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TWENTY FIRST CENTURY ENERGY
DECLINE OF FOSSIL FUELS
INCREASE OF RENEWABLE
NON-POLLUTING ENERGY SOURCES

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ABSTRACT

The world must prepare for the transition to renewable non-polluting energy sources to ensure the continuous flow of energy to the world's increasing population and expanding economies. World oil supply will meet demand until the peak plateau of world oil production is reached which is estimated to be between the years of 2010 and 2030. Ultimate oil recovery will range from a conservative 2700 GBO (billion barrels oil) or an optimistic 3640 GBO (billion barrels oil). Declining production after peak oil production occurs will cause a global energy gap to develop because energy demand will continue to grow. This energy gap can be avoided by forward planning. Energy conservation, improved energy efficiency, expanded production of unconventional oil and conversion of natural gas to liquids will help extend the time of peak oil production. The long-term solution to energy supply is conversion to renewable, non-polluting energy sources, which include, solar, nuclear, hydroelectric, geothermal, wind, biomass and hydrogen. Solar, nuclear and hydrogen should become major power source in the 21st century.

INTRODUCTION

This paper is a revision of the author's first paper on 21st century energy (Edwards, 1997). Topics to be discussed are 1) Objectives of this paper, 2) Driving forces for increasing world energy demand, 3) World petroleum during the 1990's, 4) United States petroleum during the 1990's, 5) World ultimate liquids production, 6) United States ultimate liquid production 7) Peak plateau of world liquid production, 8) Fossil fuel challenges (oil, natural gas and coal), 9) Renewable non-polluting energy sources, 10) Sustainable energy supply and 11) Conclusions. Energy sources in this paper are described as conventional oil, unconventional oil, natural gas liquids, oil equivalent of conversion of natural gas to liquid and oil equivalent of coal, hydroelectric, nuclear and all renewable energies. Petroleum liquids include conventional and unconventional oils, natural gas liquids and natural gas converted to liquids.

OBJECTIVES

The principal purpose of this paper is to inform the petroleum industry, governments and the general public of the risks, challenges and opportunities that will occur as peak world oil production is approached in the first quarter of the 21st century. The inevitable control of earth resources over nations and individuals must be recognized. (Youngquist, 1998). The transition to alternate energy sources is inevitable because fossil fuels, which now supply 85% of world energy, are exhaustible resources (Table 1).

Oil production, which now supplies 40% of the world's energy, will decrease when peak production occurs. The petroleum industry will then have opportunities to develop and supply renewable, non-polluting energy instead of only fossil fuels. In anticipation of this transition, research and development of renewable energy sources should begin soon. World energy demand will continue to increase. Producing and marketing competitively priced, convenient, readily available renewable energy supplies will become profitable during the first quarter of the 21st century.

DRIVING FORCES FOR INCREASING WORLD ENERGY DEMAND

Population growth, expanding industrialization and improving life styles, principally in the developing countries, are the causes of continued increase in world energy demand. World population passed 6 billion in October 1999 (Table 2). During the 20th century, global population has tripled. Improvements in medicine, agriculture, education and communication have caused decreases in both mortality and fertility rates. However, the present population of two billion under the age of 20, mainly in developing countries, even with decreasing fertility rates, guaranties continued population growth at least to the middle of the 21st century. The world's present annual population growth rate is 1.4%, which adds 80 million per year. The developing world's population growth rate is 1.7% (Table 3). World population will probably reach 8 billion by 2025 and could reach 9 billion by 2050 (Population Reference Bureau 1999, United Nations, 1999). There is a reasonable possibility that world population will peak at or below 10 billion between 2100 and 2150.

Most industrial growth and 98% of population growth are expected to occur in developing countries. This growth will increase the demand and competition for natural resources, particularly energy. World oil production verses demand by region is shown on Table 4. Notice that the developed countries produce 1/3 and the developing countries produce 2/3 of the world's oil. But the developed countries use 2/3 while the developing countries use only 1/3 of the world's oil. Per capita oil consumption in developing countries is 1.9 barrels per year, while the average in developed countries is 14.3 barrels per year. The annual per capita oil consumption in the United States is 25 barrels. (Table 5). World population growth has outpaced world oil production since 1979 (Duncan and Youngquist 1998). A major shift of demand from developed to developing countries can be expected in the next few decades. This change is driven by the predominant growth of population and industry in the developing world. Annual world oil production is estimated to continue to increase into the first quarter of the 21st century at a rate of about 1.5 %. If this rate persists, annual world demand for oil will increase from 24 GBO in 1999 to about 38GBO in 2030, which is 104 million barrels per day.

WORLD PETROLEUM DURING THE 1990'S

Annual world crude oil demand increased from 22 to 24 billion barrels from 1990 to 1998 and is expected to continue to rise. World conventional oil reserves remained above 1000 GBO since 1993, peaked at 1163 GBO in 1997 and were 1034 GBO in January 1999. However, 300 GBO are suspect as political reserves booked by OPEC during 1987-1989 to support their production quotas. These reserves may be real but include probable and speculative oil from future discoveries and development. Cumulative world oil production reached 812 GBO in January 1999 (Figure 1) (Degolyer and MacNaughton, 1998,Oil and Gas Journal, 1998).

During the decade of the 90's, major oil and gas discoveries have been made most notably in deep offshore waters of the U.S. Gulf Coast, Angola, Brazil and the Caspian Sea. Significant additional oil and gas reserves have been discovered on the Northwest Australian Shelf and in Indonesia, China, Iran, Iraq, Saudi Arabia, Egypt, Algeria, Nigeria, the North Sea, Alaska, Canada, Columbia and Venezuela, Peru and Brazil. New technologies have been successfully applied. These include rapid computer software data analysis, 3D and 4D seismic, extended reach and underbalanced horizontal wells, new drilling tools, new logging and completion methods, seismic sequence stratigraphy, petroleum systems analysis and detailed reservoir studies. These techniques have improved success rates for wildcats, development wells and have added reserves in old fields. Many new oil and gas discoveries will be made throughout the world in the next few decades. Deep-water discoveries in new areas will undoubtedly be found. Unfortunately, no new giant oil provinces have been found since the North Sea and offshore Mexico in the 1960's. Peak world discovery volumes occurred 35 years ago during the mid-1960's. Super giant field discoveries, greater than 5 GBO, have declined, however, four recent discoveries in Iran, Iraq and Saudi Arabia, each over 10 GBO, has increased world reserves by almost 50 GBO.

During 1998 and 1999 the petroleum industry was forced to deal with excess oil supply and low prices resulting from reduced demand from shaky economies in Asia, the Former Soviet Union and Latin America. Companies downsized, restructured, merged, and cut budgets. Reserve replacement has declined for many companies because of declining production in old fields, sale of marginal production, plugging of stripper wells, record low drilling rates, and low discovery rates.

Fortunately oil prices recovered during 1999, due to production cuts by OPEC, Norway and Mexico. Reduced production by OPEC and prices over $20 per barrel are supposed to last until March 2000. This price rise has stimulated upstream activity, although many companies apparently intend to maintain their economic yardstick of profitable Exploration and Production operations at $10 to $12 per barrel. Excess OPEC productive capacity overhanging the market should hold the price of crude oil at or below $20 during the near future.

UNITED STATES PETROLEUM DURING THE 1990's

United States annual crude oil production from 1990 to 1999 decreased from 2.7 to 2.3 GBO, while annual natural gas liquids (NGL) production remained flat at about 0.8 GBO. Total United States liquid production has decreased from 3.43 GBO to 3.05 GBO from 1990 to 1999. (Degolyer and MacNaughton, 1998) (Figure 2). Imports of crude oil and products, on the other hand, have increased from 2.9 GBO to 3.8 GBO per year during this past decade. Total United States oil consumption increased from 6.35 to 6.83 GBO per year from 1990 to 1999 (Figures 3). United States reserves of crude oil and NGL have declined from 34 GBO in 1990 to 30.5 GBO in 1999. During this period crude oil reserves dropped from 26 GBO to

22.5 GBO while NGL reserves remained at about 0.8 GBO (Figure 4). Reserve growth in existing fields has become the dominant component of reserve additions in the United States and is likely to remain so in the future (Klett, Ahlbrandt, Schmoker, and Dolton 1997).

