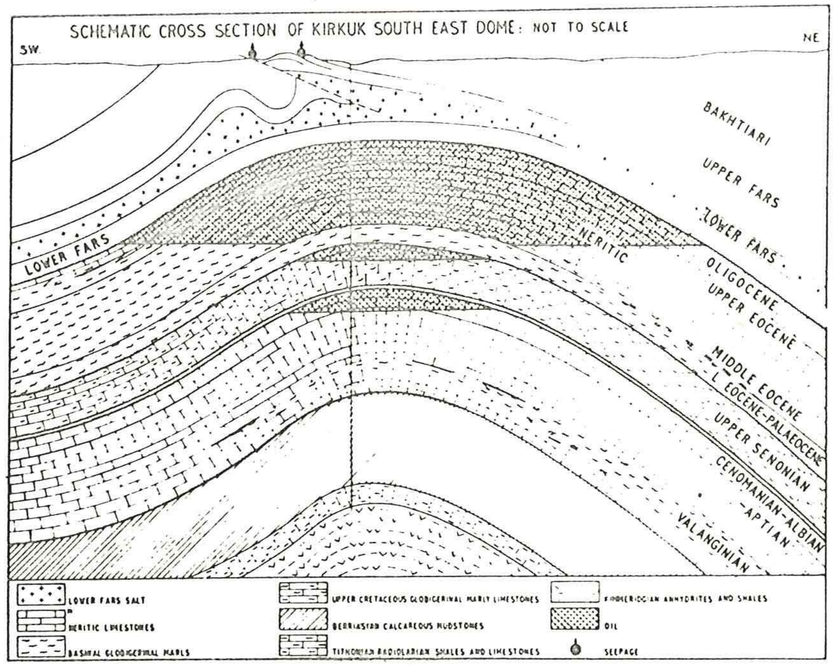

FIGURE 24[57]

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[56] *Ibid.* (Reprinted with permission of the AAPG and Dunnington.)

[57] *Ibid.* (Reprinted with permission of the AAPG and Dunnington.)

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(3) South China Sea (compression between a continental plate and an ocean floor plate, deltas, reefs, Mesozoic-Cenozoic, some gas already discovered).

(4) East China Sea (compression between a continental plate and an ocean floor plate, deltas, reefs, Mesozoic-Cenozoic).

(5) Sea of Japan (compression between a continental plate and an ocean floor plate, deltas, reefs, Mesozoic-Cenozoic, part of it is fairly deep, but edge possibilities seem present).

(6) Sea of Okotsk (compression between a continental plate and an ocean floor plate, deltas, reefs, Mesozoic-Cenozoic).

(7) Bering Sea (compression between a continental plate and an ocean floor plate, deltas, Mesozoic-Cenozoic).

