Insular Area Energy Vulnerability

Technical Appendix I

Puerto Rico and the U.S. Virgin Islands

May 1994

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Insular Area Energy Vulnerability:

**Puerto Rico
U.S. Virgin Islands**

Prepared for:

Office of Emergency Planning
U.S. Department of Energy
Washington, D.C. 20585

Prepared by:

Mathtech, Inc.
210 Carnegie Center, Suite 200
Princeton, N.J. 08540

With assistance from:

Ensys Energy & Systems, Inc.
P.O. Box 2320
Flemington, NJ 08822

Mark Stern
Emmet E. Willard
Stanley Efferding

MASTER

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The study team consisted of the following members:

Mathtech, Inc.

Dr. Ernest H. Manuel, Jr.
Dr. Kelly Eastman-Perl
Ms. Susan Simonelli

EnSys Energy and Systems, Inc.

Mr. Martin R. Tallett
Mr. Daniel N. Dunbar
Mr. James E. Webb, Jr.

Consultants

Mr. Mark Stern
Mr. Emmet E. Willard
Mr. Stanley Efferding, Jr.

TABLE OF CONTENTS

VOLUME 1

	<u>Page</u>
EXECUTIVE SUMMARY	vii
INTRODUCTION	1
OVERVIEW OF THE CARIBBEAN OIL MARKET	3

VOLUME 2

PUERTO RICO	1
1. INTRODUCTION	1
1.1 <u>Geography</u>	1
1.2 <u>Demographics</u>	1
1.3 <u>Relationship with the United States</u>	2
1.4 <u>Government Structure</u>	2
2. ECONOMIC PROFILE	3
2.1 <u>Overview</u>	3
2.2 <u>Major Economic Sectors</u>	6
2.3 <u>Economic Development Incentives</u>	6
3 ENERGY PROFILE.	11
3.1 <u>Introduction</u>	11
3.2 <u>Electricity Demand, Supply and Distribution</u>	11
3.2.1 <i>Electricity Demand</i>	11
3.2.2 <i>Electricity Supply and Distribution</i>	14
3.2.3 <i>Fuel for Electric Power</i>	17
3.3 <u>Petroleum Demand, Supply and Distribution</u>	19
3.3.1 <i>Introduction to the Petroleum Sector</i>	19
3.3.2 <i>Petroleum Demand</i>	20
3.3.3 <i>Petroleum Refining</i>	23
3.3.4 <i>Petroleum Supply/Demand Balances</i>	31
3.3.5 <i>Petroleum Distribution, Storage and Logistics</i>	35
3.4 <u>Institutional and Regulatory Infrastructure</u>	44
3.4.1 <i>Electric Power</i>	44
3.4.2 <i>Petroleum</i>	45
3.5 <u>Energy Supply/Demand Outlook</u>	46
3.5.1 <i>Energy Demand Outlook</i>	46
3.5.2 <i>Energy Supply Outlook</i>	49

4	VULNERABILITY ASSESSMENT: INTRODUCTION AND SUMMARY	57
4.1	<u>Introduction</u>	57
4.2	<u>Factors That Contribute to Unique Energy Vulnerabilities</u>	57
4.2.1	<i>Petroleum Supply System Vulnerabilities</i>	57
4.2.2	<i>Electric Power System Vulnerabilities</i>	58
4.2.3	<i>Transportation System Vulnerabilities</i>	59
4.2.4	<i>Economic Vulnerabilities</i>	59
4.3	<u>Methodology</u>	59
4.4	<u>Findings and Lessons Learned</u>	60
4.4.1	<i>Local Energy Supply Disruptions</i>	60
4.4.2	<i>Global Oil Disruptions</i>	61
5	EXPERIENCE FROM PAST DISRUPTIONS	64
5.1	<u>Global Disruptions</u>	64
5.1.1	<i>Characteristics of Global Oil Supply Disruptions</i>	64
5.1.2	<i>Middle East Crisis – Global Impacts</i>	65
5.1.3	<i>Middle East Crisis – Puerto Rico Petroleum Supply Impact</i>	67
5.1.4	<i>Impact on Electric System</i>	85
5.1.5	<i>Economic Impacts</i>	88
5.2	<u>Local Disruptions - Puerto Rico</u>	94
5.2.1	<i>Hurricane Hugo -- Puerto Rico Petroleum Supply Impacts</i>	94
5.2.2	<i>Impact on Electric System</i>	95
5.2.3	<i>Economic Impact</i>	96
6.	POTENTIAL IMPACTS OF FUTURE EMERGENCIES	98
6.1	<u>Impacts of Postulated Global Oil Supply Disruptions</u>	98
6.1.1	<i>Year 2000 BAU Base Case</i>	99
6.1.2	<i>Year 2000 Disruption Cases</i>	100
6.1.3	<i>Economic Impact</i>	107
6.2	<u>Impacts of Postulated Local Energy Supply Disruptions</u>	112
6.2.1	<i>Introduction</i>	112
6.2.2	<i>Physical Characteristics of Key Petroleum Facilities</i>	113
6.2.3	<i>Vulnerabilities of Key Petroleum Facilities to Local Disruptions</i>	121
6.2.4	<i>Physical Characteristics of Key Electric Power Facilities</i>	130
6.2.5	<i>Vulnerabilities of Key Electric Power Facilities to Local Disruptions</i>	134
6.2.6	<i>Economic Impact</i>	139
7	ACCESS TO VITAL OIL SUPPLIES IN AN EMERGENCY	144
7.1	<u>Introduction: Scope of Response Options Evaluated</u>	144
7.2	<u>U.S. Strategic Petroleum Reserve Policy</u>	145
7.3	<u>Increase in Commercial Stocks</u>	146
7.4	<u>Island-Owned Product Reserve</u>	147
7.5	<u>Regional Support Alliances</u>	154

7.6	<u>Futures Market Hedging</u>	155
7.7	<u>Emergency Access to U.S. Military Petroleum Supplies</u>	155
7.8	<u>Guaranteed Insular Area Access to the SPR</u>	155
7.9	<u>Island Component of U.S. Crude/Product SPR</u>	155
7.10	<u>Special Waivers</u>	156
7.11	<u>Concluding Comments</u>	156
8	PREPAREDNESS AND VULNERABILITY REDUCTION STRATEGIES	157
8.1	<u>Institutional Preparedness</u>	157
8.1.1	<i>Personnel Resources and Training</i>	158
8.1.2	<i>Staged Development of Computer Systems</i>	158
8.1.3	<i>Establishing Inter-organizational Links and Information Sources</i>	160
8.1.4	<i>Fostering Links with the Energy Industry</i>	160
8.1.5	<i>Developing an Integrated Energy Planning Capability</i>	160
8.2	<u>Increased Energy Conservation and Efficiency</u>	160
8.3	<u>Fossil Fuel Diversification</u>	162
8.4	<u>Renewable Energy</u>	163
8.5	<u>Definition and Exploitation of Island Oil & Gas Resources</u>	165
8.6	<u>Refining Sector Enhancement</u>	166
8.7	<u>Options for Reducing Petroleum System Physical Vulnerability</u>	168
8.8	<u>Options for Reducing Electric Power System Physical Vulnerability</u>	168
8.8.1	<i>Electric Generation</i>	169
8.8.2	<i>Transmission</i>	169
8.8.3	<i>Distribution</i>	169
8.8.4	<i>Communications and Control</i>	169
8.8.5	<i>Customer Preparedness</i>	170
8.9	<u>Concluding Comments</u>	170

VOLUME 3

U.S. VIRGIN ISLANDS	1
1. INTRODUCTION	1
1.1 <u>Geography</u>	1
1.2 <u>Demographics</u>	1
1.3 <u>Relationship with the United States</u>	2
1.4 <u>Government Structure</u>	2
2. ECONOMIC PROFILE	4
2.1 <u>Overview</u>	4
2.2 <u>Major Economic Sectors</u>	4
2.3 <u>Economic Development Incentives</u>	5
3. ENERGY PROFILE	9

3.1	<u>Introduction</u>	9
3.2	<u>Electricity Demand, Supply and Distribution</u>	9
3.2.1	<i>Electricity Demand</i>	9
3.2.2	<i>Electricity Supply and Distribution</i>	12
3.2.3	<i>Fuel for Electric Power</i>	14
3.3	<u>Petroleum Demand, Supply and Distribution</u>	16
3.3.1	<i>Introduction to the Petroleum Sector</i>	16
3.3.2	<i>Petroleum Refining</i>	16
3.3.3	<i>Petroleum Supply and Demand</i>	17
3.3.4	<i>Petroleum Distribution, Storage and Logistics</i>	20
3.4	<u>Institutional and Regulatory Infrastructure</u>	20
3.4.1	<i>Electric Power</i>	21
3.4.2	<i>Petroleum</i>	21
3.5	<u>Energy Supply/Demand Outlook</u>	22
3.5.1	<i>Energy Demand Outlook</i>	22
3.5.2	<i>Energy Supply Outlook</i>	23
4	VULNERABILITY ASSESSMENT: INTRODUCTION AND SUMMARY	24
4.1	<u>Introduction</u>	24
4.2	<u>Factors That Contribute to Unique Energy Vulnerabilities</u>	24
4.2.1	<i>Petroleum Supply System Vulnerabilities</i>	24
4.2.2	<i>Electric Power System Vulnerabilities</i>	25
4.2.3	<i>Transportation System Vulnerabilities</i>	25
4.2.4	<i>Water Supply System Vulnerabilities</i>	25
4.2.5	<i>Economic Vulnerabilities</i>	26
4.3	<u>Methodology</u>	26
4.4	<u>Findings and Lessons Learned</u>	27
4.4.1	<i>Local Energy Supply Disruptions</i>	27
4.4.2	<i>Global Oil Disruptions</i>	28
5	EXPERIENCE FROM PAST DISRUPTIONS	31
5.1	<u>Global Disruptions</u>	31
5.1.1	<i>Characteristics of Global Oil Supply Disruptions</i>	31
5.1.2	<i>Middle East Crisis - Global Impacts</i>	32
5.1.3	<i>Middle East Crisis - U.S.V.I. Petroleum Supply Impacts</i>	34
5.1.4	<i>Impact on Electric System</i>	35
5.1.5	<i>Economic Impact</i>	36
5.2	<u>Local Disruptions - U.S. Virgin Islands</u>	41
5.2.1	<i>Hurricane Hugo - U.S.V.I. Petroleum Supply Impacts</i>	41
5.2.2	<i>Impact on the Electric System</i>	41
5.2.3	<i>Economic Impact</i>	44
6	POTENTIAL IMPACTS OF FUTURE EMERGENCIES	45
6.1	<u>Impacts of Postulated Global Oil Supply Disruptions</u>	45
6.1.1	<i>Year 2000 BAU Base Case</i>	47
6.1.2	<i>Year 2000 Disruption Cases</i>	48

6.1.3	<i>Economic Impact</i>	.56
6.2	<u>Impacts of Postulated Local Energy Supply Disruptions</u>	.58
6.2.1	<i>Introduction</i>	.58
6.2.2	<i>Key Petroleum Facilities in the U.S. Virgin Islands</i>	.59
6.2.3	<i>Vulnerability of Key Petroleum Facilities</i>	.61
6.2.4	<i>Physical Characteristics of Key Electric Power Facilities</i>	.65
6.2.5	<i>Vulnerabilities of Key Electric Power Facilities to Local Disruptions</i>	.68
6.2.6	<i>Economic Impact</i>	.69
7	ACCESS TO VITAL OIL SUPPLIES IN AN EMERGENCY	.73
7.1	<u>Introduction: Scope of Response Options Evaluated</u>	.73
7.2	<u>U.S. Strategic Petroleum Reserve Policy</u>	.74
7.3	<u>Island-Owned Product Reserve</u>	.75
7.4	<u>Futures Market Hedging</u>	.82
7.5	<u>Standby Line of Credit</u>	.82
7.6	<u>Emergency Access to U.S. Military Petroleum Supplies</u>	.83
7.7	<u>Guaranteed Insular Area Access to the SPR</u>	.83
7.8	<u>Island Component of U.S. Crude/Product SPR</u>	.83
7.9	<u>Concluding Comments</u>	.84
8	PREPAREDNESS AND VULNERABILITY REDUCTION STRATEGIES	.85
8.1	<u>Institutional Preparedness</u>	.85
8.1.1	<i>Continuing Emergency Simulation</i>	.85
8.1.2	<i>Fostering Coordination</i>	.86
8.1.3	<i>Continuing to Develop and Maintain Energy Data and Models</i>	.86
8.1.4	<i>Enhancing Training and Resources</i>	.88
8.2	<u>Increased Energy Conservation and Efficiency</u>	.88
8.3	<u>Fuel Diversification -- Renewable Energy</u>	.89
8.4	<u>Options For Reducing Electric Power System Physical Vulnerability</u>	.93
8.4.1	<i>Electric Generation</i>	.93
8.4.2	<i>Transmission</i>	.94
8.4.3	<i>Distribution</i>	.94
8.4.4	<i>Communications and Control</i>	.94
8.4.5	<i>Customer Preparedness</i>	.94
8.5	<u>Concluding Comments</u>	.94

APPENDICES

APPENDIX A:	LIST OF OFFICIALS INTERVIEWED	A-1
APPENDIX B:	REVIEW OF MAJOR OIL DISRUPTIONS	B-1
APPENDIX C:	GENERAL BACKGROUND AND THE CONDITIONS FOR RELEASING AN SPR DRAW	C-1

EXECUTIVE SUMMARY

Purpose of the Study

This report was prepared in response to Section 1406 of the Energy Policy Act of 1992 (P.L. 102-486). The Act directed the Department of Energy (DOE) to "conduct a study of the implications of the unique vulnerabilities of the insular areas to an oil supply disruption," and to "outline how the insular areas shall gain access to vital oil supplies during times of national emergency." The Act defines the insular areas to be the U.S. Virgin Islands and Puerto Rico in the Caribbean, and Guam, American Samoa, the Commonwealth of the Northern Mariana Islands (CNMI), and Palau in the Pacific. This report is the analysis of Puerto Rico and the U.S. Virgin Islands.

Study Design

In the study, "unique vulnerabilities" were defined as susceptibility to: (1) more frequent or more likely interruptions of oil supplies compared to the mainland, and/or (2) disproportionately larger or more likely economic losses in the event of an oil supply disruption. In order to assess unique vulnerabilities, the study examined the insular areas' experience during past global disruptions of oil supplies and during local emergencies caused by natural disasters. The effects of several possible future global disruptions and local emergencies were also analyzed. Analyses were based on historical data, simulations using energy and economic models, and interviews with officials in the insular governments and the energy industry.

Factors Contributing to Insular Area Energy Vulnerability

Puerto Rico and the U.S. Virgin Islands have quite different economies, population sizes, and energy supply situations. However, they share several common characteristics that render them uniquely vulnerable to oil supply disruptions.

- They are almost entirely dependent upon petroleum for their primary energy needs. In comparison, petroleum provided only 41 percent of overall U.S. mainland energy in 1992.
- They must import 100 percent of their petroleum, compared to 41 percent import dependence on the mainland.
- Petroleum is used for nearly all electricity generation in both areas, whereas the mainland generates only 3 percent of its electricity using petroleum. The U.S. Virgin Islands also produces much of its potable water by desalinization using petroleum fuels and electricity.
- The U.S. Virgin Islands, and to a lesser extent Puerto Rico, are highly dependent on tourism, and tourism is adversely affected by economic downturns that typically follow global oil supply disruptions.
- Both areas spend a substantially larger share of their income on imported petroleum than does the mainland. In 1991, their expenditures on imported petroleum as a

percent of Gross Domestic Product (GDP) ranged from 5% to 7% compared to 0.8% for the mainland.

Findings: Oil Supply Interruptions

Despite the existence of unique vulnerabilities to oil supply disruptions, neither Puerto Rico nor the U.S. Virgin Islands has experienced petroleum supply shortages since World War II, including during the oil crises of 1973-74, 1979-80 and 1990-91. According to historical data and reports from island government and oil industry officials, the oil companies serving the islands and large oil users such as the electric power authorities maintained adequate inventories to meet all petroleum requirements.

A future "worst case" global oil disruption could cause temporary oil supply difficulties in Puerto Rico. During this time, the Commonwealth would need to rely on available inventories until regional supply imbalances were rectified. Neither Puerto Rico nor the U.S. Virgin Islands are likely to experience actual oil supply shortages for the following reasons:

- The global oil market is now highly interconnected electronically. Compared to the 1970s and early 1980s, oil companies are much more able to identify and respond quickly to supply imbalances worldwide.
- Seven oil companies, including four with on-island refineries, supply petroleum products to Puerto Rico. Their resources, together with on-island oil inventories maintained by the electric power authority, should be adequate to handle any short term or local oil supply disruptions. Large global disruptions would be addressed worldwide by releases of U.S. and allied strategic oil stocks.
- The U.S. Virgin Islands is home to and is served by one of the world's largest petroleum refineries.
- The U.S. Virgin Islands and Puerto Rico are located in the midst of an active oil trading region and a short distance from the U.S. Gulf Coast and the Strategic Petroleum Reserve (SPR). These islands have ready access to oil supplies both from local inventories and nearby suppliers.
- These islands are frequently subjected to hurricanes, and to a lesser extent earthquakes. While these disasters have caused extensive damage to homes, buildings, electric power distribution systems and other infrastructure, they have not caused interruptions in oil supplies on the islands.

Findings: Economic Impacts

The primary vulnerability of these areas to global oil supply disruptions is the susceptibility of their economies to larger economic losses from sudden, large petroleum price increases. Oil supply disruptions can be expected to have larger economic impacts in the insular areas because imported oil has a much larger role in their economies and there are currently no substitute fuels; the economies are less diversified than in the mainland; and both islands depend on tourism, which tends to decline significantly during and after global oil disruptions.

The data for Puerto Rico illustrate the economic effects of the global oil disruptions of 1973-74, 1979-80 and 1990-91 compared to the U.S. mainland:

- The GDP growth rate declined more in Puerto Rico than in the mainland during two of the three disruptions.
- The unemployment rate increased more than in the mainland during all three disruptions.
- The inflation rate increased more than in the mainland in two of the three disruptions.

Simulations of future global oil disruptions using energy and economic models also projected larger economic impacts in Puerto Rico compared to the mainland, including larger GDP losses and larger terms of trade losses. Inflation rate increases are larger in Puerto Rico only for severe disruptions; for smaller disruptions, inflation increases are comparable or less than the mainland.

Historical economic data are incomplete for the U.S. Virgin Islands. Suitable macroeconomic models are also lacking. Thus, it is not possible to assess economic effects as comprehensively as for Puerto Rico. However, it is predicted that GDP losses and terms of trade losses would be larger in the U.S. Virgin Islands than on the mainland.

Access to Vital Oil Supplies in an Emergency

In view of the above findings, it is highly unlikely either Puerto Rico or the U.S. Virgin Islands would require access to additional oil supplies during an oil crisis because shortages are highly unlikely. Furthermore, additional oil supplies would not solve their economic problems that are caused by increased oil prices during disruptions. Indeed, the best defense against increased oil prices in a global oil emergency would be to rely on a release of the U.S. SPR (and strategic stocks held by the allies) to dampen world oil prices. This is the current U.S. Government policy.

Nevertheless, to fulfill the Congressional mandate, we analyzed a wide range of options that might provide additional oil supplies in an emergency and/or reduce the economic effects of increased oil prices. The options could be adopted singly or in combination.

The following options could be implemented by the island governments directly without Federal assistance:

- Increase the on-island commercial oil inventories held by the oil companies and large oil users such as the electric power authorities.
- Develop an island-owned and -controlled petroleum product reserve on Puerto Rico to serve both Puerto Rico and the U.S. Virgin Islands.
- Develop bilateral or multilateral mutual support agreements with neighboring islands and oil suppliers.
- Establish and maintain sets of rolling futures contracts covering designated volumes of crude oil, gasoline and other products, to hedge against sudden price increases.

- Establish standby lines of credit with financial institutions to provide additional financial liquidity during oil emergencies.

Because no Federal role would be required, the islands are free to decide among these options based on their relative advantages and disadvantages as summarized in the main report.

Three other options were examined that would require action or financial assistance by the U.S. Government. These were:

- Provide the insular areas with emergency access to U.S. military petroleum supplies stored on the islands.
- Guarantee the insular areas priority access to the U.S. SPR.
- Develop a Federally-owned and -controlled petroleum product reserve in the Caribbean.

DOE found that access to military supplies could be valuable in the Pacific, where military inventories are large, but not in the Caribbean where they are small. Guaranteed access to the SPR would have small benefit. A Federally-owned reserve in the Caribbean, under current policies, would provide some additional supply security, but at substantial cost and with little benefit to the island economies during an emergency.

Options for Improving Emergency Preparedness and Reducing Vulnerabilities

Puerto Rico and the U.S. Virgin Islands could reduce their energy and economic vulnerabilities to oil supply disruptions. Several options were examined, all of which could be pursued by the island governments with little or no Federal action. The options were:

- Enhance the institutions concerned with energy emergency planning and response.
- Increase energy conservation and energy efficiency.
- Diversify the mix of fossil fuels used.
- Increase the use of renewable energy sources.
- Define the size of potential oil and gas reserves (Puerto Rico only)
- Enhance the petroleum refining and distribution system (Puerto Rico only)
- Reduce petroleum system physical vulnerability (Puerto Rico only).

These options were based on an initial review of petroleum and electric power systems in the islands. A more detailed analysis by the island governments is warranted.

INTRODUCTION

Section 1406 of the Energy Policy Act (EPACT) of 1992 (P.L. 102-486) requires the Secretary of Energy to conduct a study that:

- (1) assesses the implications of the unique vulnerabilities of the insular areas to an oil supply disruption; and
- (2) outlines how the insular areas shall gain access to vital oil supplies during times of national emergency.

The Act defines the insular areas to include Puerto Rico and the Virgin Islands in the Caribbean and American Samoa, the Commonwealth of the Northern Mariana Islands (CNMI), Guam and Palau in the Pacific.

In response to the EPACT requirement, the Department of Energy (DOE) contracted with Mathtech, Inc., to undertake a study to evaluate the unique vulnerability of the Caribbean islands to oil supply disruptions and to present options for supplementing oil supplies in an emergency. DOE engaged the East-West Center to perform a similar study for the Pacific islands. DOE expanded the scope of the Congressional requirement by having both studies examine options for reducing the islands' vulnerability to oil supply disruptions in the long run.

For this study, *unique* vulnerabilities were defined as susceptibility to:

- (1) more frequent or more likely interruptions of oil supplies compared to the mainland; and/or
- (2) disproportionately larger or more likely economic losses in the event of an oil supply disruption.

The disruption can result from either a global oil supply disruption or a natural disaster. The term *national emergency* is defined as any emergency where economic losses are large and human lives are threatened, with or without a Presidential declaration of emergency.

This study was conducted with considerable assistance from the island governments and the oil companies and electric power authorities that serve them. A list of the individuals contacted is provided in an appendix to this report. Various elements of DOE also contributed data, modeling results and helpful suggestions.

This report is organized into two parts. Part 1 is concerned with Puerto Rico and Part 2 with the U.S. Virgin Islands. This format was used in order to provide each island government with a separate, self-contained study that focusses on each island. Parts 1 and 2 are preceded by an overview of the Caribbean oil market which provides an essential context for assessing the islands' energy vulnerability.

Each part of the report contains eight sections. *Sections 1, 2 and 3* are overviews of the insular areas, their demographics, economies, and energy sectors, respectively.

Section 4 identifies the unique energy vulnerabilities of the insular areas, describes the methodology used to assess them, and presents the major findings. *Sections 5 and 6* provide detailed back-up material. *Section 5* examines the experience during past energy disruptions, and *Section 6* considers possible future disruption scenarios.

Sections 7 and 8 review options available to the insular areas for reducing their energy vulnerability. The options considered concentrate on actions the islands can take themselves and which supplement measures the U.S. Government and its allies might take from which the insular areas would expect to benefit. *Section 7* focusses on means to enhance physical oil availability and/or to reduce the economic impacts of oil supply disruptions. *Section 8* offers ways to improve emergency preparedness in the islands and to reduce energy vulnerability over the medium and long term.

OVERVIEW OF THE CARIBBEAN OIL MARKET

Market Geographical Scope

Puerto Rico and the U.S. Virgin Islands are components in a 65 million barrel per day global petroleum market. They are most affected, however, by their Caribbean regional market. From a petroleum industry perspective, the Caribbean market includes the regions interconnected by the Caribbean itself, the Atlantic and, via the Panama Canal, the Eastern Pacific Ocean. The region and market encompasses:

- the central Caribbean islands including Puerto Rico and the U.S. Virgin Islands
- the southern Caribbean islands of Trinidad and the Netherlands Antilles
- South America, notably the northern producing nations of Venezuela, Colombia and Ecuador and, more peripherally, Brazil, Argentina and Peru
- Panama and the other Central American countries
- Mexico
- the Gulf Coast region of the USA (PADD III)
- the East Coast region of the USA (PADD I)
- West Africa, notably Nigeria, Angola, Gabon and other oil producing nations.

Puerto Rico and the U.S. Virgin Islands occupy a central location within this "Greater Caribbean" market region. It is situated "short haul" distance from key areas in the region:

- less than 500 nautical miles from Venezuela, Trinidad and the Netherlands Antilles,
- 1000 miles from Colombia,
- 1500 miles from the U.S. East Coast and from Ecuador (via Panama),
- 1800 miles from Mexico and the U.S. Gulf Coast.

West African ports are 4,500 nautical miles away, still not a great distance in comparison to the 6,000 to 11,000 mile voyages common for deliveries from the Persian Gulf to major markets. Steaming times from Venezuela, Netherlands Antilles and Trinidad are 2 to 3 days. From other ports in the region, they are generally less than 7 days for tanker movements, 11 days for barges.

Figure 1
Caribbean Energy Market

Table 1

NAUTICAL MILEAGES AND STEAMING TIMES TO PR/USVI			
port	steaming distance nautical miles	tanker steaming time days	barge steaming time days
Venezuela (Amuay Bay)	498	1.7	3.0
Trinidad (Port of Spain)	423	1.5	2.5
Ecuador (Esmeraldas) - via Panama Canal	1534	5.3	9.1
Mexico (Coatzacoalcos)	1809	6.3	10.8
U.S. Gulf Coast (Houston)	1862	6.5	11.1
U.S. South East Coast (Port Everglades)	1014	3.5	6.0
U.S. North East Coast (New York)	1475	5.1	8.8
Nigeria (Port Harcourt)	4369	15.2	-
Congo (Pointe Noire)	4737	16.4	-
Saudi Arabia (Ras Tanura) - via Cape of Good Hope	10654	37.0	-
Notes:			
1. Actual distances are to St. Croix, (HOVIC).			

Regional Trade Flows

Puerto Rico and the U.S.V.I. sit astride major crude and products trade flows within and through the Caribbean region. These include:

- crude oil movements into the U.S. Gulf and East coasts from:
 - Alaska via Panama (although this is likely to moderate or cease as ANS production declines)
 - Mexico
 - South America (especially Venezuela, Colombia, Ecuador) from both the Atlantic and Pacific coasts
 - Persian Gulf
 - West Africa
 - Northern Europe

- crude oil movements into Caribbean island refineries and transshipment terminals, such as in the Bahamas. Principal sources are Venezuela and Mexico, (under the San Jose Accords), the Persian Gulf and, until recently, the ex Soviet Union for supplies into Cuba
- products movements from Venezuela, Netherlands Antilles, Mexico, Bahamas and other regional export refining and trans-shipment locations into the U.S. East and Gulf Coasts
- product movements from the U.S. gulf Coast to Mexico and, in generally small volumes, to Jamaica and other Caribbean islands, Panama and other Central American countries.

This situation affords Puerto Rico and the U.S.V.I. a wide range of choice in terms of selection of crude and non-crude feedstocks, intermediate and finished product supplies, many of which are obtainable at short notice by virtue of proximity to the sources.

The Caribbean islands are supplied with crude primarily from Venezuela and other regional producers, but with substantial volumes from the Middle East and West Africa. (Much of the Middle East and West African crude goes into the Hess Virgin Islands refinery.) Alaskan crude oil has traditionally flowed into the U.S. Virgin Islands and Puerto Rico at a total rate of 100,000-120,000 bpd. This is likely to decline or cease, however, as ANS production declines. The main crude oil flows into Central and South America come from the major local producers. The exception is Brazil's large intake of Middle Eastern crude.

Tables 2, 3 and 4 indicate crude and product flows, production and demand in the region. Adjusting for crude imports to the U.S. East Coast and to South America (Brazil) that do not truly pass through the Caribbean, but also for additional Mexican and Venezuelan crude exports to destinations outside the region, the total daily crude oil flow in and through the Caribbean market is approximately 6 million bbls. By comparison, non-refinery petroleum product consumption in Puerto Rico/U.S. Virgin Islands equates to less than 3%/0.5% of this crude flow.

Petroleum product flows through the region are also substantial, totalling around 3 million bpd. Of this, 1.1 million bpd is trade between the U.S.A. and other countries in the region. The major product flows through the region are of imports into the U.S.A. In 1991, the main products imported into the U.S.A. from regional exporters were:

residual fuel	304,000 bpd
unfinished oils	158,000 bpd
jet/kero/distillate	205,000 bpd
gasoline	123,000 bpd

The largest regional exporters of product into the U.S.A. in the same year were:

Venezuela & Netherlands Antilles ¹	447,000 bpd
U.S.V.I.	243,000 bpd
Mexico	48,000 bpd

Venezuela and Mexico dominate regional trade with the U.S.A., exporting over 1.8 million bbls/day of crude and products. Colombia, Ecuador, Trinidad and the U.S. Virgin Islands are the other main suppliers to the U.S.A., exporting over 0.5 million bpd of crude and products. The U.S.A. exports over 200,000 bpd of products to the region, primarily from Gulf Coast refineries. The main trade is to Mexico, around 100,000 bpd. This includes LPG traded on a counter-seasonal basis between the U.S.A. and Mexico.

Total refined products demand in the Caribbean energy market exceeds 12 million bpd. Puerto Rico/U.S. Virgin Islands non-refinery demand thus comprises a very small proportion (1.4%/ 0.1%) of total market demand.

¹The Netherlands Antilles Curaçao refinery currently operates under a lease arrangement with PdVsa and, therefore, effectively comprises Venezuelan refined product output.

Table 2

MAIN CRUDE OIL FLOWS WITHIN AND THROUGH THE CARIBBEAN 1990 <i>Source: EIA International Energy Annual 1991</i> <i>thousands bbls/day</i>			
sources	destinations		
	USA	Caribbean Islands	Other Central & South America
USA		97	0
Mexico	689	44	22
Venezuela	685	239	57
Trinidad	76	0	0
Ecuador	38	67	53
Colombia & Other C&S America	152	54	22
Europe	252	59	2
USSR	1	29	5
Middle East	1858	226	525
West Africa	864	85	101
Totals	4,615	900	787
Notes: 1. Caribbean islands include Puerto Rico and U.S. Virgin Islands. 2. Movements of U.S. crude into the Caribbean are Alaskan North Slope mainly into U.S. Virgin Islands. 3. Mexico and Venezuela supply approximately 160,000 bpd of crude oil to Caribbean and Latin American countries under the San José accords.			

Table 3

PETROLEUM PRODUCT FLOWS BETWEEN THE USA AND CARIBBEAN REGION COUNTRIES <i>Source: EIA Petroleum Supply Annual 1991</i> <i>thousands bbls/day</i>		
	flows to USA	flows from USA
Mexico	48	99
Venezuela	366	15
Netherlands Antilles	81	19
Trinidad	15	1
Puerto Rico	27	6
U.S. Virgin Is- lands	243	0
Jamaica	0	22
Bahamas	35	19
Central American countries	0	25
Argentina	12	2
Brazil	22	13
Colombia	40	3
Ecuador	10	15
Total	899	239

Table 4

MAIN CARIBBEAN AREAS PETROLEUM SUPPLY & DISPOSITION - 1990 <i>Source: EIA International Energy Annual 1991</i> <i>thousands bbls/day</i>						
	crude production	crude imports	crude exports	product exports	product imports	apparent consumption
U.S. East Coast (PADD I)	26	1209	0	44	940	4716
U.S. Gulf Coast (PADD III)	3419	3729	0	454	200	3407
Mexico	3009	0	1277	110	104	1725
Venezuela	2268	0	1242	639	9	396
Trinidad	153	18	76	70	3	20
Colombia	450	0	208	68	28	197
Ecuador	288	0	172	27	8	97
Brazil	803	571	0	93	70	1339
Puerto Rico	0	110	0	59	69	140
U.S. Virgin Islands	0	356	0	285	2	55
Totals	10,416	5,993	2,975	1,849	1,433	12,092

Regional Refining Capacities

Table 5 indicates refining capacities in the market region. The distribution of refining capacity in the Caribbean energy market reflects the diverse nature of the countries making up the region, from small developing nations to oil producing exporters to major importers (U.S. East and Gulf Coasts). In terms of total capacity and upgrading complexity, U.S. Gulf and East Coast refineries dominate the region, with total capacity of 8.3 million bpd. However, this capacity is overwhelmingly geared to meeting Mainland product demand; product exports total 500,000 bpd, only 6% of nominal refining capacity.

Nonetheless, the sheer scale of this U.S. Mainland refining system means that even small changes that modify export or import patterns could have a significant impact on crude and product volumes being offered into or demanded from the Caribbean market. One such change could be a trend toward increasing exports of conventional gasoline and distillates as a result of the EPA's reformulated fuels regulations. A parallel larger trend is likely to be increased imports into the U.S.A. of reformulated gasoline and distillates as non-U.S. refiners are attracted by the high prices of these premium products and as U.S. refining capacity continues to contract in the face of rising environmental and safety costs.

Table 5

MAIN CARIBBEAN AREAS REFINING CAPACITY - 1992 <i>Source: Oil & Gas Journal Dec 21, 1992</i> <i>thousands bbls per calendar day</i>			
main countries		Caribbean islands	
U.S. East Coast (PADD I)	1408	Puerto Rico	127
U.S. Gulf Coast (PADD III)	6888	U.S. Virgin Islands	545
Mexico	1524		
Venezuela	1167	Netherlands Antilles	470
Ecuador	147	Trinidad	120
Colombia	264	Barbados, Dominican Rep. Jamaica, Martinique	99
Brazil	1402	Cuba	280
Central America			
Panama	100	Guatemala	16
Costa Rica	15	Honduras	14
El Salvador	15	Nicaragua	16

The Caribbean islands themselves contain a mix of smaller refineries geared primarily to local demand (Barbados, Dominican Republic, Jamaica, Martinique, Cuba, Puerto Rico) and of large refineries that have traditionally served the U.S. as well as local markets (U.S. Virgin Islands, Netherlands Antilles, Trinidad). Most other countries in the region operate refineries geared to local demand. The major exception is Venezuela. Petroleos de Venezuela (PdVsa) owns 4 major refineries, with a combined capacity of 1.167 million bpcd, which in 1990 exported 639,000 bpd of products (over half to the U.S.A.). PdVsa also leases the 320,000 bpd Refineria Isla refinery on Curaçao, but would appear to be running this at around 200,000 bpd. PdVsa, in addition, owns 480,000 bpd of U.S. refining capacity, placing it tenth among U.S. refiners. The U.S. facilities provide consistent outlets for Venezuela's heavier crude oils. These are not always saleable in the open market since they require specialized processing.

In total, Caribbean market refining capacity exceeds 14.5 million bpd. Of this, approximately 2 million bpd is geared to exports, providing significant opportunity to compete with local Puerto Rico/U.S. Virgin Islands refineries for their local demand but, also, substantial regional options for supply of refined product.

Regional Petroleum Storage and Inventories

Functioning refineries on the Caribbean islands (including Puerto Rico, U.S.V.I., Netherlands Antilles, Trinidad and smaller islands) operate with an estimated 25-30 million bbls of total crudes, intermediates and products in inventory. The Venezuelan export refineries are estimated to maintain approximately the same level of total inventory (i.e. 25-30 million bbls).

In part because of its history of large scale refining, the Caribbean islands possess substantial tankage capacity that is either idle or is used for terminalling/trans-shipment storage.²

- Hess is reported to use several million bbls of storage on St. Lucia as an integral part of its U.S. Virgin Islands operations
- Saudi Arabia typically maintains 5-6 million bbls of crude oil on the island of Aruba under a long term lease. The Saudis were also reported as interested in purchasing the 5.2 million bbl Burmpac facility in the Bahamas
- PdVsa owns or leases a total of 24.3 million bbls of storage between the BORCO, Bahamas facility and tankage on Bonaire and Curaçao
- CORCO maintains 8 million bbls of active tankage (plus 5 million bbls that could be rehabilitated) on Puerto Rico
- TRINTOC possesses several (possibly 4-5) million bbls unutilized tankage at its two refineries and is reported to have considered rehabilitating part of this for terminalling/trans-shipment use

In total, these terminalling/trans-shipment stocks represent an estimated further 25-30 million bbls of crude and product inventory. These stocks are all private sector, with – in some cases – inventory held for specific third parties, including traders and consumers. Total petroleum stocks on the Caribbean islands are thus estimated to be on the order of 50-60 million bbls, or 75-90 million bbls if Venezuelan export refineries are included. Stocks in Mexico, Ecuador, Colombia and Central America are estimated to total a further 100 million bbl.

As summarized in *Tables 6 and 7*, total petroleum stocks on the U.S. Gulf and East Coasts (PADDs III and I, respectively) were 163.5 and 328.1 million bbls in 1992. These data indicate a total petroleum commercial inventory within the Caribbean Basin market³ of at least 650-700 million bbls. This figure nearly doubles if the U.S. SPR is included.

²The data that follow were taken principally from "A Proposal for a Strategic Regional Reserve of Refined Products for Puerto Rico Emergencies", Juan J. Rigau & Associates, draft report, April 1993. This, in turn, included data from *Petroleum Intelligence Weekly*.

³Including the Caribbean Islands, Venezuelan export refineries, U.S. East and Gulf Coasts, Mexico, Colombia, Ecuador, Central America, but omitting West Africa.

Table 6

U.S. EAST AND GULF COAST PETROLEUM STOCKS (millions of barrels)		
	PADD I	PADD III
Crude Oil	17.0	161.4
Leaded Gasoline	0.1	0.4
Unleaded Gasoline	50.8	43.5
Gasoline Blending Components	3.8	14.9
Naphtha Jet Fuel	0.3	1.9
Kerosene Jet Fuel	10.1	15.9
Distillate Fuel Oil	54.1	28.4
Residual Fuel Oil	15.4	13.7
Unfinished Fuel Oils	11.9	48.0
Total Products	146.5	166.7
Total Petroleum Stocks ¹	163.5	328.1
Notes:		
1. Data are from the <i>Oil and Gas Journal Data Book</i> , 1993 Edition, p. 352, Penwell Books. These are API statistics and, because of the magnitude of the quantities, they apparently include both in-refinery and terminal stocks held by oil companies.		

Table 7

U.S. EAST AND GULF COAST TERMINAL STORAGE CAPACITIES (millions of barrels)		
	PADD I	PADD III
New England	36.3	
New York/New Jersey	101.5	
Total ¹	137.8	125.0
Notes:		
1. Source is report to the Congress on the "Storage of Refined Products and on Regional Supply Interruptions", Vol. II, DOE/NBB-0089P, p. 155. ("Petroleum Product Storage Facilities: An Assessment of Immediately Available Space and Potential Long-Term Contract Rates in the Northeastern United States, California, Hawaii and U.S. PADD III", by ICF Resources, Inc.)		

These stocks are, however, under private control; they are "operational" or exist primarily to exploit market opportunities or to meet contractual demands. The degree to which they could be made available during an emergency is, therefore, open to question barring any pre-negotiated contingency supply arrangements.

Regional Developments

The Greater Caribbean region is one of the most active areas in the world today in terms of petroleum developments. These center on:

- increasing privatization,
- growing exploration and production,
- refinery upgrading,
- improving export potential for crude and clean products.
- compliance with new environmental standards

and will shape the future of production, refining and trade in the region.

The East-West Center, Honolulu, has estimated that Latin American economies may have to spend \$98-180 billion by 2000 to keep their total reserves/production ratio at its current level⁴; also that Latin America and the Caribbean will seek external capital totalling \$40-50 billion in the next five years. Depending on the rate of economic growth the region sustains, petroleum demand growth may out-strip growth in supply, reducing the volumes of crude oil available for export.

Venezuela, Colombia, Ecuador, Mexico and other regional producers all have active E&P programs geared to maintaining and expanding crude output. In Venezuela and Ecuador, the trend is toward increased heavy crude production. In Venezuela, this includes production of Orimulsion, a heavy crude/water mix suitable for use as a heavy fuel oil. Colombia recently announced a major find of light crude oil (the Cusiana field).

In the refining sector, the region is undergoing a steady resurgence in its role as an offshore refining center for the U.S.A. In the 1960's and 1970's, the emphasis was on producing residual fuel. Today, it is on upgrading residual fuel, notably from heavy crude oils, into clean and "reformulated" light products geared to the U.S. market. Again, PdVsa is playing a lead role. Two major upgrading projects at its Maraven Cardon and Lagoven Amuay refineries have a combined cost of \$3.2 billion. PdVsa is also reported to be in discussion with TRINTOC over rehabilitating the latter's Point Fortin refinery. TRINTOC is itself completing the first phase of a project to add and reactivate upgrading capacity at its Pointe-à-Pierre refinery and to raise effective capacity from 80,000 bpd to 120,000 bpd.

