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Comparison of RAMS World Oil Model with "NEPP (1985) Projections to 2010"

L. D. Trowbridge

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Engineering Physics and Mathematics Division

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Comparison of RAMS World Oil Model with "NEPP (1985) Projections to 2010"

L. D. Trowbridge

SUMMARY

The Department of Energy's Office of Policy, Planning and Analysis recently released a new series of detailed projections of national and world energy trends (NEPP-85).[1] This study presents a comparison of the behavior of the RAMS World Oil Model with the NEPP-85 results. Two goals were defined for this study:

1. Determine the changes necessary to RAMS input parameters to approximately duplicate NEPP-85 results.
2. Determine effect of replacing the existing input assumptions in the standard version of RAMS with corresponding NEPP-85 assumptions.

The changes made to RAMS in this study were to the numeric values of the standard scenario parameters. In no case were the model equations altered.

The results that are compared in this analysis are the projected trajectories of World Oil Price and (non-communist) World Oil Production. In general, as will be seen below, the RAMS model, with appropriate parameter adjustments, appears to be able to do a reasonable job of duplicating the long-term trends found in the NEPP-85 study. It does less well at duplicating the detailed short-term behavior ('85-'90) of NEPP-85.

INTRODUCTION

The RAMS (Research and Development Analysis Modeling System) World Oil Model[2] was developed in 1985 for the Department of Energy's Assistant Secretary for Oil, Gas, Shale, and Coal Liquids by Applied Management Sciences and Oak Ridge National Laboratory. This model, described in more detail in Appendix A, is a relatively simple, PC-based equilibrium model of the long- term world oil market. It was designed

to provide an easy-to-use tool for qualititively examining market penetration of nonconventional liquid fuels into the world oil market under a wide range of future market conditions. In both level of detail and treatment, RAMS is not an elaborate model.

The NEPP-85 study is based primarily on results of a model named WOIL, which is conceptually similar to RAMS, but much more detailed in many respects. For example, NEPP-85 treats all energy sources (allowing fuel switching) whereas RAMS examines only crude oil; NEPP-85 utilizes 6 demand regions to RAMS' 3; NEPP-85 calculates yearly results while RAMS uses 5 and 10-year periods.

INPUT ASSUMPTIONS

NEPP-85 presents a number of scenarios in addition to the Base case. These include low and high world energy demand scenarios, alternate USA resource base scenarios, and alternate USA energy efficiency scenarios. Only the alternate world energy demand scenarios will be examined here.

In addition to the obviously much broader scope and greater level of detail in the models used in the NEPP-85 study, there are a number of discrepancies in the presentation or meaning of data in NEPP-85 as compared to RAMS. These should be kept in mind when examining the comparisons. Specific differences are:

1. RAMS uses 5 and 10-year calculation intervals, and the initial conditions (e.g. world oil price and regional production rates) are in turn averages over the five years leading up to the model starting date (1980). NEPP-85 states that the WOIL model uses a calculation interval of one years (though the results are displayed for 5-year intervals). This discrepancy is most striking in comparing the starting (1980) world oil price in the two models: RAMS (Average '76-'80) = $29/bbl vs. NEPP-85 (Average 1980) = $44/bbl. Properly speaking, to compare NEPP-85 with RAMS, one would have to calculate multi-period averages or interpolate. RAMS, at least, was never intended to be so precise a tool. To avoid distraction, these comparisons will show period values from RAMS and NEPP-85 as if they were directly comparable.

2. Except for coal liquids, the NEPP-85 document doesn't distinguish nonconventional liquids from conventional. Thus, RAMS may "produce" more heavy oil and tar sands than NEPP-85 in later years. This can have a significant effect on the later phases of the price projection, but is not explored here.

3. NEPP-85 does not list 1985 values. NEPP-85's "'84 estimates" are treated here as '85 values for purposes of display.

4. RAMS excludes natural gas plant liquids from oil production whereas NEPP-85 includes them. Thus a given RAMS quantity will be comparable to a NEPP-85 value 4%-8% higher.

Several scenarios have been run in this comparison study. These fall into three sets as summarized in Table 1. The first was a "minimal adjustment" set, the second was an attempt to incorporate all directly applicable NEPP-85 assumptions into corresponding input parameters in RAMS, and the third was an attempt to force-fit the NEPP-85 Base case results by arbitrary adjustments of RAMS input parameters. The first and second set of scenarios compare Low, Base, and High energy growth scenarios between RAMS and NEPP-85.

Table 1. RAMS/NEPP-85 comparison scenarios

Set 1	
Base	Minimal changes (4 parameters) to
High	RAMS Standard Scenario:
Low	
Set 2	
Base	All possible NEPP-85 input assumptions
High	incorporated into RAMS
Low	
Set 3	
Base	Force-fit of NEPP-85 Base scenario

The first set of RAMS scenarios was created by adjusting only four parameters. The most significant adjustments were the reduction of the supply and demand elasticities, which are discussed in more detail below. The other parameters altered were the upper and lower OPEC capacity constraints, reduced slightly to align the RAMS capacities with NEPP-85 assumptions. The RAMS standard and adjusted values of these parameters are listed in Table 2.

The second set of scenarios incorporates all the NEPP-85 assumptions that appear to correspond directly to input parameters in RAMS. The input parameter values changed are listed in Tables 2 and 3. These cover:

1. One coal liquid technology in RAMS (Surface non-direct liquefaction) was reduced in cost so that it would activate commensurate with the behavior of "Coal Liquids" in NEPP-85.

2. CPE Exports to the West: NEPP-85, like RAMS, considers centrally planned economies (CPEs) only to the extent of their net exports to the remainder of the world. The NEPP-85 estimates for future net exports of liquids are considerably lower than the earlier estimates used in the RAMS standard scenario.

3. Skan production is limited (due to pipeline capacity constraints) to the lower NEPP-85 value.

4. GNP growth parameters for three aggregate world regions are listed in the NEPP-85 document, as are figures on energy consumption enabling derivation of energy growth:GNP growth ratios. These two sets of parameters replace the RAMS standard values in defining future oil demand.

5. Starting (1980) values primary energy demand for three RAMS demand regions (OECD, OPEC, and LDC) were taken from NEPP-85.

One input data set not changed (because it wasn't conveniently available in NEPP-85) was the set of initial production rates and resource bases. This could have a significant effect on the detailed distribution of production (which is not examined in this study). For example, RAMS tends to produce more OPEC and less non-OPEC oil than NEPP-85.

Table 2. RAMS parameter changes to Scenario Sets 1 and 2

		NEPP Emulation	Standard Scenario	
OPEC Production limits	:	80%	85%	Max
(% of Pot'l Capacity)	:	40%	45%	Min
DEMAND ELASTICITY	:	-0.5	-1.	
SUPPLY ELASTICITY	:	0.2	0.4	

Table 3. RAMS parameter changes to Scenario Set 2

		NEPP Emulation	Standard Scenario	
Coal NDL Surface	:	$30 in 2000	$50 in 1990	
Alaska Pipeline Cap.	:	1.8	2.1	MMB/D
CPE Export 85/90/95/...	:	2.0/0.5/ 0/ 0	2.4/1.9/1.9/...	MMB/D

RESULTS

Scenario Set 1: (Minimal Adjustment Set)

Scenario Set 1 is defined by the changes listed in Table 2 and the standard energy growth parameters listed in Table 4. Figures 1 through 3 display the oil price projections for the first scenario set. As can be seen in Figure 1, the long-term trend of the Base NEPP-85 price trajectory can be duplicated reasonably well by RAMS. This is accomplished mainly by adjustment of the elasticity values, which control the price responsiveness of demand and OPEC supply. Shorter-term projections ('85-'90) are not duplicated as well.