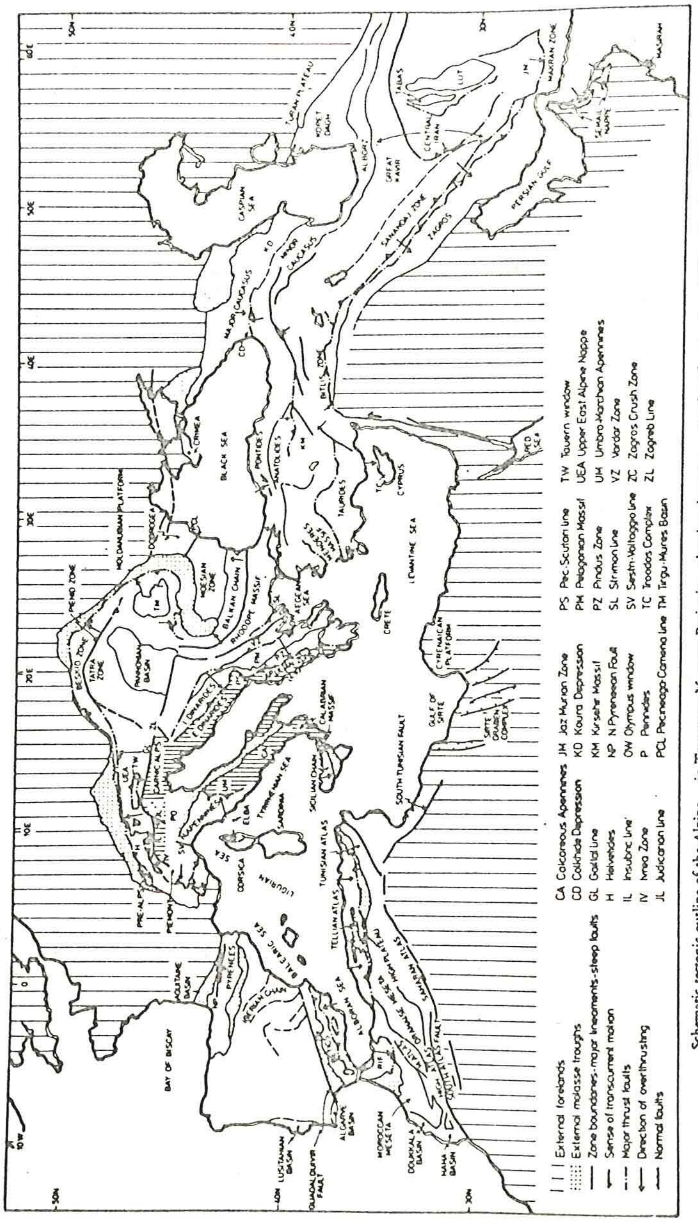
(8) Eastern Mountain belt of Australia and the accompanying basins (compression by a continental mass against an ocean floor plate, elongate, reefs, Paleozoic-Mesozoic-Cenozoic).

(9) New Zealand-Tonga Basin (compression between a continental plate and an ocean floor plate, elongate, reefs, Mesozoic, source of basin sediments an unknown).

(10) Upper Amazon Valley, Ecuador, Eastern Peru, eastern Colombia, Bolivia, and a part of Venezuela (compression between a continental plate and a sea floor plate, elongate, reefs, partly enclosed in the past, Mesozoic-Cenozoic, production known).

(11) Patagonia and the southern Argentinian Atlantic shelf (compression betweeen a continental plate and a sea floor plate, elongate, reefs, Mesozoic-Cenozoic, some production known).

(12) Waddell Sea, off Grahamland, Antarctica (compression between a continental plate and a sea floor plate, deltas, reefs, Mesozoic-Cenozoic).



Schematic tectonic outline of the Alpine System of Europe, North Africa, and the Middle East in Transverse Mercator Projection, showing the zones and structures referred to in the text. Based mainly on Bogdanoff and others (1964), Choubert (1968), and Stöcklin (1968).

FIGURE 25[58]

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[58] Dewey, Pitman, Ryan, and Bonnin, "Plate Tectonics and the Evolution of the Alpine System," 84 Geol. Soc. Am. Bull. 3137-3180 (1973). (Reprinted with permission of the Geol. Soc. Am. and Dewey, Pitman, Ryan, and Bonnin.)