Other major refinery additions include the 75,000 bpd cat cracker project at Hess U.S. Virgin Islands. With ancillary MTBE, TAME and visbreaker units, this project will substantially raise the refinery's output of light products including reformulated gasoline. In addition, Coastal

⁴*Oil & Gas Journal*, October 18, 1993.

recently acquired the Exxon refinery at Aruba and has rehabilitated this to run at 150,000 bpd as a component of Coastal's U.S. refining system.

The Caribbean energy market is characterized by a mix of private and national oil companies involved in all stages of the petroleum industry. The two leading players are both integrated national oil companies, namely Petroleos Mexicanos (PEMEX) and Petroleos de Venezuela (PdVsa). Both were created when private oil companies were nationalized, in 1938 in Mexico and in 1976 in Venezuela. From limited beginnings, both corporations have emerged to join the ranks of the world's largest oil companies. 1992 gross revenues for each company were close to \$21 billion.⁵

Under the Mexican constitution, PEMEX maintains monopoly control over exploration, production, refining and basic petrochemicals production. Cooperation with private companies is, however, increasing across all sectors of activity.

PEMEX is the world's sixth-largest producer of oil. Approximately half of crude oil output is consumed domestically, the other half exported. The company is Mexico's largest exporter, accounting for \$8 billion/year in export earnings in recent years. Stated goals under a recent corporate re-structuring include increasing petroleum exports and improving product quality. In terms of refining and marketing, PEMEX's primary focus continues to be on satisfying domestic demand for finished products. It has experienced recent domestic refining problems, notably the closure of its Mexico City refinery. To help replace lost product output, provide clean gasoline for domestic use, and a secure outlet for some of its heavy crude production, PEMEX has entered into a venture with Shell Oil Company for 50:50 ownership of Shell's 225,000 bpd Deer Park, Texas, refinery. The refinery will be able to process heavy Mayan crude oil and will supply PEMEX with up to 45,000 bpd of gasoline. (In 1992, PEMEX had to import 75,000 bpd of gasoline.)

PdVsa has developed into a major, integrated oil company with substantial oil and gas reserves and international as well as domestic refining, storage, transport and marketing activities. Traditionally operating as a monopoly, PdVsa has acknowledged that foreign investment will be needed for it to reach its goal of raising crude production capacity to 4 million bpd by 2000. Under a new ten-year business development plan⁶, PdVsa is targeting new growth markets in Asia and Latin America in order to place the 3.1 million bpd of crude and products it expects to export by 2003. Total investment to implement this plan is estimated by PdVsa at \$47 billion. In August 1993, Venezuela's congress approved two heavy oil projects with a combined cost of more than \$4.8 billion.⁷ PdVsa's strategy is to sell part of the heavy oil (as low as 9° API gravity) as "Orimulsion" boiler fuel and to upgrade part to a lighter, low sulfur "syncrude" using coking, conversion and desulfurization processes.

PdVsa now owns or has interests in six U.S. refineries, which constitute a primary market for its heavier crudes. PdVsa also has joint venture refining interests in Germany with Veba. To

⁵Oil & Gas Journal, August 16, 1993, pp 50, 55.

⁶Oil & Gas Journal, August 23, 1993, p 22.

⁷Oil & Gas Journal, August 23, 1993, p 22

ensure it can meet future U.S. shipping standards, set out in the Oil Pollution Act of 1990, PdVsa has begun building a fleet of eight double-hulled tankers.⁸ The first 86,000 DWT vessel was delivered in January 1993.

In August 1993, Venezuela's congress also approved the \$5.6 billion Cristobel Colon LNG project.⁹ This represents the first time direct foreign equity investment will be allowed in an oil and gas production project. The partners with PdVsa subsidiary Lagoven will be Royal Dutch/Shell, Exxon and Mitsubishi. Exports are expected to begin in 1999 and could reach 6 million metric tons per year, with the U.S. Northeast and Europe targeted as the primary markets. Gas will be gathered from several fields to a coastal liquification plant on the Paria Peninsula and then exported in 50,000 DWT LNG tankers. The Puerto Rico/U.S. Virgin Islands area will thus be along the route for export shipments and a short distance from the export facility.

As discussed earlier, PdVsa is very active in refining and marketing in and to the Caribbean region with major refinery upgrading projects underway which are geared to increasing clean product exports. In 1990, Chevron completed sale of its moth-balled 500,000 bpd Freeport, Bahamas, refinery and associated storage facilities to PdVsa. PdVsa reportedly made a feasibility study into reactivating the refinery but currently uses only the terminalling and storage facilities. PdVsa's lease on the large Curaçao refinery and use of TRINTOC refining capacity in Trinidad, together with major acquisitions of U.S. (Citgo, Unoven, Lyondell) and European (Veba refiner-marketers), all point to a growing regional and international presence.

A relative unknown in the Caribbean energy picture is Cuba. The then Soviet Union curtailed oil supplies to Cuba in the late 1980's after decades of providing crude oil, part of which the Cuban government re-sold to gain hard currency. The loss of this subsidy had contributed to the reduction in Cuba's Gross National Product. It has also spurred initiatives in Cuba (which consumes 230,000 bpd of oil¹⁰) to attract E&P investment and expand its refining activity.

Cuba currently produces around 15,000 bpd of crude oil. While major discoveries are unlikely, Cuba had declared an aim to attract E&P joint ventures¹¹ and is reported to have signed agreements with several foreign firms. In 1989, Cuba's product imports were mostly fuel oil (61,500 bpd) and diesel fuel (27,000 bpd). The island possesses four rather simple refineries with total distillation capacity of 295,000 bpd. The Cuban government has been reported holding discussions regarding processing Colombian crude. The gasoline output would return to Colombia to reduce its imports.

Overall, the numerous actual and potential developments in the Caribbean energy market present a changing environment for Puerto Rico/U.S. Virgin Islands energy and emergency planning. They represent both challenges and opportunities, from shifts in future regional crude supplies and competition from export refineries to the potential for processing deals to cover

⁸Oil & Gas Journal, May 24, 1993, p 26

⁹Oil & Gas Journal, August 16, 1993, p 28

¹⁰Oil & Gas Journal, July 6, 1992

¹¹Oil & Gas Journal, April 26, 1993

regional refining shortages. Future energy planning within Puerto Rico/U.S. Virgin Islands needs to track and be set in the context of these regional developments.

Insular Area Energy Vulnerability

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Prepared for:

Office of Emergency Planning
U.S. Department of Energy
Washington, D.C. 20585

Prepared by:

Mathtech, Inc.
210 Carnegie Center, Suite 200
Princeton, N.J. 08540

With assistance from:

Ensys Energy & Systems, Inc.
P.O. Box 2320
Flemington, N.J. 08822

Mark Stern
Emmet E. Willard
Stanley Efferding

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TABLE OF CONTENTS

PUERTO RICO	1
1. INTRODUCTION	1
1.1 <u>Geography</u>	1
1.2 <u>Demographics</u>	1
1.3 <u>Relationship with the United States</u>	2
1.4 <u>Government Structure</u>	2
2. ECONOMIC PROFILE	3
2.1 <u>Overview</u>	3
2.2 <u>Major Economic Sectors</u>	6
2.3 <u>Economic Development Incentives</u>	6
3 ENERGY PROFILE	11
3.1 <u>Introduction</u>	11
3.2 <u>Electricity Demand, Supply and Distribution</u>	11
3.2.1 <i>Electricity Demand</i>	11
3.2.2 <i>Electricity Supply and Distribution</i>	14
3.2.3 <i>Fuel for Electric Power</i>	17
3.3 <u>Petroleum Demand, Supply and Distribution</u>	19
3.3.1 <i>Introduction to the Petroleum Sector</i>	19
3.3.2 <i>Petroleum Demand</i>	20
3.3.3 <i>Petroleum Refining</i>	23
3.3.4 <i>Petroleum Supply/Demand Balances</i>	31
3.3.5 <i>Petroleum Distribution, Storage and Logistics</i>	35
3.4 <u>Institutional and Regulatory Infrastructure</u>	44
3.4.1 <i>Electric Power</i>	44
3.4.2 <i>Petroleum</i>	45
3.5 <u>Energy Supply/Demand Outlook</u>	46
3.5.1 <i>Energy Demand Outlook</i>	46
3.5.2 <i>Energy Supply Outlook</i>	49
4 VULNERABILITY ASSESSMENT: INTRODUCTION AND SUMMARY	57
4.1 <u>Introduction</u>	57
4.2 <u>Factors That Contribute to Unique Energy Vulnerabilities</u>	57
4.2.1 <i>Petroleum Supply System Vulnerabilities</i>	57
4.2.2 <i>Electric Power System Vulnerabilities</i>	58
4.2.3 <i>Transportation System Vulnerabilities</i>	59
4.2.4 <i>Economic Vulnerabilities</i>	59
4.3 <u>Methodology</u>	59
4.4 <u>Findings and Lessons Learned</u>	60

4.4.1	<i>Local Energy Supply Disruptions</i>	.60
4.4.2	<i>Global Oil Disruptions</i>	.61
5	EXPERIENCE FROM PAST DISRUPTIONS	.64
5.1	<u>Global Disruptions</u>	.64
5.1.1	<i>Characteristics of Global Oil Supply Disruptions</i>	.64
5.1.2	<i>Middle East Crisis – Global Impacts</i>	.65
5.1.3	<i>Middle East Crisis – Puerto Rico Petroleum Supply Impact</i>	.67
5.1.4	<i>Impact on Electric System</i>	.85
5.1.5	<i>Economic Impacts</i>	.88
5.2	<u>Local Disruptions - Puerto Rico</u>	.94
5.2.1	<i>Hurricane Hugo -- Puerto Rico Petroleum Supply Impacts</i>	.94
5.2.2	<i>Impact on Electric System</i>	.95
5.2.3	<i>Economic Impact</i>	.96
6.	POTENTIAL IMPACTS OF FUTURE EMERGENCIES	.98
6.1	<u>Impacts of Postulated Global Oil Supply Disruptions</u>	.98
6.1.1	<i>Year 2000 BAU Base Case</i>	.99
6.1.2	<i>Year 2000 Disruption Cases</i>	100
6.1.3	<i>Economic Impact</i>	107
6.2	<u>Impacts of Postulated Local Energy Supply Disruptions</u>	112
6.2.1	<i>Introduction</i>	112
6.2.2	<i>Physical Characteristics of Key Petroleum Facilities</i>	113
6.2.3	<i>Vulnerabilities of Key Petroleum Facilities to Local Disruptions</i>	121
6.2.4	<i>Physical Characteristics of Key Electric Power Facilities</i>	130
6.2.5	<i>Vulnerabilities of Key Electric Power Facilities to Local Disruptions</i>	134
6.2.6	<i>Economic Impact</i>	139
7	ACCESS TO VITAL OIL SUPPLIES IN AN EMERGENCY	144
7.1	<u>Introduction: Scope of Response Options Evaluated</u>	144
7.2	<u>U.S. Strategic Petroleum Reserve Policy</u>	145
7.3	<u>Increase in Commercial Stocks</u>	146
7.4	<u>Island-Owned Product Reserve</u>	147
7.5	<u>Regional Support Alliances</u>	154
7.6	<u>Futures Market Hedging</u>	155
7.7	<u>Emergency Access to U.S. Military Petroleum Supplies</u>	155
7.8	<u>Guaranteed Insular Area Access to the SPR</u>	155
7.9	<u>Island Component of U.S. Crude/Product SPR</u>	155
7.10	<u>Special Waivers</u>	156
7.11	<u>Concluding Comments</u>	156
8	PREPAREDNESS AND VULNERABILITY REDUCTION STRATEGIES	157
8.1	<u>Institutional Preparedness</u>	157
8.1.1	<i>Personnel Resources and Training</i>	158

8.1.2	<i>Staged Development of Computer Systems</i>	158
8.1.3	<i>Establishing Inter-organizational Links and Information Sources</i>	160
8.1.4	<i>Fostering Links with the Energy Industry</i>	160
8.1.5	<i>Developing an Integrated Energy Planning Capability</i>	160
8.2	<u>Increased Energy Conservation and Efficiency</u>	160
8.3	<u>Fossil Fuel Diversification</u>	162
8.4	<u>Renewable Energy</u>	163
8.5	<u>Definition and Exploitation of Island Oil & Gas Resources</u>	165
8.6	<u>Refining Sector Enhancement</u>	166
8.7	<u>Options for Reducing Petroleum System Physical Vulnerability</u>	168
8.8	<u>Options for Reducing Electric Power System Physical Vulnerability</u>	168
8.8.1	<i>Electric Generation</i>	169
8.8.2	<i>Transmission</i>	169
8.8.3	<i>Distribution</i>	169
8.8.4	<i>Communications and Control</i>	169
8.8.5	<i>Customer Preparedness</i>	170
8.9	<u>Concluding Comments</u>	170

Section 1406 of the Energy Policy Act (EPACT) of 1992 required the Secretary of Energy to conduct a study of the energy vulnerability of the U.S. insular areas and identify their options for obtaining oil supplies during times of national emergency. The Department of Energy (DOE) contracted with Mathtech to perform the study of the Caribbean insular areas (Puerto Rico and the U.S. Virgin Islands) and with the East-West Center for the Pacific insular areas (American Samoa, Commonwealth of the Northern Marianas, Guam and Palau).

The Mathtech report is organized into three volumes. Volume 1 contains an executive summary, an introduction, and an overview of the Caribbean oil market. Volume 2 contains the report on Puerto Rico, and Volume 3 the report on the U.S. Virgin Islands.

PUERTO RICO

1. INTRODUCTION¹

1.1 Geography

Puerto Rico is located in the Caribbean Sea approximately 1000 miles east-southeast of Miami, Florida and less than 500 miles east-northeast of Venezuela. The island is approximately 100 miles long and 35 miles wide. Many of the island's 3.5 million people are concentrated in the San Juan metropolitan area which is located on the northeastern coast of the island. Other large population concentrations are on the south and west coasts, leaving a lightly developed, mountainous interior where elevations exceed 4000 feet.

1.2 Demographics²

The 1990 population of Puerto Rico was 3,522,037 and 90.9 percent of the population was born on the island. The rate of population growth has fallen over the past two decades, mirroring the pattern in the mainland U.S. As shown in Table 1, the population of Puerto Rico grew by 17.9 percent between 1970 and 1980. From 1980 to 1990 population growth fell to 10.4 percent. Population is expected to increase by only 7.5 percent between 1990 and 2000.

The driving age population in Puerto Rico is of particular interest. Approximately one third of all petroleum consumed in Puerto Rico is motor gasoline. This is due to the absence of a significant mass transit system and the heavy reliance on the automobile for local transportation (in San Juan in 1990, only 14.6 percent of workers traveled to work using public transportation). The driving age population is approximated by the number of persons age 16 and older. As shown in Table 1, the population age 16 and older has been growing somewhat faster than the overall population.

¹Much of the information in this section is from the Official Statement of the September 1, 1992 Electric Power Revenue Bonds of the Puerto Rico Electric Power Authority (hereinafter "1992 PREPA OS").

²Data in this section for 1990 are from: U.S. Department of Commerce, Bureau of the Census, *1990 Census of Population and Housing, Summary Social, Economic, and Housing Characteristics, Puerto Rico* (1990 CPH-5-53), February 1993, Tables 1, 3 and 7. The sources of the other data in this section are cited in the tables.

Table 1

POPULATION: PUERTO RICO, 1970-1992p (in thousands of people)							
	1970	1980	1983	1990	1992p	PRO- JECTED YR 2000	1983-92 AVER- AGE % CHANGE
TOTAL POPULA- TION	2,712	3,197	3,252	3,528	3,580	3,792	0.011
NO OF PERSONS 16 OR OLDER			2,256	2,473	2,536		0.013
Percent of Total			69.4%	70.1%	70.8%		
LABOR FORCE			927	1,124	1,170		0.026
Percent of Total			28.5%	31.9%	32.7%		
Source: Economic Report of the Governor 1992, Puerto Rico Planning Board, Statistical Appendix, Tables 32 and 33, April 3, 1993, pp. A-37, A-38, and Table Comparing Census Population Data: 1970-1990.							

Educational attainment in Puerto Rico mirrors that in the U.S. Among persons 25 years of age and older in 1990, 49.7 percent graduated from high school, and 14.3 percent hold a bachelor's degree or higher. For the U.S. as a whole, the corresponding figures were 75.2 percent and 20.3 percent, respectively.

1.3 Relationship with the United States

The relationship between Puerto Rico and the United States is in the nature of a compact which was established over a two year period in the early 1950s, following a long period of territorial status commencing in 1898 when Spain relinquished sovereignty over Puerto Rico to the United States. Under the terms of the compact and other federal statutes, citizens of Puerto Rico are also citizens of the United States. However, Puerto Ricans do not vote for President, are not represented in the U.S. Senate, but are represented in the House of Representatives by a non-voting Resident Commissioner. The currency of Puerto Rico is the U.S. dollar, the official language is Spanish (although English is widely taught and spoken as a second language), and Puerto Rican citizens are exempt from Federal taxes on income earned in Puerto Rico, except Social Security taxes.

1.4 Government Structure

Under its constitution, Puerto Rico has executive, legislative and judicial branches of government. Both the Governor and members of the bicameral legislature are popularly elected to four-year terms. The government has powers similar to those of U.S. state governments and additionally has responsibility for local police and fire protection, education, public health and welfare programs and economic development.

2. ECONOMIC PROFILE

2.1 Overview

Over the past decade, the Puerto Rican economy has grown slightly faster than the U.S. economy, aided in part by tax incentives and other development initiatives provided by the U.S. and Puerto Rican governments. The manufacturing sector, led by the chemical/ pharmaceutical industries, has been the major engine of growth. Exports have increased substantially faster than imports, creating a growing balance of trade. Nonetheless, unemployment remains stubbornly high, and Puerto Rican per capita incomes are well below the lowest of the 50 states.

Some general economic indicators are shown in Table 2. As the table shows, gross domestic product (GDP) in nominal dollars grew at the annual average rate of 7.8 percent between 1983 and 1992.³ During this same period, the U.S. gross domestic product expanded at an average annual rate of 6.4 percent.⁴ Employment in Puerto Rico increased by an average of 3.6 percent per year while U.S. employment grew 1.7 percent per year over the same period.⁵ However, the unemployment rate did not fall below 14 percent, and the 1992 per capita personal income of \$6,360 is about 32 percent of the U.S. average of \$19,805.⁶

Puerto Rico has developed a growing trade surplus that approached \$5.9 billion in 1992. As shown in Table 3, Puerto Rico's economy is highly integrated with the U.S. economy. In 1992, 87.5 percent of Puerto Rico's exports went to the U.S., and 67.7 percent of its imports originated in the U.S. Thus, fluctuations in the mainland economy are felt quickly in Puerto Rico.

One factor affecting trade between the U.S. mainland and Puerto Rico is the "Jones Act." In particular, trade between the mainland and Puerto Rico is considered domestic commerce and is therefore subject to Jones Act (46 U.S.C. 883) requirements.⁷ Under the Jones Act, all shipments between domestic ports must be carried by ships built and registered in the U.S. This requirement would also apply to shipments of petroleum during an emergency unless waived by the Federal government.

³Gross domestic product differs from gross product in that the former includes net payments abroad.

⁴U.S. Department of Commerce, Bureau of Economic Analysis, *Survey of Current Business*, May 1993; *1991 Economic Report of the President*, February 1991.

⁵*Ibid.*

⁶*Survey of Current Business*, May 1993. Note: the Puerto Rico figure is for the fiscal year ended June 30, 1992; the U.S. figure is for calendar year 1992.

⁷U.S. Department of Energy, *Report to the Congress on the Storage of Refined Petroleum Products and on Regional Supply Interruptions*, Vol. II, June 1991, p.289.

Table 2

GENERAL ECONOMIC INDICATORS: PUERTO RICO 1983-1992									
YEAR	GROSS PRODUCT (\$ millions)	GROSS DOMESTIC PRODUCT (\$ millions)	RECORDED IMPORTS (\$ millions)	RECORD- ED EXPORTS (\$ millions)	BALANCE OF TRADE (\$ millions)	EMPLOYMENT ¹	UNEMPLOYMENT RATE (%)		PER CAPITA PERSONAL INCOME (\$)
							PR	US	
1983	\$13,048.5	\$17,276.6	\$8,506.8	\$8,521.1	\$14.5	709	23.5	9.6	\$3,897
1984	14,183.0	19,162.6	9,528.5	9,146.0	(382.4)	754	22.0	7.5	4,100
1985	15,002.2	20,289.2	10,112.2	10,543.7	431.5	774	21.4	7.2	4,337
1986	16,014.4	21,969.4	10,098.9	11,571.4	1,472.5	798	20.5	7.0	4,554
1987	17,152.7	23,878.0	10,723.8	12,068.2	1,344.4	863	17.7	6.2	4,815
1988	18,549.8	26,178.4	11,859.1	13,952.8	2,093.7	909	15.9	5.5	5,151
1989	19,954.2	28,266.8	14,042.8	16,354.9	2,312.2	948	14.4	5.3	5,518
1990	21,619.1	30,603.8	15,721.6	19,305.4	3,583.8	963	14.3	5.5	6,008
1991	22,857.2	32,591.1	15,904.3	21,323.0	5,418.7	977	15.2	6.7	6,155
1992p	23,619.5	33,969.1	15,194.5	21,051.2	5,868.7	977	16.5	7.4	6,360
1983-92 Annual % Change	6.8%	7.8%	6.7%	10.6%		3.6%	-3.9%	-2.9%	5.6%

¹No. of employed persons, in thousands.

p = preliminary figures

Source: Economic Report of the Governor 1992, Puerto Rico Planning Board, Statistical Appendix, Tables 9, 25, 32, April 3, 1993.

Table 3

	1989		1990		1991		1992	
TOTAL EXPORTS	16,354.9		19,305.4		21,323.0		21,051.2	
		% of total		% of total		% of total		% of total
To United States	14,245.5	87.1%	16,780.5	86.9%	18,484.4	86.7%	18,410.3	87.5%
To Foreign Countries	1,939.1	11.9%	2,252.2	11.7%	2,567.9	12.0%	2,395.6	11.4%
To U.S. Virgin Islands	170.4	1.0%	272.7	1.4%	270.7	1.3%	245.3	1.2%
TOTAL IMPORTS	14,042.8		15,721.6		15,904.3		15,194.5	
		% of total		% of total		% of total		% of total
From United States	9,443.9	67.3%	10,801.2	68.7%	10,739.2	67.5%	10,290.7	67.7%
From Foreign Countries	4,586.1	32.7%	4,911.1	31.2%	5,134.7	32.3%	4,872.4	32.1%
From U.S. Virgin Islands	12.8	0.1%	9.3	0.1%	30.4	0.2%	31.4	0.2%
BALANCE OF TRADE	2,312.1		3,583.8		5,418.7		5,856.7	
United States	4,801.6		5,979.3		7,745.2		8,119.6	
Foreign Countries	(2,647.0)		(2,658.9)		(2,566.8)		(2,476.8)	
U.S. Virgin Islands	157.6		263.4		240.3		213.9	

Source: Economic Report of the Governor 1992, Puerto Rico Planning Board, Statistical Appendix, Table 25, April 3, 1993, p. A-28.

2.2 Major Economic Sectors

Table 4 provides a breakdown of Puerto Rico's GDP by sector over the period 1983 to 1992. As the table shows, Puerto Rico's economy is highly diversified. Manufacturing accounted for 38.7 percent of GDP in 1992, and grew at a slightly faster rate (8.3% per year in current dollars) than the overall economy (7.8%) between 1983 and 1992. Wholesale and retail trade accounted for 14.7 percent of 1992 GDP and grew at about the same rate (7.7%) as the overall economy. The finance, insurance and real estate sector represented 13.1 percent of GDP and grew at the rate of 8.0 percent per year. Services grew at 9.4 percent per year and now account for 10.4 percent of GDP. The government accounts for 11.0 percent of GDP and is growing at a slower rate than the overall economy.

A somewhat different view of the economy is provided in Table 5 which displays employment by major economic sectors. As can be seen in the table, the largest sectors of employment in 1992 were services (22.9%), government (22.4%), wholesale and retail trade (19.8%), and manufacturing (16.8%). Manufacturing accounts for the largest share of GDP but is only the fourth largest employment sector. This is most likely explained by the prevalence of more capital intensive, higher wage industries (e.g., pharmaceuticals) within the manufacturing sector, and lower wage jobs in the services, government and trade sectors. Overall job growth averaged 3.6 percent per year between 1983 and 1992. The highest growth rates occurred in construction (6.6%), services (6.0%), finance, insurance and real estate (4.3%), and communications (4.2%).

Puerto Rico's imports and exports in 1992 are detailed in Table 6. The close integration between the U.S. and Puerto Rican economies in the chemicals/pharmaceuticals area is illustrated by the high volume of imports and exports in that sector. Active trade also occurs in the food industry and the machinery industries.

2.3 Economic Development Incentives

The pharmaceutical companies and other companies have been attracted to Puerto Rico in part by a provision in the U.S. tax code. Section 936 of the code allows U.S. corporations that meet certain requirements to reduce their U.S. corporate income tax by the amount of tax attributable to income derived within Puerto Rico.⁸

The Section 936 tax benefit has had a substantial positive impact on the Puerto Rican economy, as documented in a recent study by the Puerto Rican Planning Board.⁹ The Planning Board found that in fiscal year 1987, there were 521 Section 936 companies in operation, representing 22 percent of all manufacturing companies in Puerto Rico. The Section 936 firms produced 81.1 percent of total manufacturing production, employed 64.8 percent of total manufacturing employment, provided 74.1 percent of total employee compensation in the manufacturing sector, contributed 87.8 percent of total value added in manufacturing, and generated 82.9 percent of merchandise exports. Section 936 firms also benefit the Puerto Rican economy by generating employment among other firms. The Planning Board estimated that for

⁸The tax legislation recently enacted by the U.S. government included changes to Section 936 that reduced the percentage of income that can be sheltered from taxes.

⁹Puerto Rico Planning Board, "The Impact of Section 936 on the Economy of Puerto Rico," March 25, 1993.

each 100 jobs in Section 936 companies in 1987, another 81 jobs were created in non-Section 936 employers.

Table 4

GROSS PRODUCT AND GROSS DOMESTIC PRODUCT BY MAJOR INDUSTRIAL SECTOR: PUERTO RICO												
FISCAL YEARS: 1983 - 1992p (\$ millions)												
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992p	SHARE OF 1992 GDP (%)	1983 1992 AVERAGE % CHANGE
GROSS PRODUCT	\$13,038 5	\$14,183 0	\$15,002 2	\$16,014 4	\$17,152 7	\$18,549 8	\$19,954 2	\$21,619 1	\$22,857 2	\$23 619 5		0 068
GROSS DOMESTIC PRODUCT	17276 6	19162 6	20289 2	21969 4	23878	26178 4	28266 8	30603 8	32591 1	33969 1	1	0 078
Agriculture	391 3	344 6	356 9	372 8	411 2	398 8	443 1	434 1	449 1	461 5	0 014	0 019
Manufacturing	6406 1	7370 8	7909 4	8548 9	9483 1	10513 3	11133 2	12125 8	12761 5	13154 9	0 387	0 083
Contract Construc- tion and mining ¹	300 6	325 6	334	330 9	417 8	551	662 1	719 9	771 4	788 7	0 023	0 113
Transportation and other public utilities ²	1600 2	1714 4	1708 9	1904 8	2044 5	2261 8	2314 5	2468 1	2677 3	2840 7	0 084	0 066
Trade	2570 4	2912	3159 9	3361 1	3745 8	4125 2	4376	4728 3	4811 2	5008 2	0 147	0 077
Finance, Insurance and Real Estate	2230 3	2420 8	2547 2	2866 9	3182 8	3545 3	3750 1	3895 8	4204 8	4458	0 131	0 08
Services	1576 1	1714 6	1836 6	1992 6	2184 1	2504 5	2699 4	3015 3	3283 9	3547	0 104	0 094
Government	2039 9	2173 5	2345 6	2444 7	2679 5	2918 2	3186 9	3337 2	3537 5	3737 8	0 11	0 07
Commonwealth ³	1734 3	1849 6	1996 1	2078	2292 6	2505 7	2745 1	2884 3	3052	3213 1	0 095	0 071
Municipalities	305 5	324	349 5	366 7	386 9	412 5	441 8	452 9	485 5	524 7	0 015	0 062
Statistical Discrepancy	161 7	186 2	90 7	146 6	(270 7)	(639 8)	(298 4)	(120 7)	94 4	(27 7)		
GROSS PRODUCT DEFLATOR (1954 = 100 0)	339 8	355 8	365 4	376 9	387 3	401	415	438 5	460 1	469 7		

(1) Negative Figures
1 Mining includes only quarries
2 Includes radio and television broadcasting
3 Includes regular agencies and public enterprises

Source Economic Report of the Governor 1992, Puerto Rico Planning Board, Statistical Appendix, Tables 4 and 9, April 3, 1993, pp A-5, A 10

p = preliminary figures

Table 5

NUMBER OF EMPLOYED PERSONS BY MAJOR INDUSTRIAL SECTOR: PUERTO RICO												
FISCAL YEARS: 1983 - 1992 p (in thousands of persons)												
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992p	Share of Employment 1992p	1983-92 Annual % Change
NO OF PERSONS 16 OR OLDER	2,256	2,296	2,332	2,363	2,384	2,410	2,435	2,473	2,515	2,536		1.3%
LABOR FORCE	927	967	985	1,004	1,048	1,081	1,108	1,124	1,152	1,170		2.6%
PARTICIPATION RATE	41.1%	42.1%	42.2%	42.5%	44.0%	44.9%	45.5%	45.5%	45.8%	46.1%		1.3%
TOTAL EMPLOYED	709	754	774	798	862	909	948	963	977	977	100.0%	3.6%
Agriculture, Forestry and Fish- ing	37	40	39	41	36	32	37	36	35	34	3.5%	-0.9%
Sugar cane	2	2	3	2	2	3	3	2	2	a/		
Coffee	9	13	13	14	13	11	13	12	13	14	1.4%	5.0%
Manufacturing	132	145	141	144	157	163	165	168	164	164	16.8%	2.4%
Textiles and apparel	27	32	28	29	31	32	31	31	30	30	3.1%	1.2%
Mining	a/	a/	a/	a/	a/	a/	a/	a/	a/	a/		
Construction	31	35	37	37	43	50	54	55	55	55	5.6%	6.6%
Trade	137	147	150	153	165	180	186	185	195	193	19.8%	3.9%
Wholesale	18	19	19	20	20	25	27	24	25	23	2.4%	2.8%
Retail	119	128	131	134	144	155	159	161	170	170	17.4%	4.0%
Finance, Insurance and Real Estate	22	22	24	27	31	31	32	30	32	32	3.3%	4.3%
Transportation	24	23	24	25	27	26	25	28	27	25	2.6%	0.5%
Communication	9	8	10	11	11	12	13	15	14	13	1.3%	4.2%
Other Public Utilities (check translation)	12	11	11	13	15	14	15	17	17	16	1.6%	3.2%
Services	133	142	154	161	173	189	201	206	221	224	22.9%	6.0%
Domestic services	6	6	7	7	7	8	7	7	9	9	0.9%	4.6%
Others	127	136	147	154	166	181	194	199	212	215	22.0%	6.0%
Public Administration	171	180	183	185	204	209	219	222	217	219	22.4%	2.8%
TOTAL UNEMPLOYED	217	212	211	206	185	172	160	161	175	193		-1.3%
UNEMPLOYMENT RATE	23.5%	22.0%	21.4%	20.5%	17.7%	15.9%	14.4%	14.3%	15.2%	16.5%		-3.9%

Table 6

IMPORTS AND EXPORTS OF RECORDED MERCHANDISE: PUERTO RICO - 1992 (\$ millions)				
	1992 IMPORTS	% of total	1992 EXPORTS	% of total
Total Manufacturing	\$14,300.2	94.1%	\$20,877.2	99.2%
Food	2,000.0	13.2%	3,006.3	14.3%
Fish	241.2	1.6%	412.1	2.0%
Tobacco	54.5	0.4%	78.2	0.4%
Apparel and textiles	756.1	5.0%	826.2	3.9%
Wood, furniture	312.9	2.1%	48.7	0.2%
Paper, printing, publishing	517.5	3.4%	104.2	0.5%
Chemical products	3,393.3	22.3%	9,169.8	43.6%
Drugs and pharmaceuticals	2,025.6	13.3%	7,255.5	34.5%
Petroleum refining products	1,047.7	6.9%	362.9	1.7%
Rubber and plastic products	627.2	4.1%	178.9	0.8%
Leather and leather products	234.4	1.5%	290.5	1.4%
Stone, glass, concrete products	157.8	1.0%	103.4	0.5%
Primary metal products	379.6	2.5%	74.1	0.4%
Fabricated metal products	332.6	2.2%	236.6	1.1%
Machinery	1,008.8	6.6%	2,667.6	12.7%
Electrical computers	361.7	2.4%	2,356.5	11.2%
Electrical machinery	1,459.5	9.6%	1,770.5	8.4%
Transportation equipment	905.0	6.0%	93.5	0.4%
Professional instruments	622.5	4.1%	1,706.9	8.1%
Miscellaneous manufacturing	490.8	3.2%	158.9	0.8%
AGRICULTURE	156.5	1.0%	111.3	0.5%
MINING	595.3	3.9%	20.8	0.1%
REPAIR SERVICES	3.1	0.0%	21.7	0.1%
MERCHANDISE, NEC	139.4	0.9%	20.2	0.1%
TOTAL	\$15,194.5	100.0%	\$21,051.2	100.0%
Source: Economic Report of the Governor 1992, Puerto Rico Planning Board, Statistical Appendix, Tables 23, 24, April 3, 1993, pp. A-26, A-27.				

3 ENERGY PROFILE

3.1 Introduction

Puerto Rico's economy is nearly totally dependent on petroleum. All crude oil and some refined petroleum products are imported. The importing, refining, and marketing of petroleum in Puerto Rico is accomplished primarily by private companies, principally subsidiaries or affiliates of multinational oil companies. The Puerto Rico Electric Power Authority also imports fuel for its own use. The Puerto Rico petroleum sector is profiled in Section 3.3 below.

Virtually all electric power in Puerto Rico is generated and sold by the Puerto Rico Electric Power Authority (PREPA), which is a public corporation and instrumentality of the Government. PREPA is governed by a nine member Board, seven members appointed by the Governor of Puerto Rico and two elected by PREPA customers. PREPA is among the largest municipal electric utilities in the United States. The electric power sector is profiled in Section 3.2 below.

Aside from small amounts of hydroelectric power, coal, bagasse (sugar cane waste), and solar energy no other sources of energy are currently used in Puerto Rico.¹ Coal, liquified natural gas, and other energy sources are under active consideration for electric power generation but have not been adopted to date.

3.2 Electricity Demand, Supply and Distribution²

3.2.1 *Electricity Demand*

In the fiscal year ending June 30, 1992 PREPA had 1.2 million customers, sold 13.6 billion kilowatt hours (kWh) of electricity, and had a system peak demand of 2,437 megawatts (MW). Table 7 shows the historical trend in peak demand, sales, number of customers, and the breakdown of sales by customer class. As the table shows, the system peak demand has been growing at an average rate of 3.1 percent per year. Annual sales have grown at an average rate of 3.3 percent per year. Commercial sector sales are growing at the fastest rate and represented 37.3 percent of total sales in 1992. The residential sector accounted for 34.2 percent of sales, and the industrial sector was 25.3 percent.

The government sector (which is included primarily in the commercial sales category) accounted for 16.6 percent of kWh sales in 1992. The ten largest industrial customers accounted for 6.4 percent of kWh sales in 1992. The ten customers included three petroleum refineries, five chemical/pharmaceutical companies and two cement companies.

¹It is reported that the island's two cement manufacturers burned coal for more than ten years (*San Juan Star*, June 29, 1993, p. 7)

²Except where noted otherwise, the data in this section came from the 1992 PREPA Revenue Bond Official Statement (OS) or was provided directly by PREPA.

Table 7

Electric Power Demand and Supply: Puerto Rico (P.R. Fiscal Years 1988 -1992)							
	1988	1989	1990	1991	1992	Average Annual Growth (%/Year)	Share of 1992 Sales (%)
Dependable generating capacity (MW)	4,192	4,192	4,208	4,208	4,219	0.2%	
Peak load, 60 minute (MW)	2,157	2,208	2,305	2,367	2,437	3.1%	
Capacity margin (%)	48.5%	47.3%	45.2%	43.8%	42.2%		
Reserve margin (%)	94.3%	89.9%	82.6%	77.8%	73.1%		
Average load (MW)	1,607	1,675	1,689	1,769	1,833	3.3%	
Load factor (%)	74.5%	75.9%	73.3%	74.7%	75.2%		
Electric energy sales (million kWh)							
Residential	4,172	4,304	4,290	4,417	4,650	2.7%	34.2%
Commercial	4,022	4,203	4,397	4,819	5,082	6.0%	37.3%
Industrial	3,131	3,359	3,324	3,437	3,446	2.4%	25.3%
Other	408	417	412	418	437	1.7%	3.2%
Total sales	11,733	12,283	12,423	13,091	13,615	3.8%	100.0%
Source: Official Statement of the September 1, 1992 Electric Power Revenue Bonds of the Puerto Rico Electric Power Authority, p. 28.							

Residential customers in Puerto Rico generally use less electricity than residential customers in the mainland. As shown in Table 8, annual demand per home in 1991 was 4,202 kWh in Puerto Rico vs. 9,660 kWh in the U.S. Part of this difference is related to the lower per capita incomes in Puerto Rico compared to the mainland, as noted earlier, which leads to lower prevalence and usage of electricity using equipment in the home. Electric rates are not necessarily a contributing factor. Costs per kWh for residential customers in Puerto Rico are less than in several higher electric cost states.

Table 9 compares average revenue per kWh by customer class in Puerto Rico and the U.S. for the year ending June 30, 1992. As can be seen, over all customer classes combined, average revenue per kWh is 8.98 cents in Puerto Rico and 6.79 cents in the U.S. The average revenue per kWh for residential customers in Puerto Rico is slightly less than the U.S. average for residential customers (7.67 cents vs. 8.16 cents). However, the average revenue per kWh for commercial customers and industrial customers in Puerto Rico is substantially higher than the U.S. average for

those customer classes (10.40 cents vs. 7.56 cents and 8.03 cents vs. 4.85 cents, respectively). The relatively high cost of electricity in Puerto Rico is viewed as a hindrance to industrial development because it makes Puerto Rico less able to compete for new manufacturing jobs compared to many areas of the U.S. mainland.

The pattern of average revenues across customer classes reflects the direct and possibly indirect subsidies received by residential customers under PREPA regulations (see Section 3.4 below regarding the direct subsidies).

Table 8

RESIDENTIAL SECTOR ELECTRIC DEMAND CHARACTERISTICS: PUERTO RICO (P.R. FISCAL YEAR 1992)		
Residential Sector	Puerto Rico	United States
Average sales per customer (kWh)	4,357	9,620
Per capita personal income (\$)	\$6,360	\$19,805
Average revenue per kWh (\$)	\$0.0767	\$0.0816
<p>Note: All data are for the Puerto Rico fiscal year ended June 30, 1992 except U.S. per capita income which is for calendar year 1992.</p> <p>Sources: 1992 Official Statement of the Puerto Rico Electric Power Authority, p. 28. Puerto Rico Planning Board, Informe Economico Al Gobernador 1992, p. A-1. U.S. Department of Energy, Energy Information Administration, April 1992 and June 1993 Electric Power Monthly, Table 51; 1991 Electric Power Annual, February 1993, Table 27. U.S. Department of Commerce, Bureau of Economic Analysis. Survey of Current Business, p. 15.</p>		

Table 9

AVERAGE REVENUE PER KWH, BY CUSTOMER CLASS: PUERTO RICO (P.R. FISCAL YEAR 1992)		
Average Revenue per kWh (\$)	Puerto Rico	United States
Residential	\$0.0767	\$0.0816
Commercial	0.1040	0.0756
Industrial	0.0803	0.0485
All Customers (incl. other)	0.0898	0.0679
Sources: 1992 Official Statement of the Puerto Rico Electric Power Authority, p. 28. U.S. Department of Energy, Energy Information Administration, April 1992 and June 1993 Electric Power Monthly, Table 51.		

3.2.2 Electricity Supply and Distribution

The Puerto Rico Electric Power Authority (PREPA) is the only electric power utility in Puerto Rico. The entire economy of Puerto Rico is dependent upon the electric power generated and distributed by PREPA.

PREPA is unique among major electric utility systems of the United States in that 98 percent of its generating energy comes from burning oil. In the 48 contiguous states only three percent of all electricity is generated from oil. Any disruption in PREPA's oil supply which retards generation can produce, at the very least, a ripple effect throughout the entire economy. Also, unlike most other mainland electric utilities, there is no interconnected neighboring power system which can come to PREPA's assistance in time of trouble.

The three major components of a modern electric power system are: (1) the generating facilities, (2) the delivery system (transmission and distribution), and (3) the dispatching, control and data acquisition system.