Table 4. Demand Growth Parameters in Standard RAMS (Scenario Set 1)

GNP = GNP Growth;
E:G = Ratio of growth of primary energy use to growth of GNP

Annual growth of energy use, barring price changes, will be the product of these two parameters.

	81-85	86-90	91-95	96-20	01-10
High Growth					
OECD GNP	2.5%	3.2%	2.9%	2.9%	2.9%
E:G	0.31	0.75	0.81	0.81	0.81
OPEC GNP	2.0%	3.5%	3.5%	3.5%	3.5%
E:G	1.22	1.20	1.10	1.01	1.01
LDC GNP	0.8%	4.5%	4.5%	4.5%	4.5%
E:G	1.05	1.09	1.16	1.16	1.14
Median Growth					
OECD GNP	2.5%	2.7%	2.4%	2.4%	2.3%
E:G	0.28	0.69	0.72	0.72	0.72
OPEC GNP	2.0%	3.0%	3.5%	3.5%	3.0%
E:G	1.22	1.20	1.08	1.08	1.01
LDC GNP	0.8%	4.0%	4.2%	4.2%	4.0%
E:G	1.05	1.09	1.16	1.16	1.10
Low Growth					
OECD GNP	2.5%	2.4%	2.0%	2.0%	2.0%
E:G	0.25	0.63	0.64	0.64	0.65
OPEC GNP	2.0%	2.5%	3.0%	3.0%	3.0%
E:G	1.22	1.20	1.10	1.01	1.01
LDC GNP	0.8%	3.5%	3.5%	3.5%	3.5%
E:G	1.05	1.06	1.08	1.08	1.06

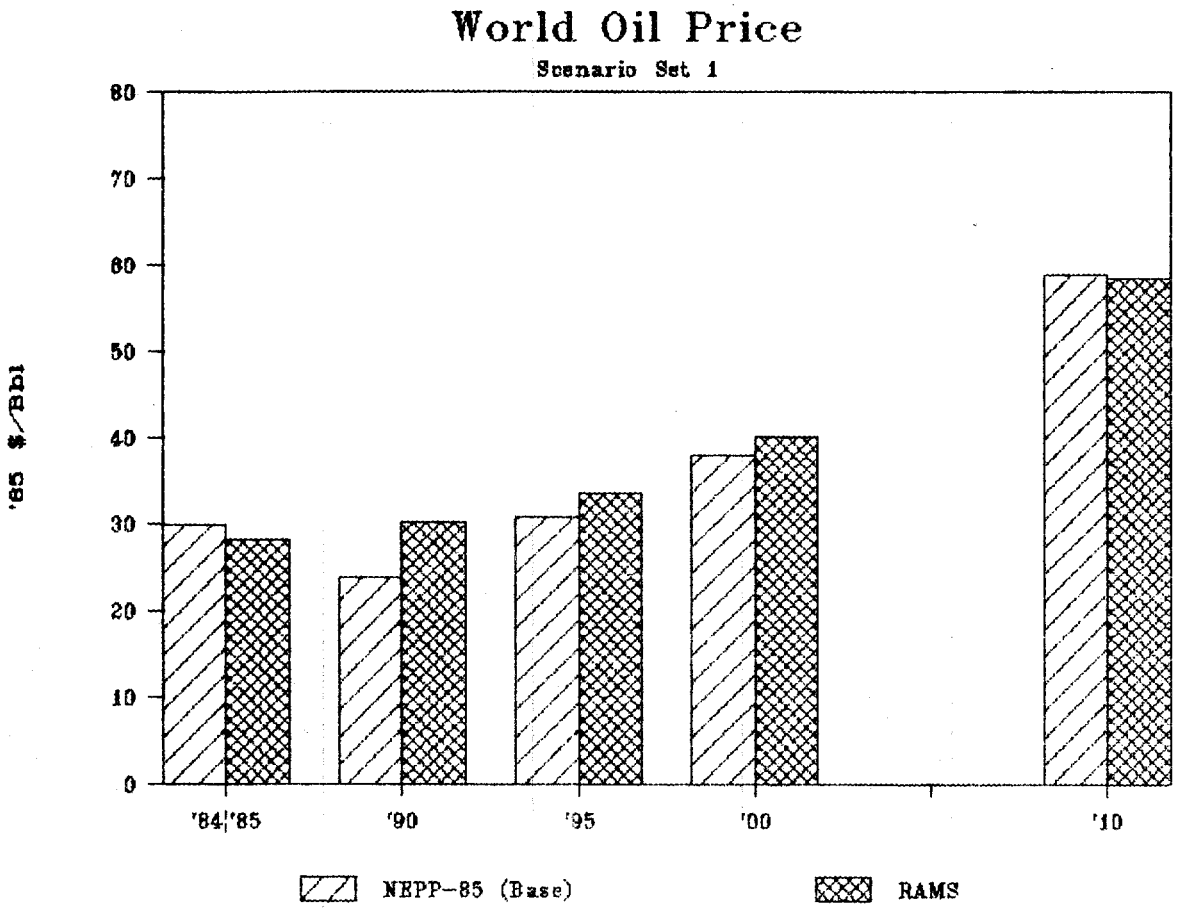

Fig. 1. Comparison of World Oil Price Projections

Scenario Set 1:
NEPP-85 Base Case vs.
RAMS Base Growth - parameter changes per Table 2