WORLD ULTIMATE LIQUID PRODUCTION

World ultimate liquid recovery is estimated to be 3640 GBO (Table 6, Case A). The ultimate could be only about 2200 GBO to 2700 GBO according to Campbell 1999 and Laherrere 1999 (Table 6, Case B). The ultimate liquid recovery of Case A consists of 812 GBO cumulative crude oil production, 1035 GBO crude oil reserves, 583 GBO future oil discoveries and oil field growth, 75 GBNGL cumulative production, 100 GBNGL reserves, 100 GBNGL future discoveries and field growth, 570 GBO of unconventional oil, and an optimistic 365 GBO from gas to liquid (GTL) conversion. GTL conversion is estimated optimistically at 20% of world gas reserves and future discoveries (10,936 TCF=1823 GBOE) (20% of 1823 GBOE = 365 GBOE) (Masters 1991, Masters 1997, OGJ, 1998, Table 6). Mean values of undiscovered oil and gas are used. Unconventional oil resources are 270 GBO of Eastern Venezuelan heavy oil and 300 GBO of Western Canadian tar sand oil (Kahn, 1998, Meyer and DeWitt 1990). Notice that neither liquid from oil shale nor coal to liquid conversion is counted.

If the projection of 3640 GBO ultimate production and the demand growth rate are correct, the peak plateau of oil productive capacity will be reached from 2020 to 2030 at about 38 GBO per year which is 104 million barrels per day (Edwards, 2000, Figure 5). If the world ultimate is only 2200 GBO to 2700 GBO, peak oil production will occur by 2010 at about 33 GBO per year, which is 90 million barrels per day (Campbell, 1999, Laherrere, 1999).

UNITED STATES ULTIMATE LIQUID PRODUCTION

United States ultimate liquid petroleum recovery is estimated to be 454 GBO. This consists of cumulative crude oil production of 178 GBO, reserves of 22.5 GBO, future crude oil discoveries and field growth of 140 GBO, NGL cumulative production of 35 GBO, NGL reserves of 8 GBO, NGL future discoveries and field growth of 30 GBO (Minerals Management Service, 1996, United States Geological Survey, 1995, Masters, 1997, Degolyer and MacNaughton 1998). An optimistic 40 GBO from gas to liquid (GTL) conversion has been added. This is 20% of United States gas reserves and estimated future gas discoveries (20% of 1205 TCF/6000= 200 GBOE; 0.20 x 200 GBOE= 40 GBO) (Gas Research Institute, 1999, Potential Gas Committee, 1998) (Table 7).

Future oil discoveries are estimated to be 45.6 GBO offshore and 30.3 GBO onshore. Future field growth is estimated to be 60 GBO onshore and 4.1 GBO offshore (Minerals Management Service, 1996; United States Geological Survey, 1995, Masters, 1997). If United States oil consumption continues to grow at 1.5% per year demand could rise to almost 9 GBO per year from 2020 to 2030, which is about 25 MBO per day. Total United States liquid production in 2030 could still be near 3 GBO per year, which is about 8 MBO per day. To supply the total United States demand in 2030 imports of 6 GBO per year will be required which is just over 16 MBO per day (Figure 6).

PEAK PLATEAU OF WORLD LIQUID PRODUCTION

Why should we be concerned about the near term peak of world oil production? The problem is not if, but when, peak world oil productive capacity will occur. There is a strong probability that peak world oil production will be reached during the first quarter of the 21st century. Peak oil production will most likely be reached between 2010 and 2030 (Table 8). The peak plateau of oil production would be suppressed and occur earlier in time if the future discovery rate is low or capital is not available to develop new production capacity. An energy supply gap could develop at that time.

Each of the 17 authors on Table 8 has made estimates of ultimate economically recoverable oil, and the year of peak oil production. These calculations have been made repeatedly in the past and will be made many times in the future. Past projections have been too low and too short. The scenarios presented here may also be inaccurate, but have credibility based upon reasonable present estimates of reserves, future oil discoveries and demand growth. Even with the addition of one trillion barrels of oil reserves above 3640 GBO, peak oil production would be extended for only about ten years (Bartlett 2000).

Oil and gas reserves will be generated from new discoveries, improved recovery technologies and huge unconventional resources, the limits of which are unknown. These include bitumen, heavy oil, oil sands, coal bed methane, deep basin gas, biomass, and possibly oil shales and gas hydrates. Oil will be more expensive as supplies diminish. However, oil will be available throughout the 21st century for high value uses such as petrochemicals and air transportation.

Some authors believe that there is no threat of an oil shortage in the foreseeable future. Price rises will generate new production. They believe that market forces, new technologies and adequate resources will insure the growth of supply to meet rising demand. (Fisher, 1991, Alelman and Lynch, 1997, Linden, 1998, McCabe, 1998, Lynch, 1999). A balanced discussion of the differing opinions of economists and geologists concerning ultimate oil reserves is presented in Riva, 1999.

Fossil fuels are exhaustible resource. The amount of oil, gas and coal that nature has formed during the past 500 million years is huge and unknown. All the oil and gas that exists in the earth will never be totally extracted just as the last ton of coal in deep, thin seams will never be mined. The United States Geological Survey estimates of world recoverable hydrocarbon resources have continued to increase as time dependent perception limits recede. (Schmoker, Dyman, 1998). The total amount of oil ultimately produced will depend upon the validity of present reserves, recovery efficiency from existing fields, quantities and qualities of future discoveries, new technologies, competition from alternate energy sources and energy demand and price changes over time.

Near the end of the 21st century, as both oil and gas production decline, oil and gas will be produced from lean, remote and expensive resources to extend production into the 22nd century. These bottom of the barrel reserves will be used only for the highest value products (PETROCHEMICALS). None of the renewable energy sources can provide all of these products.

FOSSIL FUELS CHALLENGES (Oil, Gas and Coal)

Fossil fuels produce 85% of world energy but are facing political and environmental constraints because of their polluting emissions. The energy industry needs to meet the clean fuel challenge (Bowlin, 1999). Competitive renewable non-polluting energy sources will ultimately replace fossil fuels.

Oil

Oil is the most valuable and most used fuel in the world today. Oil provides 40% of world and United States energy supply (Table 1). Oil with its high energy density, ease of transport and storage, today has no comprehensive substitute. The world will remain critically dependent on oil well into the 21st century. It is impossible to imagine anything but a continued increase in the demand for oil (Robinson, 1998).

The United States Geological Survey (USGS), in its ranking of world petroleum provinces, has identified 406 petroleum-bearing provinces among the world total of 954 geological provinces. Exclusive of the United States, 76 provinces with the largest petroleum volumes contain 95% of the worlds known petroleum. Future discoveries are likely to come from these same provinces (Klett et al, 1997).

The price of oil will rise as the approach of peak oil production is recognized. Even with new discoveries, conservation and improved efficiency of use demand for oil will increase beyond the capacity of petroleum supplies. Peak liquid petroleum production can be extended by increased use of natural gas, coal and increased production from unconventional oil resources. These are Eastern Venezuelan heavy oil deposits, estimated to contain 270 GBO recoverable from an in-place resource of 1200 GBO and Western Canadian tar sands, estimated to have 300 GBO recoverable from an in place resource of 1686 GBO (Masters, 1991, Meyer, 1987, Meyer and Dewitt, 1990, Kahn, 1998). Even United States and other world tar sands and oil shales may produce oil during the 21st century.