PREPA's generating facilities are 98 percent oil fired and have a total dependable capacity of 4,219 MW. There are four major power plant sites, two of which are located in the metropolitan area of San Juan, and two others, on the south coast, which are 32 and 48 miles, respectively, outside of San Juan. Smaller power plants are located at several sites around the island. The plant locations and major transmission lines are shown in Figure 1. Eighteen steam generators contribute three-fourths (3,080 MW) of the generating capacity and gas turbines contribute nearly one-fourth (1,037 MW). The balance (102 MW) is provided by small hydro units and diesel plants. Modernizing, upgrading and rehabilitation programs are on-going.

PUERTO RICO ELECTRIC SYSTEM

AS OF JUNE 30, 1992

Figure 1

Because PREPA has no neighboring power systems with which it can interconnect, it must have generating reserves in excess of the electric systems of the continental U.S. Mainland systems have assistance agreements and transmission interties which provide support in emergency situations and economic exchange of power and energy at other times. Because PREPA stands alone, it must have sufficient generating capacity available to provide for scheduled maintenance, emergency outages, system operating requirements, and unforeseen customer demands. Additionally, PREPA's annual load factor is 75 percent (for comparison, the U.S. mainland average is 61 percent³), which means that average electrical demand is 75 percent of the peak annual demand. This high load factor makes it more difficult to take units out of service for scheduled maintenance.

The excess of generating reserves over system peak demand is known as capacity margin or reserve margin.⁴ Interconnected utility systems in the mainland U.S. can operate safely with capacity margins on the order of 15 percent to 30 percent, depending on the situation. By this criterion, PREPA's capacity margin should be on the order of 45 percent. PREPA, and its consultant, United Engineers and Constructors (UE&C), have developed an index called equivalent availability which reflects actual experience and the need for an aggressive upgrading and modernization program, and clearly illustrates the need for a higher capacity margin than interconnected systems enjoy.

In order to achieve an adequate capacity margin and meet load growth, PREPA has two major generation additions scheduled by 1995-96. The first is an addition, near Arecibo, of 250 MW of oil-fired combustion turbine capacity. The second is the proposed purchase of up to 300 MW of coal-fired capacity from Cogentrix of Mayaguez, Inc, an independent power producer (IPP).⁵ PREPA's planning office is also looking at opportunities to integrate other non-utility generation (NUGs), in addition to the Cogentrix project. An interagency task force currently studying generation options has received approximately ten cogeneration proposals from IPPs.

PREPA's major transmission facilities consist of nearly 2200 miles of 38 kilovolt (kV), 115 kV, and 230 kV lines terminated by 175 substations and switchyards. The system is, according to UE&C, "...in good repair and sound operating condition."

The distribution facilities consist of over 25,000 miles of lines and 870 substations (575 of which are customer owned). This system is also rated by UE&C to be in sound operating condition.

³North American Electric Reliability Council, *Electricity Supply and Demand, 1992-2001*, June 1992, pp. 7-8.

⁴*Ibid.*, p. 12. U.S. mainland electric utilities use the term "capacity margin," which is defined as the difference between generating capacity and annual peak demand, divided by generating capacity. PREPA uses the term "reserve margin" which is defined as the difference between generating capacity and annual peak demand, divided by annual peak demand.

⁵The Puerto Rican government has refused to issue necessary permits to Cogentrix for the Mayaguez project, making it highly unlikely that the project will be implemented in its planned location and form. (*San Juan Star*, June 29, 1993, p. 7)

The system control facilities are combined into an Energy Management System (EMS) which consists of a centralized computer-based network with 208 remote units located throughout the island's various electrical facilities. This EMS allows supervisory control of generation, transmission, and distribution. The EMS gathers information, makes operating decisions, and orders the rest of the system to perform in an appropriate way to achieve the desired results. This automated control system becomes especially critical when the electric system comes under stress, such as weather disturbances, fuel shortages, natural disasters, or human subversion. PREPA's EMS is newly installed state-of-the-art equipment and should contribute to mitigating the impacts of system disruptions.

The total investment in PREPA's plant is now about \$2.7 billion, with another \$1.6 billion programmed by 1997.

3.2.3 Fuel for Electric Power

Ninety eight percent of the net electric energy generated by PREPA in 1992 was produced by burning oil. The major steam-electric plants burn No. 6 residual fuel oil, and the combined-cycle units and the smaller gas turbines burn No. 2 distillate fuel oil. The combined-cycle units are being converted to burn No. 6 fuel oil, which is less expensive, and three of the eight had been converted as of mid-1992 but were still burning No. 2 fuel oil at that time.

The quantity and cost of fuel oil used by PREPA in recent years is shown in Table 10. The following items are notable:

- The average cost of fuel per kWh sold during the period shown ranged from 2.9 cents to 3.8 cents. In comparison, the U.S. average was 1.2 cents during the most recent year available (calendar year 1991).
- Fuel cost as a percent of revenue from electric sales ranged from 33 to 40 percent during the period shown. The U.S. average in calendar year 1991 was 17 percent.

In other words, PREPA's dependence on petroleum greatly increases the cost of fuel for electric power generation compared to the rest of the U.S. which relies more heavily on less expensive fuels: coal (56.3%), nuclear (22.1%), gas (9.4%), hydro (8.6%) and other (0.4%), compared to petroleum (3.2%) for electric generation.⁶

As of June 1992, PREPA was obtaining approximately 53 percent of its fuel oil under renewable one year contracts primarily from local suppliers. A second major source was a two year fuel oil contract with Venezuela which provides PREPA with up to 30 percent of its fuel oil requirements. The balance of fuel oil supplies were obtained from contracts of less than one year in duration and spot market purchases.

⁶Data on U.S. electric generation by source are from U.S. Department of Energy, Energy Information Administration, *Electric Power Monthly*, June 1993, Table 3.

Fuel oil refined off the island is shipped to Puerto Rico by ocean-going tankers and barges and off-loaded at docks close to the power plants. Further distribution, and shipments from local refineries, is done by barge, pipeline or truck.

Table 10

QUANTITY AND COST OF FUEL USED FOR ELECTRIC POWER: PUERTO RICO (P.R. FISCAL YEARS 1988 -1992)						
	1988	1989	1990	1991	1992	U.S. Calendar Year 1991
Quantity of fuel oil used (million barrels)	23.6	24.7	26.1	25.9	27.3	
Average cost per barrel (net of handling)	\$16.16	\$14.40	\$17.95	\$17.96	\$14.58	
Average fuel cost per kWh sold	\$0.0325	\$0.0289	\$0.0376	\$0.0355	\$0.0293	\$0.0117
Fuel cost % revenue from electric sales	40.3%	37.6%	40.0%	36.8%	32.6%	17.3%
Source: Official Statement of the September 1, 1992 Electric Power Revenue Bonds of the Puerto Rico Electric Power Authority, p. 28, 33. U.S. Department of Energy, Energy Information Administration, 1991 Electric Power Annual, February 1993, Tables 1 and 23.						

PREPA owns storage facilities at its power plants and elsewhere with a total capacity of 2.8 million barrels. PREPA also has a five year contract effective February 1993 to lease storage facilities at the now closed Commonwealth Oil Refining Corporation (CORCO) refinery on the south coast of Puerto Rico, including storage for approximately 1.454 million barrels of No. 6 fuel oil and 0.450 million barrels of No. 2 fuel oil. PREPA customarily maintains a 25 day supply of fuel oil in storage facilities at the power plants and elsewhere.⁷ In fiscal year 1992, PREPA used an average of 74,800 B/D of fuel oil. Thus, a 25 day supply would be just under 1.9 million barrels, or well within the available storage capacity. PREPA states that it has never had to curtail service to customers due to a shortage of fuel.

⁷For comparison purposes, Hawaii, which also uses primarily petroleum for electric generation, had a 32 day supply of petroleum on hand at the end of 1991, the most recent full year available. The New England states, which rely on petroleum for about 60 percent of electric generation, had a 45 day supply. Source: U.S. Department of Energy, Energy Information Administration, *Electric Power Annual 1991*, February 1993, Tables 18, 21, 46.

3.3 Petroleum Demand, Supply and Distribution

3.3.1 *Introduction to the Petroleum Sector*

Unlike the U.S. Mainland, Puerto Rico possesses no proven hydrocarbon resources. It is 98% dependent upon imported petroleum for its energy needs, with hydropower and bagasse⁸ providing the small remainder. Petroleum refining, importation, exportation, and power generation from petroleum thus dominate the Puerto Rican energy sector.

The island possesses a refining sector whose active capacity peaked in 1981 at 325,000 barrels per day (bpd). The sector developed primarily in the 1960's and 1970's under incentives created by Section 936 of the U.S. federal tax regulations and the then-existing Federal Mandatory Oil Import Program. Section 936 provides favorable tax terms for certain types of U.S. corporations operating in Puerto Rico. The Mandatory Oil Import Program had the effect of giving Puerto Rico refiners a significant feedstock cost advantage. Under those favorable terms, Puerto Rico's refining sector flourished and benefited from a large export market to the U.S., including for residual fuel. Elimination of the Mandatory Oil Import Program, the decline in the U.S. residual fuel market and the oil price shocks of 1973 and 1979-80 led to a decline in island refining and petrochemicals activity.

At present, there are four active refineries on the island, namely Sun Oil, Phillips, Caribbean Petroleum, and Peerless Oil & Chemical. Their typical combined throughput is around 145,000 bpd. These refineries export the bulk of their petrochemicals and lubricating oils production. Their fuels products output does not, however, match the demands of Puerto Rico's economy. Consequently, the island is an importer of fuels products, especially gasoline, middle distillate and residual fuel.

In part because of its history as a refining center, Puerto Rico possesses a significant quantity of petroleum tankage; nearly 24 million barrels of active capacity plus approximately 6 million barrels of tankage that could be rehabilitated. Actual and potential usage of this tankage is discussed in detail in the body of this report.

Puerto Rico is subject to Jones Act regulations. Therefore, all movements of petroleum between Puerto Rico and the Mainland must take place in U.S. flag vessels. All petroleum movements into and out of Puerto Rico are by marine tanker and barge. In addition, there is a substantial coastal flow of products by barge from island refineries in the South to San Juan in the North and to lesser demand points. Inland distribution is entirely by truck. The only active pipeline delivers jet fuel to the San Juan Airport from the major San Juan bulk terminal six miles away.

Under Puerto Rican law, companies involved in refining generally may not also be involved in marketing to retail clients.⁹ The bulk of fuels products marketing in Puerto Rico is undertaken

⁸Waste from sugar cane production that is burned for fuel.

⁹At present, Caribbean Petroleum is the one exception to this, as it retains use of the Gulf name and operates 260 "Gulf" gasoline stations.

by three oil majors - namely Shell, Esso and Texaco - as well as a significant number of smaller distributors and retailers. The petroleum supply and marketing sector of Puerto Rico is thus entirely in the private sector. Products pricing in Puerto Rico is based almost entirely on - and moves with - open market international prices.

3.3.2 Petroleum Demand

Petroleum demand in Puerto Rico has fluctuated with the fortunes of the island's economy, as shown in Figure 2.

Figure 2

In 1992, demand totalled 176,000 bpd. Of this, approximately 10,000 bpd was primarily process gas and residual fuel consumed internally by the island's refineries. Non-refinery consumption (which is not directly related to island refinery throughputs) was therefore approximately 166,000 bpd. Table 11 contains an estimate of 1992 petroleum supply and demand. This is broken down by product, distinguishes between consumption by the island refineries and consumption by all other sectors of the island economy, and identifies island refinery production, imports and exports. Demand is dominated by two products, namely gasoline at 53,000 bpd and residual fuel at 66,000 bpd, as can be seen in Figure 3.

Table 11

ESTIMATED 1992 PUERTO RICO PETROLEUM CONSUMPTION			
Product	Economy	Refinery	Total
LPG & Refy Gas	5.0	0.0	5.0
MOTOR GASOLINE	53.2	0.0	53.2
AVIATION GASOLINE	1.0	0.0	1.0
AVIATION KERO-JET	12.8	0.0	12.8
BURNING KEROSENE	1.3	0.0	1.3
DIESEL/NO2			
- PREPA COMB CYCLE	18.9	0.0	18.9
- OTHER	8.0	0.0	8.0
TOTAL DISTILLATE	26.9	0.0	26.9
RESIDUAL FUEL			
- PREPA	58.7	0.0	58.7
- BUNKERS	1.9	0.0	1.9
- INDUSTRY	1.0	4.1	5.1
TOTAL RESID	61.6	4.1	67.1
OTHER PRODUCTS			
- PROCESS GAS	0.4	5.0	5.4
- PETROLEUM COKE	0.0	0.5	0.5
- LUBES & WAXES	1.4	0.0	1.4
- PITCH & ASPHALT	2.9	0.0	2.9
- SOLVENTS/MISCL	0.2	0.0	0.2
TOTAL OTHER	4.9	5.5	10.4
GRAND TOTAL	166.7	9.6	176.3
Estimates are derived from several sources, including DACO and EIA consumption statistics, PREPA information and import and refinery production data.

Figure 3

The high level of gasoline demand has developed because of Puerto Rico's limited public transportation system and heavy reliance on automobiles and light trucks. The high residual fuel demand is directly related to Puerto Rico Electric Power Authority's (PREPA) virtually total reliance on petroleum for power generation. Small volumes of residual fuel are consumed by some industrial customers on the island, and bunker fuel demand includes approximately 2,000 bpd of residual fuel demand. This latter is a function of the level of refining activity on the island but has also increased in recent years in line with growing trade and cruise ship visits.

Jet fuel and middle distillate (diesel fuel and No.2 oil) constitute much of the balance of non-refinery demand. Jet fuel demand has risen appreciably as American Airlines, in particular, has expanded its activities at San Juan International Airport, making it into a primary Caribbean hub. Diesel/No.2 fuel demand totals 27,000 bpd, of which 19,000 bpd is consumed by PREPA (especially in its combined cycle units). The balance of 8,000 bpd is used primarily for on-road heavy vehicles, off-road vehicles and construction equipment.

Puerto Rico also consumes around 5,000 bpd of LPG. It is distributed predominantly throughout rural areas of the island, where it is used mainly for cooking. In San Juan, a small gas distribution system exists. This takes refinery gas, enriched with refinery LPG from the CAPECO Refinery and feeds local customers.

Geographically, demand is concentrated in the Greater San Juan area. Of Puerto Rico's population of 3.5 million people, some 70% live in the Greater San Juan area. Similarly, around 70% of gasoline, diesel fuel and No.2 fuel oil and virtually 100% of aviation fuel is consumed within this area. Demand for residual fuel and No.2 fuel oil consumed by PREPA is based on the locations of its power stations, which are essentially all coastal.

Figure 4

Approximately 37% of PREPA's fuel demand is for its two power stations in San Juan and 63% for its two plants on the South Coast (at Aguirre west of Guayama and Costa Sur adjacent to the CORCO/Arochem complex).

3.3.3 Petroleum Refining

As summarized in Table 12, Puerto Rico possesses a total of six oil refineries, four of which are currently operating. The CORCO refinery has been shut down since 1982. It is considered extremely unlikely that it will resume refining operations. The Arochem facility comprises two processing trains which were originally part of the CORCO complex. Arochem Corporation was formed in 1987 and ran from mid 1988 through late 1991, using tankage, dock and truck loading facilities leased from CORCO. In December of 1991, Arochem was shut down by order of a Connecticut bankruptcy court and a bid package for sale of the facility was prepared.

At the time of preparation of this report, the refinery has been sold at auction but has not yet been restarted. The new owners are First Oil, the same company that owns Caribbean Petroleum. Current plans call for restart in 1994 subject to closure on some \$30 million of required financing. This is needed to enable the refinery to be in environmental compliance and to undertake process modifications.

Table 12

REFINERIES OF PUERTO RICO			
Refinery	Capacity (bpcd)	Status	Location
Caribbean Petroleum	42,000	operating	greater San Juan
Sun Oil	85,000	operating	south east coast
Phillips	50,000	operating	south central coast
Peerless Oil & Chemical	8,000	operating	south west coast
Arochem	80,000	shut down - operable	south west coast
CORCO	140,000	shut down - inoperable	south west coast

Located in the same vicinity as the CORCO/Arochem complex is the small Peerless Oil and Chemical refinery. The remaining three refineries - Sun, Phillips and Caribbean Petroleum - comprise essentially all the current refining activity in Puerto Rico. Like the CORCO/Arochem complex and the adjacent Peerless refinery, both the Phillips and Sun refineries are located along the South Coast of Puerto Rico (See Figure 5). Caribbean Petroleum, located in the Cataño suburb of San Juan, is the only refinery located within Puerto Rico's primary demand center, i.e., Greater San Juan.

Figure 5

The Puerto Rican refining sector is somewhat atypical compared to average Caribbean or U.S. Mainland refineries:

1. The Puerto Rican refineries are smaller and simpler than their Mainland counterparts. The four operating island refineries have a combined average capacity of around 42,000 bpcd. This is roughly half the 82,000 bpcd average for U.S. Mainland refineries. Reactivation of the Arochem facility would raise the Puerto Rican average capacity to 48,000 bpcd, still well below the Mainland norm.
2. The island refineries are relatively highly concentrated on production of petrochemicals and specialty fuels¹⁰, with associated use of a high proportion of non-crude oil feedstocks, namely naphtha, very light "condensate" crude oils, and also residual and vacuum gas oil feeds. Specifically, the Sun refinery possesses around 4% of total U.S. lubes capacity. The Phillips refinery and the shutdown Arochem facility produce a mixture of petrochemicals and fuels products. Caribbean Petroleum is the only refinery whose configuration is broadly comparable to Mainland refineries, possessing cat cracking capacity and producing essentially entirely fuels products. (A more detailed description of each island refinery follows.)
3. Unlike Mainland refineries, which generate much of their electrical power needs internally, the Puerto Rican refineries all rely on power supplies from the island grid, with tie-ins to typically two or three PREPA generating stations.

Caribbean Petroleum Corporation, Cataño

Caribbean Petroleum is a 42,000 bpcd refinery originally built by Gulf Oil in 1955. Since 1987, it has been owned by First Oil Corporation of the British Virgin Islands.¹¹ The facility is a "cracking" refinery, i.e. it possesses, as do many U.S. refineries, catalytic cracking and catalytic reforming units geared toward gasoline production, together with hydrotreating for distillate products. Box 1 provides a breakdown of the major refinery units.

¹⁰lubricating oils and waxes

¹¹First Oil has recently purchased the Arochem facility at Guayanilla.

**PROCESSING CONFIGURATION
CARIBBEAN PETROLEUM CORP.**

	<u>bpcd</u>	
Crude distillation	42000	
Vacuum distillation	22000	
FCC	14200	
Cat Reforming	6500	Semi regen/conventional catalyst
Cat Hydrotreating	6800	Reformer feed
Cat hydrotreating	11000	straight run distillate
Polymerization	1300	
Asphalt	1000	
Sulfur tpd	12	

Construction: None

(refinery completed a recent modernization/debottlenecking project reported at \$25 million)

BOX 1

Caribbean Petroleum runs crude oil as its predominant feedstock. Typically, its crude intake is in the 21°-29° API gravity range. At this level, its crude slate is heavier than that of the average U.S. refinery (1992 average gravity around 31.2° API), but is of a quality that is increasingly common among U.S. Gulf Coast refineries in particular. The refinery's crude oil intake comes predominantly from Venezuela and other producers in the Greater Caribbean region.

Since its sale to First Oil, the refinery has undergone a modernization project geared to debottlenecking its major units. Located within the urban San Juan area, the refinery is subject to strict - and tightening - EPA emissions regulations. Its FCC unit has been subject to throughput constraints imposed by the EPA to contain atmospheric emissions.

Production of major products from the refinery is split roughly evenly between gasoline, distillate and residual fuel. Part of the refinery's process gas and LPG production is fed into a gas pipeline system run by San Juan Gas which feeds customers in the local area. Gasoline output goes into the local market. The refinery also produces diesel/No.2 and burning kerosene, but before 1989 did not produce kero jet fuel. The majority of residual fuel product is currently purchased by PREPA. Caribbean Petroleum also produces around 1,000 bpd of asphalt for local consumption.

Sun Oil, Yabucoa

The Sun Yabucoa Refinery was originally built in 1971 and has a rated capacity of 85,000 bpd. Typical present-day throughput, however, is nearer 55,000 bpd of crude oil feedstock supplemented by residuum and vacuum gas oil. The bulk of Sun's crude oil supplies come from

Caribbean producers. Crude quality ranges from 0.5-2.0% sulfur and 28°-33° API. Box 2 gives a breakdown of the refinery's major processing units.

**PROCESSING CONFIGURATION
SUN OIL**

	<u>bpcd</u>	
Crude distillation	85000	
Vacuum distillation	45000	
Cat Reforming	20000	semi regen - bimetallic catalyst
Cat Hydrocracking	15600	for lube oil production
Cat Hydrorefining	10000	heavy gas oil desulfurization
Cat Hydrotreating	20000	reformer feed
Lubes	9200	
Hydrogen, MMSCFD	19	steam naphtha reforming
sulfur tpd	50	

Construction: None

BOX 2

The primary economic driving force of the Sun refinery is the production of lubricating oils and waxes.¹² Typical out-turn of these products is 6,000 - 8,000 bpd, nearly all of which is exported to the U.S. Mainland and other regions. The refinery produces lubricating oils using a hydrocracking process which affords a wide range of flexibility in feedstock selection. Lubes operations aside, Sun's processing configuration constitutes a simple "hydro-skimming" facility comprising distillation and catalytic reforming units geared to production of a mixture of gasoline, distillates and residual fuel. The catalytic reformer was added in 1988 to produce gasoline from a naphtha cut which had previously been sent to island petrochemicals units.

Sun is the only refinery on Puerto Rico that has consistently produced jet fuel over an extended period.¹³ Its typical output is less than island consumption, leaving a balance to be filled by imports and, since 1989, supplies from the CAPECO refinery. Its hydrocracking unit will provide it with the capability to produce small volumes of ultra low sulfur (0.05%) diesel when this becomes mandatory in October 1993.

¹²The Sun refinery's lubes and wax capacity of 9,200 bpd comprises 4% of total U.S. capacity.

¹³The Arochem facility reportedly has the capability to produce kero-jet at up to 7,000 bpd.

Phillips, Guayama

The Phillips "refinery" is first and foremost a petrochemicals facility. Its primary function is to produce a range of petrochemicals from naphtha feedstock. This is achieved by processing naphtha through two catalytic reformers. The product is highly aromatic and is further processed through extraction and related units to produce benzene, toluene, xylenes and cyclohexane "aromatics", together with paraffinic naphtha by-product sold as ethylene cracker feedstock. Gasoline is produced as a major co-product comprising roughly 50% of total output. It is blended from butane, naphtha, full reformer product, excess aromatics and "raffinate" by-product. Normally, all gasoline output stays on the island. Box 3 shows the processing configuration. The refinery obtains its feedstocks from a wide range of sources; Venezuela, however, is the predominant source.

**PROCESSING CONFIGURATION
PHILLIPS PUERTO RICO INC.**

Crude	<u>bpcd</u> none	
Cat Hydrotreating	50000	naphtha/reformer feed
Cat Reforming	38400	low pressure
	14400	high pressure
Aromatics	15000	
Products:		
Benzene	411,000	MTY
Cyclohexane	290,000	MTY
Toluene	336,000	MTY
Orthoxylene	59,000	MTY
Paraxylene	260,000	MTY

Construction: None

BOX 3

Phillips has recently authorized installation of additional process facilities based on Chevron technology. These will enable the refinery to reduce output of "raffinate" by-products. They will also enable it to process lower cost naphtha feedstocks.

Commonwealth Oil Refining Corporation, Guayanilla

The CORCO refinery once constituted Puerto Rico's largest petroleum and petrochemicals facility. For the purposes of evaluation in the island's present-day energy sector, the facility can best be considered as comprising three elements:

1. the original Commonwealth Oil Refining Corporation crude processing facilities,
2. the adjacent Commonwealth Petrochemical, Inc. (CPI) petrochemicals processing facilities,
3. the tankage, dock and pipeline facilities that supported the refining and petrochemicals operations.

The original CORCO crude oil refinery had a rated distillation capacity of 141,000 bpd. It included atmospheric and vacuum distillation units, two catalytic crackers, a visbreaker, an alkylation unit, and naphtha and distillate hydrotreating units. The refinery generally processed a mix of low and high sulfur crude oils. Its product slate comprised significant volumes of gasoline, together with LPG, No.2 heating oil and residual fuel. All of the middle distillate and roughly half of the gasoline was shipped to the U.S. East Coast. The balance of the gasoline and the majority of the residual fuel were sold on-island. The refinery also supplied aviation gasoline to Puerto Rico markets.¹⁴ The processing facilities were shut down in 1982 after CORCO had been in receivership since 1979/1980. It is generally considered that the facilities are not in a condition to be restarted.

The CPI facility comprised two petrochemicals processing trains (known as CPI-I and CPI-II). These were moth-balled by CORCO in 1982 and became the basis of the Arochem facility described elsewhere in this report.

The CORCO off-site facilities comprise extensive tankage, plus marine docks, truck loading racks, pipeline inter-connections to local consumers and producers (notably, the PREPA power station and the Peerless refinery) and a clean products pipeline that runs northeast across Puerto Rico to Cataño. The CORCO tankage totals some 13 million bbl, of which 8 million bbl is operational. Five million bbl is not functional but could be partially or wholly repaired and restored to operation. The pipeline to Cataño is shut down but is also estimated as restorable to service.

The dock facilities and operational tankage are operated by CORCO as a terminalling and storage facility. In the period from 1988 through 1991, when Arochem was operational, CORCO leased over 5 mmbbl of tankage to Arochem, together with tanker/barge dock and truck loading rack facilities. Today, tankage is leased to PREPA (1.5 mmbbls for residual fuel storage), to two of the island's major distributors, and to a number of third parties.

¹⁴Since CORCO's shut-down, all Puerto Rico's aviation gasoline demand has been met from imports.

Arochem, Guayanilla

The Arochem facility comprises two processing trains that were originally built by CORCO. They have the combined capacity to process 60,000-80,000 bpd of light crude oil or "condensate" ranging in gravity from 38° to 70° API. The crude units produce naphtha, jet fuel, diesel and residual fuel. Of these, the last three would generally be sold directly as finished products or as feedstocks.¹⁵ The naphtha normally is fed into a 32,500 bpd catalytic reformer with associated petrochemicals units similar to those at the nearby Phillips refinery. Together, these units produce a mixture of LPG, gasoline, and benzene, toluene and xylene petrochemicals products. Box 4 summarizes the main Arochem processing units.

During the period of preparation of this report, the Arochem facility was sold at auction to First Oil, the owners of the CAPECO refinery in San Juan. The new company is to be known as Gulf Chemical Corporation under First Oil's license to use the Gulf name. Currently, Gulf Chemical is seeking financing for plant modifications to meet EPA standards and to enhance processing capability. The company's reported intention is to re-start operations, process 60,000+ bpd of feedstock and product fuels and petrochemicals products as discussed above.

**PROCESSING CONFIGURATION
AROCHEM**

	<u>bpcd</u>	
Crude/condensate	75000	
Naphtha hydrotreating	34500	reformer feed
Catalytic reformer	30000	low pressure bi-metallic catalyst
Pentane/hexane isomerization	12000	
BTX aromatics extraction	17000	
Toluene hydrodealkylation	2800	

Construction: None under way

BOX 4

The Arochem facility possesses very little of its own tankage, only some 26 small tanks comprising 206,000 bbl of working capacity. In order to function, the facility is reliant on using dock facilities, tankage and truck loading facilities leased from third parties, notably CORCO. Specifically, when operational, Arochem is serviced by the following facilities:

¹⁵The residuum product is typically very low in sulfur and other contaminants and therefore commands a premium as a cat cracker feedstock or high quality No.6 residual fuel blendstock.

1. Dock facilities owned and operated by CORCO for tanker intake of crude oil/condensate and product output by barge
2. Truck loading rack owned and operated by CORCO
3. LPG storage and terminalling facility owned and operated by Procaribe
4. Joint venture dock at nearby Tallaboa controlled by the Port Authority of Puerto Rico and operated by CORCO and Procaribe.

Peerless Oil & Chemical and Union Carbide Caribe, Inc., Guayanilla

The Peerless refinery is located in the same vicinity as CORCO/Arochem. Originally constructed as a petrochemical plant, it was converted to a refinery and began processing crude oil in 1978. Because of the design of the plant, it is able to process only light low sulfur crudes and condensate from such sources as North Africa and the Pacific. It is a simple distillation refinery with a nominal capacity of 8,000 bpd. Recently, it has been processing around 2,000 bpd of condensate and, with added blendstocks from island refiners, producing small volumes of gasoline, distillates and residual fuel.

Peerless has been a supplier of naphtha-type JP4 jet fuel to the U.S. military. With the military's switch to kerosene-based JP8, Peerless has had to re-evaluate its strategy. At the time of this study, Peerless was reportedly considering installing a distillate hydro-treater and hydrogen plant so that it could produce JP8. Its reported intention was to raise throughput to as much as 35,000 bpd.

Peerless leases tankage from an adjacent Union Carbide facility. In 1980, the Carbide facility constituted a major ethylene cracking complex processing around 30,000 bpd of naphtha feed and producing ethylene, polyethylene and various by-products. The naphtha cracker was subsequently shut down, dismantled and relocated to Argentina. The Union Carbide off-sites facilities remained, however, and today Peerless uses around 1.5 mmbbls of Union Carbide tankage.

3.3.4 Petroleum Supply/Demand Balances

As mentioned elsewhere in this report, Puerto Rico has no domestic oil or gas production. Therefore, all petroleum either processed or consumed on the island is imported. Island refineries export selected products, notably petrochemicals and lubricating oils, principally to the U.S. Mainland. Additional fuels products - notably gasoline and residual fuel - are imported to make up deficits between Puerto Rican refinery production and Puerto Rican demand.

Table 13 gives a detailed breakdown of crude oil imports into Puerto Rico for 1992. Puerto Rico has traditionally imported a small volume of Alaskan North Slope crude, although this dropped to zero in 1992. The island's main sources are regional producers; 77% of total imports come from Venezuela, Colombia, Ecuador and Mexico. 46% of the island's total feedstock imports come from Venezuela, with Phillips (naphtha) and Caribbean Petroleum (crude oil) being especially linked to Venezuelan supplies. One-third of raw material imports - and thus refinery inputs - comprise non-crude oil feedstocks (mainly naphtha). This compares to 8.5% non-crude feedstock inputs for U.S. Mainland refineries.

Table 13

Puerto Rico Petroleum Imports (gross) - 1992					
COUNTRY OF ORIGIN	CRUDE OIL FEEDSTOCKS MBPD	NON-CRUDE FEEDSTOCKS MBPD	PRODUCT MBPD	TOTAL MBPD	TOTAL %
VENEZUELA/ NETH ANTILLES	31.5	29.6	36.6	97.6	46.5%
COLOMBIA	25.3		12.3	37.5	17.9%
ECUADOR	11.8		1.2	12.9	6.2%
MEXICO	9.6		4.1	13.7	6.5%
SAUDI ARABIA	5.5			5.5	2.6%
INDIA		4.6		4.6	2.2%
UK		4.4	1.1	5.4	2.6%
US MAINLAND			7.3	7.3	3.5%
USVI			0.5	0.5	0.2%
OTHER	6.0	8.0	11.0	25.0	11.9%
TOTAL	89.6	46.5	73.9	210.0	100.0%
Note: 1. Data are taken from EIA sources with adjustments. 2. Non-crude feedstocks include naphtha (mainly for Phillips), residua and vacuum gasoils together with gasoline blendstocks.					

Table 14 illustrates petroleum product and blendstock import and export movements between Puerto Rico and the U.S. Mainland for 1991. Much of the exports to the U.S.A. are from the Sun and Phillips refineries to clients and other refineries within the Sun and Phillips Mainland systems.

Table 14

PETROLEUM EXPORTS TO U.S.A./IMPORTS FROM U.S.A. - 1991 (Source: EIA Petroleum Supply Annual)				
	Exports To U.S.A.		Imports From U.S.A.	
	P.R.	U.S.V.I	P.R.	U.S.V.I.
Gasoline	--	44.2		0.8
Jet	9.4	16.4	0.4	
Kero	8.0			
Distillate	0.0	51.8	1.6	
Resid	--	52.8	1.0	
Petrochem Naphtha	9.0	--		
Lubes	6.3	--	0.4	0.12
Other Products (incl waxes)	1.3	--	1.8 ¹	0.03 ¹
Petroleum Coke				3.1
LPG			0.2	
Asphalt & Road Oil				0.05
Unfinished Oils	1.3	66.0		
Gasoline Blendstocks	0.7	4.0		
TOTAL PRODUCTS	36.0	235.2	5.4	4.1
Crude Oil			4.0	107
Notes:				
1. Special naphthas				

Table 15 indicates an overall supply-demand balance for Puerto Rico for 1992. This incorporates island refinery production, exports and imports, and distinguishes island economy from internal refinery demand. Table 16 summarizes supply and import dependency for key fuels products.

Table 15

PUERTO RICO SUPPLY-DEMAND BALANCE 1992							
Product	Economy	Refinery	Total Demand	Production 1992	Imports 1992	Exports 1992	Net 1992
LPG & REF GAS	5.0		5.0	2.1	3.4	0.5	5.0
MOTOR GASOLINE	53.2		53.2	45.3	12.6	4.7	53.2
AVIATION GASOLINE	1.0		1.0	0.0	1.0	0.0	1.0
AVIATION JP4	0.0		0.0	3.2	0.0	3.1	0.0
AVIATION KERO-JET	12.8		12.8	10.0	3.0	0.2	12.8
BURNING KEROSENE	1.3		1.3	1.3	0.0	0.0	1.3
DIESEL/NO2:							
- PREPA COMB CYCLE	18.9		18.9				
- OTHER	8.0		8.0				
- TOTAL DISTILLATE	26.9	0.0	26.9	14.0	14.3	1.4	26.9
RESIDUAL FUEL:							
- PREPA	58.7		58.7				
- BUNKERS	1.9		1.9				
- INDUSTRY	1.0	4.1	5.1				
TOTAL RESID	61.6	4.1	65.7	32.0	38.4	4.7	65.7
OTHER PRODUCTS:							
- PROCESS GAS	0.4	5.0	5.4	5.4	0.0	0.0	5.4
- PETROLEUM COKE	0.0	0.5	0.5	0.5	0.0	0.0	0.5
- LUBES & WAXES	1.4	0.0	1.4	8.6	0.2	7.4	1.4
- PITCH & ASPHALT	2.9	0.0	2.9	0.9	2.0	0.0	2.9
- SOLVENTS/ MISCL	0.2	0.0	0.2	0.2	0.0	0.0	0.2
- PETROCHEMICALS	0.0	0.0	0.0	20.2	0.0	20.2	0.0
TOTAL OTHER	4.9	5.5	10.4	35.8	2.2	27.6	10.4
GRAND TOTAL	166.7	9.6	176.3	143.7	74.9	42.2	176.3
Estimates are derived from several sources:							
1. DACO statistics							
2. Purvin & Gertz report, "Strategic Options for the Puerto Rico Petroleum and Related Products Industry", April 1993.							
3. EIA import, export and refinery production data							

Table 16

Puerto Rico Petroleum Demand, Production and Import Dependency - 1992				
Key Fuels Products	Non Refinery Demand (bpd)	Island Refinery Production (bpd)	Net Product Imports (bpd)	Product Import Dependency (%)
LPG	5,000	2,100	2,900	58%
Gasoline (motor & aviation)	54,200	45,300	8,900	16%
Jet/kero	14,100	11,300	2,800	20%
Diesel/No2	26,900	14,000	12,900	48%
Residual Fuel	61,600	32,900	33,600	55%
Other*	4,900			
Total**	166,700	105,600	61,100	36.6%
* includes refinery gas, lubes & waxes, solvents/misc. and asphalt. ** refinery demand is an additional 9600 bpd gas, coke, resid				

As can be seen from the table, island refineries' production (net of refinery fuel) corresponded to 80% of island economy consumption in 1992. The proportions of demand met by island refineries for individual products, however, varied widely. Among the major products, import dependencies are highest for LPG (58%), residual fuel (55%) and diesel/No.2 (48%), followed by kero-jet at 20% and gasoline at 16%. Largest net import volumes are for residual fuel (33,000 bpd) and diesel/No.2 (12,900 bpd), reflecting PREPA's requirements, and for gasoline (8,900 bpd). Among the minor products, 100% of aviation gasoline is imported and two-thirds of pitch and asphalt. These dependencies on finished product imports compare to 7.6% for the U.S. Mainland.

Exports comprise predominantly non-fuel petrochemicals (20,200 bpd), lubes and waxes (7,400 bpd), with lesser volumes of JP4 (until the U.S. military changed to JP8) plus cross-traded motor gasoline and residual fuel. The effects of refining sector developments on import dependency are discussed under "Supply Outlook".

3.3.5 Petroleum Distribution, Storage and Logistics

Because of its history of refining activity, Puerto Rico possesses extensive tankage for petroleum feedstocks and products. Table 17 shows the breakdown of tankage on the island by energy sub-sector (namely refineries, wholesaler/distributor and PREPA), and Table 18 by operating status. Total active storage is 23.7 million bbl. An additional 6 million bbl of storage in need of repair exists, principally at the CORCO facility. 80% of the island's active tankage is located at refinery sites. 14% is owned by PREPA and only 6% by wholesalers/ distributors.

Table 19 illustrates the location of tankage on the island by geographic region. Consistent with the location of all refineries except Caribbean Petroleum on the South Coast, and the majority

of PREPA's power stations along the South Coast, 83% of the island's active tankage is located along the South Coast. The remaining 17% is located in the Greater San Juan area. Of this, nearly half is tankage in the Caribbean Petroleum refinery. The balance is tankage at the Esso/Shell/Texaco Cataño terminal, at the San Juan airport and at the two PREPA power stations in San Juan. Less than 1% of the island's tankage is located in the Northwest region.

Of the total 23.7 million barrels of tankage in active use, some 28.7% is in crude oil and naphtha/ condensate feedstock service. Approximately 19% is dedicated to motor gasoline and 15.5% to light and middle distillates products.¹⁶ 21.7% is in residual fuel service, 1.3% LPG, and 1.6% is used for lubricating oils and waxes. The balance of 12.2% comprises tankage for petrochemicals products and refinery intermediate products.

¹⁶This includes aviation fuels, kerosene, diesel and No.2.

Table 17

TANKAGE NUMBERS AND CAPACITIES BY SUPPLY SUB-SECTOR & SERVICE								
Service	Refineries		PREPA		Others		Total	
	Tanks	Bbls	Tanks	Bbls	Tanks	Bbls	Tanks	Bbls
1 Feedstocks/ Intermediates								
a) Crude Oil	13	2,813,000	0	0	0	0	13	2,813,000
B) Naphtha/Condensate	18	3,973,000	0	0	0	0	18	3,973,000
C) Intermediates	18	1,250,000	0	0	0	0	18	1,250,000
	49	8,036,000	0	0	0	0	49	8,036,000
2 LPG Products	55	116,000	0	0	287	206,140	342	322,140
3 Light Clean Products								
A) Motor Gasoline	48	4 025,000	0	0	14	492,000	62	4,517,000
B) BTX and Derivatives	53	1 539,000	0	0	0	0	53	1,539,000
C) Solvents	4	16,000	0	0	1	7,000	5	23,000
	105	5,580,000	0	0	15	499,000	120	6,079,000
4 Mid-Clean Products								
A) Aviation Fuel	7	526,000	0	0	29	478,000	36	1,004,000
B) Kerosene	6	341,000	0	0	2	9,000	8	350,000
C) Diesel/ No 2/ Distillate	20	1,554,000	20	662,000	5	117,000	45	2,333,000
	33	2,421,000	20	662,000	36	604,000	89	3,687,000
5 Dirty/Heavy Products								
A) Residual	30	2,336,000	16	2,744,000	3	80,000	49	5,160,000
B) Lubes/ Waxes	14	372,000	0	0	9	30,000	23	402,000
C) Asphalt	0	0	0	0	0	0	0	0
	44	2,708,000	16	2,744,000	12	110,000	72	5,562,000
6 Unallocated/Unknown	0	0	0	0	5	4,200	5	4,200
Total - All Classes	286	18,861,000	36	3,406,000	355	1,423,340	677	23,690,340

Table 18

SUMMARY OF TANK STATUS BY OPERATING STATUS AND SERVICE						
Service Class	**In Use**		**In Need of Repair**		**Total**	
	Tanks	Bbls	Tanks	Bbls	Tanks	Bbls
1. Feedstocks/ Intermediates	49	8,036,000	21	5,185,000	68	13,221,000
2. LPG Products	342	322,140	0	0	342	322,140
3. Light Clean Products	120	6,079,000	6	339,000	126	6,418,000
4. Mid-Clean Products	89	3,687,000	6	118,000	95	3,805,000
5. Dirty/Heavy Products	72	5,562,000	3	187,000	75	5,749,000
6. Unallocated/Unknown	5	4,200	6	133,000	11	137,200
Total All Classes	677	23,690,340	42	5,962,000	719	29,652,340

Table 19

SUMMARY OF TANKAGE BY REGION						
Service Class	**In Use**		**In Need of Repair**		Total	
	Tanks	Bbls	Tanks	Bbls	Tank	Bbls
Northwest	95	15,956	0	0	95	15,956
San Juan	190	3,955,667	3	107,000	193	4,062,667
Southeast	200	8,987,499	0	0	200	8,987,499
Southwest	187	10,727,018	39	5,855,000	226	16,582,018
Vieques	5	4,200	0	0	5	4,200
Total All Classes	677	23,690,340	42	5,962,000	719	29,652,340

Table 20 indicates estimated actual inventories by major raw material and product, with a breakdown by sub-sector. In this instance, CORCO tankage leased by wholesalers/distributors or PREPA is shown under those categories rather than under refineries (as is the case with). As can be seen from this table, typical inventories on the island stand well below available tankage capacity.¹⁷ On the basis that an inventory level of around two-thirds of shell capacity represents "full" use of the tankage¹⁸, island LPG tankage appears nearly fully utilized at 59.5% - with a possibility of tightness should demand continue to grow. With inventory levels in the range of 45-50%, tankage for crude oil, lubes and residual fuel also appears to be relatively well utilized. Distillates inventories (kero-jet, diesel, No2) appear significantly below available tankage capacity. At very low levels versus available shell capacity are motor gasoline and petrochemicals, at 28% and 23% respectively. This is not totally unexpected however, since the Arochem facility being shutdown means that very substantial volumes (5+ million bbls) of tankage geared to light feedstock and product are potentially idle. A restart of the Arochem facility would appreciably alter this picture, as discussed under *Supply Outlook*. At present, however, it would appear that island inventories stand at roughly 30% of total tankage shell capacity.

