Projecting Energy Trends Into the New Century

OP 49 (Revised)

November 2000

Hillard G. Huntington, Stanford University
Mark Rodekohr, US Energy Information Administration

This paper is a preliminary draft of a chapter that will be published in the Encyclopedia of Life Support Systems, EOLSS Publishers Oxford, UK. Please do not cite without prior permission.

Energy Modeling Forum
406 Terman Center
Stanford University
Stanford, CA 94305-4026

Projecting Energy Trends Into the New Century[1]

Hillard G. Huntington, Energy Modeling Forum, Stanford University
Mark Rodekohr, US Energy Information Administration

November 2000

Introduction. Well before the 1973 oil price shock, analysts frequently forecasted future energy market conditions (e.g., see Putnam 1953 and Schurr and Netschert 1960). Today the U.S. Energy Information Administration (EIA) and the International Energy Agency (IEA) routinely report energy outlooks based upon evolving technology, economics, and policy assumptions. We will refer to such systems as energy-projection frameworks. In addition, many energy-based models have been recast to help analysts project long-term energy patterns and their influence on global climate change. We will refer to these systems as integrated assessment (IA) models (Weyant 1999). This article briefly discusses the more readily available and routinely produced energy projections from the first group of models and highlights their most recently available estimates. It will focus on the underlying energy trends to provide a perspective on future emissions growth but will not directly examine the environmental implications of these energy projections.

Energy-Evaluation Systems. Energy models consider fuel supplies and demands in different regions with considerable detail. Supply conditions often include resource bases, performance characteristics of key technologies, break-even or required costs, and

1 The expressed views are the authors' and are not attributable to either the Energy Modeling Forum or the U.S. Energy Information Administration. We would like to acknowledge the helpful comments of Mark Schwartz and Michael Whinihan, although responsibility for the conclusions is the authors. The energy outlooks discussed here are reported in U.S. Energy Information Administration (2000) and International Energy Agency (1998). For another interesting set of scenarios that are not discussed here, please see Nakicenovic et al (1999).

technical change. Demand conditions include economic and demographic growth, energy prices, and non-priced adjustments in an economy's aggregate energy intensity. Both technical change at the end use as well as the shift away from energy-intensive activities (e.g., the shift from metals production to information production) account for the observed, long-term trend of improving energy productivity (or declining energy intensity).

Energy models can differ in the method used for determining fuel prices, consumption, and production. Most energy-projection frameworks emphasize the demand for energy and use supply conditions informally to check on the reasonableness of their projections. However, supply conditions do not directly constrain energy demand by raising prices, at least not formally within the model. As a result, the full reporting of all fuel prices is often ignored when results are released. There are two reasons for ignoring a full supply-demand balance for determining all fuel prices. One factor is that market-clearing models have not performed well in the past, with small errors in either supply and demand conditions causing large errors in prices. These large errors occur due to the relatively low elasticities of energy supply and demand in the short to intermediate run. The second observation is that outside of external factors such as supply disruptions, the price of oil has been very stable (in real terms) over a long period of time. Therefore, analysts have focused on the supply and demand conditions consistent with fairly stable real prices.

IA frameworks frequently use the detailed supply and demand conditions to solve for prices and quantities that will satisfy both producers and end users. The quantity supplied for a particular fuel will expand only if the price increases to cover its higher costs. The quantity demanded for that same fuel will decline as its price increases. Moreover, changes in other substitute fuel prices could cause the entire fuel demand condition to shift outward. The model seeks to solve for an equilibrium where supply and demand conditions will not force prices to rise or fall during that period. Higher prices would attract more-expensive production but reduce consumption. Lower prices would attract consumers with lower energy values but reduce production. Supply and demand conditions are balanced at this market equilibrium.

The World Energy Projection System (WEPS). The US Energy Information Administration (EIA) maintains the World Energy Projection System (WEPS) model, which is an extremely well-documented example of an energy-projection model. It links economic growth with income elasticities for energy to determine growth in international energy use in 14 Excel (spreadsheet) files. The projection period extends from the beginning year through 2020. The model computes total energy consumption and the use of coal, oil, natural gas, and other energy for a number of different countries. The user can change input assumptions for a country's economic growth, income elasticity, and the share of total energy by fuel type.

Oil and nuclear consumption are set exogenously according to results from other EIA models. When total energy use increases with higher economic growth or a higher income elasticity, the model first subtracts oil and nuclear consumption. Remaining energy is allocated to coal, gas, and other sources (excluding nuclear) according to sharing parameters. This procedure means that new oil and nuclear projections must be incorporated into the framework whenever total energy use increases.

