Natural Resource Accounting:
A Case Study of Natural Gas in Thailand

by

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ABBREVIATIONS AND ACRONYMS

AIC	Average Incremental Cost
bcf	billion cubic feet
boe	barrel oil equivalent
CCA	Capital Consumption Allowance
DMR	Department of Mineral Resources
EGAT	Electricity Generating Authority of Thailand
EGCO	Electricity Generating Company Limited
GNP	Gross National Product
GSP	Gas Separation Plant
Gwh	Gigawatt-hour
IPP	Independent Power Producers
kbd	thousand barrels per day
LPG	Liquefied Petroleum Gas
MEA	Metropolitan Electricity Authority
MMBTU	million British thermal units
MMcfd	million cubic feet per day
MWe	Mega-Watts
NEPC	National Energy Policy Committee
NEPO	National Energy Policy Office
NESDB	National Energy and Social Development Board
NFC	National Fertilizer Corporation
NGL	Natural Gas Liquid
NNP	Net National Product
NPC	National Petrochemical Public Company Limited
PEA	Provincial Electricity Authority
PTT	Petroleum Authority of Thailand
SCC	Siam Cement Company
SPP	Small Power Producers
THR	Total Hotelling Rent

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1. An Overview of the Natural Gas Industry in Thailand

INTRODUCTION

This paper considers the effects of resource depletion on sustainable consumption. The application of two rules, Hotelling's and Hartwick's, gives us conditions for maintaining constant consumption through investing resource rents. A recent model of resource depletion for a small, open economy such as Thailand is then used to adjust conventionally measured Net National Product for the effects of natural gas depletion.

The paper is organized as follows. The current section provides a description of the Thai natural gas industry. Section two examines the historical and future demand and supply of natural gas in Thailand. Section three discusses prices and section four takes up the costs. Section five develops the theoretical framework and leads into section six, our empirical results on adjusted NNP. Finally, section seven summarizes the main conclusions.

NATURAL GAS

Natural gas can be used as a fuel or as a source of it in its raw form and as a source of combustion, feedstock and components in petrochemical processes after separation. Like oil, natural gas is formed through the decomposition of plants and animals from millions of years ago. It is a hydrocarbon which contains mostly methane, and ethane, butane, pentane, hexane and others, depending on source. In Thailand, the composition of natural gas is about 83.35% methane, 5.95% carbon dioxide, 5.42% ethane and 2.09% propane (as well as trace amounts of nitrogen, iso-butane, normal-butane, iso-pentane, normal-pentane, hexane-plus and heptane). This means Thai natural gas is plentiful in hydrocarbons, dry and sulfur-free.

The key organizations involved in the natural gas industry in Thailand are summarized in Table 1.1.

Table 1.1
Key Agencies and Functions

Organization	**Role**
Petroleum Authority of Thailand(PTT)	Empowered to handle all industrial and commercial aspects of the petroleum business
National Economic and Social Development Board(NEDSB)	The government's main economic planning agency - develops five year plans
Department of Mineral Resources(DMR)	Responsible for the surveying of energy resources, and issuing liscences for exploration and development
Electricity Generating Authority of Thailand(EGAT), Metropolitan Electricity Authority(MEA) and Provincial Electricity Authority(PEA)	The three government state enterprises responsible for the generation and distribution of electricity
National Energy Policy Committee(NEPC)	Committee chaired by the Prime Minister acting as the supreme policy-making body for energy matters
National Energy Policy Office(NEPO)	Established by the NEPC and acts as the energy policy planning coordinator

HISTORY OF NATURAL GAS IN THAILAND

The history of natural gas production in Thailand began in 1971, with the commencement of exploration drilling and the first natural gas discovery. The Petroleum

Act was passed in that year and set out the conditions to explore, produce, store, transport and sell petroleum from their concession areas. The first oil crisis and the large reserves discovered in Thailand made the development of the natural gas industry seem logical.

In 1980, the National Petroleum Policy Committee laid out the following priorities for the development and use of natural gas in Thailand:

(i) as a feedstock for industrial and agricultural use, particularly in petrochemical and fertilizer manufacture;

(ii) as fuel for electrical power generation;

(iii) as process materials in industrial applications: and,

(iv) as an industrial fuel to replace fuel oil in the cement and textiles industries.

This order reflects the original priorities of the government. However the increase in oil prices in the late 1970s meant that power generation and cement manufacturing were given higher priority so as to decrease dependency on imported oil.

Natural gas production really took off in Thailand in the early 1980s. The first gas pipeline, from the Gulf of Thailand, was built in by PTT 1981 and the first gas separation plant was built in Rayong province in 1984.

Natural gas pockets are located in the Gulf of Thailand and in the Northeastern part of Thailand. Production occurs on shore at Sirikit and Nam Phong, and offshore at Bongkot, Erawan, Baanpot, Satun (and south Satun), Platong (and Kaphong), Funana, and Surat.

CONCESSIONAIRES

Petroleum and gas exploration in Thailand is carried out by concessionaires who do both exploration and production and determine a "well head cost" - the cost of the gas at the platform when ready for delivery to the PTT pipeline, which includes taxes and royalty charges. Concessions are granted by the DMR with a contract period of 3 years for exploration (extendible for 3 years) and 20 years for production (extendible for 10 years).

Depending on the date the concession was granted, concessionaires are charged royalty, income tax and special remuneratory benefits as outlined in the Petroleum Act. To increase natural gas exploration and development in small and high cost fields, the Petroleum Tax and Petroleum Income Tax Act were amended in 1989. The flat 12% of production value royalty was changed to a "sliding scale", whereby fields producing under 60 cubic barrels are subject to a 5% royalty, those producing 60-150 cubic barrels are subject to 6.15% and so on, up to a maximum of 15% for over 600 cubic barrels. This policy is aimed at encouraging production in smaller, previously less profitable fields. The early fiscal regime was biased against small fields, which are the predominant type in Thailand. The introduction of the "sliding-scale" royalty rate will help to correct this. This, like most natural gas policies in Thailand, resulted from a change in oil tax policy.

Table 1.2 provides a historical look at wells drilled by concessionaires in Thailand.

TABLE 1.2
Wells Drilled in Thailand

	Exploration Wells	Appraisal Wells	Development Wells
1989	2	14	46
1990	31	14	77
1991	3	19	56
1992	5	22	64
1993	11	8	85
1994	11	18	75

Source:PTIT Focus:Special Annual Issue 1994

To the end of 1994, the total number of wells drilled was 1088; 189 exploratory, 212 appraisal, 656 development, 29 stratigraphic and 2 service wells. More wells were drilled in 1994 than 1993 (113 versus 104). Of those wells drilled in 1994, 101 were offshore and 12 were onshore. Of the 8 exploration wells drilled onshore, one well found gas, two found traces and the remaining four were dry, and one was left uncompleted. The three onshore exploratory wells all came up dry. All 27 appraisal wells were offshore and of the 75 development wells drilled, only 9 were onshore.

There are currently at least 20 concessionaires in Thailand. Unocal is responsible for 68% of natural gas production in Thailand, and Total for 20%.

END-USERS

Thailand's natural gas transmission pipeline system falls under the auspices of the PTT. PTT has laid down pipelines from Erawan, Kapong, Platong, Pladaeng, Satun and Banpot to the Eastern mainland seaboard. The offshore gas is brought onshore at Ban

Nong Faep, Map Ta Put, Rayong Province and is piped further to the Bang Pakong and Electricity Generating Authority of Thailand (EGAT). See Figure 1.1 for more detail.

Most of Thailand's natural gas is used for energy production. About 80% of Thailand's gas production currently (1994) goes to EGAT, 13% to gas separation plants and the remaining 7% to industries. Natural Gas accounted for about 17% of the overall energy requirements of Thailand.

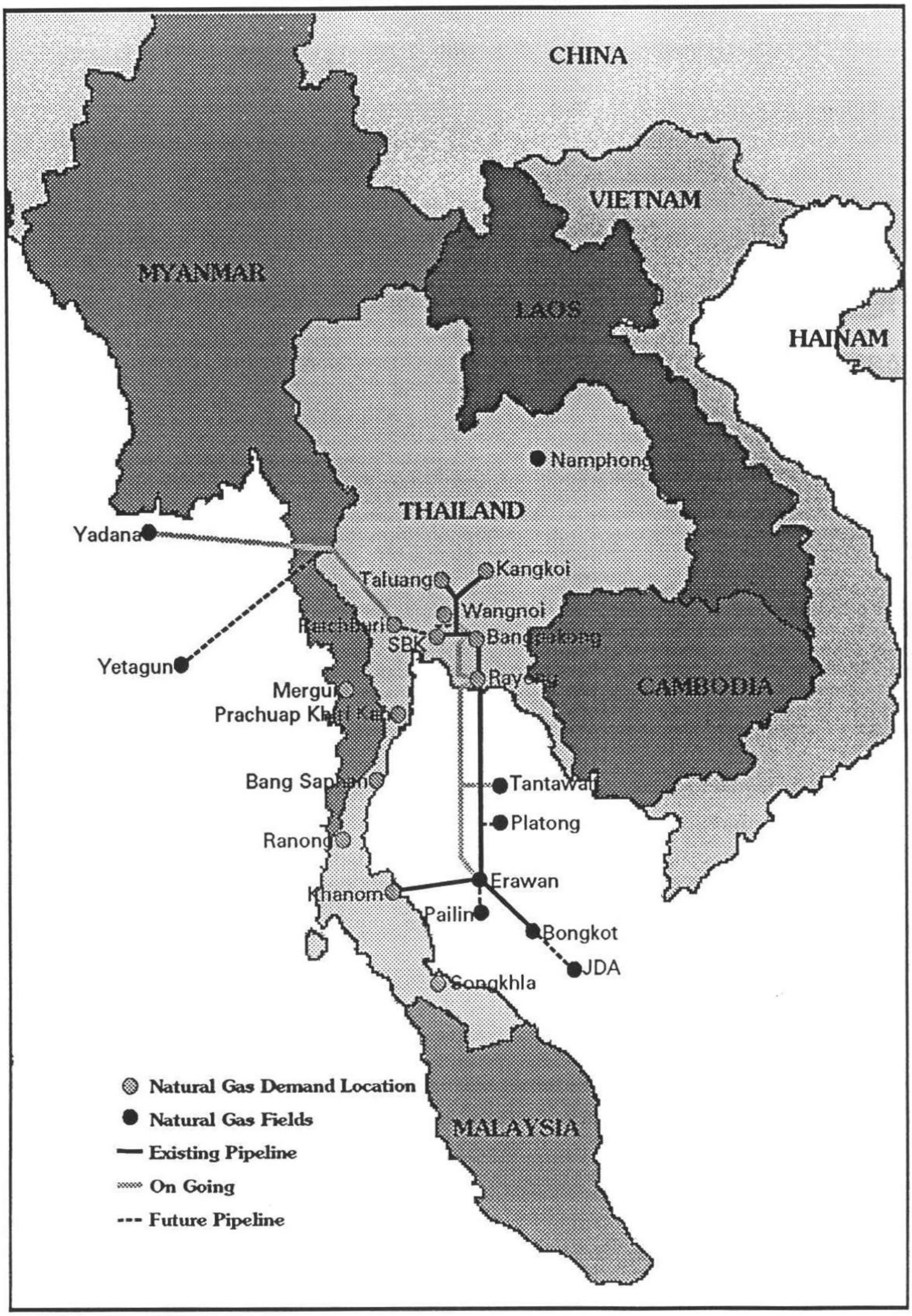
EGAT relies on natural gas for about 45% of its energy production. EGAT has recently undertaken a study on the merits of building nuclear power plants after 2005, which would decrease its dependency on natural gas for electricity.

The next biggest users of natural gas are the Gas Separation Plants. These plants extract the gaseous hydrocarbons methane, ethane, propane, LPG and natural gasoline. Methane is an industrial fuel, a feedstock for fertilizers, synthetics and herbicides, and can be compressed to become natural gas for vehicles. This fuel is starting to be used in buses of the Bangkok Mass Transit Authority. LPG is used for household cooking and as a transport fuel. Natural Gas Liquid can be refined to become gasoline. Ethane and propane are raw materials in the petrochemical industry.

There are currently two Gas Separation Plants (GSPs) in Thailand, both owned and operated by PTT. GSP I has been on-line since 1984, has a capacity of 350 million cubic feet per day (MMCFD), and separates methane and ethane for use as feedstocks in the production of ethylene, for the petrochemical industry and for the manufacture of LPG. Its products include dry gas, ethane, propane, LPG, stable NGL, and carbon dioxide. GSP II began production in 1990 and has a capacity of 250 MMCFD. Its

Figure 1.1

NATURAL GAS PIPELINE SYSTEM



products include dry gas, ethane, LPG and stable NGL. A third and fourth plant, GSP III and GSP IV, will be completed in 1996 with a capacity of 350 MMCFD and 250 MMCFD, respectively.

Various hydrocarbons can be used as feedstocks into the process whereby "crackers" are used to manufacture olefins and aromatics. For example, ethane can be used to manufacture ethylene (an olefin) by cracking. Polymerization (where a series of identical molecules are linked together into long chains of repeating pieces) of ethylene makes polyethylene, a plastic.

In addition to the petrochemical industry, other final users include cement factories (the most important of these), as well as ceramics and sanitary wares, glass, iron, steel, copper and chemicals. Gas is used in these industries as a substitute for other fuels and as a raw material in processing. The Siam Cement Company converted its two Saraburi cement plants to dual natural gas/fuel oil firing systems in 1984. The National Fertilizer Corporation was established in 1982 to develop a plant that uses domestic natural gas to manufacture fertilizer. To date, the plant has not been built, and it is not clear that it will be.

This concludes the overview of the natural gas industry in Thailand. The following section provides a more detailed examination of historical and projected demand and supply.

2. Historical and Future Demand and Supply of Natural Gas in Thailand

HISTORICAL DEMAND

Energy use increased in the 1980s, and the energy mix in Thailand changed, largely because of government policies to encourage development of domestic energy sources. This resulted in an increase in natural gas use from a little more than 2% of total domestic energy demand in 1981 to 20% in 1989 (Table 2.1).

40% of primary commercial energy demanded is now (1994) satisfied domestically, energy supply, up from 12% in 1981.

TABLE 2.1

Primary Commercial Energy Demand and Supply Balance
Thousand Barrels Per Day
(Crude Oil Equivalent-kbd)

DEMAND	1981	%	1989	%	1994	%
Petroleum	220.10	87.76	332.41	64.29	566.11	62.91
Natural Gas	**5.30**	**2.11**	**104.08**	**20.13**	**186.48**	**20.72**
Lignite	10.10	4.03	50.75	9.82	107.19	11.91
Imported Coal	0.80	0.32	4.20	0.81	19.00	2.11
Hydroelectricity	14.50	5.78	25.61	4.95	21.10	2.34
Total Demand	250.80	100.00	517.04	100.00	899.88	100.00

Sources:National Energy Policy Office;National Energy Administration

SUPPLY	1981	%	1989	%	1994	%
Domestic Production						
Crude Oil	0.30	0.12	21.32	4.10	26.55	2.97
Condensate	1.20	0.48	16.78	3.22	27.86	3.11
(including Export)						
Natural Gas	**5.30**	**2.12**	**104.08**	**19.99**	**186.48**	**20.83**
Lignite	9.20	3.68	54.33	10.44	107.60	12.02
Hydroelectricity	13.20	5.28	24.51	4.70	19.55	2.18
TOTAL DOMESTIC	*29.2*	*11.69*	*221.02*	*42.45*	*368.04*	*41.11*
IMPORT:						
Crude Oil	164.40	0.66	204.18	39.22	372.89	41.65
Oil Products	54.20	21.69	104.58	20.09	165.51	18.49
Coal	0.80	0.32	4.20	0.81	19.00	2.12
Net Electricity	1.28	0.52	1.06	0.21	1.55	0.17
TOTAL IMPORT	*220.7*	*88.32*	*314.06*	*60.33*	*542.28*	*60.58*
EXPORT:						
Condensate	0.00	0.00	-14.46	-2.78	-15.16	-1.69
Total Net Supply	249.88	100.00	520.57	100.00	895.16	100.00

Sources:National Energy Policy Office;National Energy Administration

Petroleum dominates energy imports, accounting for about 60%.