Table 21 contains estimates of available inventories for key fuels products expressed in bbls and as "days of demand". In developing these estimates, a distinction was made between finished product inventory on the one hand (held by refiners, distributors and major consumers), and feedstock inventory (held by refiners only) on the other. It was assumed that (in an emergency) finished products tanks could be drawn down to the level of undrawable bottoms. Conversely, for practical operational reasons, it is generally not possible to do the same with raw materials/intermediates tankage.

Inventory effectively available in finished products tankage was estimated as total available inventory minus undrawable bottoms. Raw materials and intermediates effective product availability was estimated by (1) subtracting undrawable bottoms from gross inventory to obtain drawable inventory, (2) taking two-thirds of the drawable inventory to obtain effective usable inventory and (3) converting usable inventory to typical product yields based on average refinery production patterns.

On this basis, (and assuming correct underlying tankage, inventory and demand estimates), it can be seen that Puerto Rico typically operates with a total of around 33 days of demand in island tankage. Days availability however varies somewhat between products, from a high of 39 days for LPG to a low of 29 days for motor gasoline. Puerto Rico inventory levels for gasoline, jet/kero and diesel/No2 days in inventory are all comparable to Mainland levels. Levels are moderately lower overall and for residual fuel, 33.4/35 versus 41 days. The major exception is LPG. U.S. mainland inventories of LPG are higher, although this may be for a range of reasons.

¹⁷The data in Table 20 were taken from a 1991 survey by DACO. EIA data for stocks at "active refineries" on Puerto Rico are believed broadly consistent, recognizing that it has not been possible to always distinguish between stocks held at a physical location (notably the CORCO facility) and the account (e.g. PREPA) under which those stocks are held.

¹⁸This is because tankage is used to maintain ullage, i.e. space, as well as stock.

Table 20

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INVENTORY "BEST ESTIMATE" FY 1989/90						
	* INVENTORY *				Tankage Capacity (Bbls)	Total Inventory As % of Total Shell Capacity
	Active Refineries	PREPA	Major Distribtrs/ Inactive Refineries	Totals		
1. Feedstocks/Intermediates						
A) Crude Oil	1,377,000	0	0	1,377,000	2,813,000	49.0%
B) Naphtha/Condensate	813,000	0	0	813,000	3,973,000	20.5%
C) Light Intermediates	0	0	0	0	702,000	0.0%
F) Heavy Intermediates	0	0	0	0	548,000	0.0%
	2,190,000	0	0	2,190,000	8,036,000	27.3%
2. LPG Products						
A) LPG/Butane	47,000	0	144,700	191,700	322,140	59.5%
	47,000	0	144,700	191,700	322,140	59.5%
3. Light Clean Products						
A) Motor Gasoline	633,100	0	650,000	1,283,100	4,517,000	28.4%
B) Petrochemicals	363,400		0	363,400	1,562,000	23.3%
	996,500	0	650,000	1,646,500	6,079,000	27.1%
4. Mid-Clean Products						
A) Aviation Fuel/ Kerosene ¹	297,500	0	200,000	497,500	1,354,000	36.7%
B) Diesel/No.2/Distillate	578,800	273,972	70,000	922,772	2,333,000	39.6%
	876,300	273,972	270,000	1,420,272	3,687,000	38.5%
5. Dirty/Heavy Products						
A) Residual/Asphalt	848,300	1,438,356	69,200	2,355,856	5,160,000	45.7%
B) Lubes/Waxes	203,500	0	0	203,500	402,000	50.6%
	1,051,800	1,438,356	69,200	2,559,356	5,562,000	46.0%
Total - All Classes	5,161,600	1,712,328	1,133,900	8,007,828	23,686,140	33.8%

NOTES:
1. Includes aviation gasoline, kero-jet and burning kerosene.
SOURCES:
DACO data for 1989/90 plus adjustments based on DoE team judgement.

Table 21

ESTIMATED MAXIMUM PRODUCT AVAILABILITY FROM TANKAGE						
	Usable Inventory in Tankage bbls	Actual Product in Tankage bbls	Potential Product Ex Usable Feedstock bbls	Actual + Potential Product bbls	Island Demand (Non- Refinery) bbls/day	Product Availability Days Demand
1. Feedstocks/Intermediates						
- Crude Oil	779,880					
- Naphtha/Condensate	408,500					
- Intermediates	109,980					
2. Key Fuels Products						
- LPG/Butane	175,593	175,593	19,045	194,639	5,000	39.0
- Motor Gasoline	1,057,250	1,057,250	529,693	1,586,943	54,200	29.0
- Aviation Fuel/Kerosene ¹	429,800	429,800	86,002	515,802	15,100	34.0
- Diesel/No.2	774,722	774,722	193,563	968,285	26,900	35.0
- Residual ²	2,097,856	2,097,856	80,266	2,178,122	61,600	35.0
Totals	5,883,581	4,535,221	908,569	5,443,790	162,800	33.4
Notes:						
1. Includes kero-jet, aviation gasoline and burning kerosene.						
2. Includes residual fuel, pitch and asphalt.						
3. Potential yield of key products ex feedstock is less than usable feedstock in tankage because production of petrochemicals and specialty products is excluded, as are refinery fuel and loss.						
4. Sources for inventory were DACO data FY 1989/90 for inventories and calendar 1992 data for demand. Inventories for "active refineries" have, according to EIA data, altered little between FY 1989/90 and calendar 1992. Since these constitute the bulk of island stock, it is estimated the estimates of days of demand on hand are reasonable.

Figure 6

As discussed earlier, the bulk of island tankage is located at refinery sites on the South Coast, whereas the bulk of demand is in the San Juan area. A clean products pipeline exists, which runs from CORCO to Cataño in San Juan. It has a capacity of approximately 24,000 bpd but is shut down. Consequently, primary movements of both clean and dirty products are:

- by barge from South Coast refineries to San Juan (the Esso/Shell/ Texaco Cataño terminal) and to coastal PREPA generating stations
- by barge and tanker from Venezuela and other overseas locations into San Juan and PREPA power stations around the coast
- by truck from Caribbean Petroleum refinery and the nearby Esso/Shell/ Texaco Cataño terminal to local area markets and by local pipeline to San Juan Airport (for jet fuel)
- by truck from South Coast refineries to inland demand points

Figure 7 illustrates the main flows.

Puerto Rico is entirely dependent on marine transport for supplies of petroleum raw materials and also exports of petrochemicals, lubricating oils and other products. All phases of feedstock supply, product distribution, product imports and exports are thus highly dependent upon tanker and barge traffic into and out of the following key ports:

1. San Juan/Cataño
2. Sun, Yabucoa
3. Phillips, Guayama
4. CORCO/Arochem/Peerless, Guayanilla/Tallaboa

Figure 7

Table 22 details key features of these primary island docks. In the main, draft limitations constrain tanker sizes (principally crude and condensate) to 60,000 DWT (dead weight tons). The principal exception is Sun's dock at Yabucoa which can accommodate 100,000 ton vessels. Barges used for local trade are typically 50,000 to 60,000 gallon capacity (around 8,000 DWT).

Table 22

PRINCIPAL DOCKS FACILITIES			
Location	Companies	Max Draft (feet)	Max Capacity (dwt)
San Juan Bay	Caribbean Petroleum, Esso/Shell/Texaco	36	60,000
Yabucoa Bay	Sun Oil	45	100,000
Joos Bay (Guayama)	Phillips	37	65,000
Guayanilla Bay	CORCO/Arochem Peerless/Union Carbide	42	82,000
Tallaboa Bay	CORCO	37	60,000

The major tank truck loading facilities on the island exist at the refineries. Total combined truck rack loading capacity at the active refineries is approximately 28,000 bpd of predominantly clean products. Reactivation of Arochem would raise this to around 37,000 bpd. Island inventory of tank trucks comprises approximately 110 clean product (gasoline/ kero/jet/diesel/No2) and 40 LPG units.

3.4 Institutional and Regulatory Infrastructure

As in most mainland states, the institutional and regulatory infrastructure affecting energy in Puerto Rico is complex, with authority and responsibility shared among numerous organizations.

Currently, Puerto Rico has no energy office. An office existed for many years, assigned to the Governors's office, but its functions were transferred in 1990 to the Department of Consumer Affairs (DOCA), and all but one of the staff were reassigned to other functions. This arrangement has hindered the effectiveness of energy emergency planning in three regards. First, it has delayed the approval of Puerto Rico's energy emergency plan, which was completed in 1991 but has yet to be approved. Second, it has impeded communications with the local energy industry because DOCA is also the agency charged with administering petroleum product price control regulations (see Section 3.3.8 below). For example, none of the oil companies interviewed for this study were aware of the Puerto Rico energy emergency plan. Prior to the transfer, the energy office reportedly had good communications with the local energy industry. Third, the lack of staff has hindered the maintenance of an energy management information system which would provide basic data on petroleum demand and supplies in Puerto Rico.

Efforts are currently underway to strengthen energy planning in Puerto Rico. The Puerto Rico legislature recently enacted legislation, signed by the Governor, establishing an energy administration within an expanded Department of Natural Resources. A director is expected to be appointed in March 1994, and the reorganization of the energy functions is to be completed over the next 12 months.

Other elements of the institutional and regulatory infrastructure for electric power and petroleum are described in the two sections below.

3.4.1 *Electric Power*¹⁹

As noted earlier, virtually all electric power in Puerto Rico is distributed by the Puerto Rico Electric Power Authority, which is a public corporation and instrumentality of the Puerto Rican government. Under the 1941 authorizing legislation, as amended, PREPA has broad powers to make contracts; acquire property by eminent domain; borrow money and issue bonds; pledge its revenues to repay bonds; and determine, fix, charge and collect reasonable rates for electric service that are sufficient to pay operating expenses, make bond repayments and meet other obligations.

PREPA has sole authority to establish the rates it charges for electric service. It must hold public hearings before setting rates. Further, the Legislature may hold hearings and review the rates established. However, the Legislature has no veto power over rates unless PREPA has acted improperly in their establishment.

PREPA's rates for electric service include a fixed charge for each customer class, energy charges, demand charges for large commercial and industrial customers, and a fuel adjustment charge which reflects increases in the price of fuel oil above a base price of \$2.00 per

¹⁹All data in this section is from the 1992 PREPA OS.

barrel. Traditionally, residential customers who used small amounts of electricity each month have received a subsidy, paid by the Puerto Rican government, towards the cost of the fuel adjustment. In 1991, PREPA acted to reduce substantially the number of customers qualifying for a subsidy. Qualified customers now include public housing residents, lifeline customers, students, the elderly and the handicapped. In fiscal year 1992 an average of 30 percent of all residential customers were receiving subsidies.

PREPA is subject to all environmental regulations of the U.S. Environmental Protection Agency and regulations of the Commonwealth Environmental Quality Board.

3.4.2 Petroleum

Activities in the petroleum industry are subject to all environmental regulations of the U.S. Environmental Protection Agency and regulations of the Commonwealth Environmental Quality Board. Transportation of hazardous materials by water is subject to regulation by the Ports Authority.

Wholesale gasoline sales are subject to price regulations administered by Puerto Rico's Department of Consumer Affairs (DOCA).²⁰ The regulations limit the wholesale gross margins to specific amounts which are adjusted quarterly. In June 1993, the allowed wholesale margin was 14 cents. Controls on wholesale margins apply only to products refined in Puerto Rico; wholesale margins on imported products are uncontrolled. Price regulation of retail gasoline sales was repealed effective January 1994.

Gasoline price regulation was instituted in 1986 when the Puerto Rican government imposed a tax on gasoline and sought to prevent wholesalers and retailers from passing along the tax to consumers. Litigation between the government and petroleum marketers concerning this issue ensued and continues today.

Puerto Rico has a standby petroleum allocation program (Regulation 660) that was put into place more than a decade ago. It would not be used during an emergency except under extreme conditions.

Transportation of crude oil and petroleum products between Puerto Rico and the U.S. is subject to Jones Act provisions requiring the use of U.S. built and registered tankers.

Puerto Rico has established foreign trade zones in San Juan, Mayaguez and Penuelas to promote economic development. The latter zone is a petrochemical zone established for storage, blending and distribution of petroleum products. Raw materials imported into the zone and finished products exported from the zone are free of tariffs.

²⁰The description of the price regulations was provided by representatives of DOCA and Esso in separate conversations.

3.5 Energy Supply/Demand Outlook

3.5.1 *Energy Demand Outlook*

Almost all of Puerto Rico's primary energy needs are provided by petroleum products. This should continue to be the case through the year 2000, although other fuels are being considered for electric generation. Forecasting energy demand, then, is almost equivalent to forecasting petroleum demand.

Petroleum demand can be disaggregated into three categories: demand for fuel for electric generation, demand for motor gasoline, and demand for other uses. Petroleum demand for electric generation fuel comprised about 44 percent of total petroleum demand in 1992; these fuels were No. 2 and No. 6 fuel oil, and about three quarters of this demand consisted of No. 6 fuel oil. Demand for motor gasoline comprised 30 percent of total petroleum demand in 1992. Demand for other uses comprised the balance of petroleum demand: about 26 percent of total petroleum demand in 1992. Other petroleum demands include demands for: refinery and LPG gases, petroleum products used by refineries, aviation fuels, burning kerosene, non-PREPA distillate, asphalt, lubricants and solvents.

Petroleum demand for electric generation has fallen considerably since 1978, largely because the 1979-80 oil crisis led to sharp oil price increases and the U.S. recession that followed in late 1981 also affected the Puerto Rico economy. In recent years, however, demand for fuel for electric generation has been increasing, although it has not reached the levels it did in the mid-seventies. Demand for motor gasoline has increased greatly since the early to mid 1980's. This comes largely as the result of higher employment:²¹ more people need to drive to work more often. Petroleum demand for other uses has grown little over the period, and fluctuates considerably from year to year.

Although alternative fuels are being considered for electric generation and other uses in Puerto Rico, this forecast assumes that no significant additions to generating capacity will be made by the year 2000 that use fuels other than petroleum. The proposed coal co-generation plants, based on coal, LNG, or Orimulsion, were presumed not to have come online before FY 2000. Other power generation options, such as OTEC and solar, are in the proposal or planning stages.

To forecast petroleum demand for Puerto Rico, each major component of demand was constructed separately, to account for different information available for each sector. Once separate demands were forecast, these were added to form an aggregate petroleum demand.

The PREPA planning office provided us with electricity load forecasts and its consequent petroleum demand. The PREPA petroleum demand was calculated assuming that the 300MW Cogentrix plant would be online in mid-1995. Because the proposed Cogentrix plant has yet to be successfully sited, it is unlikely that it will be online even before 2000. Therefore, PREPA petroleum demand for electric generation had to be re-forecast to account for the Cogentrix plant's

²¹Higher employment in this sense means not only more people employed, but also employed people working more hours; Puerto Rico has a substantial part-time work force. About 80 percent of Puerto Rican workers worked 40 weeks or more in 1989; about 60 percent worked full time: more than 50 weeks at 35 more hours or more a week.

absence. This forecast was derived in the following manner. Actual PREPA oil consumption was compared to actual electricity demand for the FY 1989 through FY 1992. From this measure, the number of barrels of oil necessary to generate 1 KWh of electricity in each year was derived. These numbers so derived varied little from year to year. In subsequent years, the average annual number of barrels of oil needed per KWh was multiplied by the PREPA load forecast in order to obtain projected PREPA petroleum consumption.

The method for PREPA petroleum demand forecasting implicitly assumes the following: no major additions to generating capacity will be made before 2000 that are significantly more efficient than average; no major non-petroleum fueled²² co-generation facilities will come on line before the year 2000. These assumptions are reasonable given current PREPA plans and current conditions. Because petroleum demand for electric generation is tied to a load forecast, this forecast is the only one for which a range is not given.

Future demand for motor gasoline is estimated by officials at Esso, one of the largest Puerto Rican gasoline suppliers, to increase at a rate between 2 and 3 percent over the next several years. This is close to the historical annual growth of motor gasoline demand for FY 1982 through FY 1989. Although motor gasoline demand surged at the end of the eighties, it is doubtful that such a surge will be sustained over the next few years. The latest year for which data is available is FY 1989.

Future demand for other uses is estimated to be grow at an annual rate of between 1 and 3 percent. Although the low end of this range is close to the historical annualized growth rate for FY 1982-FY 1989, the high end of this range is somewhat above it. Higher growth rates are assumed because 1) American Airlines, the dominant airline in Puerto Rico, anticipates doubling its flights out of San Juan in the next few years, and 2) depressed petroleum prices could raise demand for petroleum products over the next few years.

As a consistency check, the percentage contribution of each sector to total petroleum demand was plotted for each forecast. In each case, the sectoral contribution to total demand was consistent with historical figures.

Total and sectoral energy demand for the average case is presented in Table 23. Average in this case means that motor gasoline demand is projected to grow at an annual rate of 2.5 percent, and other demand is projected to grow at an annual rate of 2 percent. Because the PREPA petroleum demand forecast was estimated based on PREPA electricity load forecasts, one PREPA petroleum forecast is used in this and all cases. The high growth forecast is presented in Table 24 and the low growth forecast is presented in Table 25.

²²Some facilities, notably the proposed 300MW Cogentrix coal co-generation facility, are in the proposal or planning stages; however, no work has started on any of these facilities; the Cogentrix facility has yet to be sited. Given the long lead times involved in building an electric generation facility, none of these are expected to come on line.

Table 23

FORECAST ENERGY DEMAND: AVERAGE GROWTH (Millions of bbls annually)									
Sector/FY	1993	1994	1995	1996	1997	1998	1999	2000	Annual ²³ Growth Rate
Motor Gasoline	21.5	22.0	22.6	23.1	23.7	24.3	24.9	25.6	2.50%
Electric Generation	28.4	29.5	30.4	31.6	32.5	33.7	34.9	36.1	3.41%
All Other	18.4	18.8	19.2	19.6	20.0	20.4	20.8	21.2	2.00%
Total	68.3	70.3	72.1	74.3	76.2	78.4	80.6	82.8	2.76%

Table 24

FORECAST ENERGY DEMAND: HIGH GROWTH (Millions of bbls annually)									
Sector/FY	1993	1994	1995	1996	1997	1998	1999	2000	Annual Growth Rate
Motor Gasoline	21.9	22.6	23.2	24.0	24.7	25.4	26.2	27.0	3.00%
Electric Generation	28.4	29.5	30.4	31.6	32.5	33.7	34.9	36.1	3.41%
All Other	19.2	19.8	20.4	21.0	21.6	22.3	23.0	23.7	3.00%
Total	69.5	71.8	74.0	76.6	78.9	81.4	84.1	86.8	3.17%

²³Growth rate means the average annualized growth rate over the FY 1993-2000 period.

Table 25

FORECAST ENERGY DEMAND: LOW GROWTH (Millions of bbls annually)									
Sector/FY	1993	1994	1995	1996	1997	1998	1999	2000	Annual Growth Rate
Motor Gasoline	21.0	21.5	21.9	22.3	22.8	23.2	23.7	24.2	2.00%
Electric Generation	28.4	29.5	30.4	31.6	32.5	33.7	34.9	36.1	3.41%
All Other	17.7	17.9	18.1	18.3	18.4	18.6	18.8	19.0	1.00%
Total	67.2	68.9	70.4	72.2	73.8	75.6	77.4	79.3	2.37%

3.5.2 Energy Supply Outlook

Petroleum Sector

For Puerto Rico, the 1980's represented a period of fluctuation in the state of its petroleum supply sector. The CORCO refinery shut down; the Arochem sub-section was formed, started up and then shut down; the Caribbean Gulf refinery was sold to First Oil to become Caribbean Petroleum and was shut down for a period in the late 1980's; the Peerless refinery, which was reported in 1980 as processing 8,000 bpd of feed, was processing 2,000 bpd by the early 1990's. On the investment side, Caribbean Petroleum underwent a de-bottlenecking project; new unit additions and revamps took place at the Sun and Arochem facilities²⁴. In terms of product quality, PREPA began to tighten its residual fuel specifications from a relatively easy-to-make 2.5% sulfur range with wide viscosity and metals allowances to lower sulfur (1.5 -1.0%), viscosity and metals.

For the last two years, Puerto Rican refining operations appear to be been stable. The Base Supply Outlook for 2000 has therefore been taken as a continuation of the present situation, i.e.,

- no major changes at active refineries and continuation of current throughputs
 - CAPECO 38,000 bpd
 - Sun 55,000 bpd
 - Phillips 50,000 bpd
 - Peerless 2,000 bpd
- Arochem either does not restart or restarts but does not remain in operation through 2000.

²⁴At Arochem, a naphtha fractionator was revamped into condensate crude distillation service and a new pentane/hexane isomerizer was installed. At Sun, a catalytic reformer for gasoline production was added.

Given the potential for both upward and downward variability in the island refining outlook, as discussed below, this Base Supply Outlook is considered a reasonable middle position.

Despite the current state of relative stability in the island refining sector, it is the authors' belief that this sector will be subject to local and international developments that could cause the year 2000 supply picture to be either markedly better or worse than that obtaining today. The future "*Business as Usual*" status of island refining will be a primary factor in determining future energy security and vulnerability. Island petroleum inventory levels and dependency on finished product imports will both be impacted.

Local Factors

The processing status of each island refinery (except CORCO) could change over the short or medium term:

- the **Caribbean Petroleum** refinery is located in what has become a densely populated suburb of San Juan. It has had difficulty complying with emissions targets set by the EPA/EQB and has had to cut back throughput on the cat cracker - its primary "value adding" unit - in order to reduce emissions to atmosphere. Further tightening of emissions and waste processing standards is possible, especially given the urban location. Concerns have been voiced that these developments could lead to shutdown of the refinery's process units with future operations continuing at the level of operating the refinery as a storage terminal and blending plant.
- the **Sun Oil** refinery is operating at throughputs well below its nominal capacity of 85,000 bpd. This is because the refinery's main economic goal of producing lubricating oils and waxes can be met at a crude throughput of around 55,000 bpd. In addition however, the refinery has the flexibility to produce lubes from a wide range of vacuum gasoil and residua feedstocks. These constitute only the heavier fractions of crude oil, can be directly processed at Sun into lubes but produce little distillate and essentially no gasoline. Today the refinery uses these feedstocks at a rate of around 5,000 bpd.

A conservative outlook for the Sun refinery is for it to concentrate increasingly on lubes production from gasoil/resid feedstocks and to cut crude intake and, consequently, output of gasoline, jet/kero and middle distillate fuels products²⁵.

- the **Phillips** refinery operates principally to produce petrochemicals with gasoline as a major co-product. Potential application of new Chevron technology at the refinery could increase its feedstock flexibility, cut feedstock costs, and improve plant viability. This would also lead to a reduction in its feedstock intake with some associated potential reduction in gasoline output.

²⁵Since the Sun refinery has very limited upgrading capability geared to fuels production, and because simple "hydro-skimming" operations are generally unprofitable in today's market, this outlook is far from extreme. Sun Oil recently cut back its Tulsa, Oklahoma refinery to a lubes-only operation.

- the **Peerless** refinery comprises only a simple distillation facility. In general, such refineries tend not to be profitable in today's market unless unique circumstances apply (such as access to local crudes or to specialty products markets). In addition, Peerless throughput has fallen from 8,000 bpd in 1980 to 2,000 bpd in 1992. The prospect must therefore be considered that this refinery will close by 2000. Alternatively, currently reported plans for expansion could result in a large increase in output to as much as 35,000 bpd, based on expanded production of military jet fuel (JP8).
- the **Arochem** facility could remain shutdown or could restart in the near term now that it has been successfully sold. Sustained operation would significantly boost the island's local production of fuels products, as well as petrochemicals, and raise island inventories.
- **major investments** at any island refinery would alter the supply picture. However, no construction projects are currently under way outside of Phillips acquisition of Chevron technology.
- the requirement for **diesel fuel** to have a maximum **sulfur content of 0.05%** from October 1993 puts all island refiners except Sun in the position of not being able to meet this quality without additional investment. Given the small volumes entailed, island diesel demand will likely be met by imports, with island refiners adapting production patterns and/or exporting conventional diesel.
- to maintain compliance with tightening EPA/EQB regulations, **PREPA is adopting stricter standards for its residual fuel**. Future requirements could be for less than 1% sulfur for all island generating stations together with already lowered targets for viscosity, metals and asphaltenes contents.²⁶ Such new standards will increase the price PREPA pays for residual fuel. They could also cause production difficulty for Caribbean Petroleum and Sun Yabucoa since they traditionally process crudes (including Venezuelan) that do not meet the sulfur specification and are high in metals. A shift to a 1% sulfur maximum, island wide, would probably cause these refineries to have to export their residual fuel output or alternatively, to purchase lower sulfur crude oils or high quality residual blendstock from Arochem if available. All options would increase supply costs. Purchase of low sulfur, medium gravity crude oil would however improve overall refinery yields and reduce emissions, including from Caribbean Petroleum's cat cracker.

Regional and International Factors

The Puerto Rico refineries operate as part of a global system, monitoring and subject to open market prices, setting operating targets and trading feedstock and product based on market conditions. These refineries and the Puerto Rico petroleum market are thus affected by developments occurring in the region and globally. Several developments are evident which will impact supply options, product import/exports and refining economics:

²⁶Fuel sulfur specifications as tight as 0.15% were discussed at a February 1994 energy conference in Puerto Rico.

- **new environmental regulations** will alter refining cost and regional demand patterns and trade flows. The Clean Air Act Amendments of 1990 and subsequent EPA regulations for reformulated fuels are having a major impact on U.S. mainland refining and supply. Puerto Rico is also subject to these and other important new federal regulations (for instance Oil Pollution Act, Resource Conservation & Recovery Act amendments).

These will raise the environmental and safety costs of island as well as Mainland refiners. They have been cited as reasons behind the recent closure of several Mainland refineries. Analysts have projected that additional closures are to come especially among refineries that are small, simple or financially weak.

Puerto Rico is in compliance with National Ambient Air Quality Standards on ozone pollution and therefore should not be required to consume reformulated gasoline (RFG). (The requirement for 0.05% sulfur diesel does however apply.) Several analysts, including the authors, have projected that Mainland requirements for RFG will lead to increased imports of gasoline into the U.S. with production opportunities for overseas refineries. Unfortunately, the Puerto Rican refineries are not well configured for RFG production and are unlikely to be able to take advantage of this new market opportunity. These same projections point to a likelihood of Mainland refiners exporting increasing volumes of conventional gasoline to the Caribbean and other regions. To the extent this practice develops, it will represent increased competition for Puerto Rican refiners in their local market.

- **regional refining developments** include major investments by Petroleos de Venezuela and also by TRINTOC in Trinidad to expand and upgrade export-oriented refineries. The effect of these investments will be to put higher volumes of clean products onto the market. In addition any change in circumstances that would lead the Hess USVI refinery to seek a share in the Puerto Rico market would also increase competition from nearby sources.
- **regional production developments** are taking place in Venezuela, Colombia, Ecuador and Mexico, all significant suppliers of crude oil to the Caribbean and Puerto Rico. In Venezuela and Ecuador, these developments center on heavier crude oils, whereas Colombia has recently found new light crude reserves.
- the **Jones Act** expires in 1997 and it is possible it may not be renewed. This would lower the cost for Puerto Rico refiners to ship product to the U.S. Mainland but conversely would reduce the cost of imports, notably from the U.S. Gulf Coast.

Overall, the prospects for the island refineries will hinge on their competitive economics versus Caribbean/Venezuelan and U.S. Gulf Coast refiners. In this regard, the island refineries possess a number of advantages but also significant disadvantages. The advantages are:

- specialty products and petrochemicals operations boost value added
- efficiently run: low manning levels, achieve U.S. service factor levels
- much of equipment is well depreciated (low capital carrying charge)

- Section 936 provides favorable tax treatment of profits
- Jones Act provides a measure of protection against imports from Mainland

The disadvantages are:

- small, lack economies of scale for new investments
- simple, limited upgrading capability
- no access to low cost fuel
- high electric power cost (165% of U.S. Mainland)
- limited local market
- subject to full EPA environmental and safety standards
- ports are limited draft; no access to VLCCs
- Jones Act constrains export trade to U.S.
- little or no local integration on semi-finished products.

Taking these factors into consideration, it is feasible that the island refining sector could maintain its activity, even grow. It is also possible that, by 2000, it will have suffered a significant further decline. Three supply outlooks have therefore been prepared:

1. Base

- no change to present operations as discussed earlier

2. Optimistic

- current refining activities are maintained
- Arochem restarts and stays in operation

3. Pessimistic

- Caribbean Petroleum shuts down processing operations and functions as a storage terminal
- Sun concentrates on lube oil production; gasoline output and inventories drop by 80%, jet, middle distillate and residual by 60%, lubes/wax output does not change
- Phillips utilizes new technology with the effect that LPG and gasoline output and inventories drop by 10%
- Peerless shuts down
- Arochem either does not restart or restarts but does not maintain operation.

Set out in Table 26 through Table 28 are quantitative estimates for key fuels products for each of the three year 2000 outlooks. The tables show refinery production, imports and days in inventory.

Table 26

BASE 2000 OUTLOOK ISLAND PRODUCTION & IMPORT DEPENDENCY <i>bbls/day</i>				
KEY PRODUCTS	NON-REFY DEMAND	REFY PRODN	PRODUCT IMPORTS	PRODUCT IMPORT DEPEND- ENCY
- LPG/BUTANE	11,240	2,100	9,140	81.3%
- MOTOR GASOLINE	66,689	45,300	21,389	32.1%
- AVIATION FUEL/KEROSENE(1)	22,773	11,300	11,473	50.4%
- DIESEL/No. 2	25,993	14,000	11,993	46.1%
- RESIDUAL(2)	86,139	32,000	54,139	62.9%
TOTALS	212,834	104,700	108,134	50.8%

Table 27

OPTIMISTIC 2000 OUTLOOK ISLAND PRODUCTION & IMPORT DEPENDENCY <i>bbls/day</i>				
KEY PRODUCTS	NON-REFY DEMAND	REFY PRODN	PRODUCT IMPORTS	PRODUCT IMPORT DEPEND- ENCY
- LPG/BUTANE	11,240	5,700	5,540	49.3%
- MOTOR GASOLINE	66,689	64,050	2,639	4.0%
- AVIATION FUEL/KEROSENE(1)	22,773	16,300	6,473	28.4%
- DIESEL/No. 2	25,993	23,500	2,493	9.6%
- RESIDUAL(2)	86,139	36,250	49,889	57.9%
TOTALS	212,834	145,800	67,034	31.5%

Table 28

PESSIMISTIC 2000 OUTLOOK ISLAND PRODUCTION & IMPORT DEPENDENCY <i>bbls/day</i>				
KEY PRODUCTS	NON-REFY DEMAND	REFY PRODN	PRODUCT IMPORTS	PRODUCT IMPORT DEPEND- ENCY
- LPG/BUTANE	11,240	900	10,340	92.0%
- MOTOR GASOLINE	66,689	17,800	48,889	73.3%
- AVIATION FUEL/KEROSENE	22,773	3,500	19,273	84.6%
- DIESEL/No. 2	25,993	2,500	23,493	90.4%
- RESIDUAL	86,139	9,300	76,839	89.2%
TOTALS	212,834	34,000	178,834	84.0%

Inventory estimates were made for the year 2000. These assume that wholesaler/distributor and PREPA inventories increase in line with growth in demand and that refinery inventories depend on level of refining activity. This situation would increase island inventories to 9 million bbls from an estimated 8 million in 1991.

Under the Base 2000 Outlook, island refiners supply some 49% of key fuels products demand, with 51% coming from imports. This compares to 19% dependency in 1992 on product imports. For LPG, Base 2000 dependency on imports is 81%, for residual fuel 63%, for jet/kero and middle distillates 45 - 50% and for gasoline 32%.

Under the Optimistic Outlook, the effect of sustained Arochem operation is to markedly lower import dependency and raise island stocks. Island refineries would supply over two thirds of key fuels products demand. Import dependency for all products except residual fuel would drop by 20 - 35%, to 10% or less for gasoline and middle distillate. Total island inventories would be around 12 million bbls versus 9 million for the Base Outlook.

Under the Pessimistic Outlook, Puerto Rico would become heavily dependent on finished product imports. Island refineries would supply only 16% of key fuels products demand. Import dependencies would be in the the 85 - 100% range for all products, except gasoline at close to 75%. It is estimated total island inventories would decline to 7.5 million bbls or lower, versus 9 million under the Base and 12 million under the Optimistic Outlooks.

One implication of these different outlooks is that there is a wide range of variability in Puerto Rico's future energy security depending on "BAU" refining developments. A second implication is that any strategy for assessing and ameliorating future energy security must take the island's refining situation fully into account. A third is that any actions that can be taken to sustain

and enhance island refining will in turn yield significant energy security benefits. These latter points are further discussed later in the report.

4 VULNERABILITY ASSESSMENT: INTRODUCTION AND SUMMARY

4.1 Introduction

Assessing the unique energy vulnerabilities of the insular areas was one of the core tasks of this study. This section first delineates Puerto Rico's unique vulnerabilities, essentially the factors in its energy and economy make-up that indicate a potentially greater risk versus the mainland of interruptions in physical oil supplies and/or susceptibility to a higher level of economic damage from oil supply disruptions. The methodologies used by the study team to assess the implications of the island's unique vulnerabilities are then outlined; in brief, a combination of approaches to analyze both the island's past record in global and local disruptions and its prospects under potential future disruptions. A primary goal here was to ascertain whether, in fact, the existence of additional vulnerabilities relative to the mainland does lead to greater loss of oil supplies and/or impacts on the island economies. The section concludes by summarizing the key findings from the vulnerability assessment, notably that, while concerns are most often raised over access to physical oil supplies, it is actual and potential damage to the island economy that is the primary consequence of its unique energy/economy vulnerability.

Sections 5 and 6 provide further details. Section 5 assesses Puerto Rico's energy vulnerability based on experience with past disruptions, and Section 6 considers the possible impacts of a range of future disruptions.

4.2 Factors That Contribute to Unique Energy Vulnerabilities

The insular areas have energy-related vulnerabilities that are unique or more severe than exist on the U.S. mainland. These vulnerabilities affect the petroleum supply systems, electric power systems, transportation systems, and the water supply systems. Ultimately, these vulnerabilities become vulnerabilities of the islands' economies. The factors contributing to Puerto Rico's vulnerability are described below.

4.2.1 *Petroleum Supply System Vulnerabilities*

The petroleum supply systems have the following unique vulnerabilities:

- Puerto Rico relies on petroleum for virtually all of its energy needs, whereas in the U.S. mainland, oil supplies only 40.6 percent of total energy needs.¹
- In Puerto Rico 100 percent of all petroleum supplies must be imported (vs. 40.7% in the U.S. mainland²).
- All petroleum entering the island must arrive by sea in tankers and barges. Unlike the U.S. mainland, the island has no land access to petroleum supplies. During an emergency, the island has no guarantee that tankers will be available to deliver supplies required.

¹EIA, *Annual Energy Review*, 1992.

²EIA, *Petroleum Supply Annual*, 1992.

- Puerto Rico has no deepwater ports and, thus, is not accessible by larger oil tankers. The largest ship that can deliver crude oil or product to Puerto Rico is 80,000 deadweight tons. It is estimated that about 75 percent of the available world tanker fleet capacity is in ships exceeding 80,000 dwt. Lightering and offshore mooring are feasible but costlier alternatives for handling larger oil tankers.
- The docks in Puerto Rico are a critical link in the island's petroleum supply system. The docks are essential for receiving all petroleum imports, and they are important for intra-island petroleum distribution via barges. In contrast, the U.S. mainland has an extensive petroleum pipeline network to distribute petroleum. An accident at the docks or in related locations such as the San Juan Bay shipping channel could inhibit petroleum resupply. As in many mainland areas, policies that allow public access to the docks compromise dock security.
- The petroleum refineries in Puerto Rico are 100 percent dependent on PREPA for electric power. In comparison, for both economy and reliability reasons, the average mainland refinery buys 73 percent of its power needs and generates 27 percent on-site.
- The refining sector in Puerto Rico is struggling economically to maintain profitable operations. One plausible scenario is that all refineries could shut down in the next few years. Loss of additional refinery capacity would further reduce on-island petroleum inventories. Mainland refineries are also struggling with changing market conditions and regulations, but unlike Puerto Rico no plausible scenario would include a total shutdown.

4.2.2 Electric Power System Vulnerabilities

The electric power system on Puerto Rico has the following unique vulnerabilities.

- PREPA produces 98 percent of its electricity using petroleum. It cannot switch fuels during an emergency. In comparison, in the 48 contiguous states only three percent of all electricity is generated from oil. Most areas of the mainland have a wider range of energy sources available, such as coal, nuclear energy, natural gas and hydro which provide lower, more stable electricity prices and greater ability to switch fuels when needed.
- All petroleum products used for electric power generation must be imported or refined locally from imported crude oil.
- PREPA is an island electric system. It does not have neighboring electric systems that can supply electric power during an emergency. As a result, to achieve levels of reliability comparable to the U.S. mainland, it must maintain larger capacity margins than U.S. mainland utilities, which increases electricity costs.
- PREPA's annual load factor is 75 percent (for comparison, the State of Florida average is 55 percent), which means that average electrical demand is 75 percent of the peak annual demand. This high load factor makes it more difficult to take units out of service for scheduled maintenance.

4.2.3 *Transportation System Vulnerabilities*

Transportation in Puerto Rico is almost totally dependent on petroleum. Thus, any petroleum supply disruption or price spike has an immediate impact on island transportation. In particular:

- Ground transportation is highly dependent on gasoline and the automobile.
- Public ground transportation options are limited. San Juan has a bus system, but has not had the resources to develop other options (e.g., fixed rail transit), despite having the population density that might support them.
- The airports in Puerto Rico are vital transportation links. San Juan's Luis Muñoz Marín International Airport is important to the Puerto Rico economy, and a growing hub for Caribbean air traffic. A severe break in the lone pipeline that supplies jet fuel to the airport would temporarily inconvenience economic activity. An oil disruption that caused a run-up in jet fuel prices would inhibit tourist and business traffic.

4.2.4 *Economic Vulnerabilities*

Puerto Rico's economy is more vulnerable to oil disruptions than the U. S. mainland economy. The vulnerability arises for three reasons:

- Puerto Rico's annual petroleum import bill is approximately 5.1% of GDP. In comparison, the oil import bill for the U.S. mainland is about 0.8% of GDP. Thus, higher oil prices caused by an oil disruption result in a much larger percentage wealth loss in Puerto Rico than in the mainland.
- Tourism is a major source of income for Puerto Rico. Tourism tends to decline disproportionately more than other economic sectors during the recessions that often follow global oil disruptions.
- Puerto Rico's manufacturers are at a competitive disadvantage compared to the mainland and other areas during global oil disruptions because they (and their electricity supplier) are unable to switch to substitute fuels. Thus, their costs of manufacturing will rise disproportionately.

4.3 Methodology

The previous subsection identified the factors that contribute to Puerto Rico's energy vulnerabilities. In order to identify and assess the implications of these factors, a combination of approaches was employed:

- Detailed historical data on petroleum and electricity supply, demand, flows, inventories and pricing were examined and compared with mainland data for periods covering recent oil supply disruptions.
- Island economy data were similarly evaluated and compared with mainland data.

- Reports prepared by island government agencies on the impacts of *past* global and local emergencies were examined.
- Scenarios were developed for possible *future* global oil disruptions of different magnitudes and locations. The impact of these disruptions on the island was estimated.
- Scenarios were developed for possible *future* local energy disruptions of different types and locations. The impacts of these disruptions were estimated.
- Island energy emergency response plans were reviewed.
- The physical vulnerabilities of the island petroleum and electricity supply systems were assessed through on-site inspection of facilities.
- Extensive interviews were conducted with island government personnel responsible for energy and emergency planning, and with industry personnel in the islands' refining, distribution, petroleum storage and electric utility sectors. These interviews served several purposes including:
 - relating first hand knowledge of experiences in prior emergencies
 - gaining perspectives on energy/economy outlooks, plans and potential for enhancing energy security
 - gaining insights into the adequacy of island government's energy and emergency institutions.