The model is essentially a framework based upon income elasticities. Energy prices do not enter the system. Supplies do not directly constrain the consumption projection, although the user can incorporate such considerations by adjusting the sharing parameters informally.

Energy Consumption Projections. Figure 1 displays the world growth rates for the economy and for commercial energy use over the 1995-2020 period for several recent major energy outlooks. The solid lower bar represents energy use and the upper bar with slashes indicates the reduction in aggregate energy intensity. Combined these two effects show the change in economic activity (gross domestic product, or GDP). The reference projections (excluding the low and high economic growth cases from the IEO) appear reasonably similar across groups. They show that economic growth near 3 percent per year results in energy use growth of about 2 percent per year.

Figures 2-4 summarize the same information for the industrialized countries, the formerly communist transitional countries, and the developing countries. Industrialized economies and their primary energy use both grow by about 1 percent per year less than their world counterparts. Transitional economies grow by 3-4 percent per year in the reference projections, while the corresponding primary energy use rises by only 1-1.5 percent per year. This result reflects the greater opportunities to substitute away from very energy-intensive production that was characteristic of these regimes when their economies were centrally controlled. And finally, the developing countries experience both higher demographic growth and increasing income per capita. These factors contribute to their economies growing by about 4.5% per year and their primary energy use to grow by 3.5% across the various reference paths. Thus, both economic and energy growth shift towards these nations. As in industrialized countries, primary energy use grows by about 1 percent per year less than the economy.

Fuel Shares Projections. Figure 5 captures how coal, oil, natural gas, and nonfossil sources (nuclear, renewables, and others) grow relative to total energy between 1995 and 2020. A bar rising above the origin indicates that the fuel's share of the total is increasing faster than for total energy, while a falling bar reveals a decrease in its share. The nonfossil category includes renewables, others, and nuclear but excludes subsistence renewables such as traditional biomass in many developing countries. In these projections, natural gas (indicated by a dashed bar) replaces coal (the black bar) and nonfossil sources (the clear white bar) in relative importance. Represented by the gray bar, oil remains steady.

Nuclear accounts for most of the relative decline in the nonfossil category in the five outlooks (all except DRI) that disaggregate this estimate. The growth in renewables and others (the vertically lined bar) almost keeps pace with total primary energy.

All projections expect a continuing long-run trend toward greater electrification in the economy's end-use pattern. As with total energy demand, this growth will be particularly strong in the developing countries. Restructuring towards more competitive electricity markets will progress in many regions. This trend may reduce investment costs in power generation but the costs of providing electricity will also depend upon the development of institutions and markets for dispatching electricity efficiently. The resolution of these issues is likely to influence future energy markets and environmental emissions in important ways.

Most reference or business-as-usual projections do not assume dramatic changes in public policy for energy and the environment. The standard assumption is to include only those policies that are currently adopted. In fact, some nations may change their policies to protect domestic supplies from the threat of foreign sources, to increase or decrease subsidies provided to certain customers, or to protect their environment as their economies grow. If nations reduced end-use subsidies and protected the environment in the future more vigorously than they do today, they may reduce their total and fossil fuel demands by more than current outlooks predict, thereby improving the environment.

Oil Price Projections. Figure 6 summarizes projections for the world oil price in the year 2020 in 1998 dollars per barrel as reported in the IEO. In addition to the three IEO outlooks for reference, high price, and low price cases, the scenarios include the reference paths for DRI, IEA, WEFA, Natural Resources (NR) Canada, and Deutsche Banc Alex Brown (DBAB). The groups measure crude oil prices differently ranging from landed import costs, refiners' acquisition costs, Brent, and West Texas Intermediate (WTI).

Many analysts have emphasized that current oil price levels heavily influence price forecasts. In Figure 6, the most recent forecast (IEO-Reference) appears higher than most of those made in the previous year (1999), reflecting the recent upswing in oil prices over the last year. However, the highest forecast (IEA) was made in 1998 at a time when oil prices were considerably lower than today, so other factors are clearly operating. There appears to be no tendency for outlooks with either greater world demand or reduced OPEC supplies to produce higher projected prices. This observation contrasts with past results from the Energy Modeling Forum (1991) study on world oil markets, where total demand and OPEC supplies had important effects on the projected price.

Table 2 provides more evidence of the influence of current prices on projected prices. This table shows the projections of world oil prices from a series of EIA projections starting in 1977. Projections of prices made for the years 1985, 1990 and 1995 are presented. The actual prices over these years are also shown. These estimates illustrate two points:

(1) The level of prices at the time of the projections has a clear influence on the EIA forecasts. When prices were high and increasing, the projections called for them to continue increasing.