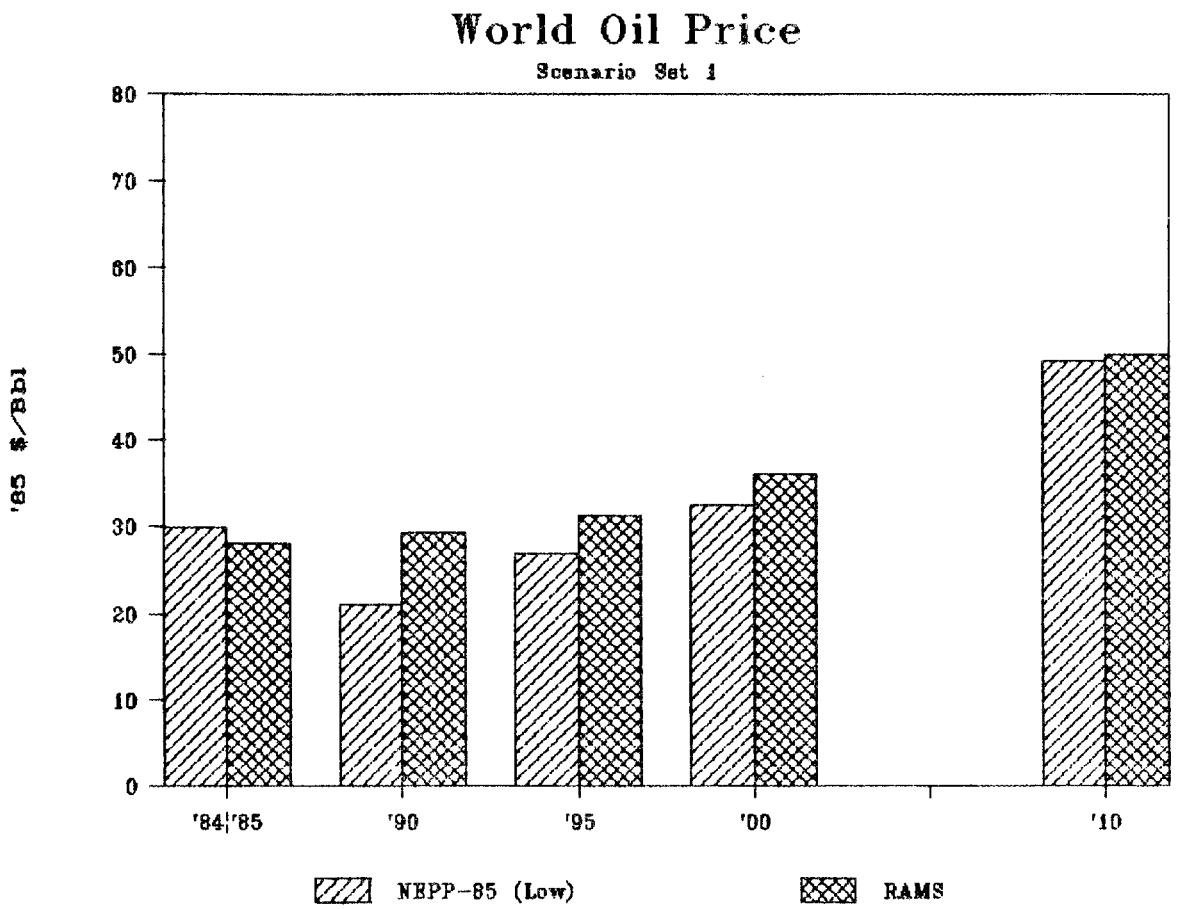

Fig. 2. Comparison of World Oil Price Projections

Scenario Set 1:
NEPP-85 Low Case vs.
RAMS Low Growth - parameter changes per Table 2

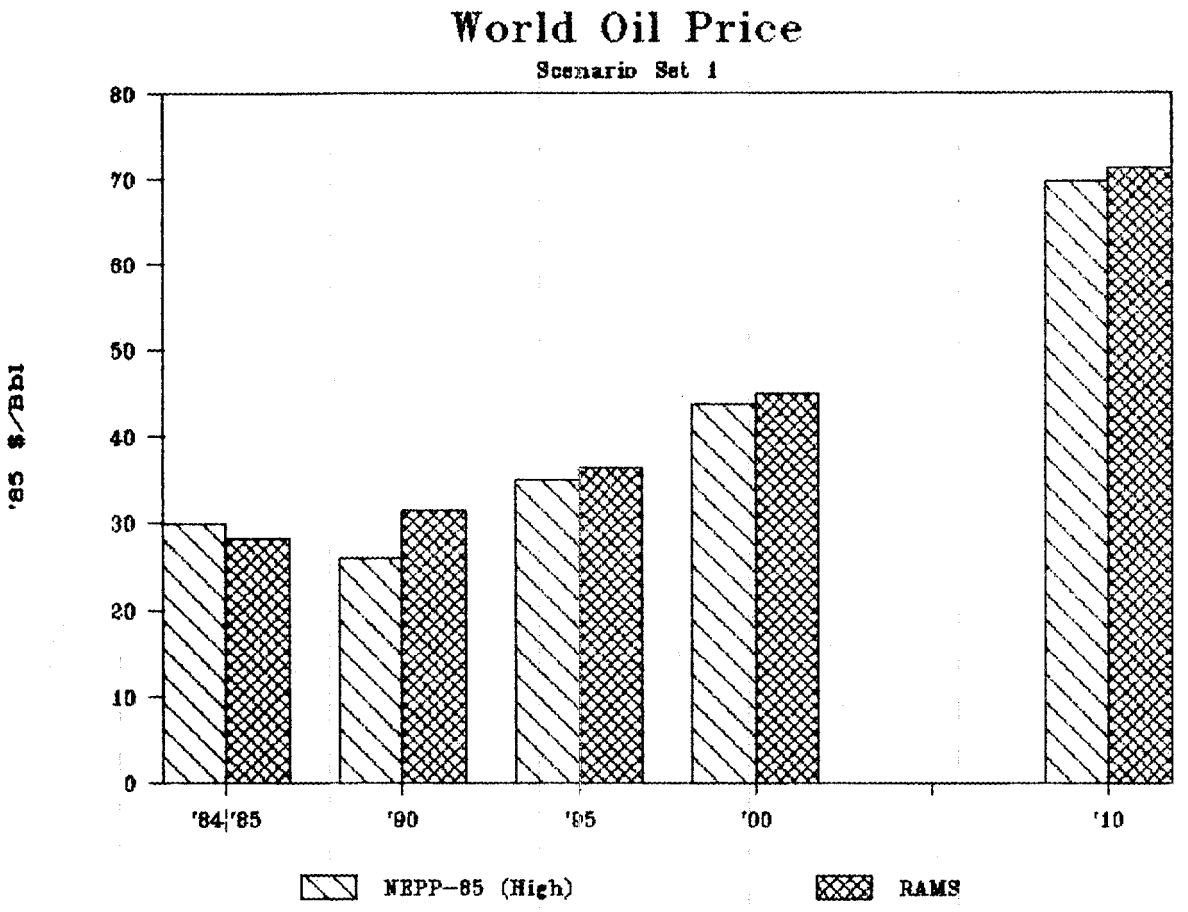

Fig. 3. Comparison of World Oil Price Projections

Scenario Set 1:
NEPP-85 High Case vs.
RAMS High Growth - parameter changes per Table 2

Figures 2 and 3 compare the price projections of the NEPP-85 "High Growth" and "Low Growth" scenarios with the RAMS scenarios of the same names (but not necessarily the same assumptions). The agreement of the price tracks from NEPP-85 and RAMS under these alternate demand growth assumptions is about the same as in the base case: long-term trends were reproduced by RAMS, but he short-term detail was not as well duplicated.

Figure 4 compares the projection NEPP-85 and RAMS of consumption by the non-communist world for the base scenario. The trends of the two agree quite well. The absolute agreement is not, however, quite as good as Fig. 4 would tend to indicate. RAMS is, in effect, predicting about 5% more consumption than NEPP-85 due to the variation in treatment of natural gas liquids. The consumption projections for high and low growth scenarios are qualitatively similar, and are not presented here.

Scenario Set 2: (Identical input assumptions to extent possible)

This scenario set was created to study the effect of making, to the extent reasonably possible, identical input assumptions in both RAMS and NEPP-85. The parameters used in Set 1 (i.e. the elasticities and OPEC capacity limits) were retained in this series. The only changes made were to alter those RAMS input parameters (of which there were many) which corresponded to available input assumptions in NEPP-85. The parameter changes have been discussed previously, and are listed in Tables 2, 3, and 5.

Figures 5 through 7 compare the NEPP-85 and RAMS price projections for the Base, Low Growth, and High Growth scenarios. Again, the long-term trends were reproduced, but more variation is exhibited in the early periods. The three growth scenarios exhibit a similar degree of agreement. Figure 8 compares the consumption projections for the base scenario. The trend of NEPP-85's projection is again followed closely. Quantitative agreement is actually fairly good, again keeping in mind the differing treatments of natural gas liquids.