Production of natural gas was 132.2 billion cubic feet (bcf) in 1985. By 1990, this had increased to 230.2 bcf and to 378.8 in 1994. See Table 2.2.

Table 2.2

Production of Natural Gas in Thailand

year	MMbtu	Y/Y % change
1985	128286380	na
1986	123902950	-3.42
1987	173298260	39.87
1988	214345750	23.69
1989	205086130	-4.32
1990	223353170	8.91
1991	277031030	24.03
1992	295225320	6.57
1993	332479140	12.62
1994	367415630	10.51

The sale of this natural gas is profiled in Table 2.3.

TABLE 2.3

Uses of Natural Gas (shares)

	1990	1994
EGAT	79.5	80.5
GSP	15.3	12.7
Industries, SCC, NPC	5.2	6.8
TOTAL	100.0	100.0

Source:"Thailand's Natural Gas for its Sustainable Development, PTT, 1994.

Note that EGAT has traditionally consumed about 80% of natural gas supply and that natural gas is responsible for about 45% of power generation.

HISTORICAL SUPPLY

In 1980, oil was the main source of energy in fueled power plants and factories in Thailand; but world oil price shocks and natural gas discoveries led the government to launch policies aimed at reducing dependence on imported oil. Production has grown every year since 1986.

According to the Department of Mineral Resources, as of January 1995, Thailand has proven reserves of about 738 million barrels of crude oil, 5.9 trillion cubic feet of natural gas and 157.0 million barrels of Condensate[1].

[1] As Adelman(1993) puts it "Proved primary reserves are those that have been proved to a high degree of probability by production from the reservoir at a commercial rate of flow or in certain cases by successful testing in conjunction with favourable complete core-analysis or reliable quantitative interpretation of log data. Probable primary reserves are those that have not been proved by production at a commercial rate of flow, but being based on limited evidence of commercially producible oil or gas within the geological limits of a reservoir above a know or inferred water table are susceptible to being proved by additional drilling and testing. Possible primary reserves are those that may exist but where available data will not support a higher classification" (page 136).

FUTURE DEMAND

Recall that in 1994, about 80% of all natural gas in Thailand went to EGAT. EGAT's projected fuel mix into the next century is shown in Table 2.4.

TABLE 2.4
EGAT Fuel Mix, 1991-2006

Type of Fuel	Unit	Year			
		1991	1995	2000	2005
Hydroelectric	Gwh	4413	5026	6273	6549
	%	9.0	6.8	5.6	3.9
Natural Gas	Gwh	19752	27469	43812	41007
	%	40.1	36.9	38.9	24.5
Heavy Oil	Gwh	11676	25657	22469	18626
	%	23.7	34.5	20.0	11.1
Diesel Oil	Gwh	217	245	630	630
	%	0.4	0.3	0.5	0.4
Domestic Coal	Gwh	12514	15240	20486	35886
	%	25.4	20.5	18.2	21.5
Imported Coal	Gwh	-	-	18219	56763
	%			16.2	34
Nuclear	Gwh	-	-	-	7008
	%				4.2
Purchase	Gwh	652	70.5	705	705
	%	1.3	1.0	0.6	0.4
Total	Gwh	49225	74342	112593	167173
	%	100.0	100.0	100.0	100.0

Source:EGAT, Power Development Plan (1992-2006), September 1992

EGAT plans to make natural gas a smaller portion of its fuel mix in the future. This is because the available supply of natural gas will be limited, and EGAT will have to rely on other sources.

The composition of demand for gas will not change much over the next five years. See Table 2.5. Natural gas use for feedstock will increase to 14% in the year 2000, from 12% in 1995; for industry will increase to 6%, up slightly; for cogeneration and small power producers to 8% from 3%; for EGCO (the Electricity Generating Co. Ltd., a subsidiary of EGAT) will decrease to 11% from 17%; for EGAT will also decrease to 55% from 62%; and finally, by the year 2000, some independent power producers (IPP), who generate and supply electricity to the PEA and MEA, will be on line, demanding 5% of available natural gas.

Table 2.5:Demand for Natural Gas (MMscfd)

	1995	1996	1997	1998	1999	2000	2005	2010
DEMAND								
FEEDSTOCK	**133**	**150**	**175**	**175**	**345**	**345**	**345**	**345**
GSP1	105	105	105	105	105	105	105	105
GSP2	25	25	25	25	25	25	25	25
GSP3	0	10	35	35	35	35	35	35
GSP4	3	10	10	10	10	10	10	10
NPC3	0	0	0	0	170	170	170	170
INDUSTRY	**63**	**113**	**136**	**142**	**151**	**154**	**292**	**292**
Cogen/SPP	**37**	**143**	**211**	**211**	**211**	**211**	**211**	**211**
NPC	17	30	30	30	30	30	30	30
Thai Cogen	7	7	7	7	7	7	7	7
COCO	13	66	66	66	66	66	66	66
Bangpakong	0	30	30	30	30	30	30	30
Ind. Power	0	0	12	12	12	12	12	12
Thai Oil	0	10	17	17	17	17	17	17
Thai Melon	0	0	15	15	15	15	15	15
Alfatech	0	0	30	30	30	30	30	30
Fertilizer	0	0	4	4	4	4	4	4
EGCO	**187**	**283**	**283**	**283**	**283**	**279**	**272**	**261**
IPP	**0**	**0**	**0**	**41**	**75**	**135**	**170**	**200**
EGAT	**673**	**673**	**501**	**516**	**787**	**1227**	**1457**	**1149**
TOTAL	**1093**	**1190**	**1321**	**1639**	**2292**	**2511**	**2740**	**2458**

Source:EGAT's PDP (1995-2011)

Table 2.6:Supply of Natural Gas (MMscfd)

	1995	1996	1997	1998	1999	2000	2005	2010
SUPPLY								
OFFSHORE								
Unocal #1-3	740	742	873	902	740	740	740	732
Bongkot	250	350	350	425	650	650	650	400
Maersk	0	0	0	100	100	100	100	100
Unocal #4	0	0	0	0	200	200	200	200
Sub-Total	**990**	**1092**	**1223**	**1427**	**1690**	**1690**	**1690**	**1690**
ONSHORE								
Nampong	65	60	60	60	60	60	51	35
Sirikit	38	38	38	37	34	36	24	16
Sub-Total	**103**	**98**	**98**	**97**	**94**	**96**	**75**	**51**
Domestic Total	**1093**	**1190**	**1321**	**1524**	**1784**	**1876**	**1765**	**1483**
IMPORT								
Yanada	0	0	0	115	408	525	525	525
Yetagun	0	0	0	0	100	200	200	200
JDA	0	0	0	0	0	0	250	250
TOTAL SUPPLY	**1093**	**1190**	**1321**	**1639**	**2292**	**2511**	**2740**	**2458**

Source:EGAT's PDP (1995-2011)s

FUTURE SUPPLY

Over the next five years, domestic supply will increase because of the development of two new fields: Maersk and Unocal #4. Demand growth will exceed that of supply. The difference will be made up through imports. In September 1994, PTT signed a Memorandum of Understanding to purchase natural gas from the Yanada gas field in Myanmar, with an initial delivery volume of *115 million cubic feet per day during* a 30-year period, commencing in 1998. To handle this quantity, a 400 km pipeline will be built from the Thai-Myanmar border to an electricity generating plant in Ratchaburi. Similar negotiations over Yetagun (also in Myanmar) are currently taking place.

In a similar vein, the Malaysia-Thailand Joint Authority was formed on April 21, 1994 to survey and exploit the natural gas fields in the Joint Development Area (JDA) held by Thailand and Malaysia in the Gulf of Thailand.

In addition to the pipeline from the Myanmar border, three others are planned for the near future. The offshore Erawan-Rayong parallel trunk pipeline, the onshore Rayong-Bang Pakong parallel pipeline and the onshore BangPakong-Wan Noi pipeline should be completed in 1996, and will contribute to the increase in future supply of domestic natural gas.

The supply of natural gas has increased every year since it was first domestically produced in 1981. Due to continued demand growth and increased pipeline capacity, this is expected to continue into the 21st century, after which the effects of scarcity of economically viable fields will reverse the trend. The supply of natural gas is expected to increase 5.3% in 1995 to 1093 MMSCFD. This follows increases of 10.5% in 1994 and 12.6% in 1993.

Since transportation costs are high for natural gas, a major portion of natural gas is generally consumed in the country where it is produced. As this forecast indicates, all natural gas supply will be domestic until 1998; but by the year 2000, it is forecasted that imports will account for almost 30% of Thailand's natural gas supply, since domestic supply will be insufficient to meet rapid demand growth. See Table 2.6.

3. Natural Gas Prices

Our estimates will require forecasts of future prices of natural gas. Because of high transportation costs, however, international markets are thin and there is no "world price" for natural gas. However, there are world prices for energy sources which can substitute for natural gas. In this way, natural gas prices are affected by international forces and can be forecast accordingly.

Our model requires both historical and future natural gas prices series. Future natural gas prices will be projected as a function of oil prices. For historical data, Thailand offers no clear explanation of the basis for its domestic natural gas prices. Prices are determined by contracts between PTT and concessionaires. The first contract between PTT and Unocal established prices as a function of a basket of energy prices, lagged 24 months, as well as of other economic indicators, including United States and Thai inflation, and the baht foreign exchange rate. The second contract between Unocal and PTT priced natural gas as a function of energy prices 12, rather than 24 months, earlier because a 24 month lag made natural gas prices uncompetitive when oil prices fell rapidly. More recent, much smaller contracts between ESSO and PTT have been based on "Basing Point pricing" which links natural gas prices to international prices of competing fuels expressed as a percentage of fuel oil prices in Singapore, and which is adjusted regularly.

There is no consistent contract approach and the pricing procedure in the industry is not evident or disclosed.

Historical wellhead prices are available from DMR[2], but there are no published price forecasts for natural gas. Since contracts are based on crude oil prices, regressions of historical natural gas prices on crude oil prices will be used with crude oil price forecasts to project future natural gas prices.

The regression equation used was:

$$\textit{natural gas price} = \beta_0 + \beta_1 * \textit{oil price}(-1) + \beta_2 * \textit{oil price}(-2)$$

where the historical natural gas prices came from the Department of Mineral Resources, and the oil prices are the average OPEC spot prices, as published by the World Bank. Oil prices are lagged one and two years to reflect the historical contracting agreements between PTT and concessionaires.

The World Bank's price projections for oil are obtained using futures price quotations for the short-term (1-2 years), futures price quotations and over-the-counter quotations for long-dated underlying derivatives (like oil swaps) for the medium term (3-4 years), and a model for the long-term (World Bank, 1993). The World Bank's rationale for using futures prices is that there is very heavy trading for oil in the futures markets with a large number of active participants. Since oil producers and refiners use spot and futures market prices in their contract negotiations, this seems sensible.

The explanatory power of this regression is obviously limited. The number of observations is low, and natural gas prices are linked to oil prices in the contracting

[2] Source: Historical natural gas prices came from the table "Production, Sales, Value and Royalty of Natural Gas" by DMR, page 1.

process, so the two series move together. Unfortunately, no natural gas price forecasts are done per se, and so there is little alternative to doing price forecasts for natural gas as a function of oil price forecasts. While there is a lack of world market for natural gas and therefore an absence in forecasts, in principle a forecasting model for Thailand could have been developed.

The results of the regression are shown in Table 3.1.

TABLE 3.1
Price Regression Results

Sample 1985 - 1995	11 observations	Dependent variable is natgas	
VARIABLE	**COEFFICIENT**	**STD. ERROR**	**T-STAT**
C	21.227263	2.9281528	7.24937
OILPR(-1)	0.0434730	0.0054548	7.96967
OILPR(-2)	0.0268187	0.0051911	5.16629

R-squared	0.953403	**Mean of dependent var**	55.17400
Adjusted R-squared	0.940089	**S.D. of dependent var**	7.745046
S.E. of regression	1.895726	**Sum of square resid**	25.15645
Durbin-Watson stat	1.850687	**F-statistic**	71.61198
Log likelihood	-18.80203		

Historical prices are listed in Section 6 with the empirical results. Both historical and projected prices appear in Appendix 3.

4. Cost of Natural Gas

Key variables in determining the cost of gas production are:

(i) size of the reserve;

(ii) rate of production per well;

(iii) location of field relative to location of demand;

(iv) composition and pressure of the gas; and

(v) amount of demand.

The analysis of supply cost for natural gas is difficult. Consumption of the first unit requires large expenditures in exploration, production, transmission, and distribution. These activities have major equipment requirements.

Exploration is the activity of discovering whether gas fields are large enough to be worth developing. Geological and geophysical surveys are studied to determine if exploratory well drilling is justified. Since exploration is a risky venture, costs must reflect this by averaging reserves over all possible basins, not just developed ones.

Development and production includes producing pipeline quality gas through the processes of development drilling, field preparation, field gathering, compression, separation of NGLs, and treatment of the gas. Development and production costs are a function of the number of wells, the condition of the reservoir and the infrastructure required.

Transmission costs are primarily a function of diameter and length of pipeline. This premium, which is charged by PTT, is undisclosed.

Finally, distribution costs to end-users differ depending on each customer's total demand. For EGAT, incremental cost is low because of the high volume of natural gas sales, which means that economies of scale are achieved. The opposite holds for smaller users.

Since production of natural gas is characterized by a few large firms, economies of scale exist. Unocal is able to provide less expensive natural gas to PTT than other companies and neighboring countries. The marginal cost of producing natural gas should be used, not the average costs. For marginal cost, the World Bank uses an "average incremental costs" (AIC) calculation. The formula for this is:

$$AIC = \frac{\sum_{t=1}^{T}[\{I_t + (R_t - R_O)\}/(1+r)^t]}{\sum_{t=1}^{T}[(Q_t - Q_o)/(1+r)^t]}$$

where I is the marginal capital cost, R_t-R_o is the marginal operating and maintenance cost due to the new demand, Q_t-Q_o is the marginal demand and r is the interest rate.

In Julius and Mashayekhi[1990], the AIC for natural gas at well-head in Thailand was calculated to be \$.80/mcf[3]. This figure is in American dollars and our volume estimates for natural gas are generally in mmbtu. One mcf=.97mmbtu and a \$1=25 baht

[3] Since prices and costs vary across end-users, well-head prices and well-head marginal cost are used, rather than to city-gate ones.

exchange rate is used. This means the World Bank marginal cost figure is 20.62 baht/mmbtu. However, this number was based on 1985 data and recent interviews with industry indicate that marginal cost is now higher than this. Unocal, which accounts for 68% of gas production in Thailand, estimates its marginal cost at $5/boe. Since 1 boe =5.3 mmbtu and we continue to assume a $1=25 baht exchange rate, the marginal cost of natural gas is 23.58baht/mmbtu. We shall assume this marginal cost applies to the industry as a whole.

5. Theoretical Framework

NOTION OF NNP

In national accounting, Gross National Product (GNP) includes natural resource input flows. These flows from the natural resource stocks should be treated in a fashion similar to capital. Flows from services of machine capital come in two types: those which will be available next year and those lost due to depreciation. Natural resources should be considered in the same way. GNP is the total value of goods and services produced in a country in one year plus the total of net income from abroad. The difference between GNP and Net National Product (NNP) is the Capital Consumption Allowance (CCA). This is the allowance made for depreciation of the capital stock, the investment in new capital to replace worn-out capital. The difference between GNP and NNP should also include a "natural resource consumption allowance", like CCA, to account for the depletion of resources.

This accounting identity version of NNP is generally considered to be a better measure of an economy's well-being than GNP. Consider two economies with identical GNPs, but where one economy uses capital moderately and has a depreciation of ten percent, while the other economy uses its capital intensively and therefore has a lower NNP (due to its higher depreciation rate). The economy with less depreciation, and therefore a higher NNP is better off. It has more capital for production next year. This principal should hold for natural resources, where a country which is intensive in its use of mineral resources has a lower NNP. It has less natural capital to work with in the next period. This depletion term is not currently included in standard capital consumption allowance.

Similarly, recall also that NNP is consumption plus net investment of an economy. With regards to sustainability of the economy, consider an economy with no net investment. In this economy, NNP equals consumption, and the capital stock (which is interpreted very broadly to include everything tangible and intangible including knowledge) does not grow or shrink, as long as consumption is constrained at being NNP, the flow from the "capital stock". If consumption is greater than NNP, our economy's consumption is eating into the capital stock. Similarly, if consumption is less than NNP, net investment must be positive, causing our capital stock to grow. Our economy with consumption equal to NNP can be thought of as having a constant consumption path, where this constant consumption is equal to the flow from "capital" and can be maintained indefinitely. Recall that "Hicksian income" is NNP since it is that part of output left over for potential consumption, capital having been maintained intact. The capital consumption allowance exists to maintain capital intact (i.e. to replace capital worn-out or used-up over the accounting period).