(2) The tendency to overpredict oil price persisted for several years after prices had started to decline. The EIA analysts expected that higher prices would be necessary to clear the market of excess demand and encourage more production (also see Table 3 through 8).

Huntington (1994) found that during the 1980s, forecasters tended to grossly overstate the expected increase in oil prices for a variety of reasons. During the first half of the decade, they overstated the increase in world oil demand due to optimistic assumptions about economic growth (especially in developing countries) and they understated how rapidly supplies outside OPEC would grow. Had they made these adjustments to reduce oil prices, however, they would have expected a sharp rebound in oil consumption and eventually higher prices in the latter half of the decade. These events did not happen because a return to low oil prices stimulated only a modest amount of additional oil use. All current outlooks now incorporate a smaller demand response to oil price declines than previous outlooks available in the 1980s. A further complicating factor was that they assumed that oil prices would begin to increase sharply once growing world oil demand began to pull cartel production above some cartel-imposed limits on their output.

The most readily available projections do not customarily report other fuel prices. This observation reflects the fact that most outlooks do not depend upon market-clearing conditions in which individual fuel prices move upward or downward until supply and demand conditions for each fuel are matched. This condition is an important limitation that future outlooks should address.[2]

Past Forecasting Errors. The EIA outlooks serve another important task in that their report discusses how closely they have forecasted a few key variables since 1985. Table 1 reveals the percent error in anticipating market economy and total world energy consumption both five and ten years from the date of the projection.

These outlooks have consistently underestimated energy consumption in the market economies, both industrialized and developing countries. However, they also did not anticipate the stagnation and collapse of the formerly communist regions. By grossly overstating energy use in these transitional nations, the EIA tended to expect too much energy use worldwide. These results emphasize not only the risks of providing credible forecasts but also the fact that errors in different components of the total can sometimes be offsetting.

In their five-year projections, the EIA underpredicted the market economy's energy consumption by 6.6% in 1990 and by 5.5% in 1995. Their error rose to 9.5% for the ten-year projections for 1995. Some world fuel estimates were very close to the actual observed data. For example, they reported that their projections for 1995 coal use were only 4.4% and 1.3% above actual levels in their five and ten-year forecasts.

Complicating this analysis of error rates is the underlying assumption that EIA and many other forecasters made with respect to changes in energy policies. At the start of every forecast cycle analysts usually assume that no new changes in energy policies will be made over the projection period. Over a ten year forecast period policies can change and have an impact on the projections. For example, the failure to reflect the corporate average fuel economy standards in vehicles could seriously bias gasoline demand projections.

Tables 2 through 4, show oil consumption projections for 1985, 1990 and 1995 respectively. For 1985 and 1990 the oil demand projections were significantly above the actual figures for these years in spite of assuming that prices would be higher than actually realized. Part of the problem with these projections relates to the relatively strong assumptions about economic growth and part is likely due missing some significant policy changes that had an impact on petroleum demand. It is interesting that by the mid 1980's the projections for 1995 improved dramatically (see Table 5). Some of this improvement can be due to improved price and economic assumptions and some due to the fact that by this time the oil market relied more on market forces and less on the effects of government regulations.

---

[2] The U.S. Energy Information Administration has plans to develop an international energy model that will include a more comprehensive treatment of the interaction between supply and demand conditions for other fuels.

Tables 5 through 8 show oil production projections for 1985, 1990 and 1995. Except for OPEC production the error rates for these projections was less than that observed for the consumption projections. The error in OPEC production was not due to OPEC's inability to produce but rather that being a swing producer there was a lack of demand for their product in the mid 1980's. Another notable error deals with the development of the North Sea which was largely ignored until the late 1980's when it became obvious that the production figures were coming in much higher than projected.

Beyond Numbers. Many policy and corporate advisors and executives emphasize the precise numerical results in these outlooks and then roundly criticize these organizations for their inability to tell the future. Such a view misses the value of such exercises. Each scenario provides a possible story about how the world and the energy system could evolve. By developing this story consistently, or at least more consistently than would be the case otherwise, the models and their estimates provide interested parties with a framework for evaluating and understanding future options. Moreover, it should be relatively easy to incorporate new assessments about technology, economics, and politics and examine their implications. Finally, one may be able to identify strategies that appear more robust than others for a range of possible outcomes.