During the course of the study, substantial amounts of energy and economy data were obtained from island governments, energy organizations and from the Energy Information Administration. The reader should be aware however that complete data were not available for any of the islands. Where "hard" data were not available, either estimates were developed or reliance was placed on island reports, on the views of island officials and on the experience and judgement of the study team.

4.4 Findings and Lessons Learned

4.4.1 *Local Energy Supply Disruptions*

Historical experience and this analysis indicate that following the types of local emergencies studied, the petroleum industry on Puerto Rico can restore product flows to consumers in 30 days or less. This is done by:

- Restoring damaged facilities
- Drawing down on-island commercial inventories
- Acquiring products from other areas.

There is no history of prolonged shortages of petroleum products in any previous on-island emergency.

The principal vulnerabilities associated with local emergencies are not petroleum supplies. They are:

- Logistical problems in transporting products around the islands
 - Loading or off-loading crude oil and refined products in the event of damage to the docks or blockage of shipping channels.
 - Moving jet fuel to San Juan's Luis Muñoz Marín International Airport in the event of a Cataño pipeline break.
- Damage to island electric power distribution systems from hurricanes and other causes.

PREPA depends on petroleum for virtually all of its generation facilities. It can obtain supplies in a local emergency by:

- Using commercial oil inventories (their own and the oil industry's)
- Acquiring fuel off-island from various suppliers.

In addition, during local emergencies such as hurricanes, electric demand declines due to damage at homes and businesses, which further reduces the utility's need for petroleum.

4.4.2 Global Oil Disruptions

Several common themes are evident from examination of actual past and potential future global oil disruptions:

- *A major disruption among Latin American oil suppliers will have severe impacts on the Caribbean, with a sustained fall-off in refinery throughputs of 25 percent compared to 5 to 15 percent for the U.S. mainland.*

Of the insular areas, Puerto Rico would initially feel the greatest impact because of its near total reliance on Latin American oil.

- *A major disruption among Pacific and Middle Eastern suppliers will impact the Pacific islands more than the Caribbean islands.*

Simulations indicate that the Far East and U.S. west coast would be more severely disrupted than other regions. However, potential reallocation of Latin American crude into the Pacific Basin could cause supply difficulties for Puerto Rico.

- *Gasoline and distillate inventories are most likely to drop sharply in local disruptions.*

This phenomenon may be due to temporary panic purchasing and hoarding and to the island power authority needing to consume a higher proportion of distillate/diesel fuel under unstable load conditions.

- *Residual fuel inventories tend to be maintained or rise in both global and local disruptions (high sulfur resid tends to surplus).*

In both local and global disruptions, island electricity consumption tends to decline and, with it, demand for residual fuel for power generation. Consequently, residual fuel inventories tend to rise. In addition, evidence from the 1990-91 Persian Gulf Crisis and from simulations of potential disruptions indicates that high sulfur residual fuel tends to become an unwanted product in disruptions and therefore tends to surplus.

- *Inventory drops are short-lived because Puerto Rico has multiple sources of supply.*

In both Hurricane Hugo and the 1990-91 Persian Gulf Crisis, inventories that dropped sharply were generally restored to near normal levels in a month or less.

- *Today's oil market is highly integrated and responds very rapidly: local price dislocations are short-lived.*

Today, the petroleum crude and products market functions as a fast-moving, open commodities market with real-time computer-based trading and information systems linking several market centers and virtually all market players worldwide, including the refiners and distributors on Puerto Rico. Under this situation, the market reacts rapidly. Consequently, any local supply and price dislocations, such as might occur on the island, would be transmitted to the market and resolved quickly.

- *Petroleum prices in Puerto Rico will move with the market.*

With their almost total dependence on open-market petroleum for energy supplies, Puerto Rico will find its crude oil and product prices inevitably move with the market, i.e., the island will be a price taker subject to the full force of market price fluctuations.

- *High oil prices that accompany global oil disruptions do more harm to the insular economies than to the U.S. mainland.*

Historical evidence from past disruptions and economic model simulations of future disruptions both show that the percentage loss in Gross Domestic Product (GDP) is generally larger in the insular economies than in the overall U.S. economy. For example, in the scenario Global I (with inventory build) described earlier, the annual GDP loss in the overall U.S. economy is 1.2 percent, compared to a 2.3 percent loss in Puerto Rico. This result is not surprising in view of the insular area's heavier dependence on petroleum fuels. The island also experiences a double blow from oil disruptions. First, it suffers the direct impact of higher oil prices on its economy. Second, because the economy is so closely linked to the mainland economy, they suffer again when the higher oil prices cause a downturn in the mainland economy.

- *Higher oil prices, not the lack of oil supplies, are the major problem facing Puerto Rico during a global oil emergency.*

The availability of multiple sources of oil supply, the island's location along major shipping lanes in the greater Caribbean oil market, and the proximity of Hess' massive inventories minimize the likelihood that Puerto Rico would be without petroleum supplies any longer than would U.S. mainland areas. However, the island's total dependence on petroleum means that the Puerto Rico economy would be more severely affected than the mainland by the price spikes that accompany an oil disruption.

5 EXPERIENCE FROM PAST DISRUPTIONS

5.1 Global Disruptions

Since October of 1973, the world supply of crude oil has been interrupted four times by political and economic forces with their origins in the Middle East. In addition, the Alaskan Valdez oil spill and the Caribbean Hurricane Hugo provided examples of the effects of localized short duration accidental and natural calamities. This section reviews the characteristics of these global disruptions, their broad impacts and their specific effects on Puerto Rico/USVI.

5.1.1 *Characteristics of Global Oil Supply Disruptions*

The major global oil supply disruptions that have occurred since 1973 have entailed supply losses of up to 5 million bpd of crude and have lasted an average of six months. Future disruptions of as much as 10 million bpd are considered plausible, given the world's dependency on Middle Eastern crude oil.

All disruptions are accompanied by an initial price shock (at times exacerbated by consumer hoarding) and a period of hectic market activity. Underlying this activity and volatility are intense trading activity generally directed to securing replacement crude oil and product supplies, together with intense supply planning activity as oil companies re-allocate crude oil shipments, re-balance refinery operations and adjust product distribution patterns. This initial period appears to last 1-3 months. Assuming no follow-on disruption shocks, what emerges is the beginnings of a new – if jittery – market equilibrium where supply and demand have begun adjusting to the new circumstances. Prices are still generally high – and volatile – but stabilizing, and even subsiding, as elasticity effects begin to curb demand.

The disruption's second phase, which may be short or long lived depending on the circumstances, generally entails a subsidence of demand as elasticity effects spread through economies. By the end of the crisis, petroleum prices may be close to or even below pre-crisis levels.

The intensity of the price and supply impacts of the disruption depend on several factors, not just on the initial supply loss. These factors include:

- the quality of the crude lost Loss of light, sweet crude has a more serious market impact than loss of heavy, sour crude, since the former creates increased difficulty in producing light clean products (gasoline, jet fuel, diesel/heating oil) and thus leads to wider light-heavy product price differentials.
- the quantity and quality of replacement surge crude production
- the degree of pre-crisis slackness or tightness in the world refining system, especially as regards capability to upgrade residual cuts to light, clean products.
- the extent and type of any loss of refinery capacity, either as an element of the disruption itself or through some unrelated incident. Loss of sophisticated refineries with a high degree of upgrading capability will have a bigger impact than loss of simple "topping" refineries.

- the extent of military action, politically-inspired embargoes, or threat of war These can have several effects from raised demand for military jet and other fuels to curtailing commercial jet traffic to disrupting or raising the costs of petroleum transportation. A threat of impending war (as was the case in the Middle East Crisis) can elevate crude and products prices to levels higher than are justified by the underlying supply situation. This, in turn, leads to an offset whereby demand is suppressed below the level of supply. As a consequence, commercial supplies of crude oil build up for as long as the "threat of war" situation obtains
- the season of the year A disruption occurring in the third and fourth quarters is likely to put maximum pressure on jet fuel and distillate prices. Jet demand is not at its peak at this time of year, but demand for premium distillate components (as used in kerojet) to meet high volume and tightened quality for winter heating oil and residual fuel is peaking.

A disruption starting during the first quarter and leading into the second quarter is likely to have relatively less severe impact, since the second quarter is a time when seasonal demand is at a minimum. In addition, many refinery process unit shut-downs and turnarounds are normally timed for the second quarter. In an emergency, many of these can be curtailed or postponed, increasing available refining capacity.

A disruption starting in the second quarter and leading into the summer is likely to put maximum pressure on gasoline supply and pricing.

- the response measures taken, notably at the national and international levels Several nations possess crude and product reserves which they may decide to draw down (the most important being the U.S. SPR). In addition, nations may implement rationing or a variety of other measures to force conservation and constrain demand. The International Energy Agency and its member countries constitute the primary international organization for instituting and coordinating response measures.

5.1.2 *Middle East Crisis - Global Impacts*

Appendix B describes the main disruptions that have occurred since 1973 and discusses in detail the characteristics of the 1990-91 Middle East Crisis, including its impacts on the U.S. petroleum sector. This section discusses those characteristics in order to use the Middle East Crisis to set a context for gauging the scale of impact of potential future disruptions.

The Middle East crisis represents a more appropriate model for future disruptions than do the earlier major crises. By 1990:

- the world refining sector had grown in processing sophistication and geographical diversity
- certain OPEC crude producers had become integrated into the downstream operations of consuming nations, a trend that is continuing

- the world petroleum market had changed in that most transactions had become linked to the spot market, active futures markets had evolved, and – thanks to electronics – the many players in the market were highly inter-linked so that price signals were transmitted to the market rapidly and globally

In addition, the magnitude and duration of the Middle East crisis were relatively "typical".

Each of the factors described in *Section 5.1.1* played a role in shaping the petroleum supply and market effects of the 1990-91 Middle East Crisis:

- An initial loss of 4.3 million bpd of Iraqi and Kuwaiti crudes in August 1990 was eliminated within four months by surge production from Saudi Arabia and other OPEC and non-OPEC countries. As a result, the average supply loss over the course of the disruption was closer to 450,000 bpd.
- The quality of the crude lost was close to the world average and similar to the quality of replacement crude from surge production.
- The pre-crisis global refinery upgrading situation was already tight. The timing of the disruption (third quarter leading into fourth quarter) allied to loss of sophisticated Kuwaiti export refining capacity, panic purchasing of kerosene and naphtha in the Far East, elevated demands for military jet, and the onset of winter product requirements all combined to create severe light-heavy product price differentials in the first few months of the crisis, with kero-jet price peaking at \$60/bbl.
- The elasticity effects of high light product prices, the crude supply over-run caused by the fear of war, and then the activation of simultaneous IEA measures and SPR drawdown led to a subsidence of demand and prices by the mid-January 1991 onset of Operation Desert Storm. The threat of war, in suppressing demand, had led to the build-up of some 80-100 million bbls of heavier Saudi and Iranian crudes in temporary storage or tankers.
- By the end of the crisis in April 1991, crude and product prices were back to pre-crisis levels.

The 1990-91 Middle East Crisis thus had all the attributes of a major crisis. In considering how it should be regarded in planning for future crises, however, several factors need to be considered:

1. Despite the crisis occurring in the Persian Gulf, no production from regional suppliers other than Iraq and Kuwait was seriously affected. If Saudi surge capacity had been constrained or Middle East production otherwise interfered with, the crisis would have been much more difficult to cope with.
2. The Allies were fortunate; things that could have gone wrong did not:
 - initial commercial stocks were high
 - replacement crude supply exceeded expectations

- outside of Kuwait, Iraq and the fire at the Aramco, Ras Tanura, refinery, there was a general lack of refinery outages. This was in marked contrast to Winter 1989-90 when several outages at large U.S. refineries created significant product supply problems.
- versus 1989-90, the Winter weather was milder (outside Europe)
- civilian jet traffic dropped, offsetting increased military jet/distillate demand
- the threat of impending war existed long enough to sustain damagingly high oil prices but also to allow creation of an extra 80-100 million bbl "reserve" of crude oil¹
- the U.S. economy was already moving toward recession in the Summer of 1990, easing petroleum demand.

The bulk of the world's proven oil reserves lie in the Middle East and the general projection is that the U.S.A., Europe and Pacific regions will become increasingly dependent on Middle Eastern oil supplies. Given this prospect, together with the "what if's" surrounding the Middle East Crisis, it is clear that Crisis provides a solid reference point for future disruptions, but does not correspond to a "worst case" for planning purposes.

5.1.3 *Middle East Crisis - Puerto Rico Petroleum Supply Impact*

As a market economy, Puerto Rico was subject to the full impact of the Middle East Crisis. Analysis of island petroleum sector data and survey of island refiners and distributors has enabled a detailed picture to be created of the impacts of the Crisis.

All of these sources point to the conclusion that the island survived the Crisis without any dislocation of oil supplies. Specific points are discussed below:

- Puerto Rico refineries appear to have had no difficulties obtaining feedstocks early in the Crisis, although non-regional crude supplies were lost (see *Figure 8*).
- Refinery inputs and production (*Figures 9 and 10*) surged above business-as-usual levels at the onset of the Crisis. They dropped substantially by February 1991 (to 3.8 million bbls per month from a pre-Crisis 5.5 million bbls per month), in line with the general collapse in refinery runs and demand, but then immediately recovered. At no time during the Crisis did refinery production drop below the levels obtaining in 1988-89. (During part of this period, the CAPECO refinery was shutdown and the Arochem refinery was not fully operational.)
- Refinery runs were supported by exports of 200,000-500,000 bbl per month of military jet fuel (JP4) in support of Desert Storm.
- Exports of petroleum products initially increased, in line with the early surge in refinery production, and then dropped as U.S. and global demand fell off (see *Figure 11*).

¹ This consisted mainly of heavier Saudi and Iranian crude oils that could not readily be sold because of their power quality.

- Imports of petroleum products initially dropped moderately and later increased to levels higher than pre-Crisis business-as-usual, signifying no difficulty in obtaining supplies (see *Figure 12*).
- Total refinery stocks had been rising immediately prior to the beginning of the Crisis. At the onset of the Crisis, they increased further, in line with the higher refinery runs. Subsequently, total stocks dropped back briefly to pre-Crisis levels before again advancing. At no time during the Crisis did total refinery stocks fall below average pre-Crisis levels (see *Figure 13*). Inventories of crude oil, other refinery feedstocks, and finished products at the end of the Crisis stood at above pre-Crisis levels (except for kero-jet, which was down slightly).
 - Gasoline stocks followed a pattern similar to total stocks with an initial doubling of inventory, presumably as island refiners covered these positions (see *Figure 14*).
 - Kerojet and kerosene stocks initially increased then fell in the first quarter of 1991, probably in line with the high output of military fuels from island refineries in support of Desert Storm (see *Figure 15*).
 - Residual fuel refinery stocks showed no significant decline but built up by 50% during the fourth quarter of 1990 before subsiding to levels still above pre-Crisis business-as-usual (see *Figure 16*).
 - Crude oil stocks showed a sharp variation over the course of the Crisis – beginning with an initial small rise followed by a near halving in the fourth quarter of 1990 followed by a re-doubling in the first quarter of 1991 (see *Figure 17*). The sharp decline may have signified a temporary difficulty in obtaining supplies, although that seems unlikely given the availability of local (Venezuelan, Mexican) surge production and the inventory patterns of products on the island.
 - "Unfinished oils" stocks, principally naphtha feedstock to the Phillips refinery and smaller amounts of vacuum gas oil/residuum feedstock for the Sun refinery, were unaffected by the Crisis apart from a drop in the first month (see *Figure 18*).
- Monthly changes in petroleum product consumption could not be estimated, but demand appears to have risen over the course of the Crisis, driven upward by underlying strong economic growth in Puerto Rico at the time.

Figure 8

Source: EIA data

Figure 9

Source: EIA data

Figure 10

Source: EIA data

Figure 11

Source: EIA data

Figure 12

Source: EIA data

Figure 13

Source: EIA data

Figure 14

Source: EIA data

Figure 15

Source: EIA data

Figure 16

Source: EIA data

Figure 17

Source: EIA data

Figure 18

Source: EIA data

While Puerto Rico survived the 1990-91 Persian Gulf Crisis without any disruption of supplies, it is clear that the impacts on the petroleum supply sector were more marked on the Island than on the U.S. mainland. *Table 29* demonstrates a greater volatility in refinery inputs and stocks in the relatively small island petroleum sector, suggesting a higher sensitivity to the effects of disruption. For instance, the initial decision (by island refiners) to build up gasoline and kero-jet inventories was important to Puerto Rico's management of the Crisis. If the supplies for this build-up had not been sought or had been difficult to obtain, compensating measures would have been required in order to maintain island inventories above a critical level.

Table 29

PUERTO RICO VS. U.S. MAINLAND PETROLEUM SECTOR IMPACTS			
maximum changes during Crisis versus July 1990	Mainland	Puerto Rico (refineries only)	
refinery output	- 10.6%	+ 27%	- 31%
stocks:			
- crude	- 6.2%	+ 13%	- 44%
- gasoline	- 5.0%	+ 98%	+ 6%
- kero-jet	- 15.5%	+ 155%	- 3%
- distillate	- 28.0%	+ 52%	- 47%
- residual	- 12.0%	- 16%	+51%
demand: (8/90 - 3/91 vs. 8/89 - 3/90)			
- total	- 2.4%	increased?	
Sources: EIA data			

Petroleum prices on Puerto Rico were, however, generally consistent with U.S. Mainland prices.² Product price spikes on Puerto Rico were less extreme than on the Mainland:

- Refiners' acquisition cost of crude oil on Puerto Rico tracked U.S. refiners' acquisition cost before, during and after the Crisis (see *Figure 19*). The only significant difference was that the October 1990 price peak was higher on the Mainland (around \$36/bbl versus \$31/bbl on Puerto Rico).
- A comparison of average Puerto Rico retail gasoline price with average U.S. refiners' price for gasoline, while not totally comparable, showed a close correspondence between Puerto Rico and Mainland prices. The main difference was that, during the

²Mainland price series were taken from EIA *Petroleum Marketing Monthly* and *Petroleum Marketing Annual*. Puerto Rico data were supplied by the Department of Consumer Affairs.

Crisis, Puerto Rico retail prices fell back more rapidly than Mainland prices in the fourth quarter of 1990, i.e. the Puerto Rico gasoline consumer was apparently less severely affected than the Mainland consumer (see *Figure 20*).

- Residual fuel prices show a similar pattern. PREPA average residual fuel acquisition cost closely tracked U.S. Mainland refiners' average realization for residual fuel before, during and after the Crisis (see *Figure 21*). The generally lower price for PREPA residual fuel may relate to differences in the average fuel (sulfur) quality between the two price series. Again, PREPA prices showed a less severe peak than Mainland prices during the Crisis.³

³The rise in distillate and residual fuel oil prices raised PREPA's monthly average fuel generation costs from 0.025 \$/kwh to 0.041 \$/kwh, or an increase of approximately 40%.

Figure 19

Figure 20

Figure 21

5.1.4 Impact on Electric System

The Persian Gulf crisis had little adverse impact upon the electric system in Puerto Rico. The crisis had no measurable effect on electric demand and no adverse impact upon electric supply. The next sections discuss the effect of the Persian Gulf crisis upon electric demand and electric supply. The discussion of electric supply will include a discussion of the financial impact of an increase in the price of oil resulting from the Persian Gulf crisis

Electric Demand

There was no measurable effect on electric sales as a result of the Persian Gulf crisis. This

Figure 22

can be shown by the difference in predicted and actual net generation.⁴ Figure 15 shows the difference between predicted⁵ and actual net generation in Puerto Rico during FY 1991, when the Persian Gulf

⁴Net generation is gross generation minus electric use by power plant auxiliary equipment

⁵Net generation appeared to have a strong seasonal component. Predicted net generation is the predicted seasonally adjusted net generation. Predicted net generation was obtained by regressing net generation on the lagged dependent variables net generation one month ago, net generation six months ago, and net generation twelve months ago. This regression was performed to account for seasonal effects in net generation. Data were obtained from PREPA from July 1988 through June 1993. Predictions could be made for generation from July 1989 through June 1993. The sharp drop in predicted September

crisis occurred. Although actual net generation was below predicted net generation for the months of November 1990 through February 1991, this difference was statistically insignificant, and not caused by the Persian Gulf crisis.⁶ This suggests that there was little or no impact on electric demand as a result of the Persian Gulf crisis.

Electric Supply

The Persian Gulf crisis had little apparent effect on aggregate fuel costs or electric rates. This was because PREPA's fuel costs, and, consequently, electric rates increased significantly in FY 1990, one year before the Gulf crisis occurred. This increase in PREPA fuel costs in FY 1990 occurred because the cold U.S. mainland winter in 1989-1990 increased the market price of fuel oil in FY 1990. Had this event not occurred, the 1990-91 Persian Gulf crisis would have had an obvious impact upon electric rates. PREPA fuel costs are displayed in Figure 23. During the Gulf crisis, PREPA experienced no problems in purchasing sufficient quantities of fuel to meet its generating needs.

1990 net generation is an effect of Hurricane Hugo, when net generation was greatly reduced

⁶This conclusion was drawn by performing the following regression: $y_t = \alpha_t + \beta_t GULF_t + \gamma HUGO_t + \delta TEMP_t + u_t$, where y_t is the difference between predicted and actual net generation at time t . In effect, y_t is the monthly random variation in net generation *not* caused by seasonal effects. $GULF_t$ is a dummy variable to measure the effects of the Persian Gulf crisis, and was set to one if the time period corresponded to the time of the Persian Gulf Crisis--August 1990 through February 1991 and zero otherwise. $HUGO_t$ is a dummy variable to account for the effects of Hurricane Hugo, and is set to 1 if the month is September and zero otherwise. $TEMP_t$ is San Juan mean temperature in Celsius and is included to account for any climactic anomalies that may have occurred over the period. The variable u_t is a random error term to account for effects unrelated to the Persian Gulf crisis, Hurricane Hugo, or seasonal effects. This equation is estimated using monthly data from July 1989 through June 1993. The estimate of the coefficient of interest, β , was positive and not significant at any reasonable level.

Figure 23

PREPA purchased relatively more No. 6 fuel oil in FY 1991 than in previous or subsequent years. As a result, total FY 1991 fuel costs, which were \$462 million, were actually lower than FY 1990 fuel costs, which were \$467.6 million. In addition to being less expensive than No. 2 fuel oil, the price of No. 6 fuel oil was less affected than No. 2 fuel oil in the Persian Gulf crisis. The average price of No. 6 fuel oil during the crisis⁷ was \$19.92 per barrel, an increase of almost 19% over the previous year's average price for the comparable period. The average price of No. 2 fuel oil during the crisis was \$33.04 per barrel, an increase of more than 25% over the previous year's average price for the comparable period. The ability to substitute the less expensive No. 6 fuel oil for the more expensive No. 2 fuel oil mitigated the adverse price impact of the Persian Gulf crisis.

PREPA profitability was not adversely affected by the Persian Gulf crisis. In fact, FY 1991 operating profits were \$232 million, an increase over the FY 1990 profits of \$161 million. PREPA cash reserves were sufficient to weather the crisis.⁸

⁷Defined for pricing purposes as August 1990 through January 1991, when the U.S. began to offer crude oil for sale from the Strategic Petroleum Reserve (SPR).

⁸PREPA had \$18.9 million in cash reserves at the end of FY 1991. This was considerably lower than the \$67.8 million cash reserves at the end of FY 1990. Cash reserves were lower at the end of FY 1991 as a result of higher negative net cashflows used for capital and other related financing activities, and were *not* related to higher fuel prices in FY 1991.

5.1.5 *Economic Impacts*

The Puerto Rico economy was severely impacted by global oil supply disruptions of 1973-74 and 1979-80. The impact of the 1990-91 Persian Gulf oil supply disruption appears to have been slight to moderate. The two earlier oil supply disruptions precipitated global recessions, as well as recessions in Puerto Rico. The Puerto Rico recessions were more severe than the corresponding U.S. recessions. In the case of the Persian Gulf crisis, the U.S. economy independently entered a recession in the third quarter of CY 1990, which likely had a greater impact on the Puerto Rico economy than the increase in oil prices. The following sections will discuss the measurement of economic losses from oil supply disruptions and the effects of each crisis on the Puerto Rico economy, including a discussion of the impact upon economic activity, unemployment, and prices.

Measurement of Economic Losses

Global oil supply disruptions adversely affect the economies of oil consuming areas such as the U.S. territories. Losses in GDP and terms of trade are widely used measures of economic impact. Other indicators are changes in inflation and unemployment rates.

Global oil disruptions generally cause GDP losses because the sudden increase in oil prices pushes the production cost of many goods and services higher than the price many consumers are willing to pay, which causes a decline in real consumption expenditures. The disruption usually also creates a more unfavorable investment climate, which leads to a decline in investment expenditures. This process occurs worldwide. Hence, foreign demand for goods and services produced in the U.S. mainland and insular areas declines. Consumption expenditures, investment expenditures and sales of goods to other countries are all major components of GDP. As these fall, so does GDP.

GDP losses tend to be larger in the insular areas because of their total dependence on imported petroleum. In addition, most of the insular areas' economies (except American Samoa's and Puerto Rico's) are heavily tourism based, and tourism is disproportionately affected in the worldwide recessions that result from global oil supply disruptions.

Oil disruptions also generally cause a transfer of wealth from net oil consuming economies to net oil producing economies. This loss is measured by the terms of trade loss. When oil consumers pay more for petroleum products in an oil disruption, they have less money to spend on other items. Hence, the oil price increase is equivalent to a wealth loss for oil consumers. This wealth that oil consumers lose is transferred to oil producers, who are receiving higher prices for their oil. Roughly, the terms of trade loss can be measured by changes in an economy's oil import bill. An economy that is relatively more dependent upon imports for oil consumption will suffer a relatively greater terms of trade loss in global oil supply disruptions.

Terms of trade losses resulting from a global oil supply disruption are proportionally larger in the insular areas than the U.S. mainland for two reasons. First, the insular areas cannot currently use other forms of energy in place of oil during a global oil supply disruption, hence their oil consumption will decrease proportionately less than will the U.S. mainland's. This fact as well as the fact that oil demand is generally inelastic implies that the insular areas' oil expenditures increase proportionately more than does the U.S. mainland's, during a global oil supply disruption. Second, unlike the U.S. mainland, all insular area oil must be imported, which means that oil import expenditures will increase proportionately more than the U.S. mainland's.

Past Global Oil Supply Disruptions

Where data were available, we calculated several indicators of the economic effect of past and potential global oil disruptions: GDP losses, proportionate terms of trade losses, inflationary effects, and a comparison of unemployment changes of past global oil supply disruptions.

The economic effects of past oil supply disruptions are shown in Table 30. The data capture what occurred in the recessions that resulted after the oil supply disruption. Data shown are average annual compounded growth rates, change in the growth rates, peak unemployment rates and changes from the pre-disruption unemployment rates, inflation rate and change in the inflation rate.

Table 30

Economic Effects of Past Global Oil Supply Disruptions			
	Disruption		
	1973-74	1979-80	1990-91
GDP Growth Rate			
U.S. mainland	-0.72%	-2.18%	0.72%
Puerto Rico	-1.3%	-1.3%	3.01%
Change from Pre-Crisis GDP Growth Rate			
U.S. mainland	-5.8%	-4.7%	-1.8%
Puerto Rico	-6.25%	-13.98%	-0.5%
Peak Unemployment Rate			
U.S. mainland	8.5%	9.7%	7.4%
Puerto Rico	20.0%	23.5%	16.5%
Change from Pre-Crisis Unemployment Rate			
U.S. mainland	2.9%	3.9%	1.9%
Puerto Rico	8.3%	6.0%	2.2%
Inflation Rate			
U.S. mainland	9.6%	11.2%	4.7%
Puerto Rico	14.2%	9.1%	4.1%
Change from Pre-Crisis Inflation Rate			
U.S. mainland	3.6%	0.5%	0.4%
Puerto Rico	11.0%	4.1%	0.2%

Several conclusions may be drawn from this table:

- The 1973-74, 1979-80 oil crises affected the Puerto Rico economy more adversely than the U.S. mainland economy. The economic impact was moderately more severe in Puerto Rico in the 1973-74 crisis and much more severe in the 1979-80 crisis.

- The 1990-91 Persian Gulf crisis had a slight, if any, long term economic impact in Puerto Rico. A larger impact likely resulted from the U.S. recession that independently began in the third quarter of CY 1990. The Puerto Rico economy appears to have been no more severely impacted than the U.S. mainland economy as a result of the crisis.

Each oil crisis is discussed in further detail in the sections that follow.

The 1973-74 Oil Crisis

The 1973-74 oil crisis initiated a worldwide recession, which in the U.S. mainland began in November 1973 and ended in March 1975.⁹ At that time, it was the longest and worst recession that the mainland¹⁰ U.S. had experienced since the end of World War II. The oil crisis also precipitated a recession in Puerto Rico that began and ended at about the same time as the U.S. recession.

The recession in Puerto Rico was somewhat more severe than it was in the U.S. Although the impact of the oil crisis on U.S. and Puerto Rico economic activity was similar, Puerto Rico employment was much more severely affected than U.S. employment; the rate of inflation was also somewhat worse in Puerto Rico. Puerto Rico gross internal product¹¹ fell by an average annual rate of 1.3% in the FY 1974-75 period,¹² while U.S. GDP¹³ fell at an average annual rate of 0.72% in the CY 1974-1975 period. The Puerto Rico unemployment rate increased from 12.3% in FY 1974 to its peak of 19.3% in FY 1976, while U.S. unemployment increased from 4.9% in CY 1973 to its peak of 8.5% in CY 1975. Inflation in Puerto Rico¹⁴ increased from an annual average rate of 3.21% in FY 1973 to an average annual rate of 14.18% in the FY 1974-75 period. Inflation in the U.S.¹⁵ increased an annual average rate of 6.03% in CY 1973 to an average annual rate of 9.6% in the CY 1974-75 period.

However, Puerto Rico recovered more strongly than the U.S. after the recession. In the subsequent recovery, annual economic growth was considerably better in Puerto Rico: Puerto Rico

⁹Source : *Survey of Current Business*, August 1993, p. C-7.

¹⁰"Mainland" U.S. means all 50 states, including Alaska and Hawaii.

¹¹Gross internal product is analogous to gross domestic product.

¹²Fiscal years are Puerto Rico fiscal years, which end on June 30.

¹³U.S. GDP and all other U.S. economic data are obtained from *Economic Report of the President*, January 1993.

¹⁴Inflation was measured as the compounded change in the price index for working families, which in Spanish is called *Indice de familia obrera*. Source: Junta de Planificacion de Puerto Rico, *Informe Economico al Gobernador*, 1992, Chapter 9, p. 3.

¹⁵U.S. inflation was measured by the compounded change in the Consumer Price Index for all urban consumers.

gross internal product grew at an average annual rate of 4.50%¹⁶ between FY 1975 and FY 1981; the comparable U.S. annual GDP growth rate was 2.75%.

As in the U.S., Puerto Rico became more efficient in its energy usage after the 1973-74 oil crisis. Energy usage, as measured by kilowatt hours consumed per dollar of gross internal product fell by a total of 18% between FY 1975 and FY 1980.

The 1979-80 Oil Crisis

The 1979-80 oil crisis precipitated a worldwide recession, which, in the U.S. mainland, began in July 1981 and ended in November 1982.¹⁷ In the U.S., the recession was the worst since the Great Depression. Puerto Rico experienced a recession that was significantly more severe than the U.S. recession.

Puerto Rico economic activity and employment were more adversely affected than U.S. economic activity and employment in this recession. Although inflation was not as high in Puerto Rico as a result of the oil crisis, the declines in economic activity and employment indicate a more severe recession in Puerto Rico than in the U.S. Puerto Rico gross internal product fell at an average annual rate of 1.3% in the FY 1982-83 period. Annual U.S. GDP fell by 2.18% in CY 1982 and increased by 3.82% in CY 1983, for an average annual increase of 0.82% in the CY 1982-83 period. The unemployment rate climbed in Puerto Rico from 18.1% in FY 1981 to its peak of 23.5% in FY 1983. The U.S. unemployment rate climbed from 7.6% in CY 1981 to its peak of 9.7% in CY 1982. Inflation was slightly lower in Puerto Rico than in the U.S. over this period. The average annual rate of Puerto Rico inflation increased from 5.00% in FY 1979 and to 9.09% in the FY 1981-82 period. The average annual rate of U.S. mainland inflation increased from 10.75% in CY 1979 to 11.24% in CY 1981-82, and U.S. mainland inflation had been approximately 6.41% in the CY 1976-78 period.

The Puerto Rico economy subsequently recovered from the recession beginning in FY 1984. The Puerto Rico recovery was stronger than the U.S. recovery. Puerto Rico gross internal product grew at very strong average annual rate of 5.4% over the FY 1984-89 period, which is somewhat higher than the 3.7% average annual rate of economic growth in the U.S. over the comparable period.

Puerto Rico, like the U.S. mainland, made further improvements in energy efficiency during the 1980s, lowering kWh consumed per dollar of gross internal product by a total of 20% between FY 1980 and FY 1989. This results in part from energy efficiency improvements and in part from the continued shift in manufacturing away from petrochemicals and refining and toward pharmaceuticals, scientific instruments, and electronics.

¹⁶Source: Puerto Rico Planning Board, *The Current Oil Situation and the Previous Crises*, October 1990. English translation September 1993.

¹⁷The oil crisis also sparked a short, relatively mild U.S. recession beginning in January 1980 and ending in July the same year.

The Persian Gulf Crisis

The Persian Gulf crisis was limited in duration, which limited the economic impact worldwide and in Puerto Rico. The U.S. had independently entered a recession starting in the third quarter of FY 1990, which also affected the Puerto Rico economy. The U.S. recession officially ended in April 1991, and has been followed by an extremely weak recovery by historic standards. The effects of the U.S. recession likely dominate any effect of the Persian Gulf crisis on Puerto Rico gross product and unemployment. However, the Persian Gulf crisis may have increased the rate of inflation in Puerto Rico, although inflationary impacts were similar in both Puerto Rico and the U.S. mainland.

Economic activity slowed and unemployment increased in Puerto Rico in FY 1991, but these changes were relatively less adverse than in the U.S. Puerto Rico gross internal product growth was 2.30% in FY 1991, the year of the Persian Gulf crisis, and 3.71% the previous fiscal year. The average annual rate of growth over the two-year period was 3.01%. The U.S. economic growth rate was -1.17% in CY 1991, and 0.81% in CY 1990. The average annual rate of growth over the comparable period in the U.S. was 0.72%. Note that the Puerto Rico economy grew faster than the U.S. economy during this period. This largely resulted from the fact that, unlike the U.S. mainland, the Puerto Rico real estate and construction sectors remained relatively strong. The Puerto Rico unemployment rate was 15.2% in FY 1991, about one percentage point higher than the FY 1990 unemployment rate of 14.3%. The U.S. unemployment rates were respectively 6.7% in CY 1991 and 5.5% in CY 1990. This shows that the impact on unemployment was about the same in both Puerto Rico and the U.S. The Puerto Rico FY 1991 inflation rate, at 4.36%, was barely above the FY 1990 rate of 3.88%. The impact on the U.S. inflation rate was similar, but the U.S. inflation rate was higher in this period.

The Persian Gulf crisis *per se* had little impact on the Puerto Rico economy. Although Puerto Rico economic activity slowed in FY 1991, this was mostly a result of the U.S. recession, which began in the third quarter of CY 1990. The Puerto Rico inflation rate increased slightly as a result of the crisis, but it was low and likely had little or no adverse effect on economic activity.

Summary of Economic Impacts

The three oil crises of 1973-74, 1979-80 and 1990-91 affected the Puerto Rico economy to various degrees. The impacts of the 1973-74 and 1979-80 crises were severe. The Puerto Rico economy was somewhat more adversely affected than the U.S. mainland economy as a result of the 1973-74 crisis. After this recession, Puerto Rico enjoyed high economic growth until the 1979-80 oil crisis, which severely impacted the Puerto Rico economy both absolutely and relative to the U.S. economy. The Puerto Rico economy also recovered from this crisis, and sustained growth significantly higher than U.S. economic growth through the 1980s economic boom. The Persian Gulf crisis has had only a slight, if any, impact on the Puerto Rico economy. A larger impact resulted from the U.S. recession that began in the third quarter of CY 1990. The Puerto Rico economy has fared better than the U.S. economy in this regard. Also, Puerto Rico inflation was moderate and similar to the U.S. mainland during the 1990-91 crisis.

As a result of these oil crises, Puerto Rico has become much more energy efficient and experienced a shift away from petroleum intensive industries. In fact, Puerto Rico used only slightly more total petroleum in FY 1989 than it did in FY 1977.

5.2 Local Disruptions - Puerto Rico

Puerto Rico must contend with the risk of natural disasters and accidents which impact petroleum supply. Hurricanes constitute the more persistent and frequent threat, although earthquakes are also a possibility. In addition, accidents can disrupt island petroleum supplies. Puerto Rico's refineries appear to have been relatively free from major fires or other disasters. However, a tanker problem in the San Juan Bay ship channel caused disruption to all shipping into San Juan for several days.

5.2.1 *Hurricane Hugo -- Puerto Rico Petroleum Supply Impacts*

Hurricane Hugo represents the most significant natural disaster or accident to have affected Puerto Rico's petroleum supply system. Set out below is a review of its main impacts.

Hurricane Hugo struck Puerto Rico in September 1989. Comparing data for August 1989 against data for September and later months has brought to light specific impacts. (See *Figures 7 through 21* for details.)

- September refinery production dropped 1.2 million bbls (30%) versus August, but recovered by November.

The production loss is believed to have been due to a mixture of causes: limited damage to refineries, precautionary refinery shut-downs initiated before arrival of the hurricane, and loss of local product demand immediately after the hurricane.

- Refinery total inventory¹⁸ dropped 1 million bbls (15%), of which:

feedstocks	- 250,000 bbls
gasoline	- 845,000 bbls
diesel/No.2	- 320,000 bbls
residual	+ 184,000 bbls, then - 437,000 bbls

The gasoline inventory drop was the most substantial (50%) but appears to have been part of a transition to sustained lower stock levels (see *Figure 14*). Residual fuel inventory initially increased. Total refinery stocks returned to normal levels by October 1989.

- Puerto Rico versus U.S. Mainland crude and product price differentials were unaffected (see *Figures 19 to 21*).

In all, the impact of Hugo was sharp but short-lived. Damage to refineries and the CORCO facility appears to have been limited; none of the major oil ports at CORCO, refineries, San Juan Bay, or PREPA power stations appears to have sustained enough damage to cause major outages. Thus, even if refineries had been down for some time, product imports would not have been restricted.

¹⁸No data were available on monthly distributors' or PREPA stocks.

5.2.2 *Impact on Electric System*

Hurricane Hugo had a moderate impact on the entire Puerto Rico electric system when it struck the east and northeast coasts of Puerto Rico in September 1989. However, local damage on the east and northeast coast was severe. Approximately 600,000 people, or just under 20% of the population, lost electric power. Power was restored to 90% of these individuals within a month,¹⁹ and was completely restored within six weeks. The outage resulted from downed transmission and distribution lines. Outages did not have an impact on emergency assistance activities.²⁰ The remainder of this section will describe the impact of Hugo on electric power demand; electric supply, including the generation, transmission, and distribution sub-systems; and the secondary impacts of the electric power losses.

Electric Power Demand

Hurricane Hugo had only a small, temporary effect on electric power demand. This can be shown by monthly net generation²¹ figures. Although there was a sharp drop in net electricity generation in September 1989, October 1989 net generation appears to have recovered to its previous levels and was in fact above its October 1988 level. This recovery corresponded with the restoration of the power supply system; power was restored by the end of October to all customers.

Net generation growth rates that take into account Hugo's impact also illustrate the negligible impact on long term demand. The FY 1990 growth rate in net generation, excluding September and October net generation, was 2.91%, which was higher than the FY 1991 figure of 2.18%. Growth rates excluding only September net generation were similar. Hence, Hugo had little, if any, effect on electric power demand.

Electric Power Supply

The damage that Hurricane Hugo inflicted on the electricity supply system was limited to transmission and distribution lines and public lighting in the north and northeast coastal areas. About 600,000 people lost power, which was restored to 90% of the affected population within a month and completely restored within six weeks. The Luis M. Marin International Airport, located in San Juan, was without power for approximately 48 hours, and major air operations were affected for almost four days after the hurricane. The Isla Grande airport, also located in San Juan, was able to continue operations. Power outages were the result of damage to the transmission and distribution systems.

Approximately eight miles of 38 kV transmission lines were downed as a result of Hugo. The transmission lines running between San Juan and Fajardo were particularly hard hit, and many transmission towers and distribution poles failed. Interestingly enough, many transmission tower and distribution pole failures were ascribed either to poor design, inappropriate design, or poor construc-

¹⁹Source: Louis L. Smith, "Hurricane Hugo in Puerto Rico," translated from "Huracán Hugo en Puerto Rico, (Desastras FEMA 0842)," April 2, 1990.

²⁰Source: "Natural Hazards Mitigation Plan, Commonwealth of Puerto Rico," April 1991 update.

²¹Net generation is defined as gross generation less electricity used by the utility's auxiliary equipment. It is the total amount of electricity initially transmitted.

tion.²² Approximately 100 miles of distribution lines were also downed. As a result of these transmission and distribution failures, voltage on generators had to be reduced for some hours to avoid damage to them. These transmission and distribution system losses represent a minuscule percentage of the PREPA transmission and distribution network, which includes 2200 miles of transmission lines and 25,000 miles of distribution lines. The reason that Hugo affected a large number of customers was that the downed lines were located in the heavily populated San Juan metropolitan area.