Natural Gas

World resources of natural gas are under-recognized and under-utilized. The ratio of known oil fields to gas fields is about 2 to 1, which probably does not represent the natural endowment of gas to oil (Klett et al, 1997). World future gas resources are estimated to be only 10,936 trillion cubic feet (TCF) (Table 6). United States future gas resources are estimated to be only 1205 TCF, (Table 7). (Masters, 1997, Potential Gas Committee, 1998). The United States estimate includes 167 TCF reserves, 896 TCF future discoveries and 141 TCF coal bed methane (CBM). Future discovery estimates for gas are probably very low because natural gas will be aggressively searched for, discovered and developed in the 21st century.

Enormous resources of natural gas are locked in methane hydrates in the deep oceans and arctic tundra. As much as 100,000 TCF is estimated to be trapped in subsea hydrates (Finley and Krason, 1989, Krason 1994, Haq, 1998). If only a few percent of this is ever commercially extractable it could extend the life of natural gas supplies for decades.

The infrastructure for worldwide distribution of natural gas and liquid natural gas (LNG) will expand and help fill the energy gap. Gas exploration and production are expected to expand rapidly as new distribution systems and markets are developed (True, 1999). Projects are planned or in progress to move stranded gas to available markets by pipeline or LNG tankers from NW Australia, Papua New Guinea, Indonesia, Malaysia, Vietnam, Kazakhstan, Oman, Abu Dhabi, Qatar, Iraq, Iran, Algeria, Nigeria, Trinidad, Columbia, Peru, Bolivia, and Argentina. Gas will reach markets as an economically competitive, preferred clean fuel.

Increasing environmental concerns will help natural gas become the electrical industry most important fuel (Otto ET al, 1999). Natural gas fired combined-cycle gas turbine and cogeneration gas-electric power plants are increasing the demand for gas throughout the world. Natural gas will also be fuel to operate fuel cells for automotive power. In the United States today alternative fuels account for only 0.2% of total transportation fuel consumption (Chang, 1999). In the near future, fuel cells energized by natural gas to hydrogen technology could power an increasing percentage of automotive transport and supply selected commercial and residential electricity (Bensabat, 1999, Chang, 1999, Fouda, 1998). Hydrogen is the ultimate non-polluting, renewable and sustainable fuel of the future (Hefner, 1999).

Gas to liquid (GTL) and possibly coal to liquid technologies will extend the life of the internal combustion engine for transportation use and help continue to supply petrochemical feedstocks (Fouda, 1998). ARCO-Syntroleum (Oil and Gas Journal, 1999b) and Chevron- Sasol (Matske, 1999) have begun GTL pilot projects. Chevron Overseas President Matzke said “Gas to liquid technology is so promising that its development could create an entire paradigm shift throughout the petroleum industry.”

Coal

World coal production of over three billion tons supplies 25% of the annual world energy demand and 37% of world electricity. United States coals production of over one billion tons supplies 22% of energy demand and 57% of electricity. World demand for electricity is increasing 5% per year (International Energy Agency, 1999). Coal, the lowest cost fossil fuel, is abundant and widely distributed. It will therefore continue to supply much of the world's expanding electricity demand in the 21st century.

Coal, however, is the most polluting of the fossil fuels. It is blamed for environmental damage, health problems and elevating the earth's surface temperature. China, the world's largest user of coal which supplies 70% of its energy, is projected to become the largest emitter of greenhouse gases by 2015 (Ebel, 1998). China already has nine of the world's ten most polluted cities (Dunn, 1999). China has 85 of 88 major cities that exceed World Health Organization air quality guidelines for particulates and half exceed the sulfur dioxide guidelines (Robinson 1998). In 1994 China became a net oil importer (Tempest, 1998). These circumstances caused China to expand coal production but restrict combustion of high sulfur coals.

Coal will continue to supply electricity in Asia-Pacific countries particularly in China and India (International Energy Agency, 1999). Near term reduction of emissions from world coal fired power plants is very unlikely even though clean coal technology is starting to be used in developing countries. However, where natural gas is abundantly available, as in Europe, electric power plants are converting from coal to gas thus reducing emissions.

RENEWABLE NON-POLLUTING ENERGY SOURCES

International consensus, by the 1997 Kyoto Protocol, supports the development of renewable non-polluting energy sources to replace the combustion of fossil fuels. The goal is to reduce emissions of greenhouse gases to 1990 levels and thus avoid the possibility of climate change and global warming. Opportunities for reduction of carbon dioxide emissions and sequestration are being pursued. But significant reduction of carbon emissions by substitute fuels for petroleum-fueled vehicles and coal fired electric power plants is very unlikely (Flannery, 1999). In fact some climate scientists now recognize that meeting the Kyoto accord will not significantly reduce the potential increase of the earth's surface temperature in the 21st century. They are recommending that society find ways to adapt to a warmer world (Science News, 1999).

Air and water pollution can be overcome by switching to alternative energy sources that replace fossil fuels. Conversion from fossil fuels to renewable, non-polluting energy sources will be the final solution to eliminate carbon dioxide, sulfur dioxide and nitrous oxides from the atmosphere.

Renewable non-polluting energy during the next century will come from solar thermal hydrogen generation, solar thermal electric, photovoltaic, hydroelectric, geothermal, wind and biomass. Commercialization and implementation of the technologies required for these renewable, non-polluting energy sources take time. Time is one of our most limited resources. Renewable energy sources will fail if their enabling technologies do not improve to ensure affordability and convenience of use (Crow, 1998).

Both BP-Amoco and Royal Dutch Shell have purchased solar power companies and are entering the photovoltaic (PV) cell market. BP, by its recent purchase of Solarex, expects to have a one billion-dollar PV business by 2010 with 20% of the world market (Oil and Gas Journal, 1999a). Shell International Renewables is investing $500 million in the next five years in solar, biomass projects and forestry. Shell International Gas and Enron are investing in gas fired electric power plants. Both BP and Shell support sustainable development, which takes into account economic, environmental and social considerations (BP-Amoco 1998, van der Veer, 1997).

A negative view of nuclear power's future is presented in a World Watch Paper (Flavin, and Lenseen, 1999). Nuclear power may plateau in the near future but its expansion will be needed before 2050.

Modular, fail safe, economically competitive nuclear electric power plants, with zero emissions, can be built to replace coal-fired power plants. The nuclear waste disposal problem must be solved. If nuclear power, the largest non-carbon energy source continues to be discouraged in the developed countries, coal, natural gas and renewable energy sources must increase to supply expanding world electrical energy demand.

SUSTAINABLE ENERGY SUPPLY

The incremental environmental impact of human activities will continue to concern both governments and industries. Demand growth for all resources will exponentially expand the volume of waste that the earth, oceans and atmosphere must absorb (Foster and Wise, 1999). These concerns encompass the quality of air, water, land, natural resources, and wildlife. The explosion of communications technology has opened the flow of information, fostered the globalization of industry and increased the quality of life expectations in the developing world. It is also causing demand for more equitable distribution of resources. These events have put greater demands on both governments and businesses for improved performance and accountability.

Unrestrained growth of both population and industry is occurring in the developing world. The pursuit of competitive advantage to the exclusion of environmental and social considerations by many governments and some international companies along with continued self-indulgent consumption in developed countries is not conducive to the establishment of a future sustainable world economy, environment and society (Robinson, 1998). The bottom line of 21st century business must be to help society achieve three interlocked goals; economic prosperity, environmental protection and societal equity (Elkington, 1998). To achieve these goals will require the collective international attention of both governments and industries.

CONCLUSIONS

The energy scenario presented here is not a forecast. However, it presents a plausible, sustainable world energy supply for the 21st century. In the next few years, three main themes appear to be obvious. We should increase efficiency of energy use, clean up the energy we are using and continue to search for cleaner forms of energy (Robinson, 1998).

World oil production will increase to a peak plateau by 2030 then decline during the rest of the 21st century. Natural gas and clean coal energy can help fill the energy gap created by declining oil production. Renewable, non-polluting energy sources must expand to replace fossil fuels and supply the world's continuously increasing energy demand. The transition to renewable energy sources will create a sustainable energy supply that is environmentally benign.