Summary. Several organizations routinely publish international energy outlooks that provide important perspectives on how the energy system might evolve over the next several decades. Several results appear robust to a range of different scenarios. They include energy use that expands but still grows by a percent per year less than the economy, faster energy use growth in the developing than the industrialized nations, energy use shifting towards greater electrification, and greater reliance upon natural gas and less reliance upon coal and nuclear.

Most projections see world oil prices rising at least as fast as inflation and often faster. Since these future trends run counter to the historical evidence, one may be concerned that future energy prices are being overestimated. Although past price projections have suffered from this problem, the projections for fuel supplies and demands have been much closer to actual levels.

Most readily available projections for international energy markets do not formally solve for a set of energy prices that balance supply and demand conditions for each fuel. More frequently, they determine energy demand outlooks based upon economic and demographic growth, prices, and detailed technical and cost information and then check those results with available estimates about resources and energy supply conditions. Without more details on the relative costs of different fuels, it is often difficult to interpret and compare these outlooks on a consistent basis. However, there has been a move towards systems that determine fuel prices from multiple supply-demand balances as analysts have begun to investigate the effects of different world strategies for reducing such problems as global climate change emissions.[3]

[3] Supply-demand balances are more important when investigating the effects of emissions constraints because the analyst can then estimate the costs of reaching different pollution targets.

Table 1. Past Errors in IEO Outlooks
(as a % of actuals)

	1990	1995
Market-Economy Energy		
Five-Year	-6.6	-5.5
Ten-Year		-9.5
World Energy		
Five-Year		4.6
World Coal		
Five-Year		1.3
Ten-Year		4.4

Table 2. World Oil Projections for 1985, 1990 and 1999
(Nominal $'s per Barrel)

Projection Year	1985 Prj.	1990 Prj.	1995 Prj.	Actual Price
1977	23.99	28.80	33.04	14.53
1978	26.66	34.82	50.75	14.57
1979	46.12	64.00	81.37	21.67
1980	53.33	70.92	99.24	33.89
1981	43.45	77.43	121.48	37.05
1982	28.16	50.03		33.55
1983	29.23	48.07	74.54	29.3
1984	29.05	37.35	57.14	28.88
1985	27.00	32.41	41.31	26.99
1986		20.81	30.05	14
1987		20.17	29.12	18.13
1988				14.56
1989		16.36	25.77	18.08
1990			24.44	21.76
1991			27.54	18.7
1992			23.87	18.2
1993			21.98	16.14
Actual Price	26.99	21.76	17.14	

Table 3. World Oil Consumption Projections for 1985
(Million Barrels per Day)

Projection Year	U.S.	Japan	Europe	OPEC	Other
1978	19.6	6.8	15.7	4.5	13.8
1979	15.8	6	12.2	3.7	10.8
1980	15.5	5.8	12.3	3.2	11
1981	17.2	5.2	11.9	3.3	11.3
1982	18.4	4.9	12.8	3.2	11.5
1983	16.1	4.5	12.5	3.2	10.7
1985 Actual	15.73	4.38	11.68	3.78	11.16

Table 4. World Oil Consumption Projections for 1990
(Million Barrels per Day)

Projection Year	U.S.	Japan	Europe	OPEC	Other
1978	19.6	7.9	17.6	6.4	16.9
1979	15.7	6.3	12.5	5	12.8
1980	15.7	6.2	12.6	4.2	13.5
1981	16.2	5.5	11.8	4.6	12.3
1982	17.4	5.3	13.5	3.9	12.7
1983	16.9	5	13.1	4.2	11.7
1984	17	4.8	12.6	4.4	11.5
1985	16.1	4.5	12.1	3.7	11.6
1986	16.2	4.6	12.6	3.7	12.3
1987	17.1	4.5	12.4	3.7	12.6
1990 Actual	17	5.14	12.63	4.61	13.79

Table 5. World Oil Consumption Projections for 1995
(Million Barrels per Day)

Projection Year	U.S.	Japan	Europe	OPEC	Other
1978	20	9.1	19.4	9	20.4
1979	15.9	7.3	13.5	6.7	15.4
1980	15.3	6.9	12.9	5.4	16.1
1981	16.4	5.8	11.7	6.4	13.6
1982					
1983	17.7	5.1	12.6	5.2	12.6
1984	18.3	4.7	12.4	5.4	11.9
1985	16.5	4.4	12.2	4.5	12.3
1986	16.5	4.6	12.6	4.2	12.5
1987	17.7	4.5	12.7	4.1	13.8
1988					
1989	17.8	4.9	13.2	4.1	14.1
1990	18.21	5.77	12.92	4.1	15.1
1991	17.9	6	13.6	4.6	15.4
1992	17.8	5.9	13.7	4.9	16.2
1993	18.2	5.7	13.9	4.9	17.1
1995 Actual	17.7	5.7	13.3	5.8	16.3