Secondary Effects

There were few secondary effects that could be ascribed to the loss of electricity. Secondary effects include the effect on telecommunications, water supply, and sanitation that can be ascribed to the loss of electricity. Electric outages had no deleterious effect on emergency assistance activities.

There were some limited adverse effects on the telecommunications system. The Puerto Rico Telephone Company was able to maintain 93% of its service, although there were brief periods during the storm when most service was interrupted. PREPA telecommunications operations²³ experienced only minimal outages as a result of Hugo. System congestion impeded incoming long distance calls, but outgoing long distance calls could be completed. Telecommunications failures were experienced by Office of Civil Defense and the U.S. Naval Station at Roosevelt Roads, which is located on the northeast coast of the island. The Civil Defense backup telecommunications system, which keeps contact with 80 municipalities in Puerto Rico "was only marginally successful"²⁴ as a result of equipment incompatibility. The naval station was without local phone service for three days; it had no Restoration Service Priority. However, it was able to maintain communications with CINCLANT (Commander-in-Chief, Atlantic) and with forces at sea.

The Carraízo dam, which supplies water to the San Juan metropolitan area, overflowed as a result of the loss of electricity and subsequent backup generator failure.

There were no epidemics. A potential problem was avoided when the carcasses of 100,000 animals killed in the storm were quickly buried.

5.2.3 Economic Impact

There was little or no long-term economic impact in Puerto Rico as a result of Hurricane Hugo. Real gross internal product grew at rate of 3.71% in FY 1990. Although growth was lower in FY 1990 than in earlier years, the lower growth rate is a consequence of slower mainland U.S. economic growth. The average FY 1990 unemployment rate in Puerto Rico was 14.3%,²⁵ slightly lower than its FY 1989 level and low by recent historic standards. These economic statistics represent a healthy,

²²Puerto Rico Department of Natural Resources, "Natural Hazards Mitigation Plan," April 1991 update, pp. 29-30.

²³Telecommunications are used to control transmission and distribution power flows.

²⁴Office of the Manager, National Communications System, *Hurricane Hugo and Loma Prieta Earthquake Telecommunications Impacts*, May 1990.

²⁵The FY 1990 labor force participation rate was slightly higher than recent historical rates, so the lower unemployment rate is not a result of large numbers of discouraged workers dropping out of the labor force.

expanding economy. While economic performance was not as good as in previous years, this can be attributed to the slowing U.S. mainland economy.

6. POTENTIAL IMPACTS OF FUTURE EMERGENCIES

The impacts of past global and local disruptions were examined in *Section 5*. In *Sections 6.1* and *6.2* below, the potential impacts of possible future disruptions are explored.

6.1 Impacts of Postulated Global Oil Supply Disruptions

Potential future global oil disruption scenarios were developed to examine the impacts on Puerto Rico and the U.S. Virgin Islands of different levels and types of crude loss and refining capacity loss. The scenarios are summarized in Table 31 and described further below.

- **Global I** represents a geographically widespread loss of medium and higher quality crude oils affecting producers in the Middle East, North Africa and the Pacific. PR/USVI refiners would be impacted directly by the lost Middle Eastern crudes and indirectly (through crude oil diversion) by the loss of high quality African and Pacific crudes.
- **Global II** represents a loss of crude oil supplies from regions on which the U.S. Virgin Islands and, especially, Puerto Rico refineries are heavily dependent, namely Latin America and secondarily West Africa. Impacts on PR/USVI refining throughputs would be expected to be substantial.
- **Global III** represents a situation akin to the 1990-91 Persian Gulf Crisis, but with the net loss of crude supply after production surges remaining larger than was the case in 1990/91. Impacts on PR/USVI refineries would be expected to be limited.

Variants of **Global I** and **II** incorporating refinery capacity losses were designed to examine the impacts on light product supply of loss of sophisticated capacity in the Middle East and Europe. In **Global III**, the variant was designed to explore the impact of an essentially total simultaneous loss of Puerto Rico and U.S. Virgin Islands refineries, e.g., through accidents and natural disaster. The implication of this variant is that petroleum product may have to be supplied entirely from off-island sources.

The analysis of the impacts of the global oil disruption scenarios was based in part on several models, including:

- DOE/EIA's Disruption Impact Simulator (DIS) Model. This projects overall market conditions, including world oil price, for a postulated disruption away from an underlying business as usual scenario. The model also projects impacts on the U.S. economy.
- EnSys' World/Regional Oil Refining, Logistics and Supply (WORLD) Model. This model integrates and simulates the activities and economics of the world-regional petroleum supply system. It outputs projected regional crude and product flows, refinery utilizations and detailed crude and product prices from base assumptions regarding disrupted supply, demand, refining capacity, transportation and the "marker" crude price.

- **The Puerto Rico Planning Board Macroeconomic Model.** This model consists of an econometric model linked to an input-output model. The model was used to simulate specific impacts on the Puerto Rico economy of the same global disruption scenarios simulated using DIS and WORLD. No macroeconomic model was available for any of the other insular areas. The Puerto Rico Planning Board model captures key effects needed for vulnerability analysis including impacts of world oil price level, interactions between the energy sector and other economy sectors and interactions between the Puerto Rico economy and the (disrupted) U.S. mainland economy.

EIA and the Puerto Rico Planning Board assisted in this study effort.

The prime purpose behind the analysis of potential year 2000 disruption scenarios was to gain a sense of how the Caribbean and Pacific insular areas could be affected (relative to the mainland) in disruptions of a world regional petroleum supply system that will have changed significantly from that obtaining today; also to explore disruptions of high severity by historical standards, as well as lesser disruptions similar to the 1990-91 Persian Gulf crisis.

Table 6.1

Potential Global Energy Disruptions			
Cases Examined (all Year 2000)			
Case (MMbpd)	I	II	III
Crisis Duration Months	6	6	6
Crude Loss Regions	Mid East, N. Africa Far East	Latin Am., W. Africa	Similar to 1990-91 Persian Gulf Crisis
Crude Loss Volume	9	6	4.3
U.S. SPR Draw	3.5	1.5	0
Foreign SPR Draw	1	0	0
Net Supply Loss	4.5	4.5	2.3 (2.0 Saudi surge production)
Crude Price (BAU \$22.90)			
- High Stock Build (\$/Bbl)	\$50	\$50	\$36
- Low Stock Build (\$/Bbl)	\$35	\$35	\$26
Case Variants	.5 Europe	.5 Europe	PR+USVI
- Refining Loss MMbpd	.5 P.G.	.5 P.G.	total loss

6.1.1 Year 2000 BAU Base Case

In constructing a basis for evaluating potential disruptions, EIA first developed a Year 2000 business-as-usual (BAU) case using EIA supply/demand projections and the EnSys *WORLD* Model.

The base case BAU 2000 results included the following features of particular interest to Puerto Rico and the Virgin Islands:

- A significant growth of refining in the Caribbean Basin region is projected by 2000 directed towards the production of reformulated gasoline for the U.S. market. The cost edge attributable to refiners in this region for reformulated gasoline production stems in part from presumed advantages in re-blending on the basis that (a) reformulated gasoline would constitute only a portion of total gasoline output and (b) the absence of "anti-dumping" constraints would enable disposition of environmentally poor quality blendstocks into conventional foreign grades. Additional factors are the closer proximity to the U.S. as compared to Europe and the Middle East, and the more stringent U.S. environmental restrictions associated with the requirements of the Clean air act and other environmental legislation. The latter could make it cost-prohibitive for U.S. refiners to upgrade their facilities.

While much of the expansion will occur in Venezuela (with several projects already underway) due to its indigenous supply of crude oil and natural gas, Puerto Rico and the Virgin Islands may also be well positioned to share in this expansion of U.S. offshore refining.

- While residual fuel oil was the Caribbean Basin's prevalent export to the East Coast of the United States up through the early 1990's, a significant swing towards lighter products is expected by the year 2000 with reformulated gasoline encompassing more than a third of the export volume.
- Most of the crude oil refined in the Caribbean Basin is indigenous to that region. The insular areas of Puerto Rico and the Virgin Islands have no production of their own and must import all of their crude oil. Traditionally, Puerto Rico has imported most of its crude oil from Caribbean neighbors (mainly Colombia, Ecuador, Mexico, and Venezuela). The Virgin Islands on the other hand has imported more than half of their crude volume from West African and Middle Eastern sources. These trade patterns are not expected to significantly change by the Year 2000.

6.1.2 Year 2000 Disruption Cases

The following sections provide a description of the EIA disruption cases and their variants. Comparisons to the 1990/91 Mid-East Crisis are made throughout since the impacts of the Mid-East Crisis described in *Section 5* provide a useful benchmark for attempting to predict the effects of the various disruptions on Puerto Rico and the Virgin Islands.

The simulations undertaken using the EnSys *WORLD* Model provide a "snap-shot" of the postulated disruption under average disruption conditions. The results obtained, therefore, most closely represent the situation where the disruption has been underway for some time and a new market equilibrium has been reached. It should therefore be borne in mind that conditions early in the disruption would likely be worse than the situations presented here, especially as regards the severity of crude and product price spikes and light-heavy product differentials.

Global I (Large)

This case showed that the sustained falloff in refinery operations in the different world regions varied between 5% and 15%. Refinery runs were down slightly more than 10% in Puerto Rico and the Virgin Islands, not disproportionately worse than the rest of the world.

Refinery output did not drop measurably in Puerto Rico during the Mid-East Crisis and rose by about 10% on the average in the Virgin Islands. Although Puerto Rico emerged from that crisis with their inventories intact and having met Island demands, a key to their successful management of the crisis was an early build-up of crude oil and gasoline stocks. The Global I case had a net sustained world crude supply shortfall of 4.5 million barrels per day as opposed to an average world shortfall of 450 thousand barrels per day in the Mid-East Crisis, with production losses being erased less than half way into the crisis.

It is not unreasonable to assume that Puerto Rico will be unable to sequester sufficient early crude oil and product supplies to ride out a crisis of the magnitude of Global I. If this be the case, an analysis of the impacts of the Mid-East Crisis on Puerto Rico indicates that their product inventories could reach an untenable position early in the course of a Global I crisis. The consequences would be that Puerto Rico may either have to be supplied from the outside, have sufficient on-island or dedicated strategic reserves, or curtail Island product sales. If supplied from the outside, the indications are that the Virgin Islands would be a favored source for supplying Puerto Rico with products.

The Global I results showed that among the most vulnerable areas were the U.S. West Coast, Southern Europe, and the Far East. The West Coast made up over one half of its shortfall from Latin American producers and additional cargoes were imported from Latin America to replace Far East oil. These indicated crude oil flow patterns would tend to bring additional pressure to bear on Puerto Rico, but to a much lesser extent on the Virgin Islands.

Crude oil and product prices between the U.S. and Puerto Rico were found to track closely during the Mid-East crisis. For Global I and its variant case, the Year 2000 U.S. East Coast prices (in 1991 dollars per barrel) were found to be:

	Base Case	Global I	Global I Variant
World Oil Price	\$22.90	\$48.20	\$48.20
Refinery Gate Prices			
- Gasoline	\$31.37	\$58.00	\$58.67
- Distillate	\$28.21	\$54.12	\$54.73
- Residual	\$14.89	\$39.20	\$39.75
- Jet Fuel	\$28.25	\$54.67	\$54.93
- LPG	\$19.23	\$43.60	\$42.68

Some of the crude oils lost in Global I were of high quality (light, low sulfur). Because of this, the price differentials between the lighter refined products and crude oil were higher than those exhibited in the pre-disruption environment. This was a result of the increased downstream processing

requirements needed to enhance the yields of the heavier crude oils (despite the lowered average refinery throughputs).

The above price structure suggests that the economic viability under disruptions of Puerto Rico and Virgin Islands refineries would be improved if their facilities were upgraded and expanded to provide complex, flexible, high conversion refineries capable of producing light products from heavy crude oils, including reformulated gasoline.¹

Table 32

YEAR 2000 REFINERY OPERATIONS - GLOBAL I PERCENT UTILIZATION OF DISTILLATION CAPACITY			
<u>Refinery Region</u>	<u>Base Case</u>	<u>Global I</u>	<u>Global I Variant</u>
North America			
- East	92.0	92.0	92.0
- Mid	92.0	81.7	81.6
- West	91.5	85.2	85.2
Caribbean Basin	90.0	72.5	72.7
Northern Europe	90.0	90.0	83.9
Southern Europe	90.0	74.9	78.1
North Africa	90.0	78.4	83.3
Persian Gulf	90.0	85.3	75.3
Pacific High Growth	90.0	83.9	85.2
Rest of World	90.0	84.4	86.7

Global I Variant

The loss of 500,000 barrels per day Middle East/Pacific refining capacity and 500,000 barrels per day of sophisticated U.S./European refining capacity was assumed and superimposed on Global I. The approximate current regional crude oil distillation capacities are given below:

¹The Hess VI upgrade moves that refinery in that direction.

	Year 2000 BAU	
	Million Barrels per Calendar Day	Refinery Percent Utilization
U.S.	15.2	92
Middle East	6.4	90
Europe	14.3 (excluding Turkey and C.I.S)	90
Pacific	7.3 (including China)	90

The refining capacity losses for this variant case therefore correspond to 3.6% of the total Middle East/Pacific capacity and 1.7% of the U.S./European capacity. Given the approximate 90% BAU capacity utilizations in the affected regions, and in light of an approximate 10% net world crude loss associated with Global I, no significant variant case impact was found. The average refinery utilization in the Global I case was 83.0%, and 83.6% for the variant case. Other than slight changes in worldwide trade flows, there was no evidence of any tight market conditions.

As was expected, light product prices were slightly higher in the variant case due to the small decline in worldwide refining flexibility.

Global II (Medium)

This case showed that the sustained falloff in refinery operations in the U.S. Gulf Coast was between 5% and 15% and by more than 25% in the Caribbean Basin. The refining areas most dependent on Latin America and/or West African crude oil in the pre-disruption environment were the Gulf Coast of the U.S. and the Caribbean Basin. The Gulf Coast was able to replace large quantities of its disrupted supply with oil from the SPR, while the Caribbean Basin partly replaced its crude oil supply with increased imports from the Middle East. Of the insular areas, Puerto Rican refiners would initially feel the greatest impact due to their almost complete dependence on Latin American oil.

As with Global I, it is not unreasonable to assume that Puerto Rico will be unable to obtain sufficient early crude oil and product supplies to ride out a crisis of the magnitude and locale of Global II as smoothly as it rode out the Middle East Crisis. Although most of the supply sources for the Virgin Islands remained secure during Global II, the Virgin Islands would be more poorly positioned than in Global I to provide the Puerto Rico with emergency product supply in the face of unforeseen events.

Global II shows the East Coast of the United States as still the primary export destination for Caribbean Basin products, but with the East Coast probably increasing their light product imports from European refiners under Global II. The average drop off in exports from Puerto Rico during the Mid-East Crisis was 25% of the export products normally flowing to the U.S. and 20% for their other export products. The average drop off in exports from the Virgin Islands was a marginal 4%, however the exports to other areas from the Virgin Islands greatly increased during the Mid-East Crisis. Therefore the ability of the U.S., particularly the Puerto Rico and the Virgin islands, to cope with the effects of Global II may be heavily dependent on the sustained ability of Europe and the Middle East to export products and crude oil during the course of Global II.

In Global II and its variant case, the Year 2000 U.S. East Coast prices (in 1991 dollars per barrel) were found to be:

	Base Case	Global II	Global II Variant
World Oil Price	\$22.90	\$48.20	\$48.20
Refinery Gate Prices			
- Gasoline	\$31.37	\$57.55	\$59.31
- Distillate	\$28.21	\$53.76	\$54.01
- Residual	\$14.89	\$39.90	\$39.61
- Jet Fuel	\$28.25	\$54.22	\$54.29
- LPG	\$19.23	\$44.17	\$43.99

The prices for refined products mirrored the increase in the world oil price without any dramatic widening of light-heavy product price differentials (once market conditions under the disruption have stabilized). This was largely due to the fact that the Global II severe disruption in Latin American petroleum supplies did not take large quantities of high quality crude oil (light, low sulfur) off of the world crude market.

The Global II reliance on the SPR (and no reliance assumed on the other IEA inventories) does not approach that of Global I. However, a 1.5 million barrels per day draw over six months will effectively reduce the present SPR crude oil inventory to 55% of its present capacity, or 65% if crude inventory is increased to 750 million barrels.

Latin America and Mexico provided only about 5% of the OPEC and non-OPEC surge production during the Mid-East Crisis. This leaves most of the peak surge production of 5.2 million barrels per day provided during the Mid-East Crisis potentially available. Also, since the Kuwaiti refineries are not down in Global II, and the Saudi products are not diverted to war purposes, the Middle East is a potential product supply region for the U.S. On the other hand, since Venezuela is anticipated to be producing significant quantities of reformulated gasoline for export to the U.S., this source of supply for the U.S. (and potentially for Puerto Rico in an emergency) is withdrawn during Global II. This argues that U.S. refining security would be enhanced by the expansion of Puerto Rico's refining facilities as a hedge against possible future world crude oil disruptions, a hedge which potentially benefits both Puerto Rico and the U.S.

Global II Variant

As is the case for Global I, the loss of 500,000 barrels per day Middle East/Pacific refining capacity and 500,000 barrels per day of sophisticated U.S./European refining capacity has little impact on the Global II case. However, as shown in *Table 33*, the loss of Latin American crude oil and products (and hence refining capability) translates into higher refinery utilizations elsewhere to compensate for the losses in the Caribbean Basin. Utilizations are up 6% in Northern Europe and 10% to 13% in the Middle-East. Since there is anticipated greater U.S. and Caribbean Basin reliance on product imports from these regions, the U.S., Puerto Rico and the Virgin Islands stand at greater potential risk under Variant II.

Table 33

YEAR 2000 REFINERY OPERATIONS - GLOBAL II
PERCENT UTILIZATION OF DISTILLATION CAPACITY

<u>Refinery Region</u>	<u>Base Case</u>	<u>Global II</u>	<u>Global II Variant</u>
North America			
- East	92.0	92.0	92.0
- Mid	92.0	81.6	81.5
- West	91.5	87.6	87.5
Caribbean Basin	90.0	63.3	50.1
Northern Europe	90.0	90.0	90.0
Southern Europe	90.0	75.1	75.1
North Africa	90.0	82.5	82.4
Persian Gulf	90.0	86.9	86.9
Pacific High Growth	90.0	84.4	84.3
Rest of World	90.0	86.4	86.3

Global III (Small)

This disruption is similar to the recent Mid-East Crisis, with a 4.3 million barrel per day disruption, Saudi Arabia making up 2.0 million barrels per day, but no U.S. SPR/IEA draw. The net supply loss is thus 2.3 million bpd. Although the fact is that the Middle East Crisis was well managed from U.S., Caribbean Basin and global perspectives, Global III assumes a sustained 2.3 million bpd global shortfall in crude supply versus an average net shortfall of 450,000 bpd during the Middle East Crisis.

Except for Southern European and the Pacific High-Growth Region refiners, world refinery utilizations were only marginally off. Because Persian Gulf crude oils are processed in significant volumes in most refining centers of the world, Global III had a major impact on the worldwide flow of crude oils and refined products. Refiners in Europe competed with the U.S. for the choice North African and West African crude oils and kept a larger percentage of their own North Sea production (as happened in the 1990-91 Middle East Crisis). The Persian Gulf production that was not disrupted ended up for the most part in Northern European and Far Eastern refineries. Refineries in Northern Europe and the East Coast of the U.S. continued to operate at capacity.

The Virgin Islands were the most adversely affected in the Caribbean Basin because they traditionally import appreciable volumes of Middle Eastern crude oils. However, they were still able to replace most of their lost crude oil with imports from their Caribbean Basin neighbors (primarily

Mexico and Venezuela) such that refinery runs were less than 5% below pre-disruption levels. Light product cargoes destined for the East Coast of the U.S. still represented the primary flow out of the Caribbean Basin, although product flows to both the U.S. Gulf Coast and the West Coast increased under this disruption.

It bears repeating that many of the events that occurred during the recent Middle East Crisis fell into place fortuitously. Therefore, it is not inconceivable that Puerto Rico will be unable to sequester sufficient early crude oil and product supplies to ride out the Global III disruption as smoothly as it did the Middle East Crisis.

In the Global III and its variant case, the Year 2000 U.S. East Coast prices (in 1991 dollars per barrel) were found to be:

	Base Case	Global III	Global III Variant
World Oil Price	\$22.90	\$33.10	\$33.10
Refinery Gate Prices			
- Gasoline	\$31.37	\$42.39	\$43.62
- Distillate	\$28.21	\$39.37	\$40.34
- Residual	\$14.89	\$24.40	\$24.05
- Jet Fuel	\$28.25	\$40.03	\$41.01
- LPG	\$19.23	\$28.60	\$28.39

The crude oil price rise agrees reasonably well with that experienced during the Mid-East Crisis. For Global III, because the disrupted Middle East crude oils were of intermediate quality, the price differentials between lighter refined products were not significantly different than those of the Year 2000 BAU case. However, the recent Mid-East Crisis experienced wider product differentials for the lighter products as shown below:

	Price Ratio to Crude Oil	
	Global III	Mid-East Crisis Nov 1990
Gasoline	1.28	1.59
Distillate	1.18	1.39
Residual Fuel Oil	0.74	0.87
Jet Fuel	1.21	1.61

The Mid-East Crisis ratios are based on U.S. refiner prices to end users, excluding taxes. The above differences may be the result of the Gulf War demand for jet and other military fuels and the tendency in that crisis for gasoline prices to hold up longer than crude oil prices.

Global III Variant

The loss of all of the refining and storage facilities in Puerto Rico and the Virgin Islands in conjunction with the approximate 5% net world crude loss associated with Global III can be accommodated on a global basis. However, Hurricane Hugo reduced Puerto Rico's refinery output by one third for one month and that of the Virgin Islands by almost one half for two months. A loss of the magnitude postulated for Variant III will result in the need to supply virtually all products for Puerto Rico and the Virgin Islands from the outside, principally from Venezuela, the United States and Europe, in a reversal of normal export patterns.

Table 34

YEAR 2000 REFINERY OPERATIONS - GLOBAL III PERCENT UTILIZATION OF DISTILLATION CAPACITY

<u>Refinery Region</u>	<u>Base Case</u>	<u>Global III</u>	<u>Global III Variant</u>
North America			
- East	92.0	92.0	92.0
- Mid	92.0	81.6	81.5
- West	91.5	87.6	87.5
Caribbean Basin	90.0	63.3	50.1
Northern Europe	90.0	90.0	90.0
Southern Europe	90.0	75.1	75.1
North Africa	90.0	82.5	82.4
Persian Gulf	90.0	86.9	86.9
Pacific High Growth	90.0	84.4	84.3
Rest of World	90.0	86.4	86.3

6.1.3 Economic Impact

The adverse economic impact of slight to moderate global oil supply disruptions is moderately larger in Puerto Rico than in the United States mainland. However, the adverse economic impact of the most severe global oil supply disruptions is much larger in Puerto Rico. This finding is consistent with Puerto Rico's almost exclusive dependence on petroleum for its primary energy needs. We demonstrate for Puerto Rico and the U.S. mainland two effects of global oil disruptions: GDP loss and

terms of trade loss. These and other measures of economic loss were described previously in Section 5.1.4.

Puerto Rico's GDP is more severely affected than the U.S. mainland's because the global oil supply disruption causes disproportionate increase in the production cost of its goods, thereby disproportionately lowering worldwide demand for Puerto Rico goods. This in turn causes the real value GDP the fall disproportionately relative to the U.S. mainland's, and results in worse employment effects.

Terms of trade losses resulting from a global oil supply disruption are proportionally larger in Puerto Rico than the U.S. mainland for two reasons. First, Puerto Rico cannot currently use other forms of energy in place of oil during a global oil supply disruption, hence their oil consumption will decrease proportionately less than will the U.S. mainland's. This fact as well as the fact that oil demand is generally inelastic implies that the Puerto Rico's oil expenditures increase proportionately more than does the U.S. mainland's, as during a global oil supply disruption. Second, unlike the U.S. mainland, all Puerto Rico oil must be imported, which means that oil import expenditures will increase proportionately more than the U.S. mainland's, even if the proportion of total oil expenditures were to remain the same.

Table 35 presents the impacts upon U.S. and Puerto Rico GDP, terms of trade, and inflation relative to a business as usual base case for the year 2000. The effects on U.S. GDP, terms of trade loss, and total economic loss were calculated by the Energy Information Administration DIS model for CY 2000. The effects on Puerto Rico GDP were calculated by the Puerto Rico Planning Board's macroeconomic model for FY² 2000. The Puerto Rico terms of trade effect was calculated in this study.

The effects presented are GDP levels and percent changes relative to a year 2000 business as usual base case. The Global I scenario is most serious and corresponds to a 6-month net loss of 4.5 million bbls/day of crude oil from the world market.³ The Global III scenario corresponds to a 6-month net loss of 2 million bbls/day of crude oil from the world market and is comparable to the recent Persian Gulf crisis.⁴ The Low and High subscenarios reflect different behavior of private inventories. In the Low subscenario, 1 million bbls/day of private crude inventories are released, buffering price increases. In the High subscenario, private crude inventories increase by 1 million bbls/day, amplifying price increases.

²This is Puerto Rico fiscal year, which ends June 30.

³The gross loss of Global I is 9 million bbls/day production cutback in export crude oil. This cutback is partially offset by combined US and allied SPR drawdowns of 4.5 million barrels a day. This results in a net loss of 4.5 million bbls/day of oil supplies in the world market.

⁴The gross loss of the Global III scenario is a 4.3 million bbls/day cutback in production by some producing countries, which is partially offset by a 2.3 million bbls/day production increase by other producing countries.

Table 35

Relative Economic Effects of Global Oil Supply Disruptions					
Scenario	BAU 2000 Base Case	Global I/II		Global III	
		Low	High	Low	High
Effect on GDP					
U.S. mainland GDP (trillions of 1987 dollars)	6.051	6.01	5.979	6.038	6.007
Change Relative to Base Case	0	-0.68%	-1.19%	-0.22%	-0.72%
Puerto Rico GDP (billions of 1991 dollars)	44.130	43.727	43.096	43.981	43.680
Change Relative to Base Case	0	-0.91%	-2.34%	-0.34%	-1.02%
Terms of Trade Loss					
U.S. mainland (billions of 1987 dollars)	0	35.51	81.80	12.61	53.42
As % of BAU 2000 GDP	0	0.59%	1.35%	0.21%	0.88%
Puerto Rico (millions of 1991 dollars)	0	467.5	989.1	134.6	508.3
As % of BAU 2000 GDP	0	1.06%	2.24%	0.31%	1.15%
Total Economic Loss ⁵					
U.S. mainland (billions of 1987 dollars)	0	86.09	182.09	33.63	123.16
As % of BAU GDP	0	-1.42%	-3.01%	-0.56%	-0.88%
Puerto Rico (millions of 1991 dollars)	0	870.5	2023.1	283.6	958.3
As % of BAU GDP	0	-1.97%	-4.58%	-0.64%	-2.17%
Effect on inflation					
U.S. mainland ⁶	0	+1.01%	+1.79%	+0.33%	+1.08%
Puerto Rico ⁷	0	+0.92%	+2.35%	+0%	+1.02%

⁵For the U.S. Mainland, Total Economic Loss is defined as (GDP Loss + Terms of Trade Loss - SPR revenues). For Puerto Rico, Total Economic Loss is defined as (GDP Loss + Terms of Trade Loss).

⁶This is the change in the Consumer Price Index caused by the disruption. The base period is set equal to the 1982 through 1984 period. This means that the average of 1982 through 1984 prices is set equal to 100.

Note that the GDP effects are slightly worse for Puerto Rico in both Global III scenarios and in the Global I Low scenario. The impact of a Global III Low type disruption would be reflected in lower than usual GDP growth rates in the year 2000. The impact of Global III High and Global I Low type disruptions would be more serious and would be reflected in very low or near zero economic growth in the year 2000.

The differential effects are most apparent in a Global I High type disruption, which is the most serious disruption. The impact of the disruption could induce a moderate U.S. mainland recession. The impact of the disruption in Puerto Rico may be a moderate to severe recession comparable to the 1974-75 recession.

It is important to note that the percentage changes presented in Table 35 are relative to what year 2000 GDP would have been in the absence of the disruption. Annual GDP growth is predicted to be approximately 2.15%⁸ in the U.S. mainland and 3.64%⁹ in Puerto Rico between now and the year 2000. Assuming that these growth rates continue, average annual rates of growth will not be completely offset in either the U.S. or Puerto Rico. However, negative growth could occur during the six months of the disruption, in which case a recession would occur.

Although information on the impact of potential disruptions on Puerto Rico employment is unavailable, historic experience indicates that employment impacts of recessions are more severe in Puerto Rico than they are in the U.S. mainland. In addition, Puerto Rico's unemployment rate has tended to be much higher and more persistent than the U.S. mainland's. This suggests that any future global oil supply disruption will have a more adverse and longer lasting impact on Puerto Rico employment than on U.S. mainland employment.

The proportionate estimated terms of trade effects are worse for Puerto Rico than they are for the U.S. mainland. This is consistent with the differences in petroleum dependence between Puerto Rico and the U.S. mainland. Unlike the U.S. mainland, Puerto Rico uses petroleum for nearly all of its primary energy needs, and all crude petroleum must be imported. Hence, unlike the U.S. mainland, Puerto Rico cannot use other forms of primary energy and cannot use domestic oil in place of oil imports in a global oil supply disruption.

Inflation rates are not directly comparable for the U.S. mainland and Puerto Rico, because the CPI, which is used for the U.S. mainland inflation change, is more sensitive to oil price increases than is the implicit price deflator, which is used for Puerto Rico. Nevertheless, some comparison can be made by examining the change in inflation caused by the disruption and comparing it to historical inflation rates separately in Puerto Rico and in the U.S. mainland. Puerto Rico's implicit price deflator grew at an annual rate of 3.60% from the FY 1983-1992 period, which shows that the oil supply

⁷This is the change in the Puerto Rico implicit price deflator caused by the disruption. The base year of the implicit price deflator is 1954.

⁸Source: Energy Information Administration, *Annual Energy Outlook*, 1993 Table A7

⁹Data source: Puerto Rico Planning Board. For details on this calculation, see the Economic Outlook section.

disruption will cause slight to moderate increases in inflation in both Global III and the Global I Low scenarios, and a moderate increase in inflation in the Global I High scenario. The U.S. mainland's consumer price index grew at an average annual rate of 3.80% between 1983 and 1992. The additions to inflation indicated in Table 35 are slight to moderate in all scenarios. It appears that the impact on U.S. inflation is smaller than the impact on Puerto Rico inflation. However, the impact in both the U.S. mainland and Puerto Rico is slight to moderate relative to historic levels. The lower inflationary impact results from increased energy efficiency in both the U.S. mainland and Puerto Rico.

The higher GDP losses and larger terms of trade losses for Puerto Rico, as well as the possibility of more damaging employment effects, show that the adverse impact on the economy is worse in Puerto Rico than in the U.S. mainland. Except in the Global I high scenario, the difference in GDP impacts is slight to moderate. The GDP impact in the Global I High scenario is considerably worse for Puerto Rico than the U.S. mainland. When terms of trade losses and probable employment losses are factored in, the total economic impact on Puerto Rico is moderately worse than in the U.S. in the case of slight to moderate oil supply disruptions, and much worse in the case of a severe (Global I High) disruption. Inflationary impacts appear to be slightly to moderately worse in Puerto Rico, but the absolute effect of the impacts is slight to moderate in both Puerto Rico and the U.S. mainland.

6.2 Impacts of Postulated Local Energy Supply Disruptions

6.2.1 *Introduction*

The terms of reference for this study call for an analysis of: (1) the unique vulnerabilities of Puerto Rico to oil supply disruptions; (2) their impact on the territory's oil supply, and (3) how the territory will maintain sufficient supplies of petroleum products in an emergency. One element of this analysis concerns the benefits to be derived from developing a strategic reserve of petroleum products to prevent serious supply dislocations in the event of an energy emergency.

In addition to international events or market conditions that might trigger a petroleum products supply shortage in Puerto Rico, this insular area also faces the risk of "on-island" emergencies which might produce severe and prolonged shortages. The function of this section is to examine the potential for such events and the severity and duration of dislocations.

Petroleum operations in Puerto Rico are conducted by a relatively small number of private sector companies that engage in oil refining, storage, transportation, and wholesale and retail marketing. The petroleum systems they operate, which are competitive, consist of a series of distinct facilities, that will be described below.

The assessment of the vulnerability of these facilities and systems is focused primarily on the refining, primary storage, and transportation segments, rather than in the area of wholesale and retail product distribution. This is not to imply that supply disruptions to marketing operations are unimportant. The reason for the decision to exclude this area from our analysis is that response options (such as a products reserve) that might provide vital oil supplies to the island are likely to provide little if any benefit to alleviate dislocations that occur downstream of refinery and primary storage operations. Alternatively stated, emergency petroleum products brought to or stored on the island would face the same obstacles in overcoming these bottlenecks as would products available from existing private sector operations.

The assessment of petroleum systems vulnerability was based on interviews with operating company personnel, review of available technical data obtained from these operators, data and reports provided by other sources, and on-site examination of selected key petroleum installations.

This vulnerability assessment was not intended to be a detailed site-by-site review of all facilities in Puerto Rico, nor to provide a technical assessment of safety design and operating procedures (audit) for each facility. The study makes no claims as to the integrity of specific petroleum facilities in the event of future emergencies.

This section on local energy supply disruptions is organized into five subsections covering the following topics:

- Physical characteristics of key petroleum facilities
- Vulnerabilities of key petroleum facilities to local disruptions
- Physical characteristics of key electric power facilities

- Vulnerabilities of key electric power facilities to local disruptions
- Economic impacts of local energy supply disruptions

Each section follows in turn below.

6.2.2 *Physical Characteristics of Key Petroleum Facilities*

For purposes of this study, a number of petroleum facilities have been identified as essential to sustaining petroleum operations on Puerto Rico. These facilities represent critical points in the movement of petroleum products to market. The loss of operations for any one of these facilities for a prolonged period would produce market dislocations, and force the operating companies to develop alternative strategies to meet market demand for petroleum products. The simultaneous loss of service at a number of these facilities would significantly raise the risk of more serious petroleum product shortages on Puerto Rico.

ESSENTIAL PETROLEUM FACILITIES ON PUERTO RICO (Currently in Operation)

Sun Oil Company Refinery (Yabucoa)
Phillips Petroleum Refinery (Guayama)
Caribbean Petroleum Corporation Refinery (Bayamon)
Commonwealth Oil and Refining Company Storage and Terminal (Guayanilla)
Cataño Terminal and Storage Facilities (Exxon, Shell, Texaco)
Cataño to San Juan International Airport Pipeline (Texaco, Shell, Corco)

* * * * *

OTHER MAJOR PETROLEUM FACILITIES ON PUERTO RICO (Currently not in Operation)

Arochem Refinery (Guayanilla)
Commonwealth Oil and Refining Company Refinery (Guayanilla)
Corco to Cataño Pipeline (Shell)

Puerto Rico is dependent totally on seaborne shipments of imported crude, naphtha, and condensate as original source feedstocks to its refineries. Petroleum product movements between refineries, and from refineries to market distribution predominantly rely on intra-island barge traffic. The majority of this traffic is directed from the operating refineries on the south coast of the island to the San Juan area, which is the largest center of population. Product barges also transport oil to Ponce and other areas with terminal facilities. Most remaining products leaving the refineries are transported by tanker trucks in small volumes to various locations on the island.

Companies also import large volumes of refined products for direct wholesale and retail use. Residual fuel oil is generally the largest of these product imports, with gross imports totaling an estimated 38,400 b/d in 1992, the equivalent of approximately 60% of residual fuel oil consumption on the

island. Gross imports of motor gasoline (est. 12,600 b/d) constitute the equivalent of less than one quarter of total consumption. The jet fuel balance (imports 3,000 b/d, exports 3,300 b/d, and production 13,200 b/d to meet a 12,800 b/d consumption requirement) is reflective of varying contractual arrangements and competition among refiners and major wholesalers and the inclusion in these figures of both civilian and military jet fuel.¹⁰

Large product inventories are maintained at storage facilities (above ground tank farms) which are sited near existing refineries. Smaller volumes of storage are maintained by wholesalers and retailers around the island. PREPA maintains relatively sizeable fuel oil inventories (approximately a 25-day supply) for its electric power generation operations. The major storage facilities are linked to consuming areas via barge traffic and tanker trucks.

Puerto Rico does not have an extensive products pipeline system or network on the island. The one major pipeline from the south to the north of the island, which is operated by Shell Oil, has been out of service for a number of years.¹¹ Prospects for reopening this pipeline as a carrier of petroleum products may be uncertain, due to the sensitivity of the operator toward environmental risks and liabilities in the event of an accident. This pipeline crosses some ecologically sensitive areas, including fresh water sources.

The only other significant pipeline operation is the line which moves products from the Cataño area to the International Airport in San Juan.

Outside Support Services

The refineries and major storage facilities on Puerto Rico rely on third party services for the primary supply of electric power and most outside communications. PREPA is the source of electric power generation to island petroleum operations. This power supply is essential for the petroleum operations to be sustained. Local independent electric power supply at these facilities generally is used to back up such functions as maintenance of computer control systems and emergency lighting, but it is insufficient to power processing operations. Loss of power supply from PREPA would necessitate a curtailment of operations.

The major petroleum facilities on Puerto Rico are moving toward increased use or emergency availability of cellular telephones. The port (tanker and barge) operations make use of radio communications with offshore traffic.

The refineries and major storage facilities on Puerto Rico have active programs with local fire and police agencies. The responsibility inside the gate of the petroleum facility in the event of a fire emergency rests with the facility operators who maintain their own fire response services and specialize in handling petroleum related fires. Local fire department personnel typically participate in fire school training offered by the operating companies.

¹⁰In 1992, Puerto Rico (Peerless Oil and Chemical) produced 3,200 bpd of JP4 and exported 3,100 bpd. On-island production of JP4 has since ceased with the changeover by the U.S. military to JP8.

¹¹ An 8-inch products pipeline with a capacity of 27,600 barrels per day.

Petroleum facilities operators have primary responsibility for maintaining plant security. Port operations also come under the purview of the U.S. Customs Service, which inspects marine traffic entering oil terminals.

The Ports Authority of the Commonwealth of Puerto Rico has the sole responsibility for providing security to refinery terminal operations in at least two of the key petroleum facilities. Although the processing and storage facilities are private property and can be closed to the general public, the terminal (dock) facilities are owned by the Commonwealth, and legally are subject to public access. This accessibility to loading and unloading operations is a potentially serious weakness in maintaining effective security.

Puerto Rico Sun Oil Company Refinery (Yabucoa)

The Sun Oil refinery, located on the southeast coast of Puerto Rico consists of processing facilities, a tank farm, and a terminal that handles tanker and barge traffic.

The port area consists of a main berth which can handle one incoming crude oil tanker or barge, and a barge dock with two berths. The Marine Department office is located at dockside by the main berth. With a dock draft of 45 feet to 48 feet, the main dock can technically handle tankers of up to between 90,000 and 100,000 deadweight tons (dwt).

Crude oil is unloaded from the main dock and may be sent to any one of six crude oil storage tanks. Total crude oil storage capacity is 1,720,000 barrels. This represents at least 20 days of storage if production were at rated capacity of 85,000 b/d. and approximately one month or so if production were at lower rates.

In the event of an emergency that forced closure of the main dock, crude oil could be unloaded (lightered) from tankers onto barges, and then unloaded through the bunker line at the barge dock.

Products are shipped from this refinery via barge or truck. Product barges move an estimated 97 percent of total products leaving the refinery. The remaining products leave through a truck loading rack which handles kerosene and diesel fuel.

Sun Oil maintains its own small fleet of barges which handle a large volume of the products moved in intra-island trade.

Power supply to the facility is provided by three 115 kV lines from PREPA. Power outages are not common, but when power supply is low, the facility can draw on a nearby PREPA power station.

Communications are provided by telephone to Sun Oil Company on the mainland United States. Radio communications are used between the terminal and the marine traffic.

Internal security inside the facility is reasonably good. In addition, municipal and state police make rounds every two hours. The docks are government property, however, and the Ports Authority has jurisdiction in this area. Existing law permits access to the dock area by the public on demand.

This allows public access past the last refinery security point. There also are plans to build a public road, which may be sited directly through the Sun Oil facility.

The Sun Oil refinery at Yabucoa is a major supplier of lube oils largely for the U.S. east coast market. The refinery also is the largest source of jet fuel to the Puerto Rican market.

Phillips Petroleum Refinery (Guayama)

The Phillips refinery is located on the southern coast of Puerto Rico at Guayama. The facility is run off a naphtha feedstock, which is imported largely from Venezuela. Capacity of the plant is rated at 60,000 b/d, but officials have used a range of 50,000 to 60,000 b/d.

The refinery receives a naphtha cargo almost every five-six days. At the time of the DOE team's visit to this facility, it was receiving three cargoes per month from the Puerto La Cruz refinery (Venezuela) and another one-two cargoes per month from Maraven (Venezuela). Phillips presently is leasing two naphtha tanks at the GATX terminal in Houston, and is contracting for one shipment from that facility on the U.S. Gulf Coast to Guayama every 15-16 days. The refinery also uses approximately 2,500 b/d of fuel oil which is barged in from Caribbean imports outside Puerto Rico (due to a price advantage over supplies on the island). The barging operation is conducted under a long term contract.