Research and development efforts should begin now to accelerate the transition to renewable, non-polluting energy sources. A sustainable future world energy supply is a must. Oil and gas reserves must be preserved for future production of petroleum's highest value products, petrochemicals. No renewable energy source can provide all these chemicals. Future generations will question why we burned almost all of this valuable nonrenewable hydrocarbon resource.

The unknowns are daunting. The changes we can anticipate are awesome. Pericles in 428 BC said, "The key is not to predict the future, but to be prepared for it." Future changes are complex, risky and threatening but offer challenges and opportunities. Sir Winston Churchill admonished that worrying should translate into advanced planning. We must plan ahead for the transition to renewable, non-polluting energy sources in the 21st century.

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UNITED STATES AND WORLD ENERGY CONSUMPTION BY SOURCE 1998

ENERGY SOURCE	UNITED STATES BBOE	UNITED STATES %	WORLD BBOE	WORLD %
PETROLEUM	6.8	40	27.1	40
NATURAL GAS	4.2	23	14.4	21.2
COAL	3.9	22	16.7	24.7
NUCLEAR	1.3	7.4	4.5	6.7
HYDROELECTRIC	0.73	4.1	1.6	2.4
BIOMASS	0.67	3.5	3.4	5
TOTAL	17.6	100	69.3	100

BP 98, OGJ 99, EIA 98
World Resources 92

Table 1

TWENTIETH CENTURY
WORLD POPULATION GROWTH

1930	1960	1975	1987	1999
2nd BILLION	3rd BILLION	4th BILLION	5th BILLION	6th BILLION
130 Years	30 Years	15 Years	12 Years	12 Years
1.5GBO*	7.1GBO*	20.4GBO*	20.4GBO*	24.3GBO*
0.75BO**	2.37BO**	5.1BO**	4.08BO**	4.05BO**

*** Prod.per Year**
**** Consumption Per Capita per Year**

Table 2

Pop. Ref. Bur. 99
Degolyer-MacNaughton 92, 98

WORLD POPULATION DATA

DEVELOPED COUNTRIES	MID-1999 MILLIONS	POPULATION % GROWTH
UNITED STATES	272	0.6
CANADA	31	0.4
EUROPE	728	-0.1
JAPAN	127	0.2
AUSTRALIA	18	0.7
NEW ZEALAND	4	0.8
TOTAL DEVELOPED	1180	0.1
DEVELOPING COUNTRIES		
CENT. AM. CARIB.	172	1.7
SOUTH AMERICA	339	1.7
AFRICA	771	2.5
ASIA	1396	1.5
CHINA	1254	1
INDIA	987	1.9
TOTAL DEVELOPING	4802	1.7
TOTAL WORLD	5982	1.4
WORLD Oct. 12, 1999	6000	

TABLE 3

POP. REF. BUR., INC
WORLD POP. DATA SHEET, MID-1999

WORLD CRUDE OIL
PRODUCTION VS DEMAND

BILLION BARRELS PER YEAR

REGION	PRODUCTION Mid 1999		DEMAND 1998	
DEVELOPED COUNTRIES				
US- CAN.	2.83		7.36	
WESTERN EUR.	2.32		5 00	
EASTERN EUR.	2.65		2.08	
JAPAN	0.005		2.15	
AUSTRALIA NZ.	0.19		0.34	
DEVELOPING COUNTRIES				
AFRICA	2.43		0.88	
LATIN AM.	3.43		2.09	
ASIA	2.38		4.34	
MIDDLE EAST	7.79		1.77	
TOTAL WORLD	24.03		26.01	
DEVELOPED	8.00	33%	16.93	65%
DEVELOPING	16.03	67%	9.08	35%
OPEC	10.14	42%	1.97	7.6%

Table 4

Degolyer-MacNaughton, 1998, OGJ, 1999

WORLD POPULATION
OIL CONSUMPTION PER CAPITA PER YEAR
MID-1999

REGION	POPULATION MILLION	OIL PER CAPITA BARRELS/YEAR
UNITED STATES	272	25
CANADA	31	22
W EUROPE	385	13
E EUROPE	343	5
JAPAN	127	17
AUST-NZ	23	16
AFRICA*	771	1.2
LAT.AM*	512	3.7
ASIA*	3351	2.1
MID-EAST*	167	8.2
OPEC*	386	5.1
DEVELOPED	1180	14.3
DEVELOPING*	4802	1.9
TOTAL WORLD	5982	4
October 12,1999	6000	4

Table 5

POP. REF. BUR., 1999
Degolyer-MacNaughton, 1998

ESTIMATED ULTIMATE WORLD LIQUID PETROLEUM

BILLION BARRELS OIL EQUIVALENT

JAN. 1999

CONVENTIONAL OIL		**Case A**	**Case B**
Crude Cum. Prod.		812	816
NGL Cum. Prod.		75	75
Crude Reserves		1035	821
NGL Reserves		100	150
FUTURE DISCOVERIES and FIELD GROWTH			
Crude Oil		583	163
NGL		100	25
UNCONVENTIONAL OIL			135
Venezuelan Heavy Oil		270	
Canadian Tar Sand Oil		300	
Coal Oil (not counted)		???	
Shale Oil (not counted)		???	
ULTIMATE LIQUID OIL PRODUCTION		3275 GBO	2185 GBO
WORLD NATURAL GAS			
Cum. Prod.	2200 TCF	366 BBOE	
Reserves	5145 TCF	858 BBOE	
Future Disc.	5791 TCF	965 BBOE	
Future Total gas	10,936 TCF	1823 BBOE	
NATURAL GAS TO LIQUID CONVERSION			
20% of future gas = 20% of 1823 BBOE =		365 GBOE	
ULTIMATE LIQUID PETROLEUM		3640 GBOE	2185 GBO
3275 GBO + 365 BBOE = 3640 GBO			2700 GBO*
FUTURE LIQUID PETROLEUM		2753 GBOE	1294 GBO
3640 GBO - (812+75) = 2753 GBO			

Table 6

Degolyer-MacNaughton 1998, OGJ 1998
Pot. Gas Com. 1998, Masters, 1998,Campbell, ,1999
Laherrere,1999*

ESTIMATED ULTIMATE
UNITED STATES
LIQUID PETROLEUM

BILLION BARRELS OIL EQUIVALENT

JAN. 1999

CONVENTIONAL OIL			
Crude Cum. Prod.			178
Crude Reserves			22.5
NGL Cum. Prod.			35
NGL Reserves			8
FUTURE DISCOVERIES and FIELD GROWTH			
Crude Oil			140
NGL			30
ULTIMATE OIL PRODUCTION			414 GBO
UNITED STATES NATURAL GAS			
Cum. Prod.	840	TCF	140 BBOE
Reserves	167	TCF	28 BBOE
Future Disc.	1038	TCF	173 BBOE
Ultimate Recovery	2045	TCF	341 BBOE
Future Total Gas	1205	TCF	200 BBOE
NATURAL GAS TO LIQUID CONVERSION			
20% of Future Gas is 20% of 200 BBOE=			40 BBOE
ULTIMATE LIQUID PETROLEUM			454 GBOE
414 GBO + 40 BBOE = 454 GBO			
FUTURE LIQUID PETROLEUM			241 GBOE
454 BGO - 178+35 Cum. Prod.= 241GBO			