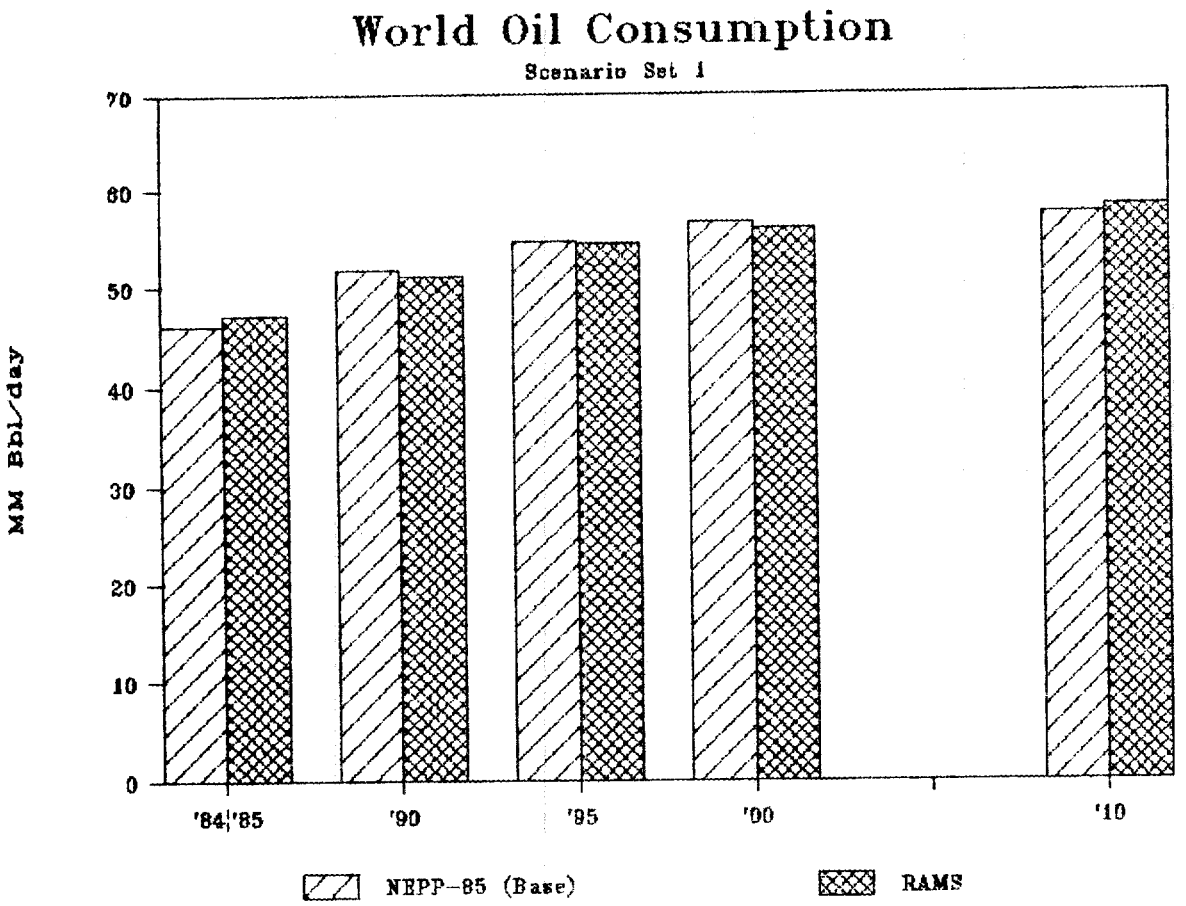

Fig. 4. Comparison of World Oil Consumption Projections

Scenario Set 1:
NEPP-85 Base Case vs.
RAMS Base Growth - parameter changes per Table 2

Table 5. Demand Growth Parameters in NEPP-85 (Scenario Set 2)

GNP = GNP Growth;
E:G = Ratio of growth of primary energy use to growth of GNP

Annual growth of energy use, barring price changes, will be the product of these two parameters.

		81-85	86-90	91-95	96-20	01-10
High Growth						
	OECD GNP	0.025%	3.5%	2.601-10		
High Growth						
	OECD GNP	0.025%	3.5%	2.601-10		
High Growth						
	OECD GNP	0.025%	3.5%	2.6%	2.9%	2.8%
	E:G	-16.00	0.64	0.49	0.47	0.54
	OPEC GNP	7.0%	4.6%	5.5%	5.0%	4.5%
	E:G	0.69	1.16	0.88	1.03	0.90
	LDC GNP	-0.3%	4.6%	5.0%	5.1%	4.5%
	E:G	-10.67	0.76	0.84	0.81	0.93
Median Growth						
	OECD GNP	0.025%	3.1%	2.2%	2.3%	2.3%
	E:G	-16.00	0.64	0.47	0.45	0.46
	OPEC GNP	7.0%	4.2%	5.0%	4.5%	4.0%
	E:G	0.69	1.13	0.89	1.05	0.93
	LDC GNP	-0.3%	4.2%	4.6%	4.6%	4.0%
	E:G	-10.67	0.74	0.87	0.82	0.96
Low Growth						
	OECD GNP	0.025%	2.6%	1.7%	1.8%	1.8%
	E:G	-16.00	0.61	0.45	0.38	0.38
	OPEC GNP	7.0%	3.7%	4.5%	4.0%	3.5%
	E:G	0.69	1.12	0.89	1.06	0.96
	LDC GNP	-0.3%	3.7%	4.1%	4.1%	3.5%
	E:G	-10.67	0.73	0.88	0.81	1.00