Table 6. World Oil Production Projections for 1985
(Million Barrels per Day)

Projection Year	U.S.	Europe	OPEC	Other
1978	10.6	4.1	34.7	11
1979	9.2	3.6	24.8	10.9
1980	9.5	3.5	23.9	10.9
1981	9.7	3	25.8	10.4
1982	10.6	3.4	25.8	10.3
1983	10.9	3.9	20.5	10.4
1985 Actual	11.19	4.25	17.61	11.3

Table 7. World Oil Production Projections for 1990
(Million Barrels per Day)

Projection Year	U.S.	Europe	OPEC	Other
1978	11.2	4.3	39.7	13.2
1979	9.6	3.5	26.3	12.9
1980	9.8	3.4	26.1	12.9
1981	10.1	3.1	25.7	11.5
1982	10	3	27.7	11.9
1983	10.9	3.4	23.5	12.4
1984	10.3	3.9	23.5	11.9
1985	10.4	4.5	20.4	11.8
1986	9.4	4	22.9	11.8
1987	9.9	4.8	21.2	12.2
1990 Actual	9.68	4.58	25.1	12.78

Table 8. World Oil Production Projections for 1995
(Million Barrels per Day)

Projection Year	U.S.	Europe	OPEC	Other
1977				
1978	11.8	4.5	42.9	18.7
1979	9.7	3.6	31	14.5
1980	11	3.5	27.3	14.8
1981	10.9	3.2	27.7	12.1
1982				
1983	10.5	3.6	24.2	14.6
1984	9.4	3.8	26	13.2
1985	8.8	4.3	24.4	12.1
1986	8.3	3.5	26.4	11.4
1987	8.8	4.3	26.1	11.9
1988				
1989	8.6	4.3	26.9	12.1
1990	8.97	5.3	26.6	13.03
1991	8.6	5.4	28.7	13.7
1992	9.1	6.2	27.1	15.8
1993	9	6.2	28.4	15.9
1995 Actual	9.4	6.1	28.4	14.4