Table 7

Degolyer-MacNaughton 1998, OGJ 1998, MMS 1997, Pot.Gas Com. 1998

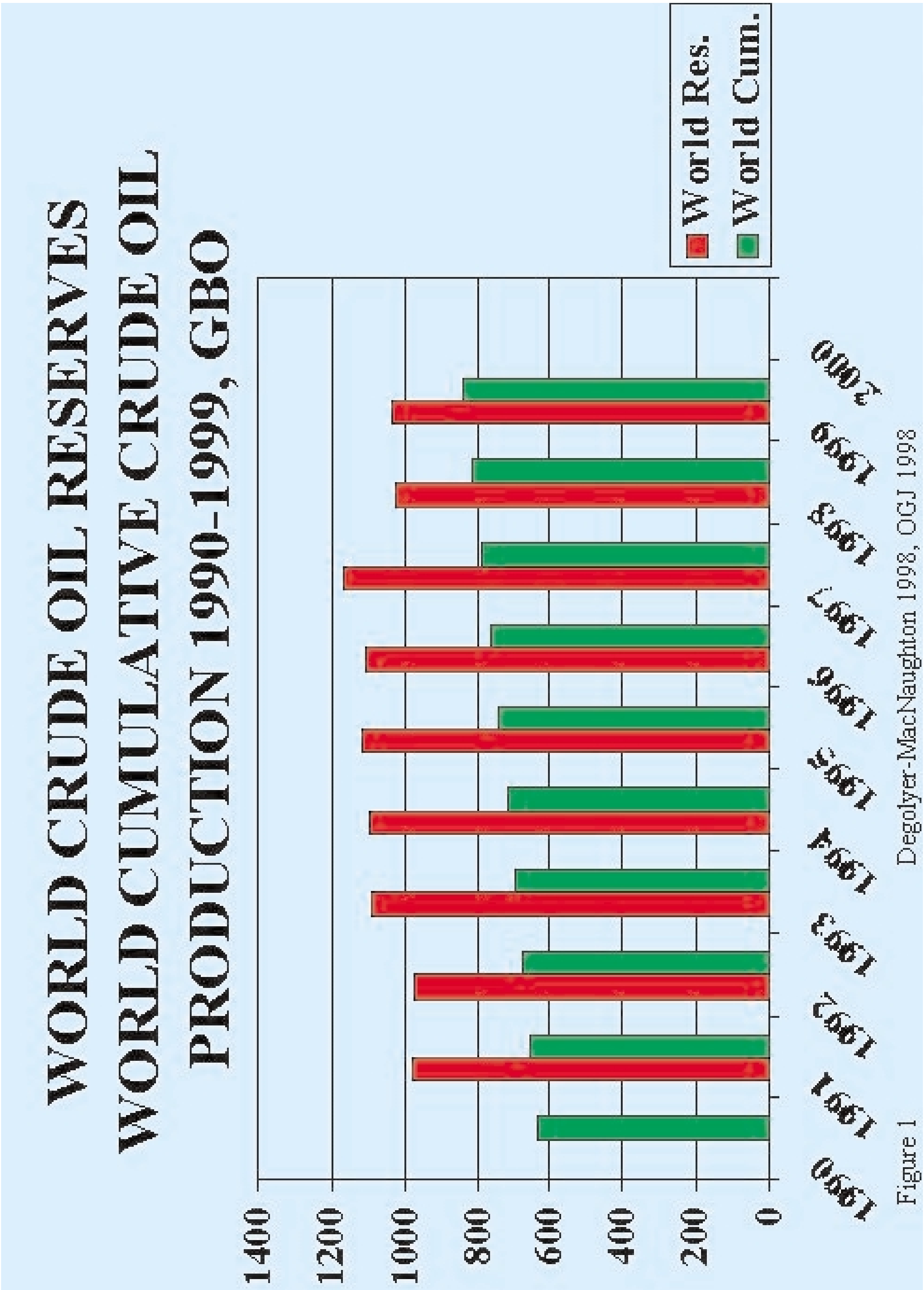
PEAK YEAR of WORLD CRUDE OIL PRODUCTION
ESTIMATED ULTIMATE RECOVERY
BILLION BARRELS

Author	Company	Year	Est. Ult.	Peak Year
Hubbert	Shell	1969	2100	2000
Moody	Cons.	1978	3200	2004
Odell	Delft	1983	3000	2025
Bookout	Shell	1989	2000	2010
Townes	AAPG	1993	3000	2010
Cambell	Cons.	1994	1650	1997
Laherrere	Cons.	1994	1750	2000
MacKenzie	W.Res.Inst.	1996	2600	2007-2019
Applebey	BP	1996		2010
Ivanhoe	Cons.	1996		2010
VanderVeer	Shell	1997		2020
Edwards	Univ.CO.	1997	2836	2020
Bernabey	ENI	1998		2000-2005
Schollnberger	Amoco	1998		2015-2035*
Duncan & Youngquist		1998		2006
IEA	OECD	1998	2800	2010-2020**
EIA	DOE	1998	4700	2030**
Laherrere	Cons.	1999	2700	2010**
Edwards	Univ.CO.	1999	3600	2020-2030**

*Oil&Gas **Total Liquids (Crude&Heavy Oil, Tar Sd Oil, GTL)

See References Cited

Table 8


WORLD CRUDE OIL RESERVES
WORLD CUMULATIVE CRUDE OIL
PRODUCTION 1990-1999, GBO
World Res.
World Cum.
1400
1200
1000
800
600
400
200
0
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Figure 1
Degolyer-MacNaughton 1998, OGJ 1998