By definition, non-renewable resources cannot be "replaced" or "kept intact" through investment. Constant flows from their finite stock cannot be maintained indefinitely. Therefore, to maintain a constant (or sustainable) level of consumption, an economy must invest in some "less exhaustible" highly substitutable capital to replace its depleting resources.

Rules can be derived to characterize the amount of investment that needs to be made to replace depleting resources in order to maintain sustainable consumption levels. Two such rules that exist in the literature are referred to as Hotelling's r% rule and Hartwick's investing resource rents rule. Solow[1986] called the constant consumption paths characterized by these rules as being "intergenerationally equitable".

HOTELLING'S R% RULE

The Hotelling r% rule states that the marginal profit on a unit extracted, or unit price less marginal cost, of a non-renewable resource should rise at the rate of return on a comparable capital asset. This is a basic asset equilibrium or portfolio condition.

Hotelling considered the problem of a firm choosing the optimal extraction path for non-renewable resources. The resource firm's extraction plans will be based on the discount rate, the initial stock and extraction costs. An optimal extraction path is one where the present value of profits is maximized subject to the size of the stock. The firm analysis can be generalized to the economy as a whole, which is deciding its optimal extraction path.

Maximize:

$$V = \int_0^T [pq(t) - C(q(t))]e^{-rt}\,dt$$

subject to:

$$\int_0^T q(t)dt \leq S_0.$$

Here, V is the value of the firm (economy), p is price, q is quantity extracted, c is the cost of extracting q(t) units of resource, S is the size of the total stock, r is the discount rate, assumed to be constant, and T is the number of periods over which the resource is extracted.

The current value Hamiltonian associated with this problem is:

$$H(t) = pq(t) - C(q(t)) + \psi[-q(t)].$$

This Hamiltonian maximized with respect to controls is:

$$\frac{\partial H}{\partial q} = 0 \Rightarrow p - C_q = \Psi$$

and maximized with respect to states is:

$$-\frac{\partial H}{\partial S} = 0 \Rightarrow \dot{\Psi} - r\Psi = 0 \qquad \therefore \frac{\dot{\Psi}}{\Psi} = r.$$

The Euler equation for the above dynamic optimization problem is therefore:

$$\frac{\overline{p - C_q}}{p - C_q} = r.$$

This is Hotelling's r% rule. The endpoint condition characterizing this optimal extraction program is:

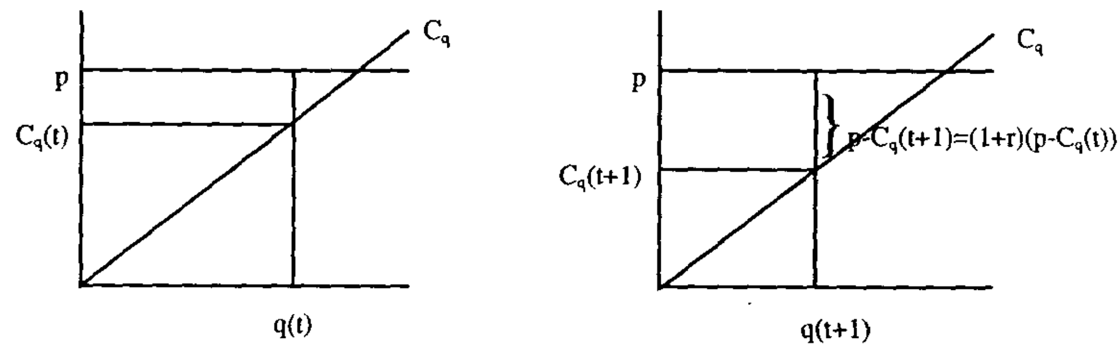
$$p - C_q(q(T)) = \frac{pq(T) - C(q(T))}{q(T)}$$

or, the marginal value of the last quantity extracted equals the average value. Intuitively, if marginal profit is greater than average profit (marginal costs is less than average costs), profits would be increased by moving resource extraction into the last period from the preceding periods. Similarly, if average cost is less than marginal cost, present value of profits would increase if the owner of the firm moved resources from the last period into preceding periods. Therefore, this r% rule ensures intertemporal profit maximization. No profit can be made from arbitraging the marginal unit of resource across time, and the present value of profits is maximized.

The profit obtained by leaving the marginal unit in the ground, $\overline{p - C_q}$, is the amount by which the marginal unit in the ground rises if unextracted. The value of the marginal unit, if extracted and invested is $r(p-C_q)$, and so the marginal unit is worth the same extracted or unextracted. The term "$p-C_q$" is referred to as dynamic or Hotelling rent per period.

The discrete time version of Hotelling's r% rule is $p-C_q\ (t+1)=(1+r)(p-C_q\ (t))$, which is presented graphically in Figure 5.1.

Figure 5.1



HARTWICK'S RULE

Hartwick's rule is that economies should invest their exhaustible resource rents in reproducible human-made capital. It turns out that rent is often the value of the decline of the stock of the resource resulting from current extraction. Hence the investment of rents in human-made capital is a means of "allowing for" the decline in the exhaustible stock. The depreciation in one stock is balanced off by investment in another.

The value of an extracting firm can be considered the present value of the future profits from its flow of services:

$$V(S(t)) = \int_{t}^{T} (pq^{*}(u) - c(q^{*}(u)))e^{-r(u-t)}du$$

where p is the price of the resource, q^{*} is the optimal quantity extracted, r is the discount rate and V(S(t)) is the value of the firm with S(t) reserves remaining.

Differentiating with respect to time yields:

$$\dot{V} = \frac{\partial V(S(t))}{\partial t} = rV(S(t)) - (pq^{*}(t) - C(q^{*}(t))).$$

This basic asset equilibrium condition holds at every instant in time. The change in the value of our firm from current extraction is profit from that extraction plus interest on the market value of the firm. Note that this particular result assumes constant prices.

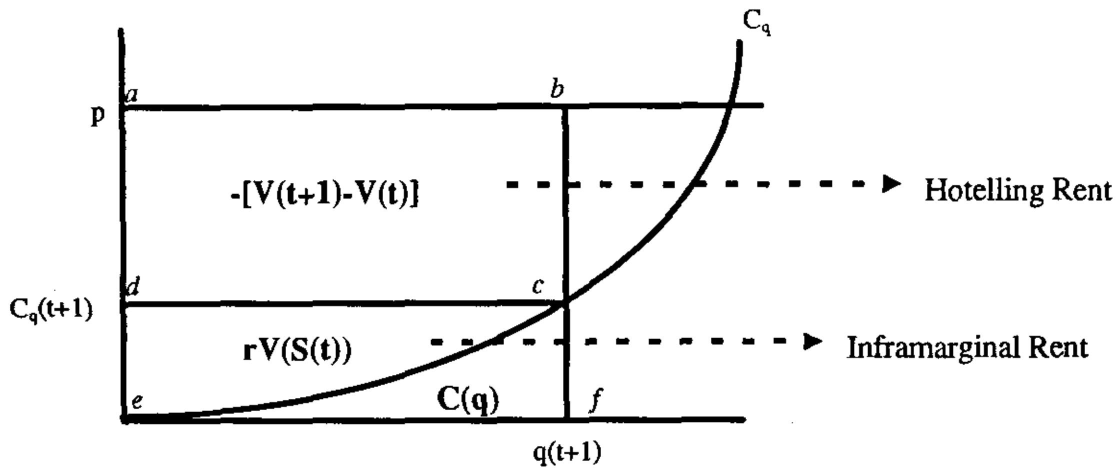
Rewritten in discrete time, this result is:

$$rV(S(t)) = pq_{(t+1)} - C(q_{(t+1)}) - [V_{t} - V_{t+1}].$$

The market price of the firm (if the firm were sold and the money earned r% from time "t" to time "t+1") equals the current income from extraction plus the depreciation of the firm, so that the owner is indifferent between selling the firm and operating it.

This $\dot{V}$ depreciation term is equal to Hotelling rent : the amount of nonrenewable resource extracted in a given period times the difference between price and marginal extraction cost (see Appendix 1 for proof). The decline in stock value equals the change in the stock's quantity multiplied by the marginal profit from an additional unit of stock, where "$p-C_q$" is marginal profit. In other words, the firm is shrinking in value by Hotelling rent: $\dot{V} = -(p-C_q(q(t)))q(t)$. Consider Figure 5.2:

Figure 5.2



Area *abcd* is Hotelling rent, or $(p-C_q(q(t+1))q(t+1)$, and area *cef* is total costs, so that the remaining area *cde* is rV(S(t)), the market value of our firm. Along the efficient path, the firm is shrinking in value by the amount of the Hotelling rent.

The concept of sustainable yield for a renewable resource (say, fish) implies that a non-declining steam of flows (harvested fish) can be extracted while maintaining a constant stock out of which the flow are drawn. Similarly, for capital, sustainable consumption can be thought of as the amount of consumption that takes place while preserving the original capital intact.

With our valuation of an asset example, the whole area *abce* could be consumed. But if the area *abcd* (the amount equal to Hotelling rent) were instead invested, original capital could be kept intact, assuming the r% rule were being followed (since it results in the maximization of profits). Hence, consumption from the original capital, which would be maintained intact, would be constant.

Each year, our economy decides how much to save and how much to consume. By this decision, future generations' utility levels are also being determined. The appropriate savings rule is an ethical decision. However, rules which yield sustainable consumption paths are attractive. This involves endowing future generations with whatever capital and/or resources it takes to achieve at least the same level of consumption as the preceding generation. This sustainable path does not imply that everything is conserved to be identical to what the preceding generation had. It only offers up endowments with which future generations can achieve the same consumption level. In the case of substituting capital for resources, future generations may inherit more capital than the current generation has, but less exhaustible resources. This is how sustainability departs from the narrow concept of maintaining each type of capital intact, and shall be the criteria we employ.

Consider potential consumption as income from this asset pq(t)-C(q(t)) and interest off our capital stock, where p is constant, plus interest from whatever other capital our economy has, K. We are postulating that if investment, $\dot{K}$, is equal to Hotelling rent, $(p-C_q(q(t)))q(t)$, that consumption will be constant. That is:

$$consn = pq(t) - C(q(t)) - \dot{K}(t) + rK(t)$$

$$\overline{consn} = p\dot{q} - C_q\dot{q} - \ddot{K} + r\dot{K}$$

where:

$$\ddot{K} = (\overline{p - C_q})q + (p - C_q)\dot{q}$$

$$so:$$

$$\overline{consn} = (p - C_q)\dot{q} - (\overline{p - C_q})q - (p - C_q)\dot{q} + r\dot{K}$$

$$\overline{consn} = -(\overline{p - C_q})q + r\dot{K}$$

$$\therefore \overline{consn} = 0 \ \ if \ \ \dot{K} = (p - C_q)q$$

since $\overline{p - C_q}$ =r(p-C_q) by Hotelling.

Therefore, if we follow our two rules, invest Hotelling rent and deplete at r% for dynamic efficiency, consumption will be constant. For a non-renewable resource, like natural gas, it is necessary to invest Hotelling rent in reproducible machine capital in lieu of investing it in the non-renewable resource, to make up for depletion.

Similarly, consider an economy where some benevolent dictator maximizes utility as a function of consumption, C, where r is the discount rate:

$$\int_0^\infty U(C)e^{-rt}dt$$

Subject to:

$$\dot{K} = F(K, L, R) - C - f(R)$$

where F(K,L,R) is our economies production function, K is capital, $\dot{K}$ is investment, L is labour (assumed to be constant), R is the current flow from a stock of non-renewable resources, and f(r) is the current cost of exhaustible resource extraction.

Weitzman[1976] noted that the current value Hamiltonian in aggregate neoclassic growth theory is an economy's NNP. Therefore, optimal growth in our economy is given through the current value Hamiltonian:

$$H(t) = U(C) + \lambda(t)[F(K,L,R) - C - f(R)] + \varphi(t)[-R].$$

This Hamiltonian maximized with respect to controls is:

$$\frac{\partial H}{\partial C} = 0 \Rightarrow U_C = \lambda(t)$$
$$\frac{\partial H}{\partial R} = 0 \Rightarrow \lambda(t)[F_R - f_R] = \varphi(t)$$

and maximized with respect to states is:

$$-\frac{\partial H}{\partial K} = 0 \Rightarrow \dot{\lambda} - r\lambda = -\lambda(t)[F_K]$$
$$-\frac{\partial H}{\partial S} = 0 \Rightarrow \dot{\varphi} - r\varphi = 0.$$

Using the linear approximation $U(C)=U_c{*}C$, we divide the revised Hamiltonian by U_c to get the dollar valued NNP:

$$\frac{H(t)}{U_C} = \frac{U(C)}{U_C} + \frac{\lambda(t)\dot{K}}{U_C} + \frac{\varphi(t)[-R]}{U_C}$$
$$\frac{H(t)}{U_c} = C + \dot{K} + \frac{\lambda(t)[F_R - f_R][-R]}{U_C}$$
$$NNP_{adj} = C + \dot{K} - [F_R - f_R]R.$$

The term F_R-f_R (the net price) times the current flow of resource is our now familiar Hotelling rent. The term F_R, the derivative of the production function with respect to natural resource, is our price. Similarly, the derivative of the cost function with respect to quantity, f_R, is our marginal cost. This term is netted out of NNP to get an adjusted NNP. In other words, CCA should be expanded to include this term. This current value Hamiltonian is the NNP function in units of utility, and this basic version can be expanded to include environmental capital, discoveries, stock size effects, and durable and renewable resources. See Hartwick[1991] for an overview.

The previous discussion has been confined to constant technology, population and endogenous prices. Constant consumption means that exogenous technical progress has been assumed to be zero, and it can be shown that if labour demand equals labour supply, regardless of the size of labour force, no new term shows up in NNP.

OPEN ECONOMY - PRICE AS A FUNCTION OF TIME

Thailand is a small open-economy subject to international prices and is therefore a price-taker. In such an open economy, the investing-resource-rent rule must be expanded to take account of capital gains/losses arising from a changing resource price (whose future path is assumed to be known).

Recall our basic asset valuation equation:

$$V(S(t),p(t)) = \int_t^T e^{-r(u-t)}[p(u)q^*(u) - C(q^*(u))]du$$

where now prices are also a function of time so:

$$\dot{V}(S(t),p(t)) = rV(S(t),p(t)) - [p(t)q^*(t) - C(q^*(t))]$$

as before, but:

$$\dot{V}(S(t),p(t)) = -[p(t) - C_q(q^*(t))]q^*(t) + \int_t^T e^{-r(u-t)}\dot{p}(u)q^*(u)du$$

(see proof, Appendix 2). Note the extra term. Before, with endogenous prices, $\dot{V}$=-(p(t)-$C_q(q^*(t)))q^*(t)$, or Hotelling rent. Now, the decline in stock value equals the change in the stock's quantity multiplied by the marginal value of an additional unit of stock plus the present value of future price changes multiplied by future flows. Our "invest resource rents

" rule has changed to "invest resource rents including the term for discounted capital gain/loss term".

In the.case of rising exhaustible resource prices, the country in question need not invest the entire Hotelling rent, but rather Hotelling rent less the capital gains associated with future price increases. Therefore, with this open economy assumption, we get an adjusted version of the traditional Hotelling rent. Rising export prices act like a free dose of current investment.

Similarly, where our change in consumption over time equals:

$$\overline{consn} = [p(t) - C_q(q(t))]\dot{q}(t) + q(t)\dot{p}(t) - \ddot{K}(t) + r\dot{K}(t)$$

(note prices are now a function of time) we now postulate that investment, $\dot{K}$ should be:

$$\dot{K} = [p(t) - C_q(q(t))]q(t) - \int_t^T e^{-r(u-t)}\dot{p}(u)q^*(u)du$$

instead of just resource rent. Now,

$$\overline{consn} = [p(t) - C_q(q(t))]\dot{q}(t) + q(t)\dot{p}(t) - \ddot{K}(t) + r\dot{K}(t)$$

where

$$\ddot{K} = [p(t) - C_q(q(t))]\dot{q}(t) + q(t)[\overline{p(t) - C_q(q(t))}] - r\int_t^T e^{-r(u-t)}\dot{p}(u)q(u)du + \dot{p}(t)q(t).$$

Substituting in $\ddot{K}$ and invoking the Hotelling r% rule yields:

$$\overline{consn} = r\int_t^T e^{-r(u-t)}\dot{p}(u)q(u)du - rq(t)[p(t) - C_q(q(t))] + r\dot{K}(t).$$

Consumption is indeed constant if we follow our new rule for $\dot{K}$, investment.