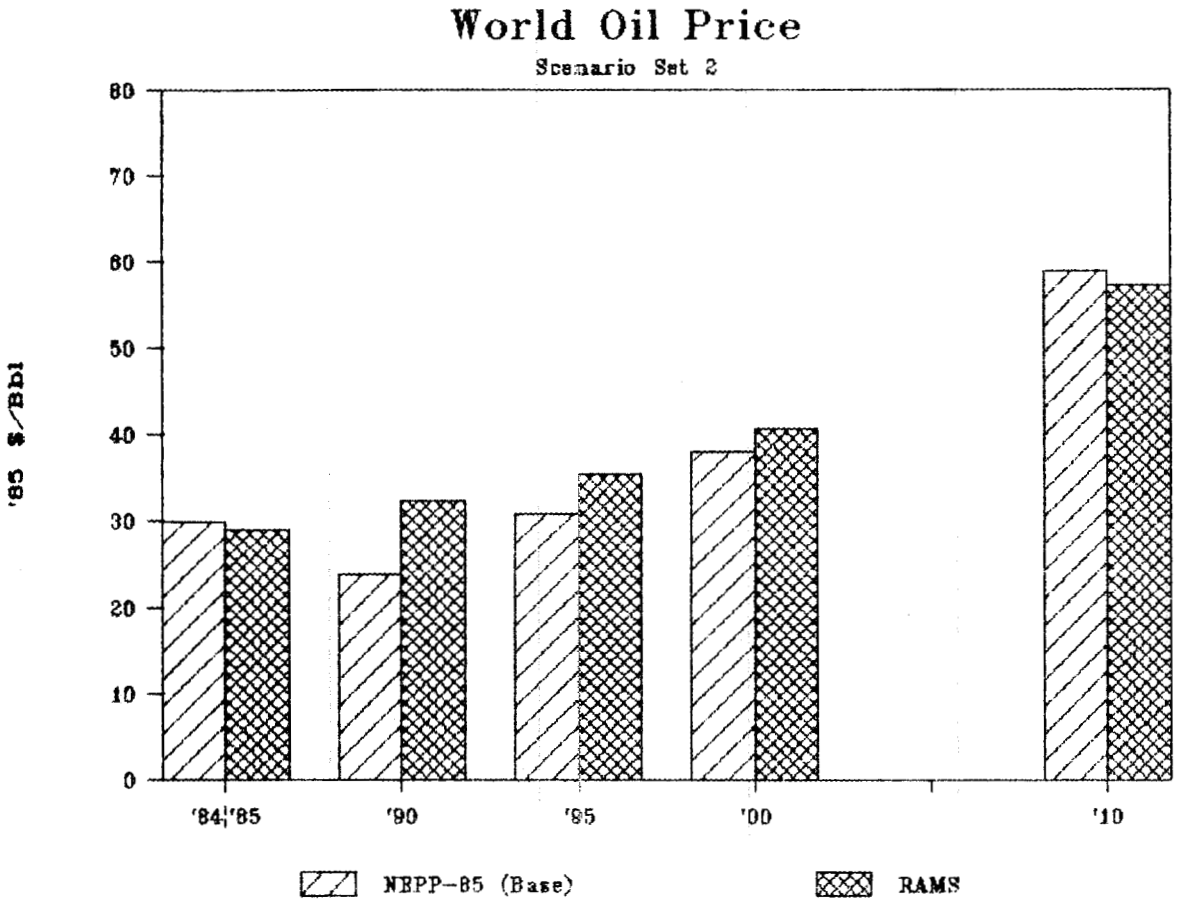

Fig. 5. Comparison of World Oil Price Projections

Scenario Set 2:
NEPP-85 Base Case vs.
RAMS Base Growth - parameter changes per Tables 2, 3, 5

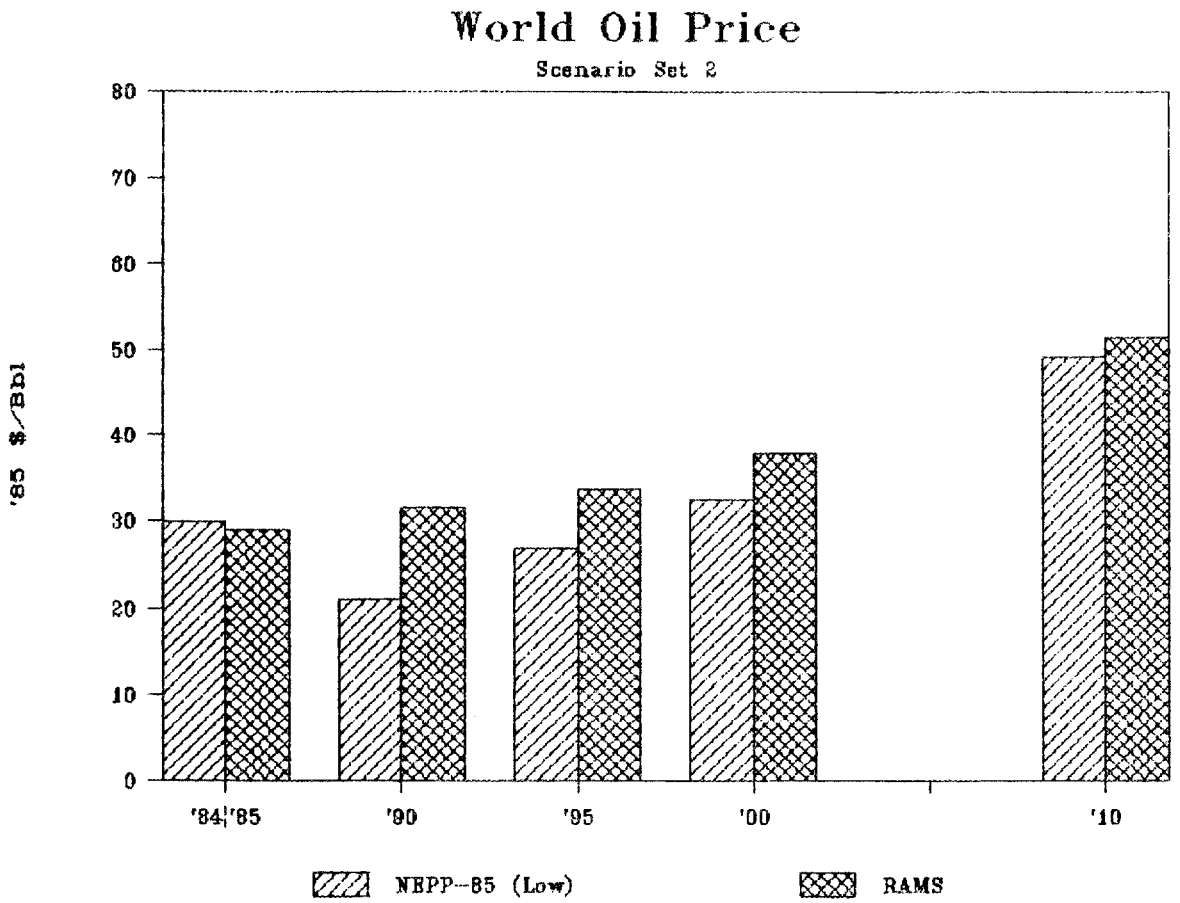

Fig. 6. Comparison of World Oil Price Projections

Scenario Set 2:
NEPP-85 Low Case vs.
RAMS Low Growth - parameter changes per Tables 2, 3, 5