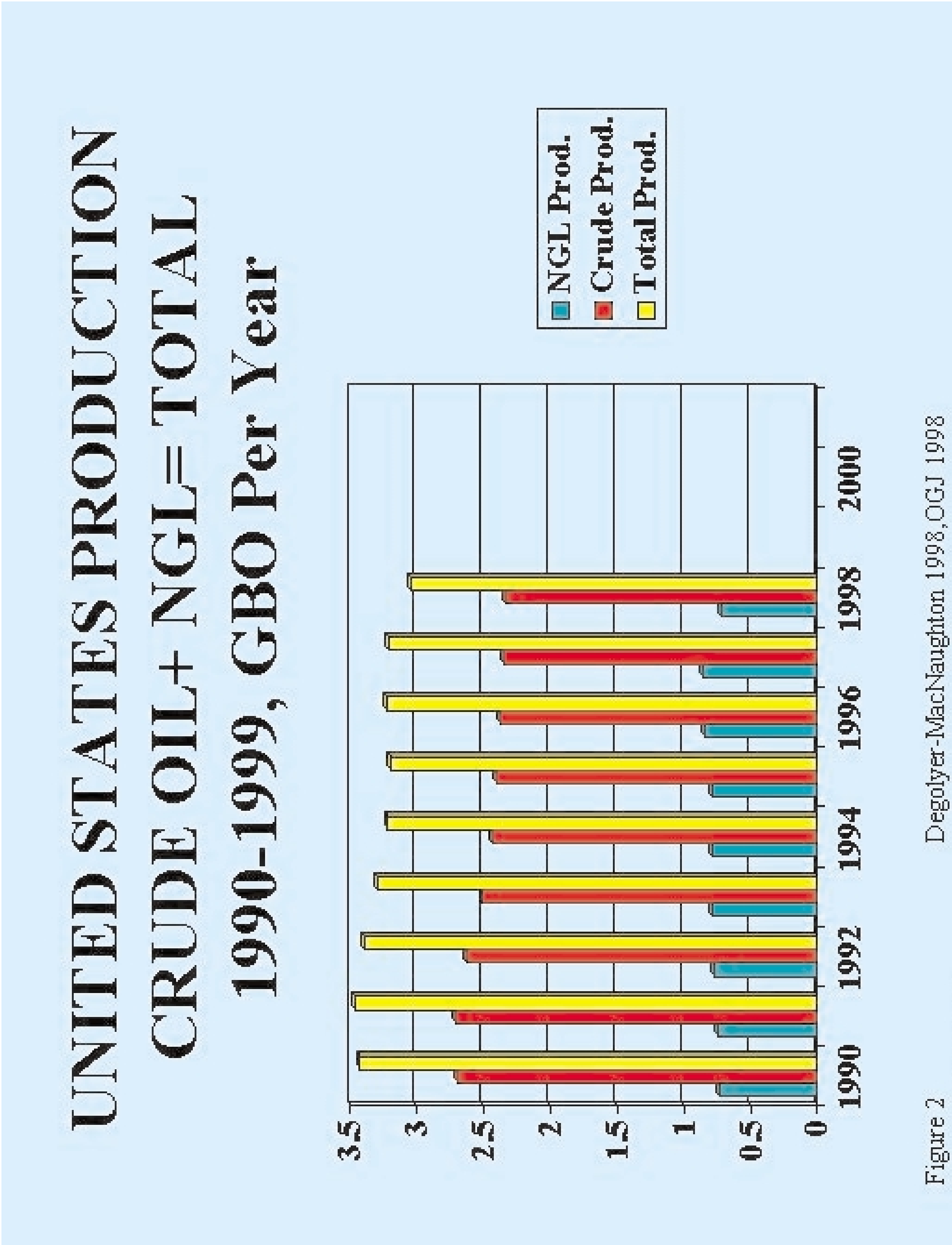
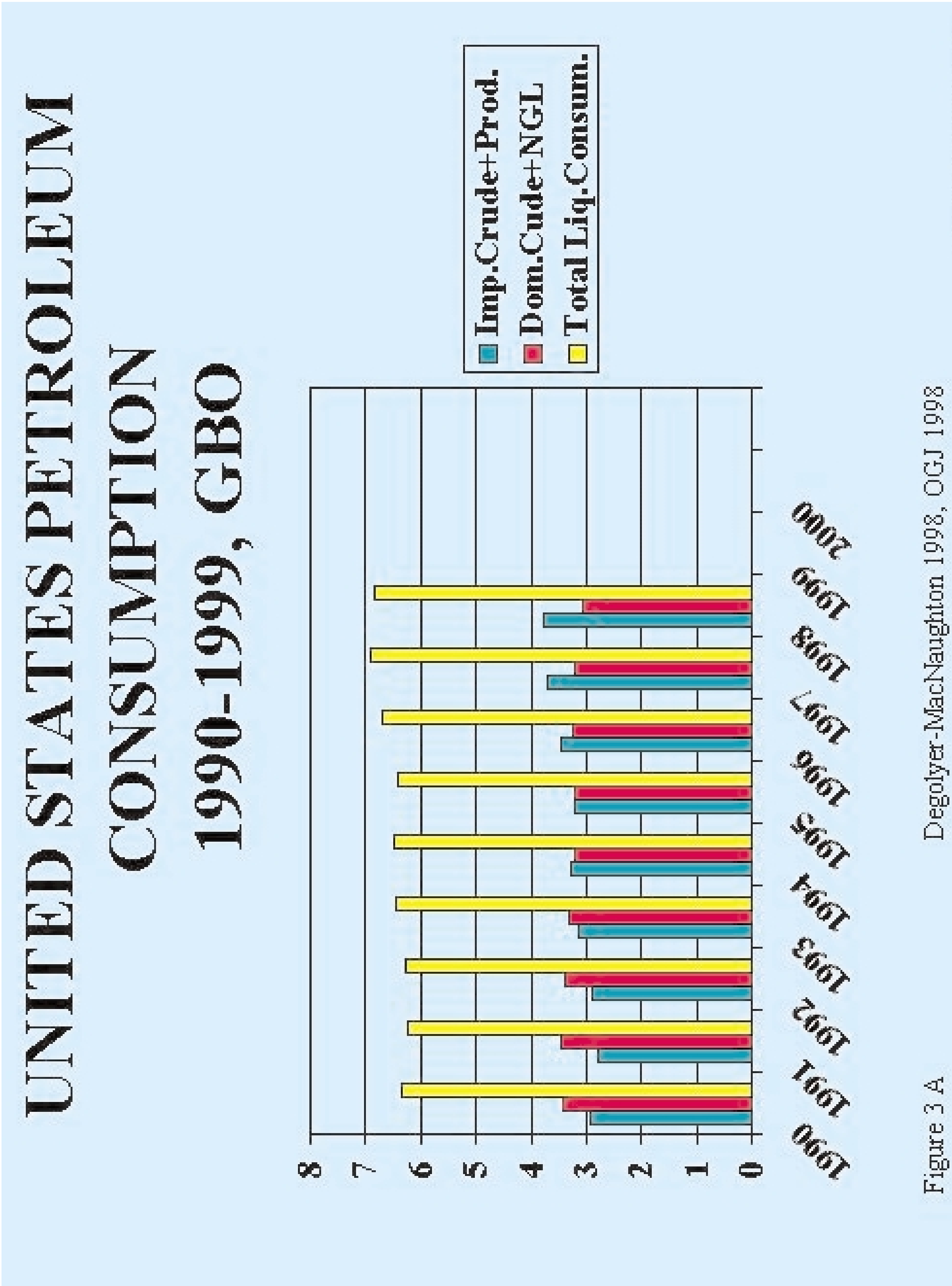
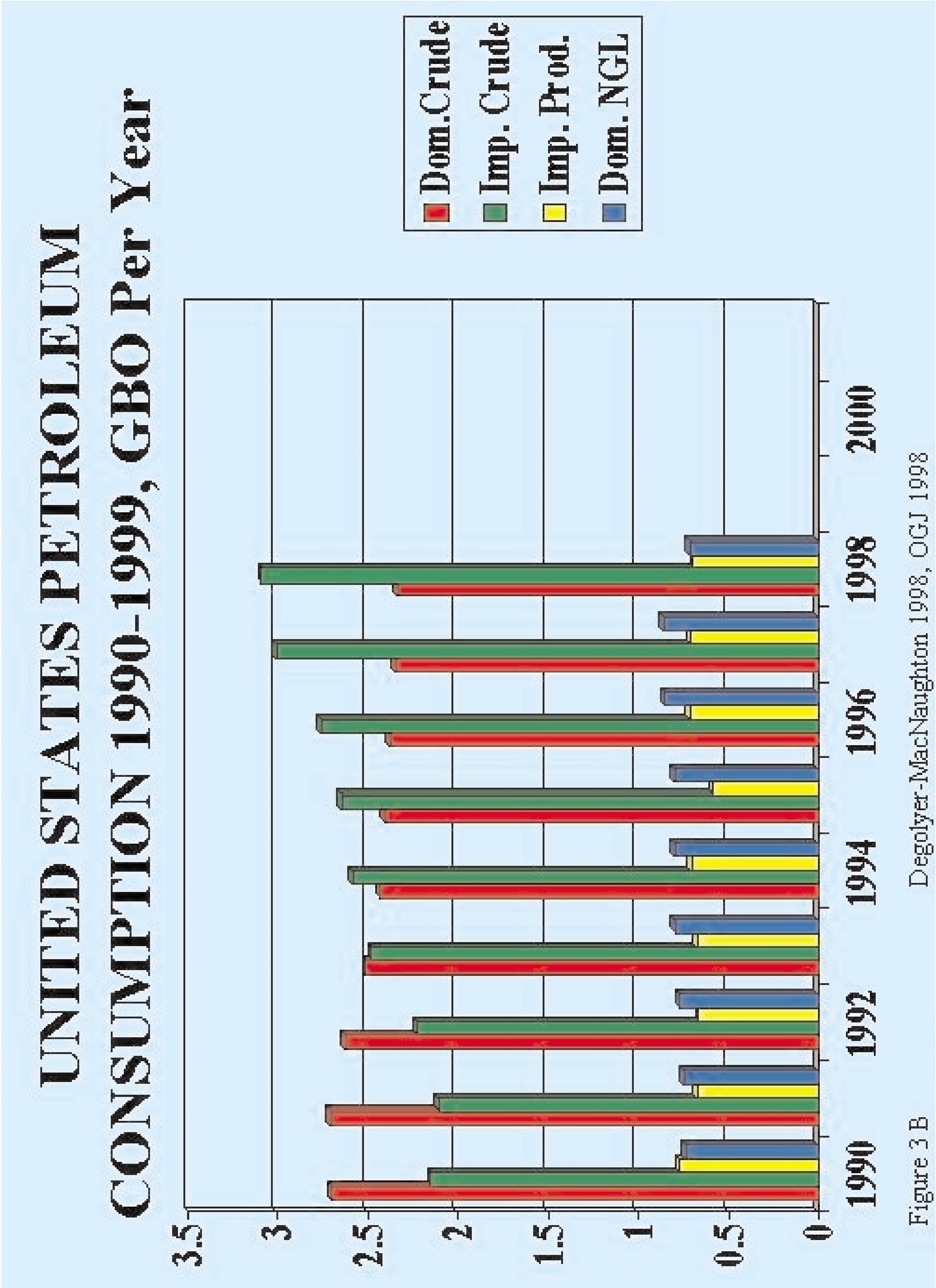
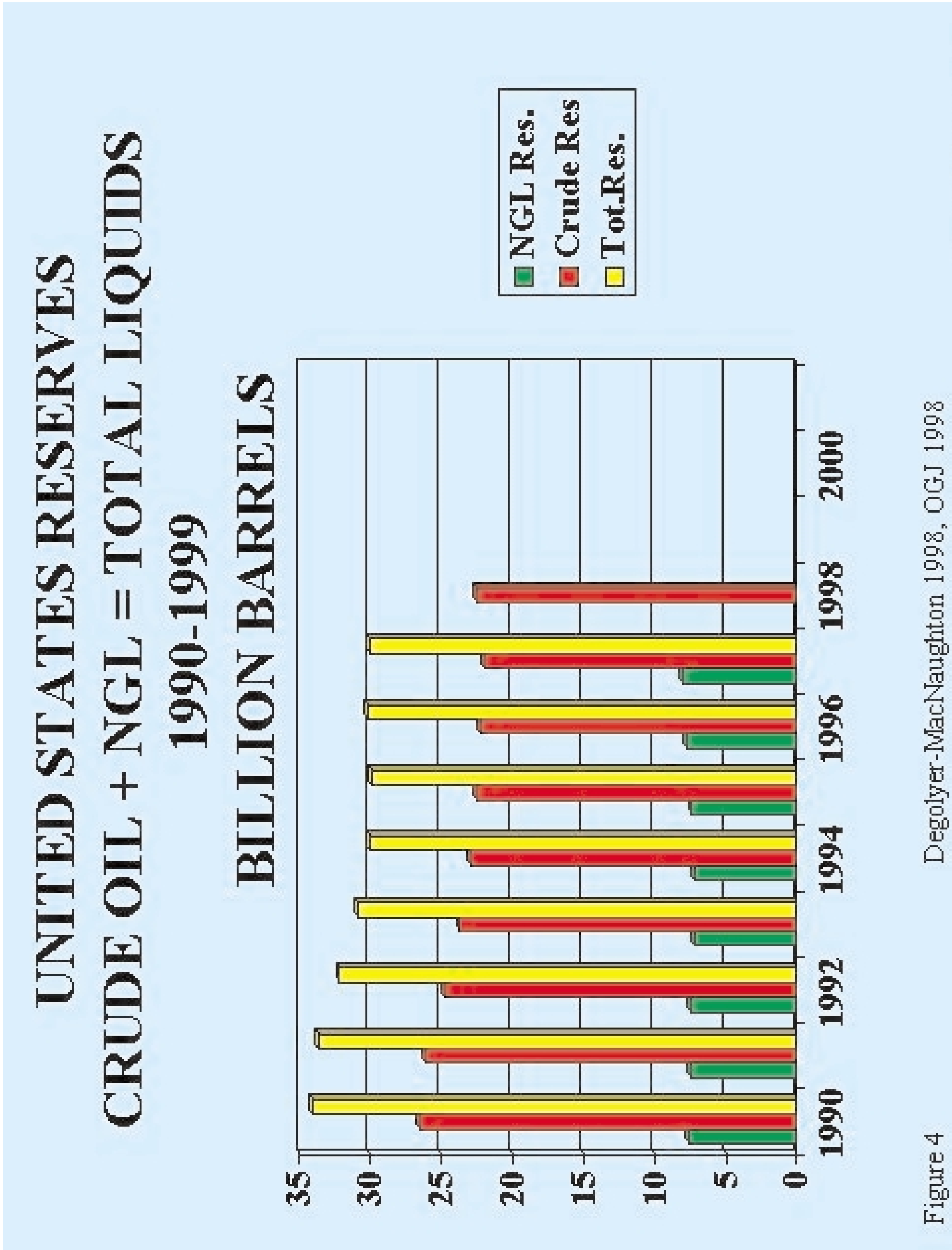