The port area consists of one dock which can berth tankers on either side. However, the facility can discharge only one vessel at a time. The berthing areas appear to be in need of maintenance which requires approval of Ports Authority which owns the facility. The tank farm has a naphtha storage capacity of 1,250,000 b/d. Company officials estimate that if the dock were out of service for 25-30 days, the refinery would be forced to shut down.

The refinery reportedly is producing 26,000 b/d of gasoline, approximately 16,000 b/d of which is barged to the San Juan area and 10,000 b/d is loaded onto trucks for distribution in the south of the island. The facility has two truck loading racks capable of moving a maximum of 19,000 b/d of gasoline. Because of this shortfall from average gasoline production, barge traffic is essential to make up the difference. New technology implementation, which is planned by Phillips to increase aromatics yields at the refinery, will reduce the amount of raffinate available for gasoline production (which probably will decline). The change may also affect sales of reformat to Peerless, a small refinery in Guayanilla, which uses this product for its blending operation.

Among other products produced at this facility, diesel accounts for one to two trucks per day, and toluene one truck per month.

Phillips is one of the largest consumers of electric power on the island. The facility is connected by PREPA through two incoming lines from different power plants. Plant officials indicated that the refinery was from time to time affected by dips in electric power supply, which have caused pumps and boilers to trip.

The Phillips refinery maintains back-up water supply from 14-16 wells in the vicinity. The water is treated prior to its use at the refinery.

The level of security at Phillips (Guayama) approximates that at the Sun Oil facility. As in the case of the latter refinery, the public has legal access to the dock area, which is in a protected harbor. It is also possible to obtain access to the area for fishing.

Caribbean Petroleum Corporation (CAPECO) Refinery (Bayamon)

This refinery is the oldest on the island of Puerto Rico. Its present capacity is variously estimated at between 42,000 to 50,000 b/d of crude oil. The location is in the greater San Juan area, in proximity to the Cataño petroleum storage facilities.

The Bayamon terminal is restricted by a 32-foot draught limitation in its channel. Existing plans call for dredging the channel in 1994 or after. The company operates one barge under charter at present.

CAPECO has a pipeline interconnection with the Exxon-Shell-Texaco storage facility at Cataño, as well as with two PREPA power plants. This would allow CAPECO to move oil products from its dock to those facilities without going through its refinery. It is possible, therefore, for CAPECO to maintain a product storage operation interlinked with the other operators, even if the refinery were closed.

CAPECO receives an average of six cargoes per month for the refinery (4 crude oil, 1 vacuum gasoline, and 1 cutter stock). It can move products at rates of 5,000-6,000 barrels per hour for gasoline a similar amount for diesel, and 2,000 barrels per hour for jet fuel. CAPECO is focused on the bunker fuels market rather than the industrial residual fuel market. It also sells jet fuel to Exxon. The principal product of the refinery is gasoline.

CAPECO is the only integrated oil company on Puerto Rico, maintaining approximately 275 retail gasoline service stations. Its objective is to ensure the supply of products to those stations.

CAPECO has had problems with the U.S. Environmental Protection Agency. The problem, which involves treatment of wastewater discharges, has required CAPECO to cut back output from its catalytic cracker from 14,000 b/d to as low as 6,000 b/d.

Commonwealth Oil Company Storage and Terminal (Guayanilla)

The Commonwealth Oil (CORCO) refinery has been closed for a number of years. Its present owners see no opportunity for it to reopen in the future, based on market conditions and the cost of restoring the facilities. Therefore, we do not consider the refinery to be an important or potentially important petroleum processing facility.

The facility, which is located on the southeast coast of Puerto Rico, has significant storage and terminal facilities that are presently active, and important to the island's energy supply.

According to knowledgeable resources, the facility has approximately 13 million barrels storage capacity at its tank farm. Of that total, about 8 million barrels is available for active storage, and the remaining 5 million barrels is in need of repair.

The present useable capacity is estimated as follows:

4.0 million barrels of dirty storage of which:

2.5 million barrels crude oil

1.5 million barrels black oil (interchangeable between residual fuel oil and crude oil)

4.0 million barrels of clean storage of which:

1.5 million barrels gasoline

2.5 million barrels of light and middle distillate products in cone roof tanks

The CORCO facility also maintains the following LPG storage capacity:

Propane	24,000 barrels (1 million gallons)
Butane	40,000 barrels

Present utilization of the storage is 4.8 million barrels. Two million barrels of this amount is being utilized by PREPA under a five-year contract. Sources have estimated that it would require at least six months to repair the non-useable tanks if there was an interest in utilizing this additional storage.

The CORCO terminal facilities include two piers, which allow for loading of up to four vessels at a time from five berths. Maximum loading/unloading capacity is four tankers, of up to 82,000 dwt, with maximum draft of 42 feet. CORCO also has truck loading facilities at six to seven racks, capable of handling two grades of gasoline, diesel, kerosene, and black oil.

CORCO TERMINAL FACILITIES				
		DWT	DRAFT	
CORCO Petrochemical Dock				
Berth 1	Barges only	small	28 feet	(Berths 1 & 2 -- only one at a time)
Berth 2	Barges only	25,000	28 feet	
Berth 3	vessels	50,000	36 feet	
CORCO Refinery Dock (owned - CORCO)				
Berth 4	vessels	82,000	42 feet	
Berth 5	vessels	82,000	42 feet	
Tallaboa Dock (owned - Ports Authority; operator - CORCO)				
East Berth	vessels	60,000	37 feet	(maximum combined loading 60,000 dwt)
West Berth	vessels	20,000	25 feet	

The significance of this facility not only relates to its own capacity as outlined above, but to the currently closed Arochem refinery which has been in bankruptcy and was recently sold to the owners of CAPECO. Arochem is co-located with the CORCO facilities, and totally relies on leased storage

and terminal access from CORCO in order to sustain the Arochem refinery operations. CAPECO plans call for reopening Arochem at a rated refining capacity of 80,000 b/d.

Cataño Storage and Terminal facilities (Exxon, Shell, Texaco)

Information on the Cataño facilities was derived from the various operating companies and a survey of petroleum facilities in 1991 by the Department of Consumer Affairs. This facility is important because of its proximity to the large population, commercial and industrial users in the San Juan area. The facility is leased to the operators by the government. Overall storage is about 1.2 million barrels.

The Cataño terminal has a main jetty capable of loading/unloading one vessel at a time. This is shared between the three operating companies. Each of the three are competitors that operate their marketing (wholesale and retail) operations independently.

According to Shell Oil, it purchases motor gasoline which is brought into Cataño in 60,000 barrel barges. The barges are generally leased from Crowley. It normally takes three days to bring in a product barge from the refineries in southern Puerto Rico. Shell is presently taking gasoline from Sun Oil. Shell also brings in a ship once a month. The company maintains a 10-day products inventory at Cataño, with total storage capacity estimated at 399,000 barrels in 1991.

Shell operates 13 trucks that belong to a cooperative, 8 of which supply its markets in the north and 5 of which supply its outlets in the south. Shell has an estimated 285 motor gasoline service stations on the island. Shell has left the aviation fuels market to other competitors.

Exxon has about 402,000 barrels of storage at Cataño to support its marketing operations on Puerto Rico, as well as product movements to the U.S. Virgin Islands. Its products include gasoline to almost 300 service stations on Puerto Rico, as well as to St. Thomas, bunker fuel to San Juan Bay, and aviation fuel. It is also the largest supplier to the petrochemical industry on Puerto Rico. Exxon maintains an estimated 10-day supply of inventory of aviation fuel to support its marketing operations.

Exxon reportedly brings in about one shipment of gasoline per month to Cataño from outside Puerto Rico, which constitutes about 50-60 percent of its market requirements.

Texaco maintains a large operation at Cataño, with a storage capacity of roughly 500,000 barrels. Texaco is the largest retail marketer in Puerto Rico, is a major supplier of gasoline, and a partner in operating the products pipeline from Cataño to San Juan International Airport.

Although Cataño contains only a fraction of the storage available in Guayanilla (CORCO) in the south, it is an important intermediate point in the petroleum product transportation system on Puerto Rico, and provides essential logistical balance for product flows coming into the San Juan area. The loss of service from Cataño would have a serious impact on the industry's ability to meet product demand by end users on the island.

Cataño to San Juan International Airport Pipeline

This 6-inch pipeline is the primary means for shipping aviation fuels to the San Juan International Airport. The loss of this pipeline system for a prolonged period would complicate the ability of the companies supplying jet fuel to move sufficient product to the end users. The alternative of trucking jet fuel from either Cataño or the refineries (assuming sufficient supplies were available) to the airport would be cumbersome; and it would be difficult for the distributors to maintain product volumes.

The airport is important to the tourist industry of Puerto Rico and the U.S. Virgin Islands, as well as to the Puerto Rican business community as a whole. The loss of this pipeline would have the potential impact of raising on-island jet fuel costs, restricting landings, and requiring aircraft to refuel elsewhere. The significance of this pipeline becomes even greater as American Airlines looks to expand the use of San Juan as a hub city, possibly doubling flights by the mid-1990s.

Interdependence of Petroleum Systems and Electric Power Systems

The integrity of both petroleum and electric power operations on Puerto Rico are closely intertwined. Each has been designed with a major dependence on the reliability of the other to sustain service. This relationship is discussed later in the section on vulnerability of electric power systems.

Communications Requirements

Petroleum systems rely on communications to support normal business operations, and particularly for emergency response in the event of unanticipated disruptions. Communications are required within facility compounds to support operations and maintain security. This ideally includes uninterrupted service to monitor and control process operations and product movements. It is also necessary to maintain business communications: (1) along system routes between facilities; (2) with corporate headquarters, and (3) with local authorities for emergency response.

The communications requirements for petroleum operations on Puerto Rico are similar to elsewhere. However, since most of the products on the island are moved by barge or truck, there is less of a requirement to maintain instantaneous contact between sites as there would be, for example, in the monitoring and control of long distance pipeline operations.

The petroleum companies operating on Puerto Rico rely extensively on telephone communications. Port operations maintain contact with maritime traffic via radio, and some use is made of microwave. Some companies maintain lease line communications with their corporate headquarters on the mainland. Cellular telephone systems are available in Puerto Rico, and are used in limited roles. Cellular service provides a useful backup in the event of outages to local telephone lines. We saw no evidence of portable satellite (VSAT) communications for critical emergency backup. Several of the oil companies whose subsidiaries operate in Puerto Rico make use of VSAT in other areas of their international operations. The decision to install a VSAT system is determined by the remoteness of the location, as well as assumptions on the reliability of existing telephone service.

6.2.3 Vulnerabilities of Key Petroleum Facilities to Local Disruptions

Several types and categories of potential emergencies might seriously disrupt petroleum industry service on Puerto Rico. The identification of these emergencies is fairly evident, and the selection was derived following discussions with operating companies and government officials, a review of the available literature, and experience in emergency planning and response elsewhere. The emergencies would have to be on an order of magnitude (intensity and duration) sufficiently significant so as to create temporary or prolonged shortages of petroleum products.

The types of emergencies we analyzed include:

Natural disasters

Hurricane

Earthquake

Accidents

Fires and explosions

Ship collisions and oil spills

Acts of Sabotage and Terrorism

The extent to which the current petroleum systems on Puerto Rico are vulnerable to major unanticipated disruption is a function of several factors, including: (1) the source or type of disruption; (2) the severity and duration of the emergency event; (3) the level of planning by the operators; (4) mitigation measures taken in advance; (5) experience in coordinating with public authorities, communications and utility suppliers, and other petroleum companies. etc.

The analytical methodology applied was to:

- (1) Develop a first order (high level) assessment for each type of emergency to determine whether, in a worst-case scenario, the losses are such so as to require access to emergency petroleum supplies either on- or off-island. If it is determined through this screening process that emergency supplies might be needed in a particular type of emergency, then, for that type of emergency
- (2) Conduct a detailed vulnerability assessment of each petroleum system for the purpose of calculating the threshold at which emergency supplies would be needed, and to determine the volume of supplies products that would be required to adequately alleviate market shortages.

In assessing the vulnerability of Puerto Rico's petroleum system in this section of the study, it was assumed that normal business conditions – current and projected – prevailed in the world oil market through the year 2000. Under this set of conditions, the access to crude oil and petroleum product procurement in the open market outside Puerto Rico (at prevailing market prices) was unimpeded. In other words, petroleum import availability: (1) remained at volumetric levels similar to that immediately before the crisis, and (2) no combination of suppliers to the world oil market conspired to deliberately withhold supplies to impede Puerto Rico's recovery. If the oil import market

were otherwise impeded at the time, then that factor, rather than a domestic dislocation on the island, would be the proximate cause for on-island emergency supplies such as a regional SPR.

The first order analysis leads to the following conclusions regarding "on-island" energy emergencies:

- (1) The Commonwealth of Puerto Rico is potentially vulnerable to each of the dislocations identified.
- (2) The losses in product supply availability to the island tend to be relatively short-term, as opposed to chronic.
- (3) Although petroleum industry operating companies would suffer business losses (financial and infrastructure) and one or more refiners might even opt to cease operations in Puerto Rico for business reasons, this would not affect the island's long-term ability to import petroleum products from world markets to meet consumption requirements. Puerto Rico is in relatively close proximity to major petroleum production and refining in the Caribbean region. The major retail suppliers (i.e., Shell, Exxon and Texaco) have access to products supplies from a number of international sources.
- (4) Petroleum industry and PREPA product inventories should be capable of buffering supply shortages on the island, assuming that some replenishment of stocks will take place during the recovery period.
- (5) A strategic oil product reserve on the island, whether located in one central site, or dispersed at several sites around the island, would:
 - a. be subject to many of the same risks and vulnerabilities as is faced by the petroleum industry on the island, and
 - b. have many of the same logistical problems as would the industry in moving oil to market from its storage area(s).

Hurricanes

Puerto Rico is considered a high risk area for seasonal hurricanes that develop each year in the Atlantic Ocean and eastern Caribbean. Although most major hurricanes statistically are not expected to cross the island of Puerto Rico, there is a reasonable probability that Puerto Rico will experience one or more major hurricanes by the year 2000.

The hurricane now historically used as a planning benchmark is Hugo, which struck the island of St. Croix (U.S. Virgin Islands) and continued on to the northeast corner of Puerto Rico and South Carolina in September 1989. This hurricane reached a strength of Category 5 in the Caribbean, and was at Category 4 when it made landfall in South Carolina. Hugo directly hit the large Amerada Hess refinery on St. Croix. This facility sustained major damage and was inoperable for approximately one month. In Puerto Rico, the storm caused major damage to electric power service. There is a large body of literature describing Hurricane Hugo and the emergency recovery.

For purposes of our analysis, we have examined two scenarios. The first assumes that a hurricane of similar magnitude to Hugo crosses the south coast of Puerto Rico in a westerly direction. The second hurricane scenario has the storm concentrated in the greater San Juan area, including Bayamon and Cataño.

As a hurricane is identified to be approaching coastal areas of Puerto Rico, the petroleum industry will undertake an orderly shutdown of operations at its various refinery, storage, and terminal facilities. The oil companies will resume service after the storm has passed by and damage assessments are conducted.

One of the typical consequences of a hurricane in a market as heavily dependent on oil supplies for energy consumption as is Puerto Rico is that in its immediate aftermath, consumption of petroleum products can be expected to decline. During cleanup and recovery, business often is closed, transportation services are curtailed, and air passenger traffic slumps. Following a storm of severe magnitude, tourist activity also will drop sharply. A major decline in petroleum consumption results from the loss of electric power service to many locations, which reduces the requirement for burning fuel for electric power generation.

On the supply side, the distribution of petroleum products to final markets also may be curtailed. In particular, transport of fuel by trucks may be restricted until roads are cleared.

Scenario 1

Our first scenario results in a severe impact on the areas of Yabucoa (Sun Oil refinery), Guayama (Phillips refinery), and Guayanilla (CORCO storage and terminal). The north end of the island is largely unaffected, and business resumes quickly, with normal rates of consumption being undertaken for most of the population.

The processing units and towers at the Yabucoa and Guayama refineries probably will remain intact. There is a high probability that the ship and barge docking facilities will remain in service, with some minor damage to the Phillips dock at Guayama. The truck loading (rack) facilities will be damaged and unavailable for immediate usage. Both refineries will suffer damage to buildings and warehouse facilities, possible loss of process monitoring. Some damage will occur to crude oil and product tanks. Communications at both facilities will be impeded. Electric power supply to the refineries will be lost due to damage in surrounding areas.

Completion of cleanup and restart of processing operations will take from four to eight weeks at each refinery. In the interim, as much as 145,000 b/d of refining capacity will be lost. The dock areas will resume initial operations after approximately ten days. This will allow barge traffic to temporarily draw down products from storage. Sun Oil and Phillips will be forced to declare force majeure on contracts.

Marketing companies such as Exxon, Shell and Texaco will draw on product storage during the first week, during which time they will enter the international products market to purchase cargoes of gasoline, jet fuel, etc. PREPA will draw on its residual fuel oil and No. 2 distillate stocks. PREPA will have the opportunity to purchase spot cargoes as required. As the scenario moves out to the year 2000, gasoline supplies from some sources in the Caribbean region may become tighter. However, the

market will be able to meet this temporary demand. Per barrel product prices will rise to account for the increased costs associated with alternative procurement and transportation differentials.

In this same scenario, the hurricane track is westward to the Guayanilla area. The storm hits the CORCO and AROCHEM facilities, causing damage to various components, including the storage area and terminal facilities. There is also a loss of electric power service. In spite of these losses, the predominant share of above ground storage tanks are undamaged. Likewise, at least some of the barge and tanker loading berths remain in service. Operations are resumed soon after the hurricane passes.

The AROCHEM processing towers are undamaged, but that facility suffers damage to equipment and buildings. Recovery of operations at the refinery is completed within a four week period.

Scenario 2

Our second scenario seriously impacts the northern areas of Puerto Rico, including the CAPECO refinery at Bayamon, and the Cataño storage facilities. The storm causes major damage around San Juan Bay. In this scenario, domestic petroleum consumption is sharply reduced due to the loss of electric power, temporary closure of the San Juan International Airport, and damage to commercial, industrial, and residential consumers of petroleum products.

Any serious damage sustained to the Cataño terminal dock would significantly complicate the petroleum industry's ability to meet demand for a range of products in the San Juan area. Alternative routing can take place through the CAPECO terminal and tank farm facilities. However, the flexibility is limited if CAPECO is to sustain its own operation at normal rates.

Products procured from elsewhere on the island would be subject to the same transportation bottlenecks faced by the wholesale operators constraining their movement of products to market. In the event of constraints to barge traffic, the only other alternative would be to transport products by truck. The present fleet of tanker trucks is inadequate to handle this volume.

If the Cataño dock area survives the storm intact, the wholesale product marketers that operate Cataño probably will continue to draw from existing commercial sources of supply.

The CAPECO refinery operation (42,000 b/d capacity) is essential to support retail gasoline operations for its service stations on Puerto Rico. It is also a large supplier of bunker fuel, and sells some jet fuel. Storm damage to the refinery at Bayamon would necessitate CAPECO expanding its procurement of gasoline supplies.

The owners of CAPECO have acquired the AROCHEM refinery at Guayanilla. The intent of the company is to operate the AROCHEM plant at close to its 80,000 b/d rated capacity (with EPA approval). They would produce jet fuel, diesel, and premium gasoline (products on which they are presently short); and lease from CORCO about 3 million barrels of storage, a truck loading rack, and marine terminal facilities. Should these arrangements be completed, CAPECO will have the capability to access these additional supplies in an emergency from a location in southern Puerto Rico.

The outages we postulate in this scenario are of a maximum duration in the range of 4-5 weeks.

Our analysis indicates that PREPA might be forced to draw down its fuel oil stocks and enter the market with new acquisitions. This analysis does not take account of any risk that storm damage might prevent PREPA from taking delivery of cargoes at its power plants in the area. CAPECO has local pipelines linked to PREPA in the Cataño area. According to PREPA, "... the Authority has never been forced to curtail service to its customers because of fuel shortages."

Earthquakes

Puerto Rico has experienced major earthquakes in its past, but at infrequent intervals. In the past 135 years, there have been two major earthquakes, the last occurring in 1918. The latter event is reported to have had an epicenter off the northern coast of the island in the Puerto Rico Trench. Each of those events had an estimated magnitude of 7.5 on the Richter Scale.

For the purpose of our vulnerability analysis, we assume that an earthquake with a magnitude of 7.5 on the Richter Scale occurs off the north coast of Puerto Rico. We assume that it has a severe impact on the population center in the north. We then analyze the likely impact on petroleum product supply.

Earthquake damage to energy systems tends to concentrate on local electric power lines, local natural gas distribution pipelines (generally found in urban areas), propane tanks and, in some cases, petroleum and natural gas transmission pipelines. Shore areas may experience a tsunami (tidal wave) associated with offshore incidents. In most cases, pipelines will be unaffected, although the operators will want to inspect the lines for integrity. The greatest probability in a catastrophic event is that bottlenecks will be concentrated largely at the product distribution and retail levels.

There are few major pipelines in Puerto Rico. The transportation pattern for petroleum products places a heavy focus on barge operations. This eliminates much of the risk related to pipeline damage. In most cases, pipeline breaks are localized and repairs can be readily made.

We have not had the opportunity to examine the right-of-way for the fuel products pipeline from Cataño to San Juan International Airport. Damage to the line itself is quickly repairable, but damage to any surrounding structures (e.g., bridges on which it is carried) would lengthen the time required to restore the line.

Damage at the CAPECO refinery probably would be minor, as would damage at the Cataño terminal storage facilities. Based on previous incidents of earthquake related damage to refineries, we anticipate that the processing, storage, and product terminal functions would remain intact, and operations would be rapidly restored after the incident.

Communications service and electric power supply interruptions, however, could constrain petroleum operations. However, we do not envision that these will be of a sufficient duration to cause market shortages of petroleum products.

As in the case of storm damage from hurricanes, overall demand for petroleum products is likely to decline immediately after the occurrence of an earthquake. This would ease pressures on the rate of drawdown of product inventories.

Fires and Explosions

This category of vulnerability generally relates to single incidents which are confined to one location, although the repercussions could potentially affect an entire petroleum system.

For purposes of our first order assessment (screening), we take a simplified approach by assuming a catastrophic accident that totally eliminates the capability of the affected facility to meet its primary functions for a protracted period. For a refinery, this would amount to a fire that destroys most of its essential processing capability. The reconstruction schedule would be on the order of one year or more, and the operator might decide, for business reasons, to permanently abandon the facility. The incident which produces that result causes damage on the order of magnitude experienced by Phillips Petroleum at its ethylene plant in the Houston area. No attempt is made in this study to perform a detailed technical review of specific plants from a safety standpoint. The cases used are purely hypothetical, and should not be construed as making any judgments regarding plant safety at the actual facilities.¹²

We make the assumption that any one of the following facilities may be lost permanently through a catastrophic accident:

- Sun Oil Refinery (Yabucoa)
- Phillips Refinery (Guayama)
- CAPECO Refinery (Bayamon)
- AROCHEM Refinery (Guayanilla)
- Peerless Oil and Chemical plant (Guayanilla)

Our analysis indicates that the petroleum market on Puerto Rico is capable of overcoming any such loss by purchasing products from the world market. Consideration had been given to closing the Phillips refinery for business reasons. When Phillips expressed this intention, its clients re-directed their product (gasoline) acquisitions to off-island sources. Phillips has since decided to retain the refining operation. Sun Oil is reported to have also considered terminating refining operations at one time. The CAPECO refinery was shut down from March 1988 to November 1989 as a result of poor refinery economics. The AROCHEM refinery was in bankruptcy proceedings and has been closed since December 1991. It is not likely to re-open until late in 1994, at the earliest.

We also mention the Peerless Oil and Chemical Company plant, which is located in the same overall complex in Guayanilla as CORCO, AROCHEM, and the former Union Carbide Plant. Peerless is a small topping plant with a capacity of about 9,000 b/d. It was closed from 1981 to 1989, when it was modified to run a condensate feedstock. Its principal contract is for the production of jet fuel and marine diesel for the U.S. Defense Fuel Supply Center. Peerless also undertakes some gasoline blending for Sun Oil. For purposes of this study, we do not consider this plant to be a key facility for the supply of petroleum products to Puerto Rico.

¹² Technical analyses employing techniques such as hazard and operability (HAZOP) studies, hazard analysis (HAZAN), and reliability studies will assist operators in: (1) determining the probability of single point or multiple failures (equipment and process design) that result in accidents, and (2) measuring the potential consequences of those accidents. Human factors analysis is another technique that examines the risks of human error. These are often employed in the processing industries as a component of the plant safety programs.

The operation of each of the above facilities is convenient for local wholesale product suppliers, but not necessarily essential. Business interruption of these refining facilities under normal market conditions will be extremely costly to the operators involved. But from the standpoint of the supply-demand balance, the petroleum industry on Puerto Rico can effectively handle this dislocation. The wholesaling companies estimate that it would take from ten days to three weeks after receiving notice of loss of supply for them to redirect purchases, secure product cargoes, and receive delivery into Puerto Rico. Petroleum product inventory drawdowns would provide some cushion in the interim and shortages of most products can be averted.

Pipeline Damage

The one significant products pipeline operation in Puerto Rico is the line which delivers jet fuel from Cataño to the San Juan International Airport. It is operated by Pipelines of Puerto Rico, Inc., which is a consortium owned by Texaco (40%), Shell (40%) and CORCO (20%). The line, which runs parallel to the road going to the airport for most of the route, is a buried line, but crosses over an inlet on a bridge. The bridge area would pose a particular vulnerability in terms of the length of time necessary restore service if the structure were damaged.

If the line were forced out of service, the only alternative means of transporting jet fuel to the airport would be by truck. Jet fuel usage at the San Juan International Airport is on the order of 10,000 b/d. There would be a shortage of trucks available to move this volume of product, and handling the required truck traffic (loading and unloading) would potentially pose a logistics and scheduling problem. At present, the small number of existing trucks in service are largely committed to transporting aviation fuels to the smaller airports around the island.

Ship Collisions and Oil Spills

Most of the crude oil and oil product movements in Puerto Rico are made by sea. The major risk to petroleum operations posed by an oil spill or maritime accident (outside of its evident ecological considerations) would occur should the incident take place in the vicinity of the terminals that handle oil barge and tanker traffic. Examples of this include damaged vessels that may block ship channels and spills that require a suspension of traffic pending clean-up.

We have analyzed several of the major oil terminal facilities, by on-site visits, and/or examination of engineering drawings and photography. These include those ports associated with each of the refineries, and the receiving terminal at Cataño.

Our first order scenario assumes for each of these ports that the facility is closed by an accident at the harbor entrance, or in the narrow channel leading to the docks at the terminal. This is particularly critical for Yabucoa (Sun Oil) and Guayama (Phillips), which both have small protected harbors with narrow entrance and one large dock to handle incoming crude. This form of emergency is a single event occurring at one site only.

The emergency spill response plan calls for booming the harbor in the event of a spill occurring at dockside or inside the harbor. It is likely that barges or tankers damaged immediately outside the harbor area will be brought in and boomed off to minimize environmental damage. The harbor would be closed to normal marine operations until cargo from the damaged vessel could be removed and the

surrounding area cleaned up. Approvals would have to be given before the harbor could reopen to operations. Depending on the extent of damage to the affected vessel(s) and the volume of spilled oil requiring cleanup, the harbor area might be closed for weeks. This assumes that the equipment and manpower contained in the spill response plan are activated on a timely basis.

In the event a vessel sinks and blocks the channel, it would have to be raised and towed away, in addition to the requisite spill containment and cleanup. Again, this effort could take weeks to complete.

Such a disruption is likely to have more of an impact on product distribution if it occurs in San Juan Bay, particularly in the area around the Cataño and CAPECO terminals. This would reduce the flexibility of the major wholesalers (Shell, Exxon, Texaco and CAPECO) to transfer products to markets along the northern part of Puerto Rico. It would also constrain their ability to draw down their existing product inventories.

Acts of Sabotage and Terrorism¹³

The key petroleum systems on Puerto Rico are vulnerable to acts of sabotage. While most acts of this nature are likely to be sporadic and haphazard with little consequence to business, a well planned and coordinated attack on the system by a small team of knowledgeable and experienced individuals could have the potential for catastrophic results.

The petroleum industry on Puerto Rico operates in a normal business environment similar to that of the industry on the mainland of the United States.

- Security consciousness and safety awareness by the industry is on par with that of the mainland,
- Many operating companies are subsidiaries of major U.S. or Western European corporations and follow the same set of practices as is carried out throughout the corporation, and
- To some extent, security practices have been adapted to fit local conditions.

The highest rate of security incidents at petroleum facilities relates to personal acts such as theft and vandalism. These acts may be perpetrated by disgruntled workers. Security at operating facilities is typically designed to counter such risks as well as to: (1) establish a boundary along the perimeter to restrict access to only those individuals with legitimate business, and (2) to support procedures that may be implemented during emergencies, such as a fire, or a release of toxic or hazardous material. The industry's security concerns are focused on these perceived risks, and investments in security measures are commensurate with those risks.

¹³ This section is not intended to imply the imminence of any risks to the petroleum facilities in Puerto Rico. No threat assessment has been conducted and no conclusions have been reached regarding plans and intentions of any individuals or groups. The section addresses the issue of hypothetical risks based on the vulnerabilities that have been identified.

One feature of the petroleum systems on Puerto Rico is that most of the facilities characterized as essential to maintaining petroleum operations are manned sites with 24-hour operations. Most of these sites have active on-site security systems (perimeter screening and manned and remote surveillance). Once inside these facilities, security tends to be minimal.

Access to these facilities, particularly the refineries, is given to permanent employees, long-term contract employees, as well as to temporary contractors and visitors. Access also is given to persons and vehicles that enter the premises for purposes of delivering equipment and supplies, loading products on tanker trucks, seaborne receipts and deliveries of crude oil and petroleum products (barge and tanker crews), etc. For security and safety reasons, the individuals will be given identification, but there is little internal monitoring of their activities. Therefore, there is some risk posed at these facilities even through unforced entry.

The high risk areas within refineries include the processing units and ancillary equipment (e.g., pumps, boilers, and cooling units). These are large custom designed capital items with a considerably long lead time to repair or replace if extensively damaged. The storage tanks are important, but a number of them would have to be damaged to seriously degrade operations. Piping manifolds that direct the flow of crude and products to individual storage and intermediate flow tanks and between processing units are important custom designed components.

The control systems at a processing plant are essential to allow for the safe and unimpeded monitoring of the units to regulate temperatures, pressures, and flows. Communications, power and water supply are other vital components of the refinery operation.

Another of the critical areas in these refineries are the marine terminals which provide the primary outlet for refined products. A unique factor is that several of these terminals are owned by the Ports Authority of Puerto Rico and leased to the operating companies. Security is the responsibility of the Ports Authority and there is some question as to what legal authority the operating companies have to enforce security at these sites. The operating companies can not necessarily restrict public access to the dock areas for individuals who want to observe activities. Individuals also would have access to the area from offshore by boat.

We have conducted a scenario analysis which assumes that a small cadre of well trained terrorists coordinate simultaneous attacks on several of the key petroleum installations we have identified, and then subsequently follow-up with other selected targets in various areas of the island. The initial acts of sabotage have a high (80% +) success rate.

The impact is a loss of most essential service at Yabucoa and Guayama, although in both cases, the operators will be able to move limited volumes of stored products by truck. The terminal facilities at Cataño also are damaged and out of service. The pipeline from Cataño to San Juan International Airport is damaged and flow of jet fuel to the airport is closed. Damage to CAPECO in Bayamon is minor and the complex of facilities in Guayanilla suffer only partial damage.

The immediate security response by federal, state, and local authorities (in addition to a heightened security reaction by the operating companies) results in a blanket being thrown around key petroleum and electric power installations, thus minimizing the risk of successful follow-up attacks.

From the perspective of the terrorist group, this is a highly successful operation which meets their objectives of: (1) causing significant economic disruption, (2) pointing up the weaknesses of public authorities, and (3) creating an enormous level of visibility for themselves and their cause in the media.

The result is a loss (at capacity levels) of an estimated 135,000 b/d of on-island refinery throughput. This loss amounts to about 73 percent of total active refining capacity on Puerto Rico (with AROCHEM closed), and 51 percent once AROCHEM has reopened. The affected refineries will have the capability to move a small volume of product out of storage and sent to market by truck.

The oil industry response is to enter the world market as buyers to make up for shortages of particular products. This effort requires from 10 days to 3 weeks to bring in the first cargoes. In the interim, the companies draw down existing product stocks. Some products may be in temporary short supply, but alternative strategies could mitigate the dislocations. For example, selected aircraft might be required to refuel either prior to or after their stop in Puerto Rico. This can be achieved on a temporary basis without necessarily having to reduce the number of flights.

From the world market and regional supply perspective, the disruption in Puerto Rico will be considered one factor in the supply-demand balance that will affect price. However, the actual immediate impact would be less than if, for example, one of the large Caribbean refineries (e.g., Curacao which had estimated refinery runs of 185,000 b/d in 1992) were idled for maintenance. Regional refineries may contractually opt to increase their refinery utilization rates to help meet this demand. Meanwhile, the market demand for crude oil into Puerto Rico would decline concomitantly.

The operators of the seriously damaged refineries would have to evaluate the costs associated with rebuilding these facilities and determine whether there is a business interest in resuming the refining operation. In this scenario, the time to restore each refinery to full service is projected at a minimum of 18 months.

The repair of damage at Cataño and to the pipeline from Cataño to the airport is essential to support bringing an adequate supply of products to the final end users. It is possible to extend the interconnections between CAPECO and Cataño to provide some limited flexibility for transferring products. A considerable amount of time and remedial work will be required if a decision were taken by the operators to reopen the south-north products pipeline which runs from CORCO to Cataño. This would not, however, solve the transportation bottlenecks downstream Cataño.

6.2.4 Physical Characteristics of Key Electric Power Facilities

Interdependence of Petroleum Systems and Electric Power System

The integrity of both petroleum and electric power operations on Puerto Rico are closely intertwined. The design of each has resulted in a major dependence on the reliability of the other to sustain service.

All of the petroleum refineries referenced above utilize electric power generated by the Puerto Rico Electric Power Authority (PREPA). There are no alternative systems inside the refinery gates capable of supplying back-up electric power in an emergency to maintain all of the essential functions.

All emergency systems derive from additional lines and capacity operated by PREPA. Massive failures in PREPA generation and transmission would force the cessation of operations at the refineries. Petroleum tank farms and terminals also would face problems in crude and refined product transfers. Retail gasoline pumping operations at service stations also would be affected by curtailments of electric power.

According to PREPA statistics, the three largest refineries operating in Puerto Rico during FY 1992 consumed a combined 351,948 kWh of electric power from the state utility, and ranked first, second, and sixth in industrial usage of electricity on the island. However, this represented only about 2.5 percent of total electric power sales (by kWh) on Puerto Rico.

PREPA INDUSTRIAL CUSTOMERS (FY ending 30 June 1992)				
Ranking	Company	Location	Electric Energy Sales	
			kWh	Revenue
---(in thousands)---				
1	Sun Oil	Yabucoa	154,846	\$10,379
2	Phillips	Guayama	134,640	\$9,233
6	Caribbean Petroleum	Bayamon	62,462	\$4,451

In the same period, PREPA used 27.3 million barrels of petroleum products, making it the largest consumer of petroleum products on the island. PREPA typically maintained an inventory of petroleum products equivalent to approximately a 25-day supply. Residual fuel oil was the largest type of fuel procured, and No. 2 distillate fuel oil was also utilized. Overall, fuel oil accounted for 98 percent of total electric power generated by PREPA in FY 1992. With PREPA fuel oil consumption averaging 74,800 b/d, it would require about 1.9 million barrels of fuel oil storage to maintain a 25-day supply based on average daily consumption, and somewhat more to support consumption rates for the same duration during peak seasonal periods.

PREPA has sought to mitigate the fuel cost by signing multi-year supply contracts at more advantageous prices with Venezuela (whose deliveries are on the order of 30 percent of PREPA's total fuel oil demand). The majority of its fuel oil acquisitions still come from purchases on Puerto Rico, which are made under one year requirement type contracts which include provisions for a one-year extension by mutual agreement. The anniversary dates of these contracts vary by power plant. Some acquisitions are made on a short-term or spot basis.

The PREPA electric power generation plants and transmission lines that service petroleum processing, storage, and transportation operations on Puerto Rico, must be considered an integral

component in a petroleum supply vulnerability analysis. A major loss of electric power systems would have a deleterious impact on the capability of petroleum systems to deliver products to market.

PREPA Infrastructure

The Puerto Rico Electric Power Authority owns and operates a number of electric generation power plants throughout the island of Puerto Rico. These plants have a combined dependable generating capacity of 4,219 MW as of FY 1992. The average load was 1,833 MW and peak load (60 minutes) was 2,437 MW in the same period.

Of the four major power plants, two (the Palo Seco and San Juan plants) are located by the north coast near the capital city in the vicinity of Cataño; and the other two (the Aguirre and Costa Sur plants) are situated on the south coast, respectively near Guayama and Guayanilla, where major petroleum facilities are located.

The PREPA electric power system is interconnected throughout the island. PREPA maintains approximately 2,200 miles of transmission lines, consisting of 38 kilovolt (kV), 115 kV, and 230 kV lines terminated by 175 substations and switchyards. Its distribution facilities consist of more than 25,000 miles of lines and 870 substations (575 of which are consumer owned). *Figure 1* shown previously on page 15 identifies the capacity and location of each PREPA power plant, and the routing of its major transmission lines.

Each of the major power plants receives its fuel oil cargoes at adjacent terminal (dock) unloading facilities which handle barge and some small product tanker traffic. In addition, the San Juan and Palo Seco plants can obtain petroleum products via pipeline from Cataño and the Caribbean Petroleum refinery at nearby Bayamon. The Costa Sur plant is connected by pipeline to nearby CORCO storage at Guayanilla.

Recent statistics provided by PREPA give an estimate of fuel use and storage capacity for the major power plants and storage facilities.

PREPA FUEL USE AND STORAGE				
Power Plant	Type of Fuel Oil	Estimated Annual Consumption (barrels)	Storage Capacity	Maximum Days
Aguirre	No. 6	6,000,000	836,000	36.4
Costa Sur ^{1/}	No. 6	7,500,000	868,000	34.7
Palo Seco ^{2/}	No. 6	4,000,000	438,000	29.2
San Juan ^{2/}	No. 6	4,000,000	178,000	11.9
Peak Units/ Combined Cycle	No. 2	4,000,000	500,000	33.3
CORCO ^{1/ 3/}	No. 6		1,454,000	
Storage	No. 2		450,000	

^{1/} A short distance products pipeline runs between CORCO storage facilities at Guayanilla and the Costa Sur power Plant.

^{2/} A common fuel distribution pipeline is available between the Palo Seco and San Juan power plants, both of which link through Cataño.

^{3/} PREPA leases fuel storage facilities from CORCO under a five year contract effective February 1993. Fuel oil from this storage can be barged to any of the PREPA power plants.

PREPA maintains control of operations through a newly installed state-of-the-art telesupervisory control system which allows for centralized dispatching and planning. The system, known as the Energy Management System (or EMS) consists of a centralized computer-based network with 208 remote units located throughout the island's various electrical facilities.

This EMS allows supervisory control of generation, transmission, and distribution. The EMS gathers information, alerts the dispatcher to upset conditions, calculates optimum operating modes for the dispatcher, and allows the operator to centrally control the entire system to achieve desired results. The EMS is typical of the latest supervisory control and data acquisition (SCADA) systems in increasingly widespread use by power companies on the U.S. mainland. This automated control system becomes especially critical when the electric system comes under stress, in such cases as weather disturbances, fuel shortages, accidents, natural disasters.

As is the case in all wide-area SCADA systems, the EMS is dependent on the ability to maintain survivable communications: (1) from remote sites to allow operators to monitor events, and (2) from the master control center (MCC) to operating facilities throughout the island to issue controls.

The failure of an MCC (including back-up systems) will necessitate conducting field operations by localized control or in a non real-time mode. PREPA's EMS functions through a microwave communication system. Microwave systems typically are looped because they are dependent on line-of-sight. Some risk to the system's integrity is posed in a severe windstorm. If towers are twisted or dishes are turned, the communication fails in that leg of the loop.

6.2.5 Vulnerabilities of Key Electric Power Facilities to Local Disruptions

There are several types and categories of potential emergencies that might seriously disrupt electric power services on Puerto Rico. This study has examined such emergencies to determine the threshold at which the intensity of damage to the electric power system and the duration of the critical path to recovery is of a sufficient magnitude so as to create serious dislocations to the petroleum sector on Puerto Rico, as well as to other essential segments of the economy.

The types of emergencies analyzed include:

Loss of fuel oil supply at the power generating plants

Natural disasters

Hurricane

Earthquake

Accidents

Fires and Explosions

Internally induced power failures

Acts of sabotage and terrorism

Loss of Fuel Oil Supply

The loss of fuel oil supply to the electric power system can be caused by at least one of three types of emergencies: (1) a general shortage in international petroleum supply, or a run-up in world oil prices to the point where the system cannot financially afford to obtain necessary volumes of fuel oil for electricity generation; (2) on-island petroleum-related emergencies which inhibit or prevent the necessary transfer of fuel oil to the electric generating plants from a transportation and logistics standpoint, and (3) direct damage inflicted on the fuel oil handling and storage facilities of PREPA.