Figure 1. World Energy & Economy Trends, 1995-2020

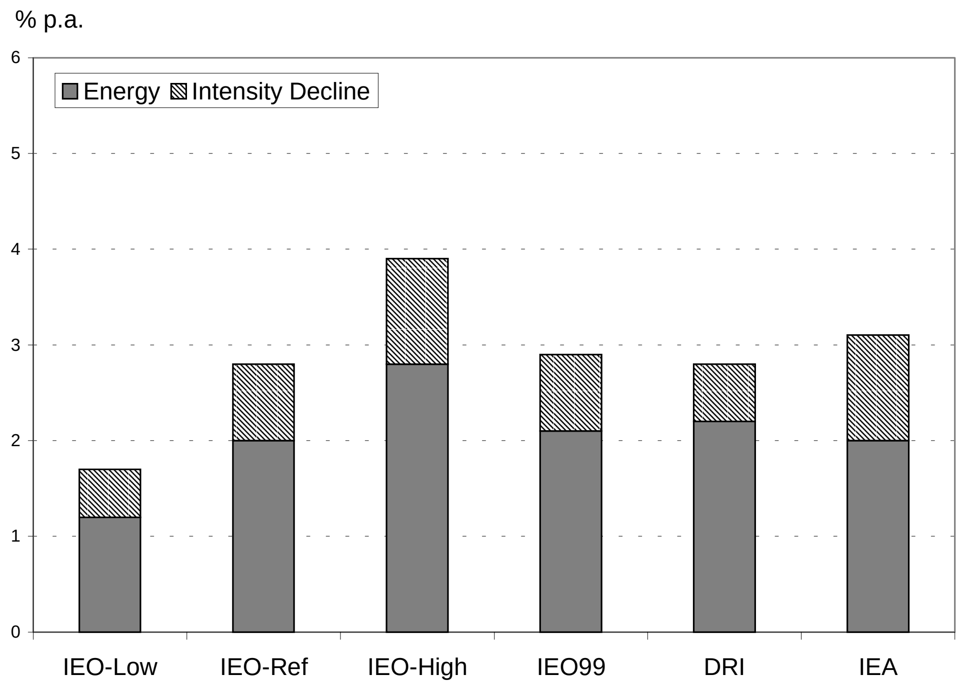


Figure 2. Industrialized Countries' Energy & Economy Trends, 1995-2020

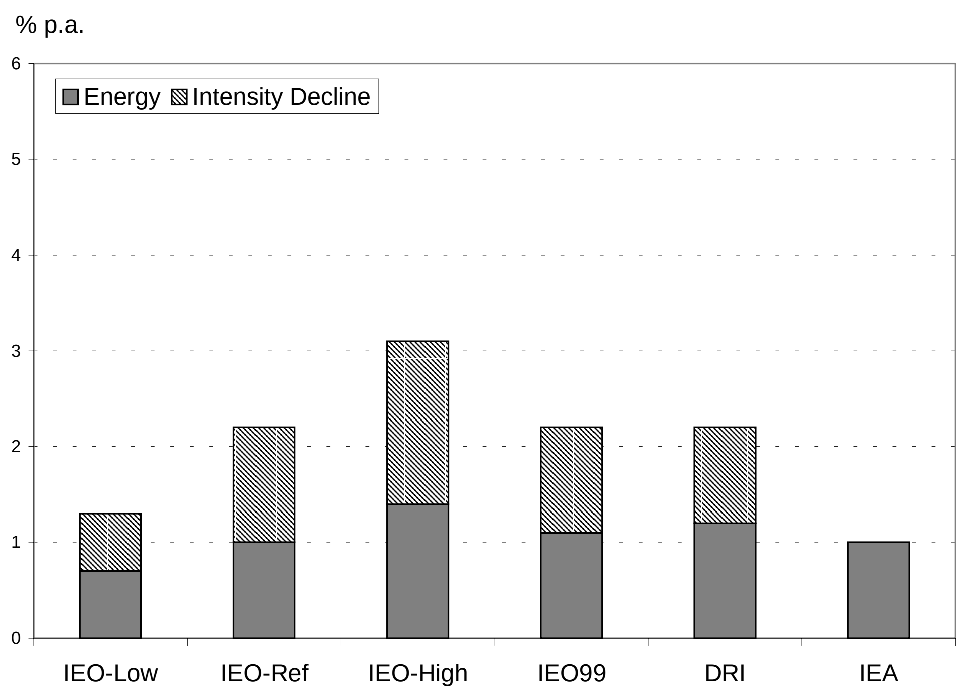


Figure 3. Transitional Countries' Energy & Economy Trends, 1995-2020

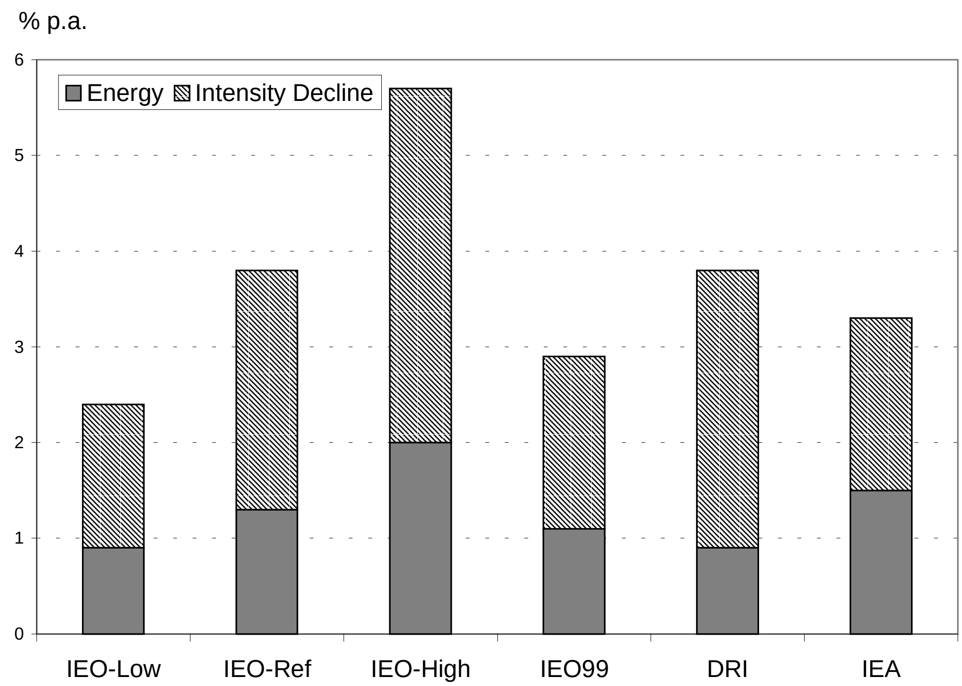


Figure 4. Developing Countries' Energy & Economy Trends, 1995-2020

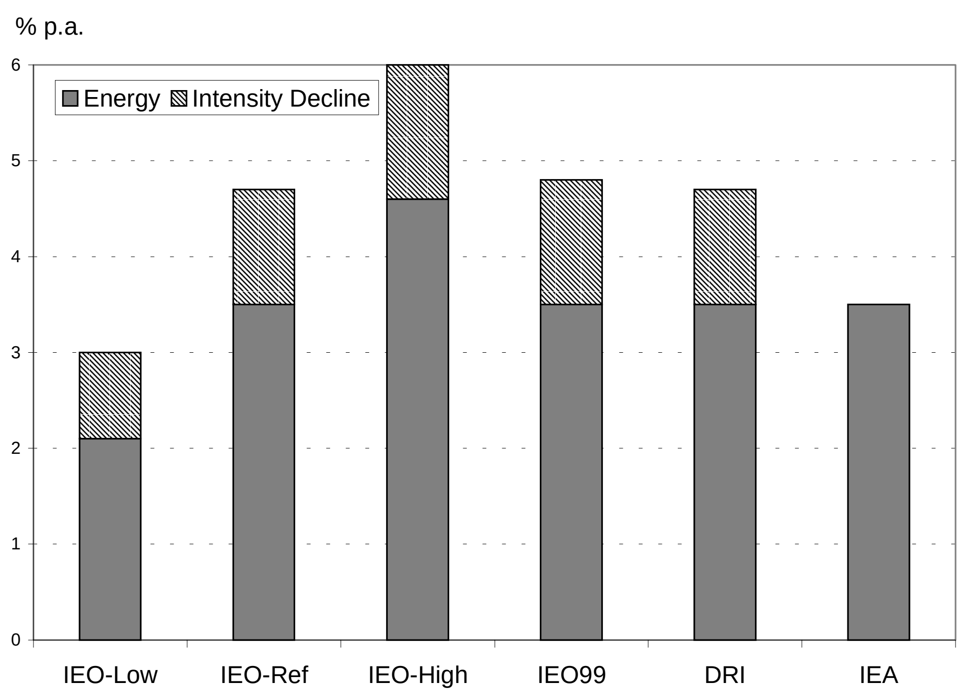


Fig 5. Relative Growth of Energy Sources 1995-2020

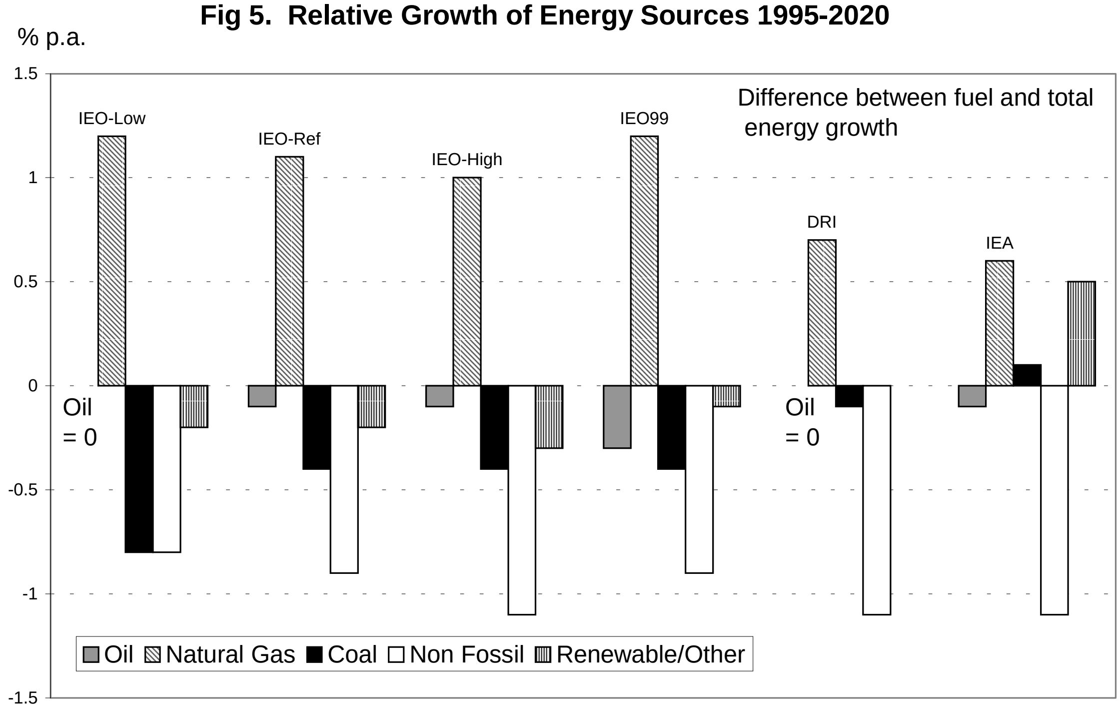
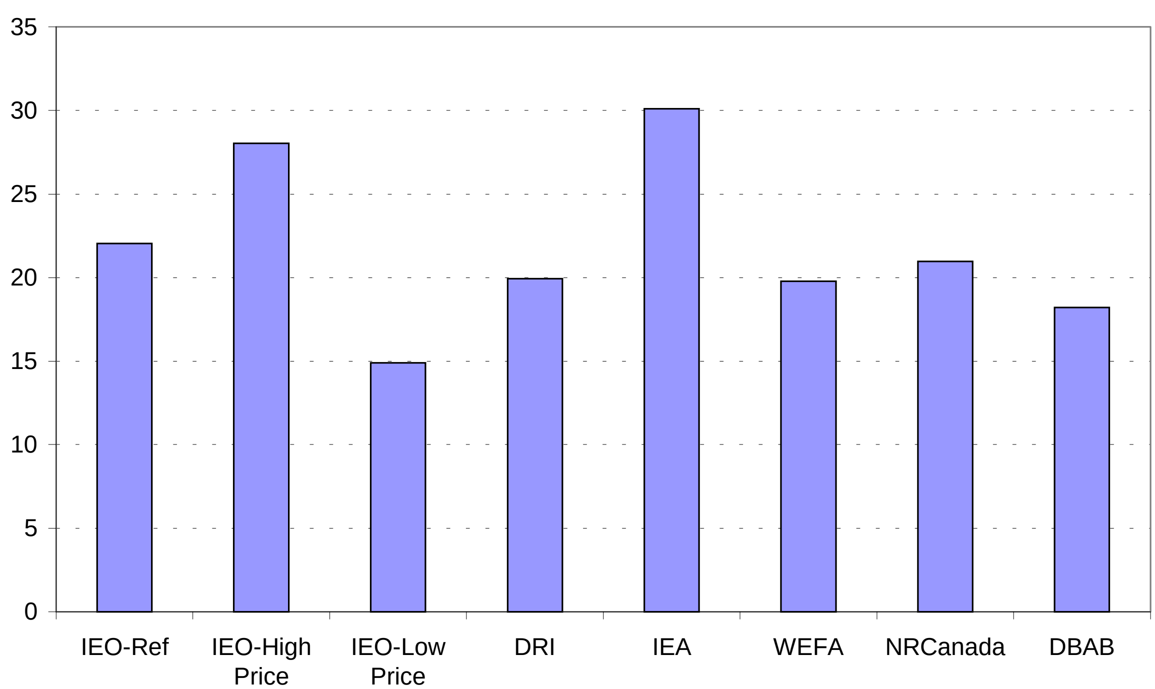


Fig 6. World Oil Price 2020 ('98 Dollars/Barrel)



References