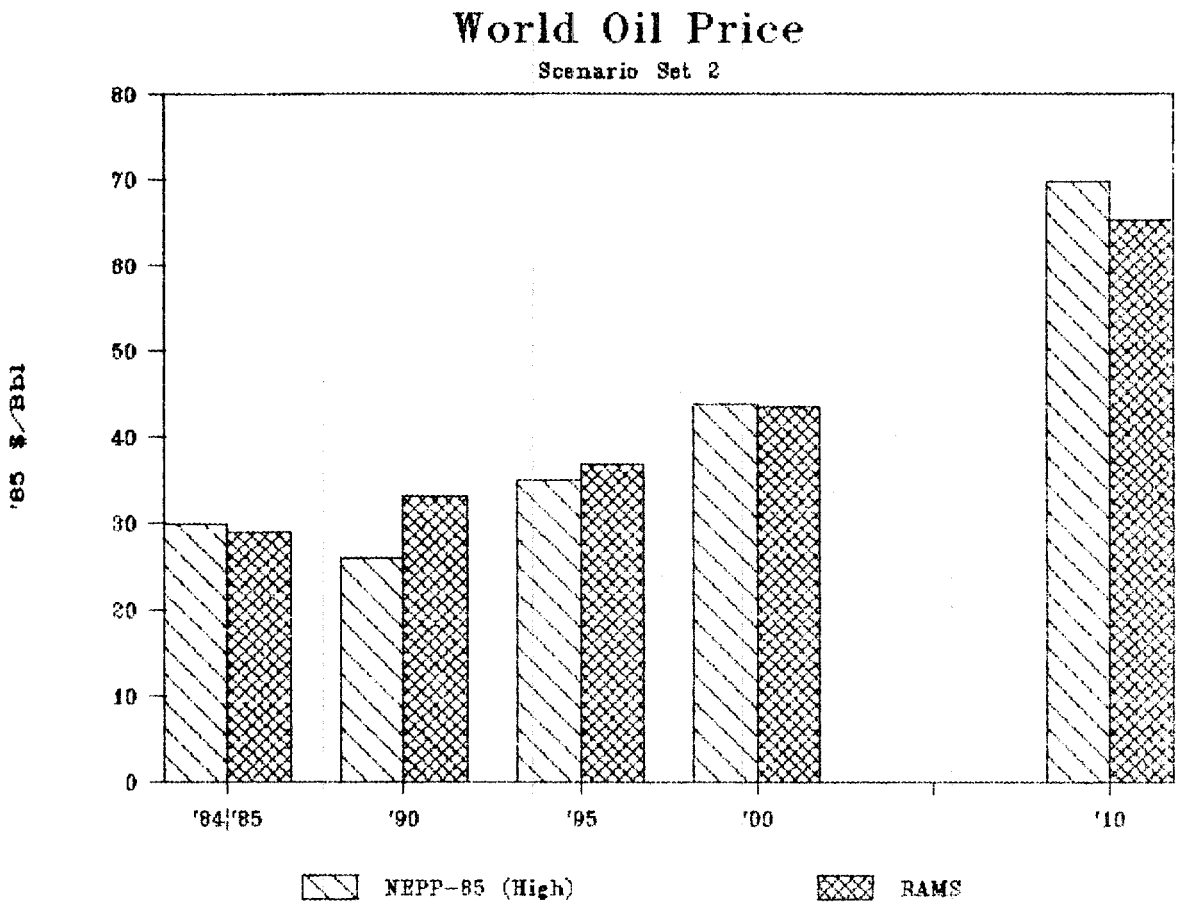

Fig. 7. Comparison of World Oil Price Projections

Scenario Set 2:
NEPP-85 High Case vs.
RAMS High Growth - parameter changes per Tables 2, 3, 5

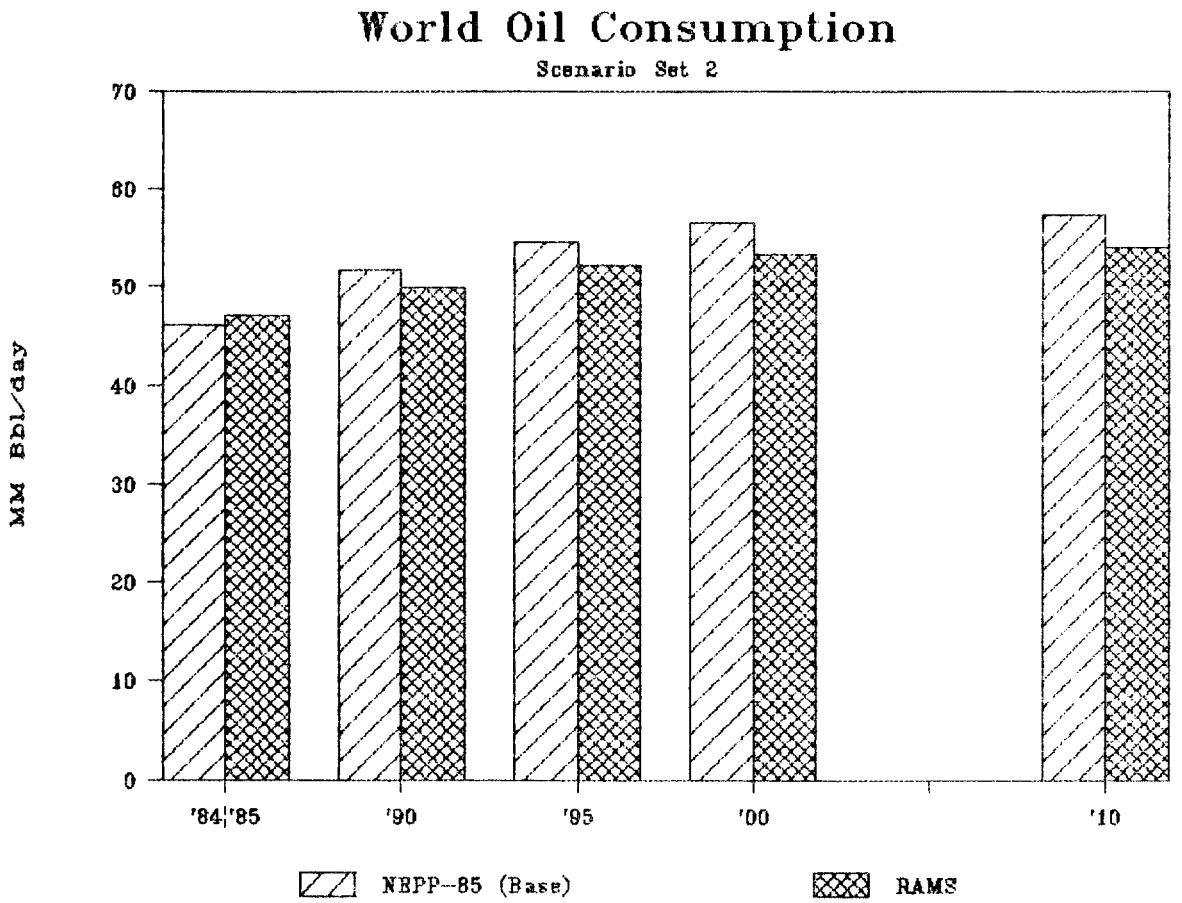

Fig. 8. Comparison of World Oil Consumption Projections

Scenario Set 2:
NEPP-85 Base Case vs.
RAMS Base Growth - parameter changes per Tables 2, 3, 5

Scenario Set 3:

While the second scenario set was an attempt to reproduce the input assumptions of NEPP-85, and allow the output to vary as it would, this scenario is an unabashed attempt to duplicate the output of NEPP-85, at the expense of using rather different input assumptions. As can be seen in Figs. 9 and 10, the RAMS output, as defined by the oil price and consumption projections, can be forced to correspond closely to NEPP-85.