6. *Empirical Results*

In this section we use the theoretical framework developed in the previous one to estimate the effects on Thailand's "real" NNP of adjusting for depletion of natural gas. NNP is adjusted downward to indicate a lower sustainable path of consumption associated with consumption of this non-renewable resource.

At 1994 production rates, according to PTT, only about 15 years will remain for natural gas production in Thailand. This is based on proven reserve estimates and will be referred to as the "economically viable" stock available. Industry anticipates that this a little conservative and that the final year will be 2016. According to DMR, if future production rates for natural gas are kept constant at the 1994 rate, it will take 40 years to fully deplete available gas, which includes probable and possible reserves, in addition to proven ones. For the calculations in our "base case", it is assumed that natural gas in Thailand will run out in about 17 years, the average of PTT and industry estimates.

Since no forecasts exist beyond 2011, it was assumed that prices increased at the same rate as the 5 year average from 2007-2011; and it was assumed that quantity decreased at the same rate as during that period.

To calculate Hotelling Rent, $p-C_q$ is multiplied by quantity of natural gas extracted. Recall that this Hotelling Rent is equal to the amount by which the country's assets are shrinking, or depreciation. This value, less the price change term associated with exogenously changing prices, needs to be subtracted from NNP to get our adjusted NNP term, which includes natural gas depletion. We subtract less than the whole amount associated with the depreciation of our non-renewable resource, because of the beneficial future capital gains associated with an exogenously increasing price.

The price change term, or present value of future price changes multiplied by future flows is:

$$\int_t^T [\dot{p}(u)q(u)]e^{-r(u-t)}du.$$

Thus, our adjusted NNP to include depletion of natural gas is the original national accounts NNP less the net adjustment term where:

$$\text{Net Adjustment} = (p - C_q)q - \int_t^T [\dot{p}(u)q(u)]e^{-r(u-t)}du$$

which is simply Hotelling rent less our price change term, and the discrete time approximation is of the price change term is:

$$\int_{86}^{2011} [\dot{p}(u)q(u)]e^{-r(u-t)}du = \frac{price87 - price86}{1.125^1} quantity87 + \frac{price88 - price87}{1.125^2} quantity88 + \ldots$$
$$+ \frac{price2011 - price2010}{1.125^{24}} quantity2010.$$

This discrete time approximation is simply the discounted future capital gains associated with our exogenously increasing price and is subtracted from Total Hotelling Rent to get our net adjustment term. By subtracting this net adjustment term from original

NNP, we arrive at a measure of NNP that is adjusted for depletion of natural gas. This result is presented in Table 6.1 and is used as our "base case".

Appendix 3 has explicit calculations of this capital gain/loss term. A discount rate of 12.5% was chosen as reflecting the amount of risk involved in this industry. Other similar studies have chosen this number (Vincent, Panayotou, and Hartwick[1985]) and we have followed their lead.

The rising price of natural gas means Thailand benefits from the capital gains associated with this price increase, and thus in most years, the net adjustment term is significantly lower than the total Hotelling rent term alone. That is, the future price change effects are non-trivial and cannot be ignored. If Thailand were to invest the total Hotelling rent term only, it would be underconsuming and depriving the current generation relative to future ones.

We have calculated our adjusted NNP figure so that it reflects depletion of natural gas. Our net adjustment term was on average about 5.5 billion baht or, as a percentage of NNP, generally under 1% and usually under 0.5%. This does not imply that since our change is small, it should be ignored. Rather, this reflects the small size of the natural gas industry in Thailand. Total Hotelling Rent grew from about 5.8 billion baht in 1985 to 8.9 billion baht in 1994, due to increased natural gas production. The capital gain/loss term in 1986 was -1012 million baht, which left our net adjustment term (using the adjusted Hotelling rent with open economy assumptions) higher than with traditional Hotelling rent alone. By 1994, our capital gain/loss term was 3834 million baht, leaving our net adjustment term lower than with only Hotelling rent.

TABLE 6.1:Base Case-NNP adjusted for Natural Gas Depletion

	I	II	III	IV	V	VI	VII	VIII	IX
	NNP (Mbaht)	Production (mmbtu)	Price (b/mmbtu)	Marginal Cost (b/mmbtu)	THR (Mbaht)	Price Change Term (Mbaht)	Net Adjustment (Mbaht)	Net Adjustment (%NNP)	Adjusted NNP (Mbaht)
1985	831975	128286380	69.47	23.58	5887.062	0	5887.061978	0.707600827	826087.938
1986	879915	123902950	67.84	23.58	5483.945	-1012.43036	6496.374922	0.738295736	873418.6251
1987	1011343	173298260	54.98	23.58	5441.565	-937.022341	6378.587705	0.630704687	1004964.412
1988	1198771	214345750	50.1	23.58	5684.449	1174.46549	4509.9838	0.376217293	1194261.016
1989	1440089	205086130	49.9	23.58	5397.867	2367.280936	3030.586005	0.210444355	1437058.414
1990	1681522	223353170	48.23	23.58	5505.656	2704.208279	2801.447361	0.166601886	1678720.553
1991	1925835	277031030	55.99	23.58	8978.576	3415.234108	5563.341574	0.288879451	1920271.658
1992	2160037	295225320	56.42	23.58	9695.200	1692.377579	8002.82193	0.370494669	2152034.178
1993	2382007	332479140	50.9	23.58	9083.330	1776.977888	7306.352216	0.30673093	2374700.648
1994	2768500	367415630	47.91	23.58	8939.222	3834.384977	5104.837301	0.184390005	2763395.163

The details of this table are as follows:

I - original NNP figure, as published in the National Accounts of Thailand.

II - annual production volumes in million British Thermal Units.

III - well-head price, based on data from DMR. Refer to details in Section 4.

IV - marginal cost, from industry estimates. Refer to details in section 5.

V - Total Hotelling Rent (THR), or, $(p-C_q)q$.

VI - term for capital gains/losses associated with future price changes, or, $\int_t^{T} [\dot{p}(u)q(u)]e^{-r(u-t)}du$. See Appendix 3 for details.

VII - "net adjustment" term or, $(p-C_q)q - \int_t^{T} [\dot{p}(u)q(u)]e^{-r(u-t)}du$, THR less the price change term.

VIII - "net adjustment" as a percentage of original NNP.

IX - new, corrected NNP figure, to include depletion of Natural Gas in Thailand, which is original NNP less the "net adjustment " term.

The key interpretation of our model is that our new, natural gas adjusted NNP is lower than what Thailand's national accounts currently maintain. That is, the unadjusted version gives an artificially high account and with it, a false sense of security. By using our resource-adjusted version, we have started to account for natural resource depletion in the same way the national accounts take into consideration depreciation of capital, and therefore have a more accurate picture of the well-being of Thailand.

A primary criticism of this model is the uncertainty associated with future prices and extraction. Since the price forecast is a regression of historical natural gas prices on oil prices, we should look at how sensitive our results are to different price scenarios.

Our first consideration was the effect of uniformly higher (or lower) levels of gas prices. If the price forecast was 0.1% higher every period than our base case, this means our economy need to invest less because it has a higher capital gains term associated with the higher future prices. Therefore, our final adjusted NNP, with this higher price forecast, is on average 13 million baht higher than our base case scenario, or, in terms of difference as a percentage of NNP, 0.0007%. These results are exactly mirrored if prices are 0.1% lower than our base case, where our economy would then have to invest more due to a decrease capital gains term. We next considered a price change of 5%. A difference between this scenario and the base case is about 0.03% as a percentage of NNP or about 637 million baht per year. For a price change of 10% higher every period than our base case, the difference as a percentage of NNP is still less than 0.1%. This seems to indicate that the results are not highly sensitive to an on average higher or lower price series than the one we have forecasted.

A more interesting scenario is one where a once-and-for-all shock occurs - perhaps an oil price shock, which is reflected in natural gas prices. Recall our capital gain/loss term uses P_1-P_0. Now, instead of a smooth series that is simply 10% higher than our originally forecast price series, we have a sudden price increase in the year 2005 where prices leap up $13 higher than the 10% progression. After this period, prices resume their 10% growth. Our most interesting results come from this scenario. Our difference as a percentage of NNP from the base case is 0.4% - much higher than any of our other scenarios. This seems to indicate that our ad hoc method of forecasting natural gas prices is mostly limited by its inability to foresee such price shocks.

In addition to making assumptions to arrive at a future natural gas price series, a discount rate of 12.5% was assumed. If the discount rate were lower, 10%, future capital gains result in lower necessary investment today since they are being discounted more slowly. Therefore, our adjusted NNP term is higher under the lower discount rate - less investment is necessary today to maintain constant consumption. The difference between this and our base case is on average 775 million baht per year or 0.04% (adjustment as a percentage of NNP). Again, this result can be mirrored (though not exactly like in the price change scenarios) by considering a 15% discount rate - 2.5% higher than our base case. This higher discount rate decreases the impact of future capital gains leaving the economy with a lower adjusted net national product. With our 15% rate, difference from the base case as a percentage of NNP is about 0.03%, or 560 million baht.

A final consideration is the discrepancy over when natural gas in Thailand will run out. The average of industry and PTT estimates indicates 17 years, however, DMR predicts 40. Having used 17 years in our base case, we now consider what would happen if it is indeed 40. We assume the average of 2007-2011 growth rates for price and quantity are constant over the next 23 years. Our adjusted NNP term will be higher because we have a longer time horizon over which to accumulate capital gains. On average, adjusted NNP is 161 million baht higher than the base case with this longer time horizon, or, as a percentage of NNP, a 0.01% difference. Each of these scenarios is included, in detail, in Appendix 3.

Other Studies

A similar study to ours was done for the nonrenewable resource coal in Thailand by Amornkosit[1993]. Her study differs from ours because it ignores open economy consideration and therefore has no capital gains/loss used in the adjustment to NNP term. Prices were determined endogeneously in the version that was used so Hotelling rent alone was used to adjust NNP.

From 1986-1990, the average adjustment as a percentage of NNP was 0.114, whereas our five year average for the same period was 0.396. It is difficult to compare these numbers directly because the natural gas industry is about three times as big as the lignite industry in Thailand, and our "adjustment term" is relatively lower because we have included future capital gains, which imply less needs to be invested than Hotelling rent.

Other empirical applications of the net investment rule in developing countries include one in Costa Rica by Repetto et al[1991], for Mexico by van Tongeren et al

[1993], for Papua New Guinea by Ernst Lutz and Stephan Shweinfest[1993] and for Malaysia by Jeffrey Vincent[1995].

Like Amornkosit, these studies do not consider open-economy assumptions. However, they include both non-renewable and renewable resources in their studies. In the Vincent paper, the renewable resource he cites is trees. Since the stock can increase or decrease, to calculate net depletion, natural growth is subtracted from the amount harvested. This means if tree growth exceeds tree harvest, our "natural resource consumption allowance" would be positive, implying an *increase* in the stock of natural resources. However, Vincent's results show all timber allowances are positive, indicating that harvesting outstrips growth and timber stocks are declining. Like our results, Vincent 's adjusted NNP is lower than the national accounting version indicating a need for more investment.

7. *Discussion and Conclusions*

HOTELLING'S R% RULE

Recall that Hotelling's r% rule is the assertion that unit price less marginal cost of a non-renewable resource should rise at the rate of return on a comparable capital asset.

Slade[1982] noticed copper prices rose and fell over time, rather than rising steadily as required by Hotelling r% efficient extraction. She attributes this movement to changing cost function. Over time, as more of the resource is exhausted, lower-grade, more expensive sources are exploited, and so stock-size effects are experienced. Declining grade will increase the cost of extraction, and this will be reflected in prices. Additionally, Slade blames technology in the early part of the century for falling prices. This argument is less compelling for the latter part of this century, where improvements in extraction technology has slowed.

For copper, a durable, we are losing the intent of Hotelling's rule, which was intended for exhaustible resources which are non-durable (he had oil in mind). While it is true (by physics) that copper above ground is depleting, this example does not parallel exactly oil and gas, which, when used, are gone forever.

Other analysis of Hotelling include empirical tests of Hotelling's Valuation Principle by Miller and Upton[1985]. They were done using the following regression:

$$\frac{V_o^{it}}{R_o^{it}} = \alpha + \beta\,(p_o^{it} - c_o^{it})$$

where V_o is the market value (value of equity) of firm "i" at time "t", R is the total recoverable reserves and p_o-c_o is our net price. Our value for α should be 0 and for β should be 1 for Hotelling to hold empirically.

Miller and Upton met with a fair amount of success. Their intercept was small, -2.240, and coefficient for β was .910. This work was done with oil companies, and constant costs were assumed. They met with less empirical success in their subsequent paper.

There is a key criticism put forward by Adelman[1993] about Hotelling's Rule. While he admits "no viable paradigm exists" (Miller and Upton 1985), Adelman rejects one of the Hotelling assumptions, that there is a fixed stock. He does not reject Hotelling 's theory, but rather asserts that "mineral scarcity is the uncertain fluctuating result of conflicting forces; diminishing returns versus increasing knowledge ... prices therefore rise and fall"(Adelman, 1993, p. 458). Adelman interprets that only a portion of what's available in the earth's crust will be used, depending on costs and prices of the resource and its substitutes. "To define the initial fixed stock as 'the economic portion' of what is in the earth and then derive a price-output profile from it is circular reasoning" (Adelman, 1993, p. 241) so he does not see using economically viable reserves in lieu of total stock size as a substitute.

However, our price forecast does have prices rising over time for natural gas, perhaps properly reflecting its increasing scarcity. We shall therefore assume the profit maximizing path implied by Hotelling based on fixed stock size as our model.

A direct test of the relation between interest rates and growth rates of net prices of natural gas in Thailand has not indicated the industry is extracting according to Hotelling's rule. We can attribute our failure to measurement error in data, the difficulty of getting an accurate idea of marginal cost or imperfect property rights leading to rapid extraction. Or, it may be that this restricted Hotelling rule doesn't accurately reflect the industry. By relaxing certainty and homogenous stock assumptions, we arrive at more general Hotelling formulations.

Stock size effects are easily incorporated into our basic Hotelling model. The cost function becomes a function not only of quantity extracted, but reserves as well, so a firm maximizes:

$$\int_0^T [pq - C(q(t), S(t))]e^{-rt} dt$$

subject to:

$$\int_0^T q(t)dt = S(t),$$

as usual.

The introduction of stock size effects (relaxation of homogenous stock assumption) gives the following more general Hotelling formulation:

$$r = \frac{\overline{p - C_q(q(t), S(t))}}{p - C_q(q(t), S(t))} - \frac{C_s(q(t), S(t))}{p - C_q(q(t), S(t))},$$

where the extra term accounts for heterogeneous stock. This is one possible departure from our classic r% rule.

Another possibility is uncertainty. Hotelling was stated in a deterministic environment. If we have uncertainty, this implies a role for diversification and recent models have tied out traditional Hotelling to CAPM from finance literature to get:

$$\frac{\overline{p-C_q}}{p-C_q} = r + \beta\,(r^m - r)$$

where this additional term is the risk premium due to uncertainty. β is the proportion of covariance of the stock or industry to the market over the variance of the market as a whole, r^m is the return on the market, and r is the risk free rate. See Gaudet and Khadr (1991) for further details.

Finally, Hotelling assumed a perfectly competitive market. In a monopolistic market, the firms marginal revenue less marginal cost is rising at r%, and the firm is extracting more slowly. With Unocal responsible for almost 70% of natural gas production in Thailand and Total responsible for about 20%, it seems sensible to point out that our failure may be due to the oligopolistic structure of the industry in Thailand. Strategic behaviour and its resulting slower extraction paths may also account for our empirical departure from the r% rule.