Energy Modeling Forum, (1991). *International Oil Supplies and Demands,* EMF Report 11, volume 1, Stanford University, Stanford, CA: September.

Huntington, Hillard G. (1994). "Oil Price Forecasting in the 1980s: What Went Wrong?" *Energy Journal 15* (2): 1-22.

International Energy Agency, (1998). *World Energy Outlook*, Paris: Organization for Economic Co-operation and Development.

Nakicenovic, Nebojsa, Arnulf Grubler, and Alan McDonald, (1998) editors, *Global Energy Perspectives*, Cambridge, UK: Cambridge University Press.

Putnam, Palmer Cosslett (1953). *Energy in the Future.* Princeton, NJ: D. Van Nostrand, 556 pages.

Schurr, Sam H. and Bruce C. Netschert (1960). *Energy in the American Economy, 1850-1975: An Economic Study of its History and Prospects.* Baltimore: Johns Hopkins Press, 774 p.

U.S. Energy Information Administration (various years). *Annual Energy Outlook,* U.S. Department of Energy, Washington D.C., January, DOE/EIA-0383.

U.S. Energy Information Administration (various years). *International Energy Outlook,* U.S. Department of Energy, Washington D.C., March, DOE/EIA-0484.

US Energy Information Administration, (2000). *International Energy Outlook 1999,* US Department of Energy, Washington, D.C., March, DOE/EIA-0484(00).

Weyant, John P., (1999) editor. The Costs of the Kyoto Protocol: A Multi-Model Evaluation, *Energy Journal*, special issue.