UNITED STATES PRODUCTION
CRUDE OIL+ NGL= TOTAL
1990-1999, GBO Per Year
NGL Prod.
Crude Prod.
Total Prod.
3.5
3
2.5
2
1.5
1
0.5
0
1990
1992
1994
1996
1998
2000
Degolyer-MacNaughton 1998, OGJ 1998

Figure 2


UNITED STATES PETROLEUM CONSUMPTION 1990-1999, GBO
Imp.Crude+Prod.
Dom.Cude+NGL
Total Liq.Consum.
0
1
2
3
4
5
6
7
8
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
Figure 3 A
Degolyer-MacNaughton 1998, OGJ 1998


UNITED STATES PETROLEUM
CONSUMPTION 1990-1999, GBO Per Year
Dom.Crude
Imp. Crude
Imp. Prod.
Dom. NGL
3.5
3
2.5
2
1.5
1
0.5
0
1990
1992
1994
1996
1998
2000
Figure 3 B
Degolyer-MacNaughton 1998, OGJ 1998


UNITED STATES RESERVES
CRUDE OIL + NGL = TOTAL LIQUIDS
1990-1999
BILLION BARRELS
35
30
25
20
15
10
5
0
1990
1992
1994
1996
1998
2000
NGL Res.
Crude Res
Tot.Res.
Figure 4
Degolyer-MacNaughton 1998, OGJ 1998