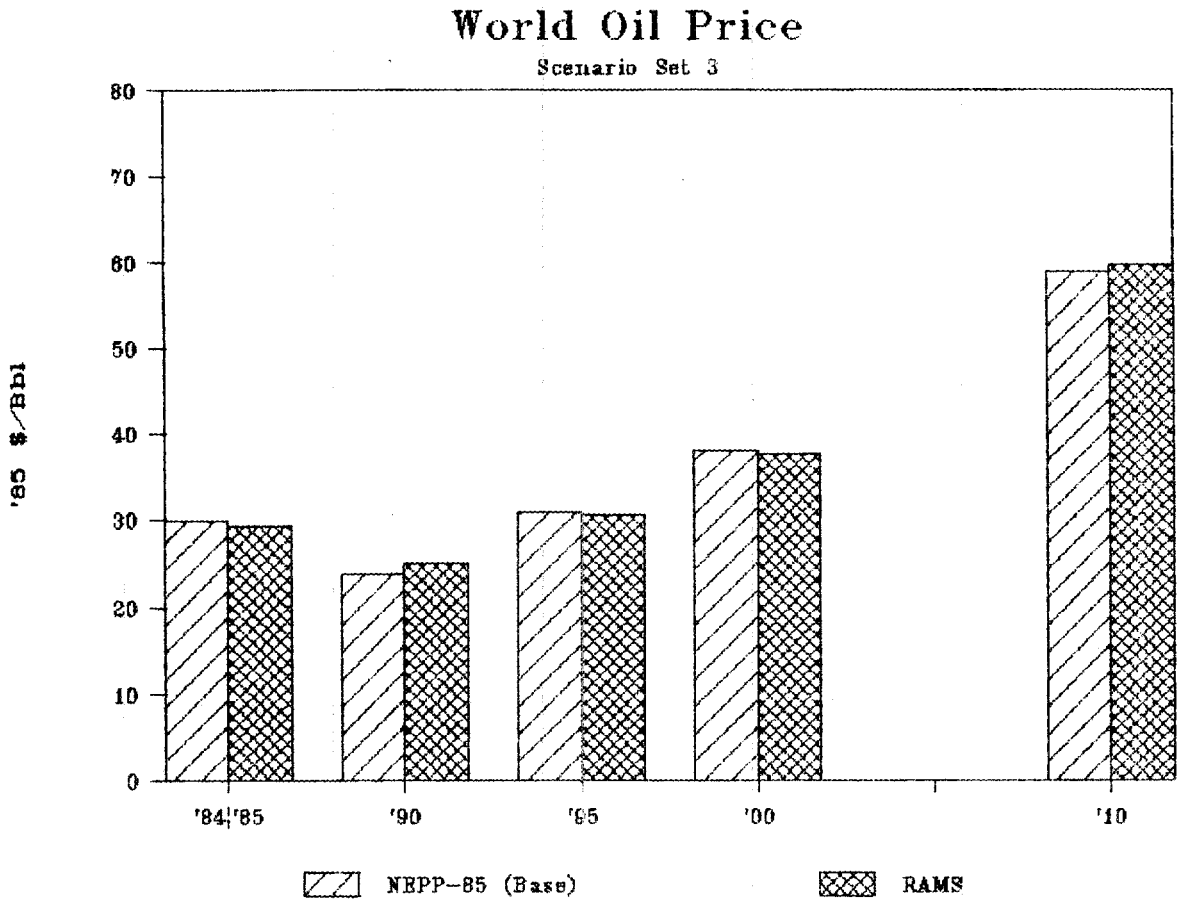

Fig. 9. Comparison of World Oil Price Projections

Scenario Set 3:
NEPP-85 Base Case vs.
RAMS Base Growth - parameter changes per Tables 2, 3, 6

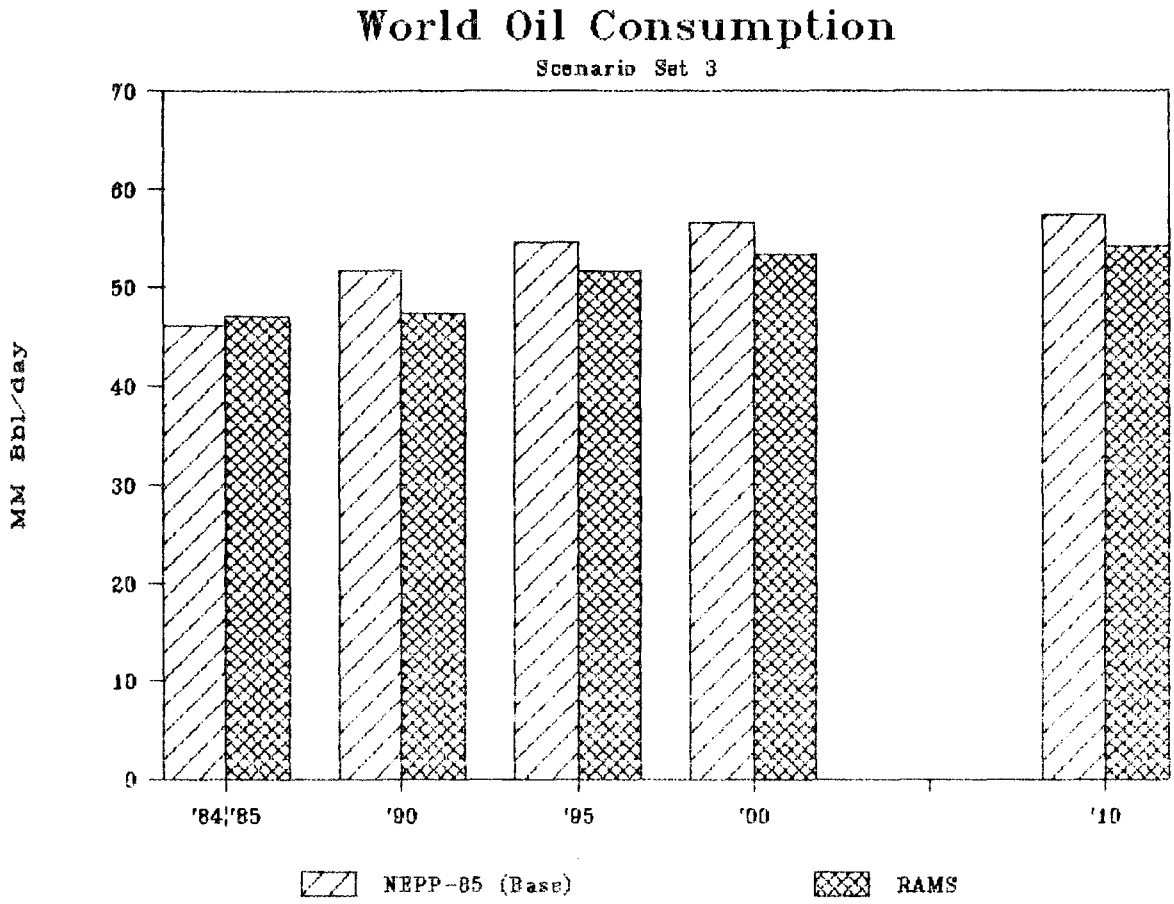

Fig. 10. Comparison of World Oil Consumption Projections

Scenario Set 3:
NEPP-85 Base Case vs.
RAMS Base Growth - parameter changes per Tables 2, 3, 6

To accomplish this, especially during the early periods, some arbitrary (and rather severe) changes were made to the energy demand growth parameters which do not correspond to the NEPP-85 values (compare Tables 5 and 6). These changes to the demand parameters create the same effect as the NEPP-85 judgements and interactions relating to short-term supply trends (particularly OPEC capacity variations and price-responsiveness of oil supplies).

Table 6. Demand Growth Parameters in Scenario Set 3 (Base Case Only)

GNP = GNP Growth;
E:G = Ratio of growth of primary energy use to growth of GNP

Annual growth of energy use, barring price changes, will be the product of these two parameters.

		81-85	86-90	91-95	96-20	01-10
OECD	GNP	2.0%	-2.5%	3.5%	3.0%	2.5%
	E:G	0.50	1.25	1.05	0.80	0.70
OPEC	GNP	7.0%	4.5%	4.5%	4.5%	4.5%
	E:G	1.00	1.00	1.00	1.00	1.00
LDC	GNP	0.0%	2.0%	4.5%	4.5%	4.5%
	E:G	1.00	1.00	1.00	1.00	1.00

DISCUSSION AND CONCLUSIONS

The most significant parameter adjustment made in emulating NEPP-85 behavior was to the demand elasticity. The value which best represented NEPP-85 projection behavior was -0.55. This value made RAMS considerably more price responsive than it is when using its default value of -1.0. The RAMS default elasticity (not used in any of the scenarios discussed here) was chosen based on recent history ('75-'84). As discussed in the RAMS documentation, a value closer to -0.5 is more representative of the earlier history. Since the NEPP-85 projections were made using WOIL, a model that calculates the world oil market

year-by- year starting in 1960 (and presumably closely calibrating the model for the historical period 1960-1984), it is not surprising that it might either implicitly or explicitly use a value more representative of that period.