Natural gas in Thailand is subject to distortions through royalty taxes. An increase in a royalty decreases the optimal depletion rate and vice versa. In 1989, the Petroleum Tax Income Act was amended to change the flat 12% royalty rate to a sliding scale regime. Small fields, faced with a 5% royalty would be extracted more quickly than before the change and large fields would be extracted more slowly given their higher, 15% rate. Facing a higher rate, firms would postpone sales to postpone the associated higher costs so they are discounted more.

Finally, the markets failure to extract according to Hotelling's r% rule can be attributed to a change in technology, which we have assumed to be constant. As discussed later, Weitzman (1995) believes the impact of this change can be enormous.

CONSUMPTION PATHS

A different point arises from the adoption of Solow's constant consumption paths as our goal for future generations. Other literature suggests this approach may be leaving too little for our successors.

Chichinilsky[1994] suggested an alternative to the utilitarian framework. Her work suggests including "Sobolev spaces", thus placing more emphasis on future generations:

$$\max \int_t^T U(C_t) e^{-r(u-t)} du + \lim_{t \to \infty} U(C_t)$$

so more stock of natural resources are preserved under this framework. This is to keep future generations from being "stuck" in our current standard of living.

Asheim[1994] felt an initial sacrifice in consumption could lead to a forever higher standard of living through current increased investment. After this initial early investment, consumption is constant, but at a higher level.

While the appropriate savings rule is an ethical decision, our rules which yield sustainable constant consumption paths do seem attractive and as such were employed.

LIMITATIONS OF OUR MODEL

Vincent[1995] points out 4 limitations with this green national accounting concept:

(1) Most empirical work to date has used average costs as a proxy for marginal cost, thus overstating the resource consumption allowance , so situations are better than the adjustment to NNP for resource depletion are larger than should be using marginal cost. We have tried to get around this problem by using the AIC method. See Section 5 for details.

(2) NNP, it could be argued, should show changes in other stocks, like human capital. By excluding human capital, net depletion of capital stocks is overstated, therefore NNP is understated. Education and other such human capital building expenditures have increased human capital stocks and should be reflected as such in national accounting.

(3) The analysis done here is only for natural gas. All other natural resources have been excluded, and for a truly "adjusted-for-resource-depletion" NNP figure, all resources should be used (including those for which there are no market prices, which is far more difficult).

(4) NNP is derived from GNP, which included marketed good and services. This excludes direct consumption of the environment. NNP is biased upwards by ignoring increased environmental degradation. The associated sustainable consumption level is therefore artificially high. While depletion of natural gas is considered, the environmental degradation associated with the production of natural gas is ignored. Our model could be extended to treat pollution as the economic degradation of environmental capital which would allow us to use our same rule : deduct the rents on the amount of the natural

resource that was used up and reinvest it in reproducible human capital. This version of the model is presented in Hartwick[1990].

In addition to Vincent's discussion, there are three more limitations that need to be considered:

(1) Future prices of natural resources are inherently volatile. This means that there is uncertainty associated with our price series which affects the accuracy of our adjustment.

(2) We have assumed technology to be constant. Weitzman[1995] offers another criticism: "Because it omits the role of technological progress, NNP, whether conventionally measured or green-inclusive, likely understates greatly an economy's sustainability". If we assume that future technological growth resembles historical, we are currently underestimating our NNP and therefore downward adjustments to NNP for resource depletion are to a certain extent counteracted (or even dwarfed) by technological progress. Weitzman arrives at this result by defining a growth statistic which captures the effect of time on productive capacity and through rough estimates comes up with a technological change premium of 50%, a number which overwhelms our results.

(3) A recent paper by Hartwick[1995] deals with a third issue: what if our small open economy is facing distorted world prices? What if we are in a world of second best? Hartwick points out that if world resource prices are increasing too slowly (because of artificially inflated world sales through failure of property rights, subsidies, or other distortionary mechanisms) relative to the efficient path, out small price-taking country will invest too much initially. In the non-distorted market, prices would rise faster, implying

higher capital gains associated with prices increases and therefore lower investment requirements for constant consumption paths. Distortions in world resource markets which result in a less steep future path for prices cause our small open economy to extract too quickly. Steeper price schedules imply a longer extraction period.

To capture this effect, Hartwick suggests "correcting" the incorrect world prices. This is achieved through subsidizing domestic markets so they faced efficient prices and in turn, extract efficiently. Or, national accounts could be adjusted to reflect that the value of the resource is worth more than world prices indicate. Some $\hat{p}$ would be used in lieu of world price where $\hat{p}$=world price+α. The α is the adjustment from world prices to scarcity prices. Hartwick recognize three problems associated with this accounting approach: firstly, how to get α, secondly, how to adjust q, and thirdly, we are dealing with two different constant prices, so we also need to adjust our price change term ($\int_t^T [\dot{p}(u)q(u)]e^{-r(u-t)}du$). While the practicality of this adjustment is questionable, a starting point of dealing with distortions has been suggested. Perhaps some shadow price method, where substitute prices were used instead of the distorted prices could be investigated.

CONCLUSION

We have shown that the NNP of Thailand is lower than what is currently show in national accounts. In measuring economic performance, trends of economic growth and setting guidelines for public policy, macroeconomists rely heavily on the aggregates in national income accounts, since they provide the relationship between outputs of economic processes and economic inputs supporting these processes. By paying sufficient attention to natural resources, an adjusted NNP figure will better identify true income and provide more relevant economic signals for policymakers to use in judging the economy. Policymakers, who may rely on natural resource revenue will become aware of the fact of limited resources and the need to invest more to sustain economic development.

Our adjusted NNP figure so that it reflects depletion of only one resource - natural gas. Our net adjustment term was on average about 5.5 billion baht or, as a percentage of NNP, generally under 1% and usually under 0.5%. This industry is a small component of total output in Thailand. Hotelling rent went from 5887 million baht in 1985 to 8939 million baht in 1994, due to increased natural gas production. The capital gain/loss term in 1986 was -1012 million baht, a capital loss associated with the fall in prices from 1995 to 1996, which left our net adjustment term higher than with Hotelling rent alone. By 1994, our capital gain/loss term was 3834 million baht, leaving our net adjustment term lower than with only Hotelling rent, because of the associated capital gain from the future price increases.

An interesting extension would be to incorporate not only the economic depletion associated with extracting this resource, but also the economic depreciation of environmental capital (pollution) that is associated with our natural gas production.

Policy makers can look at our results and note that our adjusted NNP figure is lower than the original national accounting version of NNP. This is because we have eliminated the "free lunch" associated with using up the exhaustible resource, natural gas. This new NNP gives a more accurate description of the well-being of Thailand and a "green" version of NNP should be used for policy formulation.

Since this analysis is done only for natural gas, it is not a complete figure. Our CCA term should be expanded to include the depreciation of all natural resources in order to get the most accurate NNP figure for Thailand. We present a starting point, focusing on only one of Thailand's natural resources.

Appendix 1

Vincent, Panayotou and Hartwick(1995) provide a similar proof to the following.

Recall our asset value is:

$$V(S(t)) = \int_t^T e^{-r(u-t)}[pq^*(u) - C(q^*(u)]du \quad \text{and:}$$

$$\dot{V}(S(t)) = rV(S(t)) - [pq^*(t) - C(q^*(t))].$$

Define :

$$J(S(t)) = e^{-rt}V(S(t)),$$

then from dynamic programming we have:

$$0 = e^{-rt}[pq^*(t) - C(q^*(t))] + J_s(-q^*(t)) + J_t \quad \text{or:}$$

$$-J_t = e^{-rt}[pq^*(t) - C(q^*(t))] - J_s q^*(t).$$

The partial derivatives of $J(S(t)) = e^{-rt}V(S(t))$ are:

$$J_t = -re^{-rt}V(S(t))$$

and,

$$J_s = e^{-rt}V_s(S(t))$$

where

$$V_s = [p - C_q(q^*(t))].$$

Substituting our partial derivatives into:

$$-J_t = e^{-rt}[pq^*(t) - C(q^*(t))] - J_s q^*(t)$$

yields:

$$re^{-rt}V(S(t)) = e^{-rt}(pq^*(t) - C(q^*(t))) - e^{-rt}V_s q^*(t) \quad \text{or:}$$

$$rV(S(t)) = pq^*(t) - C(q^*(t)) - V_s q^*(t).$$

Since $V_s = [p - C_q(q^*(t))]$ and $rV(S(t)) = [pq^*(t) - C(q^*(t))] + \dot{V}(S(t))$, we conclude that $\dot{V}(S(t)) = -[p - C_q(q^*(t))]q^*(t)$.

Appendix 2

Note that the proof in Appendix 1 assumed prices were not a function of time. By relaxing this assumption, we get our "capital gain/loss term". Vincent, Panayotou and Hartwick(1995) provide the following proof.

Our asset's value is still:

$$V(S(t),p(t)) = \int_t^T e^{-r(u-t)}[p(u)q^*(u) - C(q^*(u)]du \quad \text{and:}$$

$$\dot{V}(S(t),p(t)) = rV(S(t),p(t)) - [p(t)q^*(t) - C(q^*(t))]$$

Define :

$$J(S(t),p(t)) = e^{-rt}V(s(t),p(t)),$$

then from dynamic programming we have:

$$-J_t = e^{-rt}[p(t)q^*(t) - C(q^*(t))] - J_s q^*(t).$$

The partial derivatives are:

$$J_t = -re^{-rt}V(S(t),p(t)) + e^{-rt}\partial V/\partial t$$

and,

$$J_s = e^{-rt}V_s(S(t),p(t))$$

where:

$$V_s = [p(t) - C_q(q^*(t))]$$

and,

$$\frac{\partial V}{\partial t} = \int_t^T \dot{p}(u)q^*(u)e^{-r((u-t)}dt.$$

Substituting our partial derivatives into:

$$-J_t = e^{-rt}[p(t)q^*(t) - C(q^*(t))] - J_s q^*(t)$$

yields:

$$rV(S(t),p(t)) = p(t)q^*(t) - C(q^*(t)) - V_s q^*(t) + \partial V / \partial t.$$

By substituting the third and fourth previous equations into the above one and recalling that $rV(S(t),p(t)) = [p(t)q^*(t) - C(q^*(t))] + \dot{V}(S(t),p(t))$ we get:

$$\dot{V}(S(t),p(t)) = -[p(t) - C_q(q^*(t))]q^*(t) + \int_t^T e^{-r(u-t)}\dot{p}(u)q^*(u)du.$$

Appendix 3

Base Case

I	II	III	IV	V									
year	price	P1-P0	MMBTU	(P1-P0)*Q	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	69.47		128286380										
1986	67.84	-1.63	123902950	-201961808.5	-179521607.6								
1987	54.98	-12.86	173298260	-2228615624	-1760881480	-1980991665							
1988	50.10	-4.88	214345750	-1046007260	-734644330.8	-826474872.1	-929784231.1						
1989	49.90	-0.20	205086130	-41017226	-25606852.26	-28807708.8	-32408672.4	-36459756.44					
1990	48.23	-1.67	223353170	-372999793.9	-206988386.7	-232861935	-261969676.9	-294715886.5	-331555372.4				
1991	55.99	7.76	277031030	2149760793	1060412902	1192964515	1342085080	1509845715	1698576429	1910898482			
1992	56.42	0.43	295225320	126946887.6	55661435.23	62619114.64	70446503.97	79252316.97	89158856.59	100303713.7	112841677.9		
1993	50.90	-5.52	332479140	-1835284853	-715291889.4	-804703375.6	-905291297.5	-1018452710	-1145759298	-1288979211	-1450101612	-1631364314	
1994	47.91	-2.99	367415630	-1098572734	-380588896.4	-428162508.5	-481682822	-541893174.8	-609629821.6	-685833549.3	-771562743	-868008085.9	-976509096.6
1995	47.37	-0.54	386980326	-208969376.2	-64351314.38	-72395228.68	-81444632.26	-91625211.3	-103078362.7	-115963158	-130458552.8	-146765871.9	-165111605.9
1996	47.85	0.48	421323503	202235281.2	55357845.13	62277575.78	70062272.75	78820056.84	88672563.95	99756634.44	112226213.7	126254490.5	142036301.8
1997	49.87	2.02	467704493	944763076.2	229875476.4	258609910.9	290936149.8	327303168.5	368216064.6	414243072.6	466023456.7	524276388.8	589810937.4
1998	52.16	2.29	539577326	1235632077	267243026.9	300648405.2	338229455.9	380508137.9	428071655.1	481580612	541778188.5	609500462.1	685688019.8
1999	54.64	2.48	631631200	1566445377	301147970.8	338791467.1	381140400.5	428782950.6	482380819.4	542678421.9	610513224.6	686827377.7	772680799.9
2000	57.31	2.67	664204110	1773424974	303057463	340939645.8	383557101.6	431501739.3	485439456.7	546119388.8	614384312.4	691182351.4	777580145.3
2001	60.20	2.89	663141950	1916480235	291114599.2	327503924.1	368441914.6	414497153.9	466309298.1	524597960.4	590172705.4	663944293.6	746937330.3
2002	61.80	1.60	663141950	1061027120	143262855.4	161170712.3	181317051.4	203981682.8	229479393.2	258164317.3	290434857	326739214.1	367581615.9
2003	62.57	0.77	629506880	484720297.8	58176260.56	65448293.12	73629329.77	82832995.99	93187120.48	104835510.5	117939949.4	132682443	149267748.4
2004	63.36	0.79	627028507	495352520.3	52846526.9	59452342.76	66883885.61	75244371.31	84649917.72	95231157.44	107135052.1	120526933.6	135592800.3
2005	64.16	0.80	624904187	499923349.3	47408146.08	53334164.34	60000934.88	67501051.74	75938683.2	85431018.61	96109895.93	108123632.9	121639087
2006	64.97	0.81	624550133	505885607.9	42643157.34	47973552.01	53970246.01	60716526.76	68306092.61	76844354.19	86449898.46	97256135.77	109413152.7
2007	65.80	0.83	622425813	516613424.8	38708843.29	43547448.7	48990879.79	55114739.77	62004082.24	69754592.52	78473916.58	88283156.15	99318550.67
2008	66.65	0.85	619947440	526955323.6	35096659.32	39483741.73	44419209.45	49971610.63	56218061.96	63245319.71	71150984.67	80044857.75	90050464.97
2009	67.51	0.86	565069168	485959484.6	28769977.62	32366224.82	36412002.93	40963503.29	46083941.2	51844433.85	58324988.08	65615611.6	73817563.05
2010	68.39	0.88	525061138	462053801.5	24315291.84	27354703.32	30774041.24	34620796.39	38948395.94	43816945.44	49294063.62	55455821.57	62387799.26
2011	69.29	0.90	483282841	434954557.1	20345965.41	22889211.08	25750362.47	28969157.77	32590302.5	36664090.31	41247101.6	46402989.3	52203362.96
					-1012430355	**-937022341**	**1174465490**	**2367280936**	**2704208279**	**3415234108**	**1692377579**	**1776977888**	**3834384977**

Base Case

	NNP	PROD'N	PRICE	Marginal Cost	THR	Price Change Term	Net Adjustment	Net Adjustment	Adjusted NNP
	Mbaht	mmbtu	b/mmbtu	b/mmbtu	Mbaht	Mbaht	Mbaht	%NNP	Mbaht
1985	831975	128286380	69.47	23.58	5887.061978	**0**	5887.061978	0.707600827	826087.938
1986	879915	123902950	67.84	23.58	5483.944567	**-1012.43036**	6496.374922	0.738295736	873418.6251
1987	1011343	173298260	54.98	23.58	5441.565364	**-937.022341**	6378.587705	0.630704687	1004964.412
1988	1198771	214345750	50.1	23.58	5684.44929	**1174.46549**	4509.9838	0.376217293	1194261.016
1989	1440089	205086130	49.9	23.58	5397.866942	**2367.280936**	3030.586005	0.210444355	1437058.414
1990	1681522	223353170	48.23	23.58	5505.655641	**2704.208279**	2801.447361	0.166601886	1678720.553
1991	1925835	277031030	55.99	23.58	8978.575682	**3415.234108**	5563.341574	0.288879451	1920271.658
1992	2160037	295225320	56.42	23.58	9695.199509	**1692.377579**	8002.82193	0.370494669	2152034.178
1993	2382007	332479140	50.9	23.58	9083.330105	**1776.977888**	7306.352216	0.30673093	2374700.648
1994	2768500	367415630	47.91	23.58	8939.222278	**3834.384977**	5104.837301	0.184390005	2763395.163