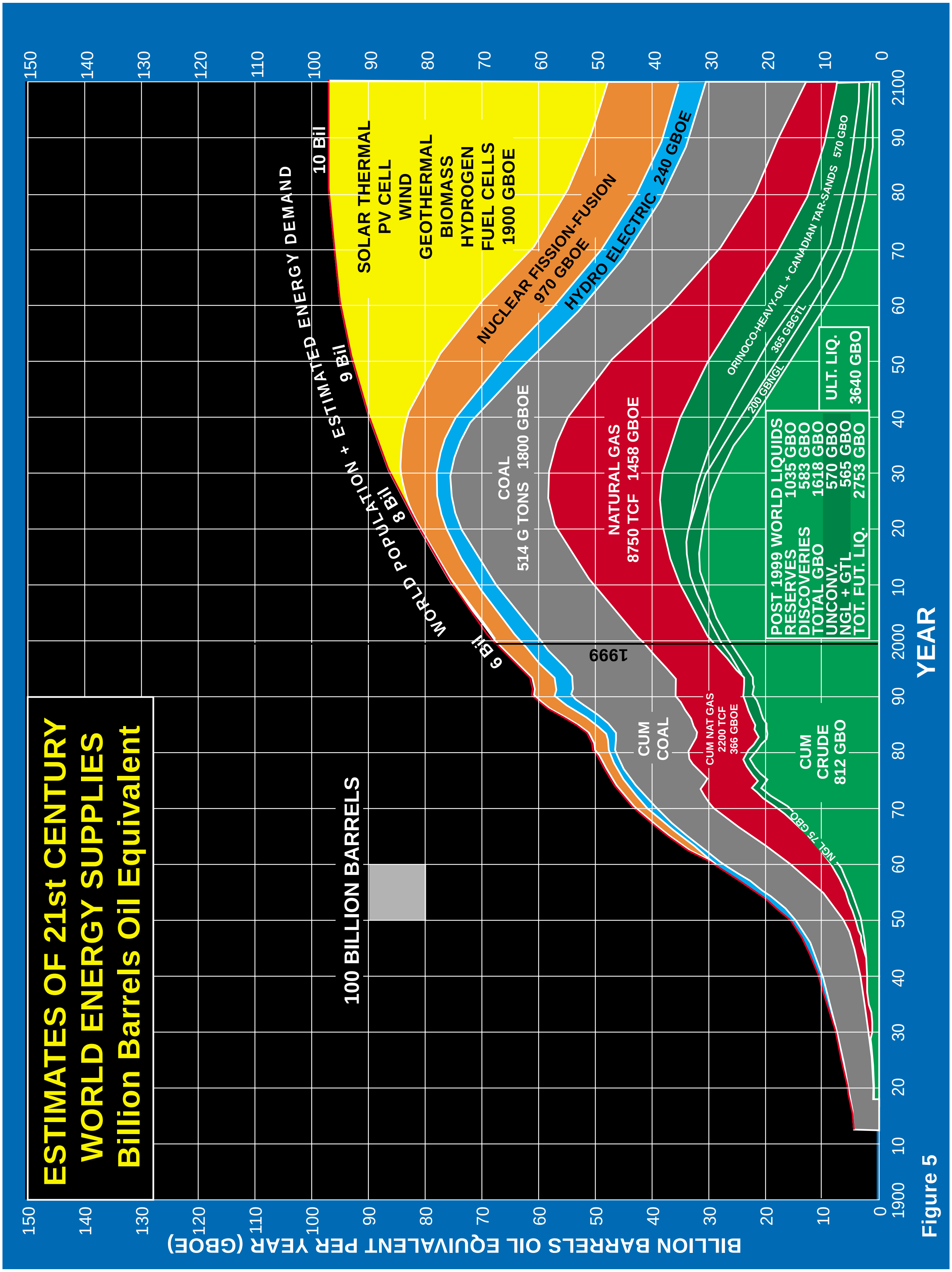

ESTIMATES OF 21st CENTURY
WORLD ENERGY SUPPLIES
Billion Barrels Oil Equivalent
100 BILLION BARRELS
BILLION BARRELS OIL EQUIVALENT PER YEAR (GBOE)
YEAR
WORLD POPULATION + ESTIMATED ENERGY DEMAND
6 Bil
8 Bil
9 Bil
10 Bil
SOLAR THERMAL
PV CELL
WIND
GEOTHERMAL
BIOMASS
HYDROGEN
FUEL CELLS
1900 GBOE
NUCLEAR FISSION-FUSION
970 GBOE
HYDRO ELECTRIC 240 GBOE
COAL
514 G TONS 1800 GBOE
NATURAL GAS
8750 TCF 1458 GBOE
CUM COAL
CUM NAT GAS
2200 TCF
366 GBOE
CUM CRUDE
812 GBO
NGL 75 GBO
1999
ORINOCO-HEAVY-OIL + CANADIAN TAR-SANDS 570 GBO
365 GBGTL
200 GBNGL
POST 1999 WORLD LIQUIDS
RESERVES 1035 GBO
DISCOVERIES 583 GBO
TOTAL GBO 1618 GBO
UNCONV. 570 GBO
NGL + GTL 565 GBO
TOT. FUT. LIQ. 2753 GBO
ULT. LIQ.
3640 GBO
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
1900
10
20
30
40
50
60
70
80
90
2000
10
20
30
40
50
60
70
80
90
2100

Figure 5

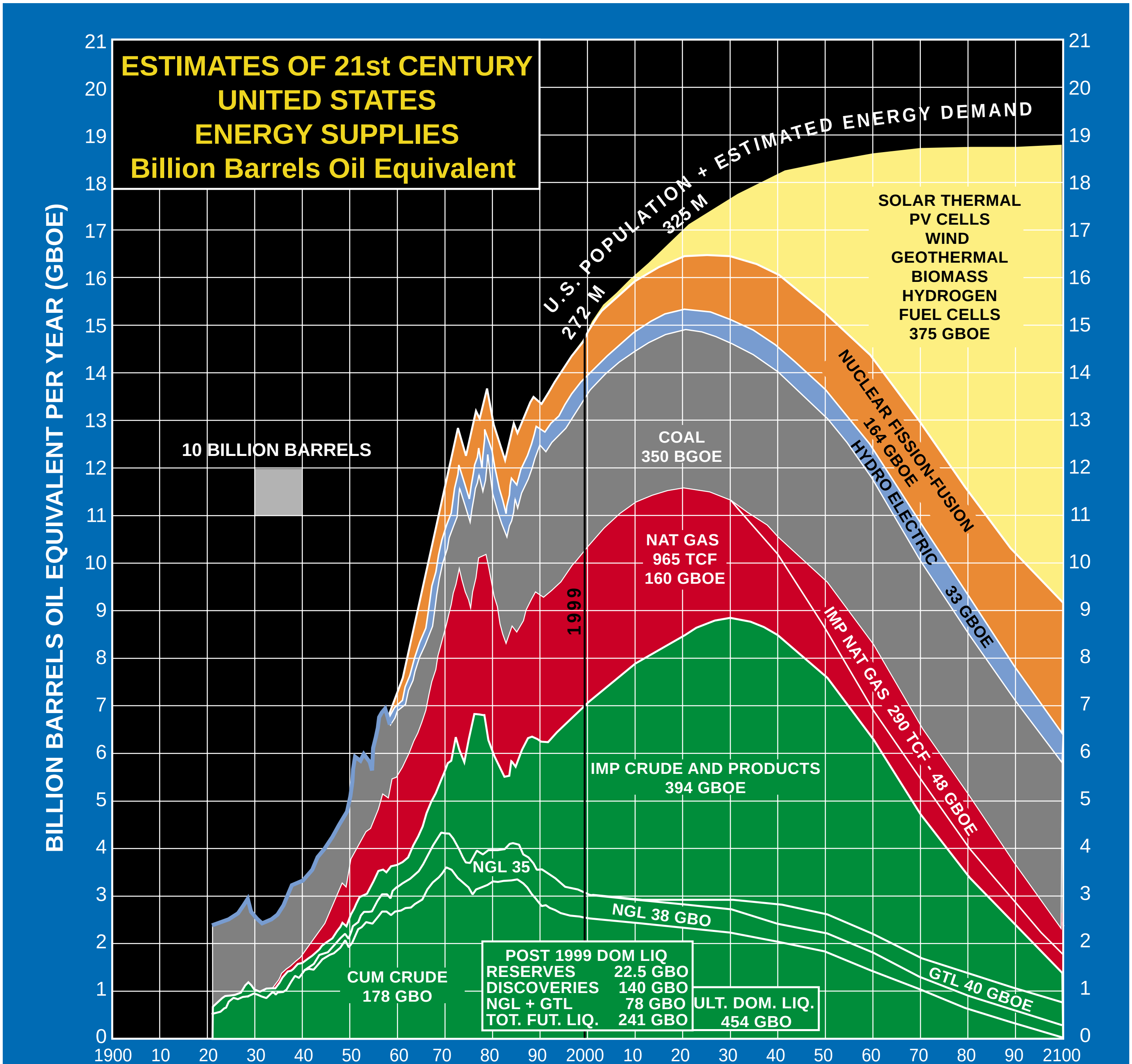

ESTIMATES OF 21st CENTURY
UNITED STATES
ENERGY SUPPLIES
Billion Barrels Oil Equivalent
BILLION BARRELS OIL EQUIVALENT PER YEAR (GBOE)
YEAR
U.S. POPULATION + ESTIMATED ENERGY DEMAND
272 M
325 M
1999
10 BILLION BARRELS
SOLAR THERMAL
PV CELLS
WIND
GEOTHERMAL
BIOMASS
HYDROGEN
FUEL CELLS
375 GBOE
NUCLEAR FISSION-FUSION
164 GBOE
HYDRO ELECTRIC
33 GBOE
COAL
350 BGOE
NAT GAS
965 TCF
160 GBOE
IMP NAT GAS 290 TCF - 48 GBOE
IMP CRUDE AND PRODUCTS
394 GBOE
NGL 35
NGL 38 GBO
GTL 40 GBOE
CUM CRUDE
178 GBO
POST 1999 DOM LIQ
RESERVES 22.5 GBO
DISCOVERIES 140 GBO
NGL + GTL 78 GBO
TOT. FUT. LIQ. 241 GBO
ULT. DOM. LIQ.
454 GBO

FIGURE 6