The RAMS model has proven capable of reproducing the long-term NEPP-85 trends of world price and consumption. Without making unreasonable parameter adjustments, RAMS does not quantitatively reproduce the detail of the near-term future as well, though it does represent the general trends. This is not especially surprising: it is evident from the NEPP-85 report that a good deal of detailed judgement went into near term predictions of energy usage, production patterns, and political events. RAMS, designed to qualitatively represent long-term trends and with very little demand detail or price-responsiveness of supplier behavior, is not designed to capture such short-term nuances.

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1. National Energy Policy Plan Projections to 2010, Department of Energy, Office of Policy, Planning, and Analysis, Washington, D.C. (Dec. 1985).

2. J. V. Conopask and E. Hicks, "The Nonconventional Liquid Fuels Research and Development Modeling System (RAMS): A Microcomputer-Based World Oil Market Model - Final Documentation, Applied Management Sciences, Silver Springs, MD (1985).

Appendix A: Description of the RAMS World Oil Model

This appendix is intended to provide an overview of the RAMS World Oil Model. This model is designed to be a tool to aid in planning of unconventional liquid fuel R & D programs. It is intended to provide a relatively simple, qualitative framework simulating long-term trends in the world oil market within which market penetration of alternative synthetic and unconventional fuels may be studied. The model design emphasizes robustness, flexibility, and transparency; it is not intended to be a quantitative tool for precise projection of future oil markets. The model is implemented as a Lotus 1-2-3 spreadsheet on an IBM PC (Ref A-1).

The purpose of the model is to permit study the penetration of unconventional oil into the world market. The means chosen to accomplish this was to devise a supply/demand equilibrium model of the world oil market (excluding the internal interactions of countries with centrally planned economies) for the 50-year period from 1980 to 2030. The supply of oil from 24 regional sources and 15 unconventional fuel technologies is balanced against oil demand from three aggregate world regions to calculate world oil production and price tracks. When the world oil price exceeds the cost of an unconventional source of oil, it will penetrate the market at a rate determined by timing and production growth parameters.

SUPPLY

Conventional oil sources follow a predetermined production path calculated from a generalized equation for production of depletable resources, the Hubbert function. The production function for a particular source of conventional oil (e.g. UK - North Sea) is influenced by the total original resource, the resource consumed up to the initial period of the model, and the initial production rate. In this model, cost does not influence these production rates. The model implicitly assumes that the production costs of conventional sources of oil are less than the world oil price. This is a design limitation of

the model: while the model will algebraically function under, say, an extreme supply glut scenario, it may be beyond its design limits while doing so.

The above treatment for conventional oil supplies is significantly modified for OPEC countries. The Hubbert function formulation is used not to define actual production, but to define the time trajectory of production capacity. Actual production is limited to a fraction of this capacity. This fraction is constrained to lie between upper and lower limits intended to reflect the extremes of recent historical behavior. Within these allowable limits, OPEC production is determined by a selection of one of three behavior options. In the standard behavior option, OPEC acts as the "swing" producer, adjusting production to accomodate variations in world demand. In the other two behavior options, OPEC attempts to either achieve a target price, or to maximize the world oil price. These behavior options are not intended to be a comprehensive simulation of cartel behavior, but to simply provide a flexible, if rudimentary, framework which can be adjusted to encompass likely ranges of long-term OPEC influence on the world oil market.

Synthetic and unconventional oil sources are represented in more detail than are the conventional sources. Fifteen sources of unconventional liquid fuels are represented. These include 5 sources of coal liquids, 4 sources of shale oil, and 6 sources of tar sands or heavy oil. Production from each unconventional source is governed by a series of user-controlled parameters relating to the economics and technology of that particular source. An unconventional source is activated when the world oil price exceeds the cost of that source. So long as that source remains economic, its behavior will be similar to that of conventional sources of oil, growing from a low initial rate early in its production history and eventually dwindling as the resource base is consumed. Should it become uneconomic due to a low world oil price, production will decline at a rate controlled by the user. Each unconventional source of oil also possesses a parameter specifying the earliest allowed year for production startup.

DEMAND

For purposes of calculating demand, three aggregate regions of the world are considered: The developed countries (OECD), OPEC, and the less-developed countries (LDC). The base demand for energy is assumed to grow at the rate of GNP growth, modified for changes in energy efficiency. Oil demand is initially taken as a historically determined share of energy demand. Oil demand will attempt to grow with energy growth, but will be modified by the the equilibration of supply and demand.

EQUILIBRIUM

Each period, the available supplies are brought into equilibrium with oil demand. This is done by adjusting both demand and OPEC production (to the extent permitted by OPEC behavior constraints) according to their corresponding elasticities. The default values of these elasticities are based on recent historical behavior,[A-6] but may be adjusted by the user. The most significant difference between the RAMS standard scenario and the the scenarios emulating NEPP-85 is the value of the demand elasticity (-1 in the standard scenario versus -.55 in the NEPP comparison scenarios).

SCENARIO OPTIONS

Wide latitude is available to the user for the generation of scenarios. The purpose of the model is to study unconventional fuel market penetration, and consequently a great deal of variability is allowed in the adjustment of parameters which modify the behavior of these sources of oil. In addition several other categories of options are available for the exploration of future world oil market scenarios. One category, OPEC behavior, has already been mentioned. Another series of options permits selection of the size of the conventional oil resource base.

The standard scenario is based on USGS mean values for estimates of economically recoverable undiscovered resources in the world.[A-2, A-3] Alternatively, one may choose to use the USGS "low" (95th percentile) or

"high" (5th percentile) estimate. A word of caution is in order here: the notion of "economically recoverable" resource base implicitly assumes some cost limitation which may not be consistent with the price track generated in more extreme scenarios.

A fourth series of options allow selection of high, medium, or low estimates of future oil demand. Alternate GNP growth/energy efficiency estimates are available which for increased or decreased future demand for oil. Both the standard and alternative demand projections are derived from OECD sources.[A-5]

OUTPUT

The primary output of the model is a forecast of world oil price and production for conventional and unconventional sources. This information, and a considerable quantity of supplemental and intermediate calculations, are available through tabular and graphic screen displays and tabular printouts.

MODEL DOCUMENTATION (Preliminary Version)

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A-2 C. D. Masters, D. H. Root, and W. D. Dietzman, "Distribution and Qualitative Assessment of World Crude-Oil Reserves and Resources," USGS Open File Report 83-728, 1983.

A-3 G. L. Dolton et al., "Estimates of Undiscovered Recoverable Conventional Resources of Oil and Gas in the United States," USGS Circular 860 (1981).

A-4 INTERNATIONAL ENERGY ANNUAL, Energy Information Administration, (1985).

Demand Projections

A-5 WORLD ENERGY OUTLOOK, International Energy Agency/OECD (1982).

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A-8 ANNUAL ENERGY OUTLOOK 1985, Energy Information Administration (1986).

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