Prices up 0.10%

I	II	III	IV	V									
year	price	P1-P0	MMBTU	(P1-P0)*Q	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	69.47		128286380										
1986	67.84	-1.63	123902950	-201961808.5	-179521607.6								
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1993	50.90	-5.52	332479140	-1835284853	-715291889.4	-804703375.6	-905291297.5	-1018452710	-1145759298	-1288979211	-1450101612	-1631364314	
1994	47.91	-2.99	367415630	-1098572734	-380588896.4	-428162508.5	-481682822	-541893174.8	-609629821.6	-685833549.3	-771562743	-868008085.9	-976509096.6
1995	47.42	-0.49	386980326	-190638118.2	-58706274.08	-66044558.34	-74300128.13	-83587644.15	-94036099.67	-105790612.1	-119014438.6	-133891243.5	-150627648.9
1996	47.90	0.48	421323503	202437516.5	55413202.98	62339853.35	70132335.02	78898876.9	88761236.51	99856391.08	112338440	126380745	142178338.1
1997	49.92	2.02	467704493	945707839.3	230105351.8	258868520.8	291227085.9	327630471.7	368584280.6	414657315.7	466489480.2	524800665.2	590400748.3
1998	52.21	2.29	539577326	1236867709	267510269.9	300949053.6	338567685.4	380888646	428499726.8	482062192.6	542319966.7	610109962.5	686373707.8
1999	54.69	2.48	631631200	1568011823	301449118.8	339130258.6	381521540.9	429211733.6	482863200.3	543221100.3	611123737.8	687514205	773453480.7
2000	57.37	2.67	664204110	1775198399	303360520.4	341280585.5	383940658.7	431933241	485924896.1	546665508.1	614998696.7	691873533.8	778357725.5
2001	60.26	2.89	663141950	1918396715	291405713.8	327831428	368810356.5	414911651	466775607.4	525122558.4	590762878.2	664608237.9	747684267.7
2002	61.86	1.60	663141950	1062088147	143406118.3	161331883.1	181498368.4	204185664.5	229708872.6	258422481.6	290725291.8	327065953.3	367949197.5
2003	62.63	0.77	629506880	485205018.1	58234436.82	65513741.42	73702959.09	82915828.98	93280307.6	104940346.1	118057889.3	132815125.5	149417016.2
2004	63.42	0.79	627028507	495847872.9	52899373.43	59511795.1	66950769.49	75319615.68	84734567.64	95326388.59	107242187.2	120647460.6	135728393.1
2005	64.22	0.80	624904187	500423272.6	47455554.22	53387498.5	60060935.81	67568552.79	76014621.89	85516449.62	96206005.83	108231756.6	121760726.1
2006	65.03	0.81	624550133	506391493.5	42685800.5	48021525.56	54024216.26	60777243.29	68374398.7	76921198.54	86536348.36	97353391.9	109522565.9
2007	65.87	0.83	622425813	517130038.3	38747552.14	43590996.15	49039870.67	55169854.51	62066086.32	69824347.11	78552390.5	88371439.31	99417869.22
2008	66.72	0.85	619947440	527482278.9	35131755.98	39523225.48	44463628.66	50021582.24	56274280.02	63308565.03	71222135.65	80124902.61	90140515.44
2009	67.58	0.86	565069168	486445444.1	28798747.6	32398591.05	36448414.93	41004466.79	46130025.14	51896278.29	58383313.07	65681227.21	73891380.61
2010	68.46	0.88	525061138	462515855.3	24339607.13	27382058.03	30804815.28	34655417.19	38987344.34	43860762.38	49343357.68	55511277.39	62450187.06
2011	69.36	0.90	483282841	435389511.6	20366311.37	22912100.29	25776112.83	28998126.93	32622892.8	36700754.4	41288348.7	46449392.29	52255566.32
					-1004845945	**-928489879**	**1184064509**	**2378079833**	**2716357038**	**3428901462**	**1707753352**	**1794275633**	**3853844940**

Prices up 0.10%

	NNP	PROD'N	PRICE	Marginal Cost	THR	Price Change Term	Net Adjustment	Net Adjustment	Adjusted NNP	Difference from Base	Diff from Base
	Mbaht	mmbtu	b/mmbtu	b/mmbtu	Mbaht	Mbaht	Mbaht	%NNP	Mbaht	%NNP	Mbaht
1985	831975	128286380	69.47	23.58	5887.061978	**0**	5887.061978	0.707600827	826087.938	0	0
1986	879915	123902950	67.84	23.58	5483.944567	**-1004.84594**	6488.790512	0.737433788	873426.2095	0.000861948	-7.58441
1987	1011343	173298260	54.98	23.58	5441.565364	**-928.489879**	6370.055243	0.629861011	1004972.945	0.000843676	-8.53246
1988	1198771	214345750	50.1	23.58	5684.44929	**1184.064509**	4500.384781	0.375416554	1194270.615	0.000800738	-9.59902
1989	1440089	205086130	49.9	23.58	5397.866942	**2378.079833**	3019.787109	0.209694478	1437069.213	0.000749877	-10.7989
1990	1681522	223353170	48.23	23.58	5505.655641	**2716.357038**	2789.298602	0.1658794	1678732.701	0.000722486	-12.1488
1991	1925835	277031030	55.99	23.58	8978.575682	**3428.901462**	5549.674221	0.288169766	1920285.326	0.000709685	-13.6674
1992	2160037	295225320	56.42	23.58	9695.199509	**1707.753352**	7987.446157	0.36978284	2152049.554	0.000711829	-15.3758
1993	2382007	332479140	50.9	23.58	9083.330105	**1794.275633**	7289.054472	0.306004746	2374717.946	0.000726184	-17.2977
1994	2768500	367415630	47.91	23.58	8939.222278	**3853.84494**	5085.377338	0.183687099	2763414.623	0.000702906	-19.46

Prices up 5.0%

I	II	III	IV	V									
year	price	P1-P0	MMBTU	(P1-P0)*Q	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	69.47		128286380										
1986	67.84	-1.63	123902950	-201961808.5	-179521607.6								
1987	54.98	-12.86	173298260	-2228615624	-1760881480	-1980991665							
1988	50.10	-4.88	214345750	-1046007260	-734644330.8	-826474872.1	-929784231.1						
1989	49.90	-0.20	205086130	-41017226	-25606852.26	-28807708.8	-32408672.4	-36459756.44					
1990	48.23	-1.67	223353170	-372999793.9	-206988386.7	-232861935	-261969676.9	-294715886.5	-331555372.4				
1991	55.99	7.76	277031030	2149760793	1060412902	1192964515	1342085080	1509845715	1698576429	1910898482			
1992	56.42	0.43	295225320	126946887.6	55661435.23	62619114.64	70446503.97	79252316.97	89158856.59	100303713.7	112841677.9		
1993	50.90	-5.52	332479140	-1835284853	-715291889.4	-804703375.6	-905291297.5	-1018452710	-1145759298	-1288979211	-1450101612	-1631364314	
1994	47.91	-2.99	367415630	-1098572734	-380588896.4	-428162508.5	-481682822	-541893174.8	-609629821.6	-685833549.3	-771562743	-868008085.9	-976509096.6
1995	49.74	1.83	386980326	707593526.7	217900700.6	245138288.2	275780574.3	310253146	349034789.3	392664137.9	441747155.2	496965549.6	559086243.3
1996	50.24	0.50	421323503	212347045.3	58125737.39	65391454.57	73565386.39	82761059.68	93106192.15	104744466.2	117837524.4	132567215	149138116.9
1997	52.36	2.12	467704493	992001230.1	241369250.2	271540406.5	305482957.3	343668326.9	386626867.8	434955226.3	489324629.6	550490208.2	619301484.3
1998	54.77	2.40	539577326	1297413680	280605178.2	315680825.5	355140928.7	399533544.8	449475237.9	505659642.6	568867097.9	639975485.2	719972420.8
1999	57.37	2.60	631631200	1644767646	316205369.3	355731040.5	400197420.6	450222098.1	506499860.4	569812343	641038885.8	721168746.6	811314839.9
2000	60.18	2.80	664204110	1862096222	318210336.1	357986628.1	402734956.6	453076826.2	509711429.5	573425358.2	645103528	725741469	816459152.6
2001	63.21	3.03	663141950	2012304247	305670329.1	343879120.3	386864010.3	435222011.6	489624763	550827858.4	619681340.7	697141508.3	784284196.9
2002	64.89	1.68	663141950	1114078476	150425998.2	169229248	190382904	214180766.9	240953362.8	271072533.2	304956599.8	343076174.8	385960696.6
2003	65.70	0.81	629506880	508956312.7	61085073.58	68720707.78	77310796.25	86974645.79	97846476.51	110077286.1	123836946.8	139316565.2	156731135.8
2004	66.53	0.83	627028507	520120146.4	55488853.24	62424959.9	70228079.89	79006589.87	88882413.61	99992715.31	112491804.7	126553280.3	142372440.3
2005	67.37	0.84	624904187	524919516.7	49778553.38	56000872.55	63000981.62	70876104.32	79735617.37	89702569.54	100915390.7	113529814.6	127721041.4
2006	68.22	0.85	624550133	531179888.3	44775315.21	50372229.61	56668758.31	63752353.1	71721397.24	80686571.9	90772393.38	102118942.6	114883810.4
2007	69.09	0.87	622425813	542444096.1	40644285.46	45724821.14	51440423.78	57870476.75	65104286.35	73242322.14	82397612.41	92697313.96	104284478.2
2008	69.98	0.89	619947440	553303089.8	36851492.29	41457928.82	46640169.92	52470191.16	59028965.06	66407585.69	74708533.9	84047100.64	94552988.22
2009	70.89	0.90	565069168	510257458.8	30208476.5	33984536.06	38232603.07	43011678.46	48388138.26	54436655.55	61241237.49	68896392.18	77508441.2
2010	71.81	0.92	525061138	485156491.6	25531056.44	28722438.49	32312743.3	36351836.21	40895815.74	46007792.71	51758766.8	58228612.65	65507189.23
2011	72.75	0.95	483282841	456702284.9	21363263.68	24033671.64	27037880.59	30417615.66	34219817.62	38497294.82	43309456.68	48723138.76	54813531.11
					-633209836.9	**-510399258**	**1654416458**	**2907225776**	**3311646224**	**4098601796**	**2461166227**	**2641865118**	**4807383110**

Prices up 5.0%

	NNP	PROD'N	PRICE	Marginal Cost	THR	Price Change Term	Net Adjustment	Net Adjustment	Adjusted NNP	Difference from Base	Difference from Base
	Mbaht	mmbtu	b/mmbtu	b/mmbtu	Mbaht	Mbaht	Mbaht	%NNP	Mbaht	%NNP	NNP level
1985	831975	128286380	69.47	23.58	5887.061978	**0**	5887.061978	0.707600827	826087.938	0	0
1986	879915	123902950	67.84	23.58	5483.944567	**-633.209837**	6117.154404	0.695198332	873797.8456	0.043097404	-379.221
1987	1011343	173298260	54.98	23.58	5441.565364	**-510.399258**	5951.964622	0.58852087	1005391.035	0.042183817	-426.623
1988	1198771	214345750	50.1	23.58	5684.44929	**1654.416458**	4030.032832	0.336180374	1194740.967	0.040036919	-479.951
1989	1440089	205086130	49.9	23.58	5397.866942	**2907.225776**	2490.641166	0.172950503	1437598.359	0.037493852	-539.945
1990	1681522	223353170	48.23	23.58	5505.655641	**3311.646224**	2194.009417	0.130477592	1679327.991	0.036124294	-607.438
1991	1925835	277031030	55.99	23.58	8978.575682	**4098.601796**	4879.973887	0.253395223	1920955.026	0.035484228	-683.368
1992	2160037	295225320	56.42	23.58	9695.199509	**2461.166227**	7234.033282	0.334903211	2152802.967	0.035591457	-768.789
1993	2382007	332479140	50.9	23.58	9083.330105	**2641.865118**	6441.464987	0.270421749	2375565.535	0.036309181	-864.887
1994	2768500	367415630	47.91	23.58	8939.222278	**4807.38311**	4131.839167	0.149244687	2764368.161	0.035145318	-972.998

Prices up 10.0%

I	II	III	IV	V									
year	price	P1-P0	MMBTU	(P1-P0)*Q	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	69.47		128286380										
1986	67.84	-1.63	123902950	-201961808.5	-179521607.6								
1987	54.98	-12.86	173298260	-2228615624	-1760881480	-1980991665							
1988	50.10	-4.88	214345750	-1046007260	-734644330.8	-826474872.1	-929784231.1						
1989	49.90	-0.20	205086130	-41017226	-25606852.26	-28807708.8	-32408672.4	-36459756.44					
1990	48.23	-1.67	223353170	-372999793.9	-206988386.7	-232861935	-261969676.9	-294715886.5	-331555372.4				
1991	55.99	7.76	277031030	2149760793	1060412902	1192964515	1342085080	1509845715	1698576429	1910898482			
1992	56.42	0.43	295225320	126946887.6	55661435.23	62619114.64	70446503.97	79252316.97	89158856.59	100303713.7	112841677.9		
1993	50.90	-5.52	332479140	-1835284853	-715291889.4	-804703375.6	-905291297.5	-1018452710	-1145759298	-1288979211	-1450101612	-1631364314	
1994	47.91	-2.99	367415630	-1098572734	-380588896.4	-428162508.5	-481682822	-541893174.8	-609629821.6	-685833549.3	-771562743	-868008085.9	-976509096.6
1995	52.11	4.20	386980326	1624156430	500152715.7	562671805.1	633005780.8	712131503.4	801147941.3	901291433.9	1013952863	1140696971	1283284092
1996	52.64	0.53	421323503	222458809.4	60893629.65	68505333.35	77068500.02	86702062.53	97539820.34	109732297.9	123448835.1	138879939.5	156239932
1997	54.86	2.22	467704493	1039239384	252863024	284470902	320029764.8	360033485.4	405037671	455667379.9	512625802.4	576704027.7	648792031.1
1998	57.38	2.52	539577326	1359195284	293967329.6	330713245.8	372052401.5	418558951.7	470878820.6	529738673.2	595956007.4	670450508.3	754256821.8
1999	60.10	2.73	631631200	1723089915	331262767.9	372670613.9	419254440.6	471661245.7	530618901.4	596946264	671564547.1	755510115.4	849948879.9
2000	63.04	2.94	664204110	1950767471	333363209.3	375033610.4	421912811.7	474651913.2	533983402.3	600731327.6	675822743.6	760300586.5	855338159.9
2001	66.22	3.18	663141950	2108128259	320226059.1	360254316.5	405286106	455946869.3	512940227.9	577057756.4	649189976	730338723	821631063.4
2002	67.98	1.76	663141950	1167129832	157589141	177287783.6	199448756.5	224379851.1	252427332.5	283980749	319478342.7	359413135.5	404339777.4
2003	68.83	0.85	629506880	533192327.6	63993886.61	71993122.44	80992262.74	91116295.58	102505832.5	115319061.6	129733944.3	145950687.3	164194523.3
2004	69.70	0.87	627028507	544887772.4	58131179.59	65397577.04	73572274.17	82768808.44	93114909.49	104754273.2	117848557.3	132579627	149152080.4
2005	70.58	0.88	624904187	549915684.2	52148960.68	58667580.77	66001028.37	74251156.91	83532551.53	93974120.47	105720885.5	118935996.2	133802995.7
2006	71.47	0.89	624550133	556474168.7	46907473.08	52770907.21	59367270.61	66788179.44	75136701.87	84528789.6	95094888.3	106981749.3	120354468
2007	72.38	0.91	622425813	568274767.3	42579727.62	47902193.57	53889967.77	60626213.74	68204490.46	76730051.77	86321308.24	97111471.77	109250405.7
2008	73.32	0.94	619947440	579650855.9	38606325.25	43432115.91	48861130.4	54968771.7	61839868.16	69569851.68	78266083.14	88049343.53	99055511.47
2009	74.26	0.95	565069168	534555433.1	31646975.38	35602847.31	40053203.22	45059853.62	50692335.32	57028877.24	64157486.89	72177172.76	81199319.35
2010	75.23	0.97	525061138	508259181.7	26746821.03	30090173.66	33851445.36	38082876.03	42843235.54	48198639.98	54223469.98	61001403.72	68626579.19
2011	76.22	0.99	483282841	478450012.8	22380561.95	25178132.19	28325398.71	31866073.55	35849332.75	40330499.34	45371811.76	51043288.23	57423699.25
					-253989318.6	**-83776174.9**	**2134367427**	**3447170615**	**3919084168**	**4781969483**	**3229954876**	**3506752347**	**5780381244**