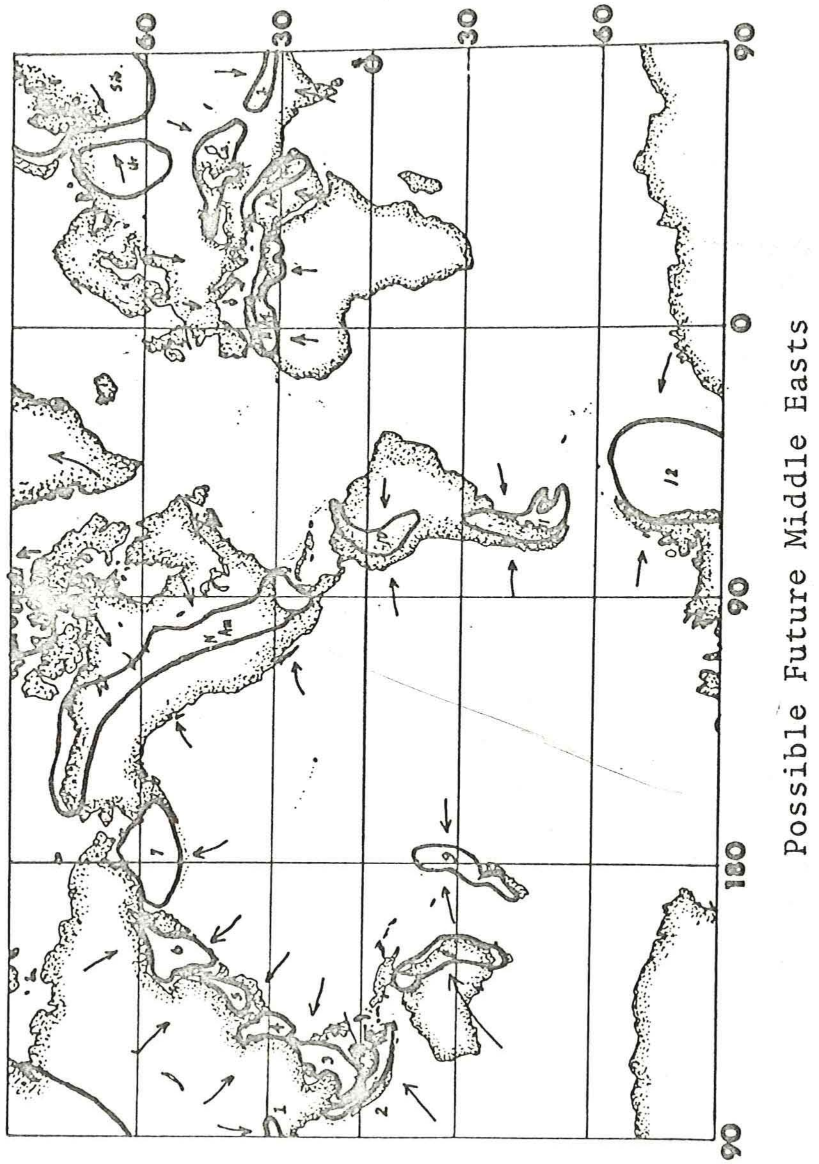

FIGURE 26

Other similar basins that are Mesozoic-Cenozioc with elongate patterns, deltas, reefs, and partial enclosures now somewhat explored and productive are: western North America from the Alaska northern slope to the Gulf of Mexico; Franklin geosyncline of the Artic Islands; North Africa south of the Atlas Mountains; small basins of western Europe such as the Aquitaine, Paris, Bavaria, Vienna, Transylvania, Muldovia, Celtic sea, and North sea; and the Caspian sea basin of southern Russia.

Similar Paleozoic basins with the same general character except for the ages of the rock are: Appalachian, Permian basin of Russia west of the Urals, a portion of the Siberian basin east of the Urals, and a part of the northern African complex.

Summary

To summarize, nine known energy resources can be considered for the future:

(1) Fossil fuels and radioactive mineral fuels are finite, nonrenewable, exhaustible, and can be depleted.

(2) With depletion of fossil fuels and radioactive minerals, mankind finally must turn to renewable solar, wind, and hydropower as a way of securing energy.

(3) Mankind will need all of the energy resources he can find in the future.

(4) During shortages of oil and gas, there will be a turn to coal and nuclear fission. These are abundant but finite.

(5) Nuclear breeder systems can extend nuclear fuel by a factor of 100. The fuel is still finite and the engineering-economics of the system is not yet feasible.

(6) Nuclear fusion offers in the future what seems to be an abundant supply of fuel in deuterium. Engineering-economic problems of the system are not yet solved.

(7) Plate tectonic concepts coupled with high organic production presents the geologist with a giant effort of finding more Middle Easts (maybe a total of 12). These are foreign or at sea. They would be interim, and would be finite.

(8) Laws of exhaustible resources, exploration density, poor balance of payments, and domestic resources of fuels are pessimistic, depressing, and foreboding.

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(9) Interim discoveries of new oil and gas, more efficient uses, conservation, and turning to nuclear and solar sources are optimistic and offer hope.

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