Prices up 10.0%

	NNP	PROD'N	PRICE	Marginal Cost	THR	Price Change Term	Net Adjustment	Net Adjustment	Adjusted NNP	Difference from Base	Diff from Base
	Mbaht	mmbtu	b/mmbtu	b/mmbtu	Mbaht	Mbaht	Mbaht	%NNP	Mbaht	%NNP	Mbaht
1985	831975	128286380	69.47	23.58	5887.061978	**0**	5887.061978	0.707600827	826087.938	0	0
1986	879915	123902950	67.84	23.58	5483.944567	**-253.989319**	5737.933886	0.652100929	874177.0661	0.086194807	-758.441
1987	1011343	173298260	54.98	23.58	5441.565364	**-83.7761749**	5525.341539	0.546337053	1005817.658	0.084367635	-853.246
1988	1198771	214345750	50.1	23.58	5684.44929	**2134.367427**	3550.081863	0.296143456	1195220.918	0.080073837	-959.902
1989	1440089	205086130	49.9	23.58	5397.866942	**3447.170615**	1950.696326	0.135456651	1438138.304	0.074987704	-1079.89
1990	1681522	223353170	48.23	23.58	5505.655641	**3919.084168**	1586.571472	0.094353299	1679935.429	0.072248587	-1214.88
1991	1925835	277031030	55.99	23.58	8978.575682	**4781.969483**	4196.606199	0.217910994	1921638.394	0.070968457	-1366.74
1992	2160037	295225320	56.42	23.58	9695.199509	**3229.954876**	6465.244633	0.299311754	2153571.755	0.071182915	-1537.58
1993	2382007	332479140	50.9	23.58	9083.330105	**3506.752347**	5576.577757	0.234112568	2376430.422	0.072618362	-1729.77
1994	2768500	367415630	47.91	23.58	8939.222278	**5780.381244**	3158.841034	0.114099369	2765341.159	0.070290636	-1946

Prices up 10.0% with shock in 2005

I	II	III	IV	V									
year	price	P1-P0	MMBTU	(P1-P0)*Q	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	69.47		128286380										
1986	67.84	-1.63	123902950	-201961808.5	-179521607.6								
1987	54.98	-12.86	173298260	-2228615624	-1760881480	-1980991665							
1988	50.10	-4.88	214345750	-1046007260	-734644330.8	-826474872.1	-929784231.1						
1989	49.90	-0.20	205086130	-41017226	-25606852.26	-28807708.8	-32408672.4	-36459756.44					
1990	48.23	-1.67	223353170	-372999793.9	-206988386.7	-232861935	-261969676.9	-294715886.5	-331555372.4				
1991	55.99	7.76	277031030	2149760793	1060412902	1192964515	1342085080	1509845715	1698576429	1910898482			
1992	56.42	0.43	295225320	126946887.6	55661435.23	62619114.64	70446503.97	79252316.97	89158856.59	100303713.7	112841677.9		
1993	50.90	-5.52	332479140	-1835284853	-715291889.4	-804703375.6	-905291297.5	-1018452710	-1145759298	-1288979211	-1450101612	-1631364314	
1994	47.91	-2.99	367415630	-1098572734	-380588896.4	-428162508.5	-481682822	-541893174.8	-609629821.6	-685833549.3	-771562743	-868008085.9	-976509096.6
1995	52.11	4.20	386980326	1624156430	500152715.7	562671805.1	633005780.8	712131503.4	801147941.3	901291433.9	1013952863	1140696971	1283284092
1996	52.64	0.53	421323503	222458809.4	60893629.65	68505333.35	77068500.02	86702062.53	97539820.34	109732297.9	123448835.1	138879939.5	156239932
1997	54.86	2.22	467704493	1039239384	252863024	284470902	320029764.8	360033485.4	405037671	455667379.9	512625802.4	576704027.7	648792031.1
1998	57.38	2.52	539577326	1359195284	293967329.6	330713245.8	372052401.5	418558951.7	470878820.6	529738673.2	595956007.4	670450508.3	754256821.8
1999	60.10	2.73	631631200	1723089915	331262767.9	372670613.9	419254440.6	471661245.7	530618901.4	596946264	671564547.1	755510115.4	849948879.9
2000	63.04	2.94	664204110	1950767471	333363209.3	375033610.4	421912811.7	474651913.2	533983402.3	600731327.6	675822743.6	760300586.5	855338159.9
2001	66.22	3.18	663141950	2108128259	320226059.1	360254316.5	405286106	455946869.3	512940227.9	577057756.4	649189976	730338723	821631063.4
2002	67.98	1.76	663141950	1167129832	157589141	177287783.6	199448756.5	224379851.1	252427332.5	283980749	319478342.7	359413135.5	404339777.4
2003	68.83	0.85	629506880	533192327.6	63993886.61	71993122.44	80992262.74	91116295.58	102505832.5	115319061.6	129733944.3	145950687.3	164194523.3
2004	69.70	0.87	627028507	544887772.4	58131179.59	65397577.04	73572274.17	82768808.44	93114909.49	104754273.2	117848557.3	132579627	149152080.4
2005	90.00	20.30	624904187	12688054605	1203218747	1353621091	1522823727	1713176693	1927323780	2168239252	2439269159	2744177804	3087200029
2006	99.00	9.00	624550133	5620951199	473812859.4	533039466.8	599669400.1	674628075.2	758956584.6	853826157.6	960554427.3	1080623731	1215701697
2007	108.90	9.90	622425813	6162015549	461707889.9	519421376.1	584349048.1	657392679.1	739566764	832012609.5	936014185.7	1053015959	1184642954
2008	119.79	10.89	619947440	6751227616	449650141.2	505856408.8	569088459.9	640224517.4	720252582.1	810284154.8	911569674.2	1025515883	1153705369
2009	131.77	11.98	565069168	6768963565	400739025.5	450831403.7	507185329.1	570583495.3	641906432.2	722144736.2	812412828.2	913964431.7	1028209986
2010	144.95	13.18	525061138	6918678110	364091101.2	409602488.9	460802800	518403150	583203543.8	656103986.7	738116985.1	830381608.2	934179309.2
2011	159.44	14.49	483282841	7004986637	327673807.5	368633033.4	414712162.6	466551182.9	524870080.7	590478840.8	664288695.9	747324782.9	840740380.8
					3165887408	**3763585143**	**6462648909**	**8316487283**	**9397065420**	**10944698391**	**10163024897**	**11306456121**	**14555047989**

Prices up 10.0% with shock in 2005

	NNP	PROD'N	PRICE	Marginal Cost	THR	Price Change Term	Net Adjustment	Net Adjustment	Adjusted NNP	Difference form Base	Diff from Base
	Mbaht	mmbtu	b/mmbtu	b/mmbtu	Mbaht	Mbaht	Mbaht	%NNP	Mbaht	%NNP	Mbaht
1985	831975	128286380	69.47	23.58	5887.061978	**0**	5887.061978	0.707600827	826087.938	0	0
1986	879915	123902950	67.84	23.58	5483.944567	**3165.887408**	2318.057159	0.263441032	877596.9428	0.474854703	-4178.32
1987	1011343	173298260	54.98	23.58	5441.565364	**3763.585143**	1677.980221	0.165916037	1009665.02	0.464788651	-4700.61
1988	1198771	214345750	50.1	23.58	5684.44929	**6462.648909**	-778.199619	-0.06491645	1199549.2	0.441133746	-5288.18
1989	1440089	205086130	49.9	23.58	5397.866942	**8316.487283**	-2918.62034	-0.20266944	1443007.62	0.413113797	-5949.21
1990	1681522	223353170	48.23	23.58	5505.655641	**9397.06542**	-3891.40978	-0.23142188	1685413.41	0.398023763	-6692.86
1991	1925835	277031030	55.99	23.58	8978.575682	**10944.69839**	-1966.12271	-0.10209196	1927801.123	0.390971412	-7529.46
1992	2160037	295225320	56.42	23.58	9695.199509	**10163.0249**	-467.825388	-0.02165821	2160504.825	0.392152881	-8470.65
1993	2382007	332479140	50.9	23.58	9083.330105	**11306.45612**	-2223.12602	-0.09332995	2384230.126	0.400060883	-9529.48
1994	2768500	367415630	47.91	23.58	8939.222278	**14555.04799**	-5615.82571	-0.20284724	2774115.826	0.387237241	-10720.7

Discount Rate : 10%

I	II	III	IV	V									
year	price	P1-P0	MMBTU	(P1-P0)*Q	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	69.47		128286380										
1986	67.84	-1.63	123902950	-201961808.5	-183601644.1								
1987	54.98	-12.86	173298260	-2228615624	-1841831094	-2026014203							
1988	50.10	-4.88	214345750	-1046007260	-785880736.3	-864468809.9	-950915690.9						
1989	49.90	-0.20	205086130	-41017226	-28015317.26	-30816848.99	-33898533.88	-37288387.27					
1990	48.23	-1.67	223353170	-372999793.9	-231603525.5	-254763878.1	-280240265.9	-308264292.5	-339090721.7				
1991	55.99	7.76	277031030	2149760793	1213483923	1334832316	1468315547	1615147102	1776661812	1954327993			
1992	56.42	0.43	295225320	126946887.6	65143825.96	71658208.55	78824029.41	86706432.35	95377075.58	104914783.1	115406261.5		
1993	50.90	-5.52	332479140	-1835284853	-856173928.6	-941791321.5	-1035970454	-1139567499	-1253524249	-1378876674	-1516764341	-1668440775	
1994	47.91	-2.99	367415630	-1098572734	-465902080	-512492288	-563741516.8	-620115668.4	-682127235.3	-750339958.8	-825373954.7	-907911350.2	-998702485.2
1995	47.37	-0.54	386980326	-208969376.2	-80566740.69	-88623414.76	-97485756.24	-107234331.9	-117957765	-129753541.6	-142728895.7	-157001785.3	-172701963.8
1996	47.85	0.48	421323503	202235281.2	70882232.33	77970455.57	85767501.12	94344251.23	103778676.4	114156544	125572198.4	138129418.2	151942360.1
1997	49.87	2.02	467704493	944763076.2	301030631.5	331133694.7	364247064.1	400671770.6	440738947.6	484812842.4	533294126.6	586623539.3	645285893.2
1998	52.16	2.29	539577326	1235632077	357918599	393710458.9	433081504.8	476389655.3	524028620.8	576431482.9	634074631.2	697482094.3	767230303.8
1999	54.64	2.48	631631200	1566445377	412494026	453743428.6	499117771.4	549029548.6	603932503.4	664325753.8	730758329.2	803834162.1	884217578.3
2000	57.31	2.67	664204110	1773424974	424543838.8	466998222.7	513698045	565067849.5	621574634.4	683732097.9	752105307.6	827315838.4	910047422.2
2001	60.20	2.89	663141950	1916480235	417081937.3	458790131	504669144.2	555136058.6	610649664.4	671714630.9	738886094	812774703.3	894052173.7
2002	61.80	1.60	663141950	1061027120	209918559.2	230910415.1	254001456.6	279401602.3	307341762.5	338075938.8	371883532.7	409071885.9	449979074.5
2003	62.57	0.77	629506880	484720297.8	87181206.21	95899326.84	105489259.5	116038185.5	127642004	140406204.4	154446824.9	169891507.3	186880658.1
2004	63.36	0.79	627028507	495352520.3	80994095.35	89093504.89	98002855.38	107803140.9	118583455	130441800.5	143485980.6	157834578.6	173618036.5
2005	64.16	0.80	624904187	499923349.3	74310420.37	81741462.41	89915608.65	98907169.51	108797886.5	119677675.1	131645442.6	144809986.9	159290985.6
2006	64.97	0.81	624550133	505885607.9	68360611.02	75196672.13	82716339.34	90987973.27	100086770.6	110095447.7	121104992.4	133215491.7	146537040.8
2007	65.80	0.83	622425813	516613424.8	63463879.13	69810267.05	76791293.75	84470423.13	92917465.44	102209212	112430133.2	123673146.5	136040461.2
2008	66.65	0.85	619947440	526955323.6	58849399.78	64734339.75	71207773.73	78328551.1	86161406.21	94777546.83	104255301.5	114680831.7	126148914.8
2009	67.51	0.86	565069168	485959484.6	49337327.28	54271060	59698166	65667982.61	72234780.87	79458258.95	87404084.85	96144493.33	105758942.7
2010	68.39	0.88	525061138	462053801.5	42645716.82	46910288.5	51601317.35	56761449.09	62437594	68681353.4	75549488.74	83104437.61	91414881.37
2011	69.29	0.90	483282841	434954557.1	36495059.1	40144565.01	44159021.51	48574923.66	53432416.02	58775657.63	64653223.39	71118545.73	78230400.3
					-439439777.7	**-281421947**	**1919051482**	**3156963890**	**3513677505**	**4238045050**	**2512088762**	**2636350750**	**4735270678**

Discount Rate : 10%

	NNP	PROD'N	PRICE	Marginal Cost	THR	Price Change Term	Net Adjustment	Net adjustment	Adjusted NNP	Difference from Base	Diff from Base
	Mbaht	mmbtu	b/mmbtu	b/mmbtu	Mbaht	Mbaht	Mbaht	%NNP	Mbaht	% NNP	Mbaht
1985	831975	128286380	69.47	23.58	5887.061978	**0**	5887.061978	0.707600827	826087.938	0	0
1986	879915	123902950	67.84	23.58	5483.944567	**-439.439778**	5923.384345	0.67317688	873991.6157	0.065118856	-572.991
1987	1011343	173298260	54.98	23.58	5441.565364	**-281.421947**	5722.987311	0.565879955	1005620.013	0.064824732	-655.6
1988	1198771	214345750	50.1	23.58	5684.44929	**1919.051482**	3765.397808	0.314104846	1195005.602	0.062112446	-744.586
1989	1440089	205086130	49.9	23.58	5397.866942	**3156.96389**	2240.903051	0.15560865	1437848.097	0.054835705	-789.683
1990	1681522	223353170	48.23	23.58	5505.655641	**3513.677505**	1991.978135	0.118462805	1679530.022	0.04813908	-809.469
1991	1925835	277031030	55.99	23.58	8978.575682	**4238.04505**	4740.530633	0.246154558	1921094.469	0.042724893	-822.811
1992	2160037	295225320	56.42	23.58	9695.199509	**2512.088762**	7183.110747	0.332545727	2152853.889	0.037948942	-819.711
1993	2382007	332479140	50.9	23.58	9083.330105	**2636.35075**	6446.979355	0.27065325	2375560.021	0.03607768	-859.373
1994	2768500	367415630	47.91	23.58	8939.222278	**4735.270678**	4203.9516	0.151849435	2764296.048	0.032540571	-900.886

Discount Rate : 15%

I	II	III	IV	V									
year	price	P1-P0	MMBTU	(P1-P0)*Q	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	69.47		128286380										
1986	67.84	-1.63	123902950	-201961808.5	-175618963.9								
1987	54.98	-12.86	173298260	-2228615624	-1685153591	-1937926629							
1988	50.10	-4.88	214345750	-1046007260	-687766752.7	-790931765.6	-909571530.4						
1989	49.90	-0.20	205086130	-41017226	-23451732.09	-26969491.9	-31014915.69	-35667153.04					
1990	48.23	-1.67	223353170	-372999793.9	-185446819.8	-213263842.8	-245253419.2	-282041432.1	-324347646.9				
1991	55.99	7.76	277031030	2149760793	929400915.3	1068811053	1229132711	1413502617	1625528010	1869357211			
1992	56.42	0.43	295225320	126946887.6	47724037.15	54882642.72	63115039.13	72582295	83469639.25	95990085.14	110388597.9		
1993	50.90	-5.52	332479140	-1835284853	-599957873.9	-689951555	-793444288.2	-912460931.5	-1049330071	-1206729582	-1387739019	-1595899872	
1994	47.91	-2.99	367415630	-1098572734	-312282935.1	-359125375.3	-412994181.6	-474943308.9	-546184805.2	-628112526	-722329404.9	-830678815.7	-955280638
1995	47.37	-0.54	386980326	-208969376.2	-51654033.85	-59402138.92	-68312459.76	-78559328.73	-90343228.04	-103894712.2	-119478919.1	-137400756.9	-158010870.5
1996	47.85	0.48	421323503	202235281.2	43469103.1	49989468.56	57487888.84	66111072.17	76027733	87431892.94	100546676.9	115628678.4	132972980.2
1997	49.87	2.02	467704493	944763076.2	176582974.2	203070420.3	233530983.4	268560630.9	308844725.5	355171434.3	408447149.5	469714221.9	540171355.2
1998	52.16	2.29	539577326	1235632077	200824756.6	230948470.1	265590740.6	305429351.7	351243754.5	403930317.6	464519865.3	534197845.1	614327521.8
1999	54.64	2.48	631631200	1566445377	221383623	254591166.4	292779841.4	336696817.6	387201340.2	445281541.3	512073772.4	588884838.3	677217564.1
2000	57.31	2.67	664204110	1773424974	217944149.2	250635771.5	288231137.3	331465807.9	381185679.1	438363530.9	504118060.5	579735769.6	666696135.1
2001	60.20	2.89	663141950	1916480235	204804219	235524851.9	270853579.7	311481616.6	358203859.1	411934438	473724603.7	544783294.2	626500788.4
2002	61.80	1.60	663141950	1061027120	98596885.95	113386418.8	130394381.7	149953538.9	172446569.8	198313555.2	228060588.5	262269676.8	301610128.3
2003	62.57	0.77	629506880	484720297.8	39167881.3	45043063.49	51799523.02	59569451.47	68504869.19	78780599.57	90597689.51	104187342.9	119815444.4
2004	63.36	0.79	627028507	495352520.3	34806103.74	40027019.3	46031072.2	52935733.03	60876092.98	70007506.93	80508632.97	92584927.92	106472667.1
2005	64.16	0.80	624904187	499923349.3	30545456.09	35127274.5	40396365.68	46455820.53	53424193.61	61437822.65	70653496.05	81251520.46	93439248.52
2006	64.97	0.81	624550133	505885607.9	26878045	30909751.76	35546214.52	40878146.7	47009868.7	54061349.01	62170551.36	71496134.06	82220554.17
2007	65.80	0.83	622425813	516613424.8	23867844.51	27448021.18	31565224.36	36300008.02	41745009.22	48006760.6	55207774.69	63488940.89	73012282.03
2008	66.65	0.85	619947440	526955323.6	21170127.24	24345646.32	27997493.27	32197117.26	37026684.85	42580687.58	48967790.71	56312959.32	64759903.22
2009	67.51	0.86	565069168	485959484.6	16976646.06	19523142.97	22451614.41	25819356.58	29692260.06	34146099.07	39268013.93	45158216.02	51931948.43
2010	68.39	0.88	525061138	462053801.5	14036102.75	16141518.17	18562745.89	21347157.78	24549231.44	28231616.16	32466358.58	37336312.37	42936759.22
2011	69.29	0.90	483282841	434954557.1	11489471.08	13212891.74	15194825.5	17474049.32	20095156.72	23109430.23	26575844.76	30562221.48	35146554.7
					-1361664361	**-1363952206**	**660070586.4**	**1805088434**	**2116868926**	**2807399058**	**1078748124**	**1113613455**	**3115940326**

Discount Rate : 15%

	NNP	PROD'N	PRICE	Marginal Cost	THR	Price Change Term	Net Adjustment	Net Adjustment	NNP Adjustment	Difference from Base	Diff from Base
	Mbaht	mmbtu	b/mmbtu	b/mmbtu	Mbaht	Mbaht	Mbaht	%NNP	Mbaht	% NNP	NNP-level
1985	831975	128286380	69.47	23.58	5887.061978	**0**	5887.061978	0.707600827	826087.938	0	0
1986	879915	123902950	67.84	23.58	5483.944567	**-1361.66436**	6845.608928	0.777985252	873069.3911	-0.03968952	349.234
1987	1011343	173298260	54.98	23.58	5441.565364	**-1363.95221**	6805.51757	0.672918839	1004537.482	-0.04221415	426.9299
1988	1198771	214345750	50.1	23.58	5684.44929	**660.0705864**	5024.378704	0.419127482	1193746.621	-0.04291019	514.3949
1989	1440089	205086130	49.9	23.58	5397.866942	**1805.088434**	3592.778507	0.249483088	1436496.221	-0.03903873	562.1925
1990	1681522	223353170	48.23	23.58	5505.655641	**2116.868926**	3388.786715	0.201530918	1678133.213	-0.03492903	587.3394
1991	1925835	277031030	55.99	23.58	8978.575682	**2807.399058**	6171.176624	0.320441607	1919663.823	-0.03156216	607.835
1992	2160037	295225320	56.42	23.58	9695.199509	**1078.748124**	8616.451385	0.398902953	2151420.549	-0.02840828	613.6295
1993	2382007	332479140	50.9	23.58	9083.330105	**1113.613455**	7969.71665	0.3345799	2374037.283	-0.02784897	663.3644
1994	2768500	367415630	47.91	23.58	8939.222278	**3115.940326**	5823.281952	0.210340688	2762676.718	-0.02595068	718.4447

Natural Gas Runs out in 40 Years

I	II	III	IV	V									
year	price	P1-P0	MMBTU	(P1-P0)*Q	1986	1987	1988	1989	1990	1991	1992	1993	1994
1985	69.47		128286380										
1986	67.84	-1.63	123902950	-201961808.5	-179521607.6								
1987	54.98	-12.86	173298260	-2228615624	-1760881480	-1980991665							
1988	50.1	-4.88	214345750	-1046007260	-734644330.8	-826474872.1	-929784231.1						
1989	49.9	-0.2	205086130	-41017226	-25606852.26	-28807708.8	-32408672.4	-36459756.44					
1990	48.23	-1.67	223353170	-372999793.9	-206988386.7	-232861935	-261969676.9	-294715886.5	-331555372.4				
1991	55.99	7.76	277031030	2149760793	1060412902	1192964515	1342085080	1509845715	1698576429	1910898482			
1992	56.42	0.43	295225320	126946887.6	55661435.23	62619114.64	70446503.97	79252316.97	89158856.59	100303713.7	112841677.9		
1993	50.9	-5.52	332479140	-1835284853	-715291889.4	-804703375.6	-905291297.5	-1018452710	-1145759298	-1288979211	-1450101612	-1631364314	
1994	47.91	-2.99	367415630	-1098572734	-380588896.4	-428162508.5	-481682822	-541893174.8	-609629821.6	-685833549.3	-771562743	-868008085.9	-976509096.6
1995	47.37	-0.54	386980326.3	-208969376.2	-64351314.38	-72395228.68	-81444632.26	-91625211.3	-103078362.7	-115963158	-130458552.8	-146765871.9	-165111605.9
1996	47.85	0.48	421323502.6	202235281.2	55357845.13	62277575.78	70062272.75	78820056.84	88672563.95	99756634.44	112226213.7	126254490.5	142036301.8
1997	49.87	2.02	467704493.2	944763076.2	229875476.4	258609910.9	290936149.8	327303168.5	368216064.6	414243072.6	466023456.7	524276388.8	589810937.4
1998	52.16	2.29	539577326	1235632077	267243026.9	300648405.2	338229455.9	380508137.9	428071655.1	481580612	541778188.5	609500462.1	685688019.8
1999	54.64	2.48	631631200.5	1566445377	301147970.8	338791467.1	381140400.5	428782950.6	482380819.4	542678421.9	610513224.6	686827377.7	772680799.9
2000	57.31	2.67	664204109.9	1773424974	303057463	340939645.8	383557101.6	431501739.3	485439456.7	546119388.8	614384312.4	691182351.4	777580145.3
2001	60.2	2.89	663141949.8	1916480235	291114599.2	327503924.1	368441914.6	414497153.9	466309298.1	524597960.4	590172705.4	663944293.6	746937330.3
2002	61.8	1.6	663141949.8	1061027120	143262855.4	161170712.3	181317051.4	203981682.8	229479393.2	258164317.3	290434857	326739214.1	367581615.9
2003	62.57	0.77	629506880.3	484720297.8	58176260.56	65448293.12	73629329.77	82832995.99	93187120.48	104835510.5	117939949.4	132682443	149267748.4
2004	63.36	0.79	627028506.8	495352520.3	52846526.9	59452342.76	66883885.61	75244371.31	84649917.72	95231157.44	107135052.1	120526933.6	135592800.3
2005	64.16	0.8	624904186.6	499923349.3	47408146.08	53334164.34	60000934.88	67501051.74	75938683.2	85431018.61	96109895.93	108123632.9	121639087
2006	64.97	0.81	624550133.2	505885607.9	42643157.34	47973552.01	53970246.01	60716526.76	68306092.61	76844354.19	86449898.46	97256135.77	109413152.7
2007	65.8	0.83	622425813	516613424.8	38708843.29	43547448.7	48990879.79	55114739.77	62004082.24	69754592.52	78473916.58	88283156.15	99318550.67
2008	66.65	0.85	619947439.5	526955323.6	35096659.32	39483741.73	44419209.45	49971610.63	56218061.96	63245319.71	71150984.67	80044857.75	90050464.97
2009	67.51	0.86	565069168.2	485959484.6	28769977.62	32366224.82	36412002.93	40963503.29	46083941.2	51844433.85	58324988.08	65615611.6	73817563.05
2010	68.39	0.88	525061138.1	462053801.5	24315291.84	27354703.32	30774041.24	34620796.39	38948395.94	43816945.44	49294063.62	55455821.57	62387799.26
2011	69.29	0.9	483282841.2	434954557.1	20345965.41	22889211.08	25750362.47	28969157.77	32590302.5	36664090.31	41247101.6	46402989.3	52203362.96

Natural Gas Runs out in 40 Years (con't)

2012	70.19	0.90	444620213.9	400500550.1	16652713.52	18734302.71	21076090.55	23710601.87	26674427.1	30008730.49	33759821.8	37979799.52	42727274.46
2013	71.10	0.91	409050596.8	373250492.6	13795255.9	15519662.89	17459620.75	19642073.35	22097332.51	24859499.08	27966936.46	31462803.52	35395653.96
2014	72.03	0.92	376326549	347854529.1	11428112.61	12856626.69	14463705.03	16271668.16	18305626.68	20593830.01	23168058.76	26064066.11	29322074.37
2015	72.96	0.94	346220425.1	324186507	9467150.073	10650543.83	11981861.81	13479594.54	15164543.85	17060111.84	19192625.82	21591704.04	24290667.05
2016	73.91	0.95	318522791.1	302128857	7842671.273	8823005.182	9925880.83	11166615.93	12562442.93	14132748.29	15899341.83	17886759.56	20122604.5
2017	74.87	0.96	293040967.8	281572009.6	6496938.595	7309055.92	8222687.909	9250523.898	10406839.39	11707694.31	13171156.1	14817550.61	16669744.44
2018	75.85	0.97	269597690.4	262413850.1	5382121.683	6054886.893	6811747.755	7663216.224	8621118.252	9698758.034	10911102.79	12274990.64	13809364.47
2019	76.83	0.99	248029875.2	244559211.7	4458597.443	5015922.123	5642912.389	6348276.438	7141810.992	8034537.366	9038854.537	10168711.35	11439800.27
2020	77.83	1.00	228187485.1	227919402.9	3693541.754	4155234.473	4674638.782	5258968.63	5916339.709	6655882.172	7487867.444	8423850.874	9476832.234
2021	78.84	1.01	209932486.3	212411766.8	3059762.82	3442233.173	3872512.32	4356576.359	4901148.404	5513791.955	6203015.949	6978392.943	7850692.061
2022	79.87	1.02	193137887.4	197959270.2	2534734.718	2851576.558	3208023.628	3609026.581	4060154.904	4567674.267	5138633.55	5780962.744	6503583.087
2023	80.91	1.04	177686856.4	184490121.4	2099796.772	2362271.368	2657555.289	2989749.7	3363468.413	3783901.964	4256889.71	4789000.924	5387626.039
2024	81.96	1.05	163471907.9	171937413.6	1739490.31	1956926.599	2201542.424	2476735.227	2786327.131	3134618.022	3526445.275	3967250.934	4463157.301
2025	83.02	1.07	150394155.3	160238791.9	1441009.235	1621135.39	1823777.313	2051749.478	2308218.162	2596745.433	2921338.612	3286505.938	3697319.18
2026	84.10	1.08	138362622.9	149336144.5	1193744.86	1342962.967	1510833.338	1699687.505	1912148.443	2151166.999	2420062.873	2722570.733	3062892.074
2027	85.20	1.09	127293613	139175313.3	988908.8527	1112522.459	1251587.767	1408036.238	1584040.767	1782045.863	2004801.596	2255401.795	2537327.02
2028	86.30	1.11	117110124	129705824.9	819220.8839	921623.4943	1036826.431	1166429.735	1312233.452	1476262.633	1660795.463	1868394.895	2101944.257
2029	87.43	1.12	107741314.1	120880640.6	678649.8622	763481.0949	858916.2318	966280.7608	1087065.856	1222949.088	1375817.724	1547794.939	1741269.307
2030	88.56	1.14	99122008.95	112655921.8	562199.5783	632474.5255	711533.8412	800475.5714	900535.0178	1013101.895	1139739.632	1282207.086	1442482.972
2031	89.71	1.15	91192248.23	104990812.9	465731.128	523947.5189	589440.9588	663121.0787	746011.2135	839262.6152	944170.4421	1062191.747	1194965.716
2032	90.88	1.17	83896868.37	97847237.99	385815.8062	434042.782	488298.1298	549335.396	618002.3205	695252.6105	782159.1869	879929.0852	989920.2209
2033	92.06	1.18	77185118.9	91189711.92	319613.2434	359564.8988	404510.5111	455074.325	511958.6156	575953.4426	647947.6229	728941.0758	820058.7103
2034	93.26	1.20	71010309.39	84985163.92	264770.4518	297866.7583	335100.1031	376987.6159	424111.0679	477124.9514	536765.5704	603861.2667	679343.925
2035	94.47	1.21	65329484.64	79202773.37	219338.1958	246755.4703	277599.904	312299.892	351337.3786	395254.5509	444661.3697	500244.041	562774.5461
2036	95.70	1.23	60103125.87	73813816.67	181701.7111	204414.4249	229966.2281	258712.0066	291051.0074	327432.3833	368361.4312	414406.6101	466207.4364
					-916258764	**-828829301**	**1296182660**	**2504212753**	**2858256573**	**3588538438**	**1887344950**	**1996316181**	**4081140557**

Natural Gas Runs out in 40 Years

	NNP	PROD'N	Price	Marginal Cost	THR	Price Change Term	Net Adjustment	Net Adjustment	Adjusted NNP	Difference from Base	Diff from Base
	Mbaht	mmbtu	b/mmbtu	b/mmbtu	Mbaht	Mbaht	Mbaht	%NNP	Mbaht	% NNP	Mbaht
1985	831975	128286380	69.47	23.58	5887.062	0	6415.602	0.771129	825559.4	0	0
1986	879915	123902950	67.84	23.58	5483.945	-916.259	6400.203	0.727366	873514.8	0.010929736	-96.1749
1987	1011343	173298260	54.98	23.58	5441.565	-828.829	6270.395	0.620007	1005073	0.010697687	-108.588
1988	1198771	214345750	50.1	23.58	5684.449	1296.183	4388.267	0.366064	1194383	0.010153293	-121.984
1989	1440089	205086130	49.9	23.58	5397.867	2504.213	2893.654	0.200936	1437195	0.009508355	-136.586
1990	1681522	223353170	48.23	23.58	5505.656	2858.257	2647.399	0.157441	1678875	0.009160886	-154.447
1991	1925835	277031030	55.99	23.58	8978.576	3588.538	5390.037	0.279881	1920445	0.008998451	-173.342
1992	2160037	295225320	56.42	23.58	9695.2	1887.345	7807.855	0.361469	2152229	0.009025669	-194.822
1993	2382007	332479140	50.9	23.58	9083.33	1996.316	7087.014	0.297523	2374920	0.00920793	-219.352
1994	2768500	367415630	47.91	23.58	8939.222	4081.141	4858.082	0.175477	2763642	0.008913005	-246.837

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