The PREPA emergency response to the first two causes of fuel oil shortages is largely market related, and must be addressed in terms of contractual relationships and alternative sources of petroleum supply. The vulnerability of Puerto Rico to international market induced disruptions (both supply and price) is discussed elsewhere in this study. The petroleum vulnerability assessment (above) addresses the risks to fuel oil supplies due to on-island disruptions.

This section focuses on the third cause of fuel oil loss – direct damage to PREPA fuel oil handling facilities. Such potential losses are discussed below in the context of the types of emergencies that may produce such losses (e.g., natural disaster, accident, sabotage, etc.). For purposes of this

analysis, it was assumed that normal business conditions — current and projected — prevailed in the world oil market through the year 2000.

It should be noted that, to date, PREPA has not experienced an emergency in its electric generation, transmission, or distribution operations that can be directly attributed to a shortage of petroleum products.

Hurricane

As described in the petroleum vulnerability section, Puerto Rico is a high risk area for hurricanes. There is a reasonable probability that at least one major hurricane will hit Puerto Rico by the year 2000. Unlike petroleum systems, electric power systems are far more susceptible to damage from hurricanes. The loss of electric power services may have a large impact on industrial, commercial, and residential energy consumers in the path of the storm, as well as those end-users dependent on service from power plants and transmission systems located in the storm area.

The electric power network on Puerto Rico is an interconnected system that allows the transmission of power supplies from one end of the island to the other. Therefore, it is possible to distribute electricity around the island from different originating power plants and through different routing. In an emergency, it is theoretically possible to impose a pre-determined rationing scheme to regulate power flow to essential and non-essential customers. In reality, the extent of damage inflicted by a hurricane often causes short-term and possible medium-term constraints in transmission routine to meet essential demand for electricity.

This study examined the relative vulnerability of the different sectors of the electric power operation (i.e., the power generation plants, transmission system, and distribution systems) as well as the vulnerability of fuel oil handling facilities for the power plants.

The precise levels of anticipated damage to each of these sectors can vary according to hurricane intensity and location. These differences often determine the time path to recovery, and which consumers will face loss of service, and the other in which service is restored.

The electric power plants tend to hold up very well to hurricanes and historic evidence suggests that little long term damage is inflicted. However, in the event that critical capital equipment is damaged at these plants, the outage (in a worst case) can last for months to more than a year.

In particular, the transmission step-up transformers in the switch yard, if requiring replacement, might require one year or more for procurement, fabrication, delivery, installation and commissioning. The chances of destroying transformers through storm damage alone are slight. Each major power plant in Puerto Rico has several banks of transformers, so that the loss of one bank will not necessarily prevent at least the partial flow of electricity into the transmission system. Moreover, it is possible to feed generated power from one yard with damaged transformers to the step up transformers in another yard at the same power plant. Even with extensive damage at one power plant, other major plants can still generate electricity into the system.

The electric power transmission system also has certain vulnerabilities. In a major storm such as Hurricane Hugo, some of the transmission field towers can be taken down or damaged. However,

on the whole, they have fared relatively well in actual major hurricanes. Transmission lines might be out of service for days or weeks until work crews can respond to repair all damage. The major power substations along the transmission lines have vulnerabilities similar to the switch yards at power plants.

Many areas of Puerto Rico are serviced by multiple lines in the network, so that at least partial long distance transmission of electricity (bypass) can take place if an individual line is lost.

Typically, a power company will initiate repair operations to each of the sectors almost immediately. The transmission system must be restored or in operating order before consumers along that transmission line can receive power supplies. It should be noted that the major petroleum refineries and petroleum storage areas are in the vicinity of large electric power plants. The amount of time necessary to repair transmission lines to restore service to these consumers of electricity is likely to be relatively small - so long as they are considered a priority consumer for early restoration.

The major damage in a hurricane is generally inflicted on the local electric power distribution system. A large number of poles are likely to go down due to heavy winds. These do not have the structural integrity of transmission field towers. Repair efforts to restore electricity to residential, commercial, agricultural, small industrial, and public consumers in the aftermath of a major hurricane may take weeks and months to complete, depending on the severity of damage.

In a severe hurricane, damage to homes, business, services, and infrastructure will tend to reduce the demand for electric power until repairs are made within the general economy. Therefore, the total demand for power generation will have an upward sloping recovery curve, as does the electric power system deliverability. This reduces the requirement for the electric power system to operate its entire generation capacity immediately after a catastrophic storm.

The critical requirement is to bring electricity to essential services, such as hospitals, public safety, sanitation, water supply, communications, etc. Thereafter, electric power services must be restored to homes for lighting, cooking, etc.; businesses to support the resumption of economic activity, and to public services. The critical path to recovery for electricity consumers in each category will, to some extent, depend on where they are physically situated with respect to the repair strategy. Residential customers may find that their power is more quickly restored if they are on the same distribution line as an essential service such as a local hospital.

The vulnerability of the fuel oil handling facilities (barge docks, pipelines, and storage tanks) also has been examined in regard to hurricanes. We have found that even in severe storms, damage to these facilities tend to be minor, and not affect the operations integrity for the power plants.

PREPA will maintain an average 25-day supply of fuel oil on site at many of its facilities. If some storage is damaged at a power plant, there probably would be sufficient fuel oil inventory in other tanks to allow operations to continue. The operator also can arrange to barge in other fuel oil supplies, if necessary, to make up for the loss in reserve inventory. If the dock facilities were damaged to the extent barges could not unload, the company would be able to draw down existing fuel oil stocks until repairs can be completed and barge service resumed. This presumes that damage is not so severe as to result in extensive repair times.

Three of the major PREPA power plants also are linked by pipeline to fuel oil supplies from petroleum refining and/or storage facilities. This provides an alternative path for fuel oil receipts.

If the loss of outside fuel oil supply is of significant duration, the power company will have to consider imposing a rationing scheme for generating power at the particular affected power plant. However, the temporary loss of a customer base immediately after a devastating hurricane (in terms of sharply reduced demand for electricity) means that the typical 25-day supply of fuel oil at a plant may be stretched significantly; the same volume of fuel oil could, in the short-term, represent a much larger number of days of supply.

Moreover, the loss of generation from one power plant, or the partial loss of generation from multiple plants, may still leave sufficient active power generation to enable PREPA to meet its electric power requirements in the short run. The most likely bottleneck in the critical path to recovery is the electric distribution system.

For purposes of our analysis, we have superimposed the same hurricane scenarios used in our petroleum assessment, and we also have considered both hurricanes (respectively hitting the north and south parts of the island) in terms of back to back storms during the same hurricane season.

The storm which is centered in the San Juan/Cataño area in the north causes significant damage to the electric distribution system. The main 230 kV and 115 kV transmission grid was in rapidly repairable condition, as were its dispersed large generators. However, the switch yards at Palo Seco and San Juan power plants were in need of substantial repair. Both retained partial capability; some banks of transformers were undamaged so that generators could continue to feed electricity into the transmission system. Fuel tanks were not damaged at any of the generation sites. The oil barge unloading piers were intact, although minor repairs would have to be made.

The storm in the south results in PREPA's 230 kV grid being severed just inland from Ponce. Steel towers were twisted and long strings of insulators snapped from their tower moorings. Transmission lines also were down in the Guayama area. The switch yards at Costa Sur and Aguirre power plants also sustained some damage, but at least partial capacity is intact at each facility.

Under these scenarios, PREPA still maintains a capability to generate electricity for its essential customers. This would include petroleum refinery operations after a short-term cleanup and repair. The major constraint in this emergency is the loss of power to retail gasoline service stations which are not able to operate their pumps, unless they have back-up generators.

Petroleum fuel oil supplies are not a critical path bottleneck to restoring electric power operations in the wake of a major hurricane.

Earthquake

The assessment of vulnerability of electric power systems on Puerto Rico to an earthquake is focused on the north coast area, based on historic information discussed in the petroleum vulnerability section of this study. We have compared Puerto Rico's electric power infrastructure to those elsewhere which have been affected by major earthquakes (on the order of 7.5 or more on the Richter scale).

As in the case of hurricanes, earthquakes are most likely to damage electric substations, generation station piping, and distribution systems. While the damage might be extensive, it is far more probable that the damage will be localized than is the case in a hurricane. There is not much evidence of long-term damage to electric generation facilities, and only some damage to the transmission lines.

The most vulnerable generation facilities based on location only, would be the Palo Seco and San Juan power plants among major facilities. Even assuming that, in a worst case, an earthquake causes one or both facilities to become either completely or partially disabled, sufficient power generation exists around the island to cover all essential electric power end-users (once transmission and distribution is restored). Moreover, we do not consider the long-term loss of Palo Seco and San Juan to have a high probability; indeed, the partial loss of service at one would have a relatively low probability.

Experience has produced little in the way of certain engineering solutions to lessen damage. Using very strong bolts and security them well into concrete pads beneath each major component seems to be the best solution to date. Overhead equipment, such as buss bars in substations, should be allowed to have some flexibility in order to ride-out the tremors and other motions born of the quake.

Feeders supplying critical or strategic industries or installations should ideally be routed through separate substations and transmission routes.

There is a very low probability that fuel oil storage tanks and unloading facilities will be subject to major damage.

There is very little likelihood that earthquake damage would constrain the petroleum industry's ability to obtain electric power on Puerto Rico, nor that such damage would lead to a shortage of fuel oil to maintain active electric power generation operations. In most cases, a temporary drop in electric power supply would cause pumps, boilers and other equipment to trip off. This upset condition is inconvenient for the refiner, but not lasting. In any case, an earthquake in the general vicinity would be felt at the petroleum refinery as well as at the nearby power generation plants. The refinery operators probably would conduct an inspection of the integrity of equipment prior to restart of operations; therefore, temporary power outages may not pose a bottleneck to refiners.

If transmission lines between the power plants and refinery were down, the refiners would have to await the restoration of at least one line. This downtime is likely to be short-term. The refineries tend to be served by multiple transmission lines originating from different power sources, for purposes of emergency back-up.

Floods

This study has not examined the vulnerability of the electric power system to floods, resulting from hurricanes or other seasonal or temporary weather conditions, accidents at dams, etc. We are aware of the incident at the Carraizo Dam in 1989 (during Hurricane Hugo) in which the multiple failure of electric power and the dam's emergency generator prevented the flood gates from opening, causing the flooding of the pump house at the dam.

Power plants, fuel pumps, switch yards, substations, and other electrical equipment associated with power production, transmission, and control, face the risk of significant damage by coastal flooding. Tidal wave action resulting from a hurricane or earthquake could possibly inundate such facilities due to their proximity to coastal areas.

Accidents

The electric utility may be subject to accidents which impair service. This might include first, explosions, loss of communications which support the central control system (EMS), etc. We judge these incidents to be localized, and as not having serious consequences for meeting the long-term electric power delivery commitments of PREPA. While such incidents might produce the temporary loss of power to particular consumers, the system is designed with sufficient flexibility in most cases to provide alternative generation and transmission capability. Loss of central control functions is inconvenient for operators, but operations can be sustained locally in an emergency, so long as communications (e.g., telephone, radio, microwave, etc.) are available, and personnel can staff the field sites.

Acts of Sabotage and Terrorism

The electric power system operation on Puerto Rico maintains a level of security equivalent to that maintained by the industry on the U.S. mainland. At the power plants, the first line of security is at the gates, but there are few layers of security beyond that. Security is designed to restrict entry. However, a knowledgeable and determined saboteur or team could access the facility and cause significant damage to critical equipment at a power plant.

The ability to impair the electric power system across the island would require simultaneous actions against several large power plants (on the assumption that security would be greatly heightened once the first attack had taken place). The principal targets are more likely to be exposed critical capital equipment in the switch yards, rather than fuel oil handling facilities, because the loss of the former would have more of an immediate and potentially long-term impact than would loss of the latter.

Other vulnerable areas would be the substations and transmission facilities. There is a possibility that particular transmission lines and substations could be targeted, possibly including petroleum refining facilities. It is more likely, however, that primary targets would relate to the objective of denying power to major metropolitan areas.

On balance, multiple outages rather than isolated attacks would have to be inflicted in order to seriously degrade the integrity of the electric power system.

6.2.6 Economic Impact

This section will discuss the economic impact of potential *local* energy supply disruptions in Puerto Rico. The types of local disruptions that could occur are natural disasters, specifically hurricanes and earthquakes; accidents, such as fires, ship collisions, and oil spills; and acts of sabotage and terrorism. Economic impact will be similar for different types of disasters because physical

destruction of facilities will be similar in different disasters. A discussion of vulnerabilities and disruption scenarios is included elsewhere in this report.

Petroleum Supply Disruptions

Puerto Rico petroleum facilities include refineries, storage terminals, docks, and one pipeline. Vulnerable facilities located on the southern part of the island include the Sun Oil refinery at Yabucoa, the Phillips refinery at Guayama, and the Commonwealth Oil terminal and storage facilities at Guayanilla. The AROCHEM refinery, also located at Guayanilla, is currently inactive but may open in the next few years. Vulnerable facilities located on the northern part of the island, all of which are in the San Juan metropolitan area, include the CAPECO refinery at Bayamon, the oil terminal and storage facilities located at Cataño, and the pipeline running from Cataño to the San Juan international airport. Petroleum facilities¹⁴ are vulnerable to the following events.

- Natural disasters, such as hurricanes or earthquakes. All petroleum handling facilities are vulnerable to hurricanes. Our worst case hurricane scenario postulates back to back Category IV¹⁵ hurricanes, the first striking the southern part of the island and the second striking the northern part of the island, including the San Juan metropolitan area. Only the facilities on the northern part of the island are vulnerable to earthquakes. Natural disasters of this magnitude would disrupt the economy even in the absence of petroleum disruptions. This section discusses only those economic impacts that can be traced specifically to the petroleum disruptions.
- Accidents, such as fires, explosions, ship collisions and oil spills. These accidents are more localized than the natural disasters and are assumed to affect one site only. These accidents can disrupt dock operations, refinery operations, and may damage storage capacity.
- Acts of sabotage or terrorism. The worst case sabotage/terrorism scenario assumes that facilities at Yabucoa, Guayama, the Cataño terminal, and the Cataño pipeline are taken out of service. Refinery capacity would be lost for up to 18 months. The facilities in Guayanilla and Bayamon would sustain only minor damage.

Different disasters can lead to similar damage of petroleum facilities. The disruption scenarios discussed above can cause the following physical disruptions to vital petroleum facilities.

- Shutdown of one or more refineries, lasting from 4 to 5 weeks in the case of hurricanes to up to 18 months in the case of terrorist activities.
- Shutdown of oil terminal and docking operations. These can last for between 10 days to several weeks in the case of oil spills.

¹⁴Although PREPA, the sole Puerto Rico electric utility, has substantial petroleum storage facilities, these will be considered separately under electrical supply disruptions.

¹⁵Hurricane Hugo and Hurricane Andrew were both Category IV storms when they hit the mainland U.S.

- Shutdown of the Cataño pipeline.

A refinery shutdown(s) would necessitate oil companies' entering the world market to secure refined petroleum supplies. Estimated delivery of petroleum supplies would take between three to ten days. In the interim, petroleum companies and PREPA, the electric utility, would draw down on existing supplies. Prices for spot market refined products may be higher than locally refined products; if this is the case, end users will pay higher prices.

The actual economic impact would depend upon the type of disaster experienced. In the case of a major natural disaster, petroleum demand would fall considerably because everyday activities would be curtailed. The additional effects of a refinery shutdown would be small relative to the economic impact of the storm. Sabotage that affected one or two refineries may have a larger impact in terms of prices. There may be a temporary speculative run-up of prices. However, once alternative supply arrangements are in place, prices will likely stabilize and may even return to their pre-disruption levels within a month or two. This would likely have little impact on economic growth; the Puerto Rico economy has grown through price increases before. We expect there will be no physical shortages caused by refinery damage *per se*, because refined products are readily accessible elsewhere.

It appears that many Puerto Rico refinery operations are marginally economic. For example, the CAPECO refinery closed from March 1988 to November 1989 for business reasons; the Phillips refinery also closed down at one point. This suggests that the advantage to the local petroleum industry of siting refinery operations in Puerto Rico is limited. Consequently, any price increases resulting from loss of Puerto Rico refinery operations may be fairly small. Also, once long-term supply contracts are in place, prices in the long run may be very close to current prices with all local refineries open.

Shutdown of terminal and docking operations is a more serious concern, because most refined product movements to and within Puerto Rico occur by sea, not land. While temporary shutdown of terminal and docking operations at either Yabucoa, Guayama, and Guyanilla is not expected to have much of a deleterious impact on the Puerto Rico economy, the shutdown of docking and terminal operations at the Cataño terminal in the greater San Juan area could have serious economic impacts. Product movements would have to occur by truck to San Juan from one of the southern terminals,¹⁶ and the present tanker truck fleet is inadequate to the task.

One result of a Cataño terminal shutdown would be a slowing of product flows into the San Juan area. If the terminal shuts down as a result of a hurricane or other natural disaster, petroleum demand would be sufficiently depressed to that there would likely be little or no additional effect from the terminal shutdown. However, if the terminal shuts down as a result of an accident or terrorist operation, petroleum products would have to be trucked in. Because the present tanker truck fleet is inadequate to meet local demand at current prices, prices would increase so that supply and demand of refined petroleum products would balance.

A sustained price increase in refined petroleum products could result in secondary price increases in intermediate and finished products within Puerto Rico and for export, and could have a slight to moderate economic impact, depending upon the time it takes to restore the Cataño terminal. Such secondary price increases could lead to declines in domestic aggregate demand and tourism. A

¹⁶Our disaster scenarios posit that not all terminals will be nonoperational for extended periods of time.

price increase lasting a month or two may have little effect; one lasting more than one or two months could have more serious economic effects. However, it is highly unlikely that the Cataño terminal would be completely shut down for more than one month.

The pipeline that runs from Cataño to the San Juan international airport is a critical supplier of jet fuel to the San Juan airport. If this pipeline were shut down, the existing fleet of tanker trucks is too small to sustain normal fuel service to the airport. A shutdown would not necessarily impede commercial air traffic in or out of San Juan in the short term: planes could refuel at other sites on a temporary basis without much disruption. A longer shutdown may inconvenience economic activity in several ways. The shutdown may: reduce tourist traffic; reduce the attractiveness of San Juan as a Caribbean hub for American Airlines and other carriers; and make business travel less convenient by restricting flight schedules. The economic impact of reduced tourism should be slight. The tourism sector comprises about 4.7% of Puerto Rico gross internal product.¹⁷ Moreover, the majority of Puerto Rico tourists are U.S. mainland residents of Puerto Rican origin who visit local residents. Tourism of this group may not be greatly affected by reduced airport operations; if this is so, the economy will suffer little impact as a result of reduced airport operations affecting tourism. If American Airlines reduces or ceases its hub operations as a result of a long-term pipeline shutdown, San Juan employment will fall slightly, but this effect will likely have a small impact economy wide. Inconvenience of business travel may be one factor against locating new business or expanding old business in Puerto Rico; this may slightly reduce future economic growth.

Electric Supply Disruptions

PREPA is the exclusive retail supplier of electricity to Puerto Rico. PREPA has several major generating stations located throughout the island and an interconnected transmission and distribution network on the island. PREPA depends upon petroleum for 98% of its electricity, and it keeps approximately at 25-day supply¹⁸ of petroleum products at most of its major generating stations. The petroleum refining and distribution industry in Puerto Rico also depends upon electricity from PREPA for its operations; no refineries or terminals self-generate. Many petroleum refineries are connected to multiple transmission lines originating from more than one generating plant in order to ensure backup. Refineries also tend to be located close to generating plants, which allows quicker restoration in the event of an electric outage.

The electric system is vulnerable to hurricanes, earthquakes, floods, accidents, and sabotage/terrorist activity. Unlike mainland utilities, PREPA is also potentially vulnerable to disruptions in petroleum supply through refinery disruptions and physical damage to its petroleum handling and storage facilities. Major generating plants have their petroleum handling terminals and docks; also, three generating plants have alternative access to fuels by local pipeline.

¹⁷Source: Junta de Planificación de Puerto Rico, *Informe Económico al Gobernador 1992*

¹⁸Under normal demand conditions.

The most vulnerable parts of the electric system tend to be the transmission and distribution networks.¹⁹ An outage affecting a significant part of the island and lasting one month or two will lead to short-term impedance of economic activity, but will have little, if any, long term economic effect if the economy is otherwise sound. This observation is borne out by the Hurricane Hugo experience. Hugo brushed the northeastern part of the island, causing loss of power to 600,000 people. Power was restored to most customers within one month. However, Puerto Rico's real FY 1990 GDP grew at a healthy rate of 3.71%.²⁰

In the event of a refinery disruption, PREPA would purchase petroleum supplies on the open market, in the meantime drawing on its inventories. This may lead to temporary, minor increases in PREPA's fuel costs, which could be passed on to consumers through higher electric rates. The economic impact of these electric rate increases would likely be slight. There was little or no economic impact resulting from the electric rate increase in FY 1990, which lasted through FY 1991; any price increase resulting from a local disruption would likely be smaller and shorter in duration.

Physical damage to PREPA petroleum handling facilities could occur through damage to its docks and terminals by a hurricane, an accident, or by sabotage. If seaborne petroleum handling facilities were disabled, the San Juan, Palo Seco, and Costa Sur plants have pipeline backup. If an individual generating plant were to shut down because of a temporary lack of fuel, PREPA should still be able to maintain normal service levels. In this case, there would be little, if any, economic impact.

PREPA has never had to interrupt electric service as a direct result of fuel shortages.

Summary

The Puerto Rico economy should be able to bear most local petroleum and electric system disruptions with slight to moderate economic impact. From an economic standpoint, the most severe energy supply disruption that could occur would be shutdown of the Cataño terminal in the San Juan metropolitan area. Supplies would have to be trucked in, and the current fleet of tanker trucks is inadequate to the task. This would restrict petroleum products supply in the San Juan area, and may cause local, nonarbitragable price increases. Should a Cataño shutdown last more than a month or two, there could be noticeable deleterious effects upon the Puerto Rico economy.

¹⁹ Although generating facilities can also be damaged, there is enough backup capacity to keep generators from being a critical factor in an emergency.

²⁰ While this was lower than in previous years, this reflects the slowdown in the U.S. economy during this time period.

7 ACCESS TO VITAL OIL SUPPLIES IN AN EMERGENCY

7.1 Introduction: Scope of Response Options Evaluated

Experience has shown that *local* emergencies are unlikely to cause a sustained major oil supply disruption in the islands. The most likely effect of hurricanes, typhoons and earthquakes on oil supply systems is damage to docks and oil storage facilities and to electric power facilities that serve them. This damage would create problems for distributing available oil supplies. However, island dock and storage facilities have survived severe storms relatively unscathed.

The analysis of *past global* disruptions has shown that the islands have consistently maintained continuous supplies. Analysis of possible future global disruptions does indicate that the islands could suffer supply interruptions under severe conditions, particularly early on in a disruption. The principal negative consequence of oil supply disruptions is, however, that the islands suffer heavy economic losses from the high oil prices obtaining during the disruption.

Given these impacts of possible local emergencies and global disruptions, efforts to increase energy security in the U.S. insular areas need to focus on: (1) methods for coping with temporary shortages that can occur until local petroleum distribution problems are resolved, or new regional supply-demand balances are established; and (2) ways to mitigate the price increases from global oil disruptions.

In recognition of the requirements of the Energy Policy Act 1992, this section concentrates on options to enhance "access to vital oil supplies". Section 8 focusses on means to improve energy emergency preparedness and to reduce energy vulnerability over the longer term.

Several of the options considered would improve physical "wet barrel" oil supplies without alleviating oil price – and therefore economy – impacts. Others, such as conservation and fuel diversification, would restructure energy demand so as to reduce the role of petroleum on the islands. Further options, notably an island-owned oil reserve and revolving oil futures contracts, would secure additional physical supplies and help mitigate disruption price effects.

It should be noted that both Puerto Rico and the U.S. Virgin Islands have energy emergency response plans approved or under development. These plans contain a variety of response measures, such as demand management, that the island governments could implement in an energy emergency. It should also be noted that the options considered here are incremental to SPR drawdown, IEA response measures and possible additional actions such as relaxation of monetary policy. The islands would all benefit from the supply and prices impacts of these national/international measures.

The following options were identified and assessed:

- Puerto Rico requires its petroleum industry to maintain excess commercial oil inventories.
- Puerto Rico alone, or together with the U.S. Virgin Islands, establishes an island-owned product SPR.
- Puerto Rico establishes support alliances with other areas and suppliers.

- Puerto Rico employs the futures market to hedge against sudden oil price increases.
- Federal government provides Puerto Rico with emergency access to military petroleum supplies on the islands.
- Federal government guarantees Puerto Rico priority access to crude oil from the U.S. SPR.
- Federal government establishes a crude/product SPR on Puerto Rico that serves both Puerto Rico and the U.S. Virgin Islands.
- Puerto Rico establishes temporary product quality waivers to be invoked during emergencies.

Each option is reviewed below.

7.2 U.S. Strategic Petroleum Reserve Policy

The U.S. currently maintains approximately 580 million barrels of crude oil for use during oil crises. The policy of the U.S. regarding the release of SPR oil is to rely primarily on market forces to allocate supply, and, in an emergency, to supplement oil supply by the early drawdown of SPR oil in large volumes, in coordination with our allies and trading partners. The main objective of the policy is to remove pressures on oil prices, thereby limiting economic losses resulting from a sudden large increase in oil prices in an emergency.

During a global oil emergency, refineries in Puerto Rico can bid on crude oil from the U.S. SPR on the same basis as mainland refineries. This option is the status quo. Accordingly, it is important to understand how the SPR would affect the island. Access to SPR crude is subject to the following major procedures: the President must decide to release SPR crude, the crude is sold on the basis of sealed bids to the highest eligible bidders, and successful bidders must transport their oil. (A detailed discussion of SPR drawdown procedure and experience is contained in *Appendix C*.) Each of these procedures has important consequences for the islands.

The need for a Presidential decision to release the SPR means that the timing of an SPR release will depend on political as well as market factors. These may lead to an early draw. However, during the 1990-91 Persian Gulf, over five months elapsed between the onset of the Crisis and the Presidential order to release the SPR. In short, from the island's perspective, the timing and probability of an SPR draw are both uncertain and outside the island's control.

In addition, the time taken for the SPR bid process, selection of winning bids, arrangement of liftings, crude shipping, refining, and distribution means there is a minimum 30-45 day period from release order to availability of product at the retail level. Announcement of an SPR draw will, however, tend to have an immediate downward effect on oil prices, easing market conditions even before physical product deliveries improve.

The sale of SPR crude to the highest bidders means that island refineries are not guaranteed SPR crude supplies. In addition, the bidding process ensures that the oil will sell at the prevailing market price, although the act of releasing the SPR will tend to depress the market price. Thus, if island refineries are among the successful bidders, the crude would be obtained at prices which may

still be substantially higher than pre-disruption prices. Hence, although SPR crude could provide additional supplies for the islands, it would not mitigate the price spike in the islands any more than it would do so for the U.S. Mainland areas.

The need for successful bidders to provide their own means of oil transport puts a premium on the availability of suitable tankers during an emergency. It also heightens the need for a Jones Act waiver because the Jones Act would apply to any SPR shipments headed for Puerto Rico. Based on the experience of the Middle East Crisis, it is understood that a Jones Act waiver would accompany any future SPR release order.

7.3 Increase in Commercial Stocks

Puerto Rico could increase on-island inventories during an emergency by requiring the petroleum companies on the island to maintain excess inventories. Some European countries have followed this approach in connection with their participation in the International Energy Agency. In order to avoid putting island refiners at a competitive disadvantage compared to off-island refiners, Puerto Rico would probably want to compensate companies for the additional cost, which might be paid for by a tax on island oil users. The mandatory stocks approach has the following advantages and disadvantages:

- Advantages:
 - Stocks can be released upon the order of the Governor of Puerto Rico, avoiding the delays associated with a Presidential decision.
 - Products remain within the industry supply system which facilitates rapid access and inventory turnover.
 - All of the costs are passed along to oil users.
- Disadvantages:
 - Puerto Rico would need to establish a program for compensating companies and monitoring company compliance with inventory requirements, which could be complicated and/or costly.
 - Some of the international oil companies that have participated in the European countries' mandatory stock programs have argued that government-held reserves are better than mandatory excess commercial reserves because government reserves:
 - Are more credible
 - Have greater positive psychological impact
 - Afford greater supply flexibility
 - Spread costs among all taxpayers not just oil users.

Puerto Rico would need to assess whether the advantages outweigh the disadvantages in their own situation.

7.4 Island-Owned Product Reserve

Another option examined was the concept of an on-island strategic products reserve that would be owned and controlled by the islands. Such a reserve could be developed by Puerto Rico alone or by Puerto Rico and the U.S. Virgin Islands together. The concept could be implemented in several ways. One possible implementation includes the following elements:

- **Financing**
 - A Puerto Rico government authority (for example, PRIDCO) would issue tax-exempt revenue bonds to pay for the reserve.
 - A dedicated tax would be levied on all island oil consumption to pay the principal and interest on the bonds, i.e. to fund the costs of establishing and maintaining the reserve. Over a period of, say, five years, the cost of the reserve – barring ongoing leasing costs – would have been fully recouped through the tax levy.
- **Storage**
 - Storage capacity would be leased from private companies on the basis of lowest bid cost for storage and inventory turnover.
 - The CORCO refinery on Puerto Rico's south coast has tankage available, and CORCO officials have expressed serious interest in the concept.
- **Operation**
 - The reserve would be operated by a petroleum company under contract to the Puerto Rico government.
 - Clean products in the reserve would be turned over (i.e. sold off and replaced) at intervals to prevent product deterioration. Market hedging methods would be used by the reserve operator to buy and sell at the same price.
 - In an emergency, the reserve would be released upon order of the Governor. If the product in the reserve had been fully paid for via the oil tax by the time of the disruption, the reserve would be released into the island market at effectively zero cost. Its effect would be to partially offset the high oil product prices obtaining because of the disruption. The mechanism for administering the release would require further study but at least two alternatives are apparent:
 1. **Zero Price Release**

Under this mechanism,

 - Oil from the reserve would be released at *zero* price into island markets. Reserve oil would combine with other oil supplies

purchased at market prices so that the effective price to oil users would be a weighted average below the market price.

- An allocation or set-aside system would be used to distribute the reserve among interested parties.
- Price controls would be applied to prevent the reserve oil from rising to market prices and to prevent windfall profits by oil companies
- Export controls would be applied to prevent reserve oil from being exported and re-imported as market oil.

2. Full Price Release

Under this mechanism,

- Reserve oil would be sold into the market at market price. In fact, the intent would be to sell at peak disrupted prices to gain the maximum benefit.
- The revenue gained from the sale would be applied as an immediate rebate or tax reduction against island prices of petroleum products. For any reserve oil used by PREPA, this would take the form of a downward adjustment to the otherwise increased fuel charge. For other products, this may take the form of a sales tax reduction or negative sales tax.
- A physical allocation or set-aside system would probably not be necessary but price and export controls may still be needed.

As mentioned above, either mechanism would require more analysis to assess its administrative feasibility and market impacts.

- **Benefits**

- During an oil disruption, product prices would reflect a weighted average of (effectively) zero-priced supplies from the reserve and market-priced supplies from the open market. This would mitigate the impact of the usual price spike on the island economies (although not the impact of a slowdown in the U.S. mainland economy).
- During the period of reserve build-up or replacement, the tax on oil consumption would encourage further conservation efforts by oil users.

- **Issues**

- Operation of the reserve would require a complex administrative system that may prove unworkable. In particular, it could require standby emergency price

controls, allocation, and export controls. All of these elements would need to be available only on a standby basis, i.e., the Governor could still proceed with previously announced intentions to dismantle Puerto Rico's current system of gasoline price controls.

- Although preliminary indications are positive, detailed analysis is required to assess whether the beneficial impact of the reserve in a disruption would exceed the cost of creating and maintaining the reserve.
- Environmental risks associated with a local reserve, and liabilities assumed by the Puerto Rico government, would need to be assessed.

The economics of an island-owned products reserve depend on numerous factors, including: the size of the reserve, the number of years the reserve is in place before a disruption, the magnitude and duration of the oil price increases during the disruption, the price of oil when the reserve is being filled, interest rates, annual costs for leasing storage capacity, the rate of growth in real oil prices over time, the administrative cost burden of price controls and allocation during the disruption, and the economic benefit to the insular economies from mitigating oil price spikes.

As part of this study, numerous cases were examined involving a range of values for the above factors.¹ It was found that for a 5 million barrel reserve, benefits exceeded costs under a wide range of reasonable parameter values. This finding appears to be due to the following factors:

- The ready availability of a large amount of existing storage tanks that could be leased on a long term basis for 15 to 20 cents per barrel per month including inventory turnover. This is at the low end of storage costs estimated in earlier studies.
- The relatively low current price of oil.
- The presumed use of tax-exempt revenue bonds to finance the reserve. This lowers the real discount rate for Puerto Rico to about 3 percent, compared to a 10 percent real discount rate for a Federal SPR.
- Use of a comprehensive measure of economic benefits that includes both the improvement in GDP and the improvement in the terms of trade that result from lower island oil prices. This is the approach adopted by a Federal interagency working group for estimating the economic benefits of the U.S. SPR.

The tax on island oil consumption required to finance the reserve would be on the order of 0.7 to 1.5 cents per gallon depending on the reserve size and the other factors mentioned earlier. Environmental risks and administrative costs were not considered in the above analysis.

Tables 36 and 37 summarize cost and benefits results designed to bracket the likely range of scenarios; from a large disruption (\$50/bbl) occurring after five years with a monthly storage cost of 15¢/bbl to a small disruption (\$35/bbl) occurring fifteen years after the reserve has been in operation

¹Environmental risks and administrative costs were not assessed as part of the study.

with a monthly storage cost of 25¢/bbl.² In the one extreme (large, early disruption, low cost storage), the indicated future value net benefit to Puerto Rico is approximately \$325 million. In the opposite extreme (small, late disruption, higher cost storage), the indicated net benefit is essentially zero. Should the period to disruption be extended beyond fifteen years, and only a small disruption then occur, the indicated net benefit would be negative.

The degree of impact from the reserve, how visible that impact is, and where it falls in the economy depends primarily on the size and mix of the reserve. In the analysis conducted for this study, drawing down a 5 million bbl reserve fully over the course of a six-month disruption resulted in roughly 15% of Puerto Rico's petroleum demand being met from reserve oil, the balance from market sources.

The product mix contained in the reserve could, of course, be varied – both initially and over time – as could the size of the reserve. In the analysis conducted for the study, the reserve was focussed primarily on gasoline (60%) and secondarily on light and middle distillates (total 30%) and residual fuel (10%). The largest impact was, therefore, on gasoline prices. Price increases were, respectively:

<u>Disruption</u>	<u>With reserve</u>	<u>Without reserve</u>
small	10.2%	47.5%
large	43.0%	94.9%

Impacts on distillate and residual fuel price increases were far smaller. A different reserve mix would have re-allocated the price impact and the reserve's effects on different segments of the economy.

Table 38 sets out key assumptions used in constructing the analysis. Any of these assumptions could be varied to examine their impacts.

²The monthly storage costs represent an "all-in" fee, including periodic product turnover as well as fill, draw and physical tankage lease costs.

Table 36

ISLAND-FUNDED PRODUCT RESERVE DIFFERENTIAL IMPACTS OF DISRUPTION ON PR RESERVE VERSUS NO RESERVE			
Large Six-Month Disruption \$50.22/bbl Monthly Storage Cost 15 ¢/bbl Future Value Basis			
\$mm (1991)	Disruption Occurs		
	after 5 years	after 10 years	after 15 years
BAU Crude Price \$22.90			
Cumulative Reserve Cost	195.4	243.9	290.5
Benefits vs No Reserve:			
- Terms of Trade Improvement	240.0	240.0	240.0
- GDP Improvement	280.1	280.1	280.1
Total Benefits	520.1	520.1	520.1
Net (Cost)/Benefit	324.7	276.1	229.5
Average Tax Cost Spread Across Total Non-Refinery Demand (assumes inventory cost of reserve fully paid off just before disruption occurs)	1.28 ¢/gal	0.85 ¢/gal	0.71 ¢/gal

Table 37

ISLAND-FUNDED PRODUCT RESERVE DIFFERENTIAL IMPACTS OF DISRUPTION ON PUERTO RICO RESERVE VERSUS NO RESERVE			
Small Six-Month Disruption \$35.10/bbl Monthly Storage Cost 25¢/bbl Future Value Basis			
\$mm (1991)	Disruption Occurs		
BAU Crude Price \$22.90	after 5 years	after 10 years	after 15 years
Cumulative Reserve Cost	225.4	303.9	380.5
Benefits vs No Reserve:			
- Terms of Trade Improvement	199.5	199.5	199.5
- GDP Improvement	182.2	182.2	182.2
Total Benefits	381.7	381.7	381.7
Net (Cost)/Benefit	156.3	77.8	1.2
Average Tax Cost Spread Across Total Non-Refinery Demand (assumes inventory cost of reserve fully paid off just before disruption occurs)	1.48 ¢/gal	1.05 ¢/gal	0.93 ¢/gal

Table 38

ISLAND FUNDED PRODUCT RESERVE - ASSUMPTIONS

BAU world crude price prior to disruption (\$1990)	\$22.90/bbl
real annual discount rate/carrying charge	3%
annual oil price gain over inflation	2%
disruption duration (months)	6
price elasticity of demand	- 0.15 ¹
size and composition of product reserve (mmbbls)	
- LPG	0.0
- gasoline	3.0
- jet fuel	0.75
- distillate (diesel/No.2)	0.75
- residual fuel	0.5
- total	5.0
recovery via tax of	
- initial cost	yes
- carrying charge	yes
- storage facilities cost	yes

Notes:

1. Price elasticities of -0.10 and -0.20 were also tested but had little impact on the results.

The general approach to the analysis was as follow:

1. Set assumptions for financial parameters, reserve size and mix, period reserve in place before disruption, length of disruption, price elasticities of demand, demand BAU growth rates.
2. Utilize results from EIA's Year 2000 analyses using EnSys' *WORLD* Model to give market prices for crude and major products for BAU and two levels of disruption ("large" and "small").

3. Select either "large" or "small" disruption.
4. From projected BAU demands, establish disrupted demands, without reserve, using price elasticities.
5. Establish adjusted island petroleum product prices resulting from injecting zero cost (i.e. fully paid for) reserve oil into the island supply. Adjust demands for these prices using price elasticities.
6. Compute an effective island oil price based on the impacts of the reserve oil.
7. Compute the oil terms-of-trade loss versus BAU for the disruption, with and without the reserve.
8. Using results from the Puerto Rico planning board model, compute the GNP loss versus BAU, again with and without the reserve's impact on island petroleum prices.³
9. Compute the total cost of the reserve assuming its inventory cost is fully paid off just before the disruption. Reserve costs include product acquisition and carrying costs together with storage facilities costs.
10. Compare the cumulative reserve cost at the time of the disruption with the combined reductions in terms-of-trade and GNP losses because of the reserve to arrive at a net benefit to the economy at the time of the disruption.

7.5 Regional Support Alliances

The location of the huge Hess refinery on St. Croix, and the special relationship that has been negotiated between Hess and the U.S. Virgin Islands' government, provides the U.S. Virgin Islands with a level of security that is unmatched among the other insular areas. While it is unlikely that Puerto Rico could match that arrangement, benefits could flow from bilateral or multilateral mutual support agreements that Puerto Rico might negotiate with other Caribbean islands or suppliers. Possible candidates include the U.S. Virgin Islands (Hess Oil), Trinidad (TRINTOC), Mexico (PEMEX), and Venezuela (PdVSa).

These agreements could take the form of guarantees to supply certain volumes of crude and/or products under defined emergency circumstances, including both global disruptions and local disasters. In essence, such agreements would be insurance policies and would likely include an initial or continuing cost.

³The Planning Board cases for island reserve drawdown assumed that Puerto Rico would operate at a lower oil price because of the reserve but that the U.S. economy would still be operating at the global disrupted oil price. Therefore, the negative impact of U.S. Mainland economic down-turn on the Puerto Rico economy was not altered by use of the island reserve.

7.6 Futures Market Hedging

The petroleum futures markets that have evolved in the last ten to fifteen years provide oil producers, processors, traders and consumers with a variety of "paper barrel" mechanisms to hedge against the uncertainty inherent in the market. For consumers in particular, they provide a way to lock in future supplies at a known cost.

It is conceivable that Puerto Rico could establish and maintain a set of rolling futures contracts covering designated volumes of gasoline and other products. Futures contracts generally run out a maximum of twelve months into the future and the timing of disruptions is, by their nature, uncertain. Therefore, the total volume of each product to be covered would have to be divided into, say, 6 or 12 contracts, each expiring in a different month. This would provide coverage of 10/12 or 11/12 of the product volume at undisrupted prices at all points in time.

The cost of this option would depend on the level of transaction costs associated with maintaining and turning over multiple futures contracts.

7.7 Emergency Access to U.S. Military Petroleum Supplies

The U.S. military maintains an inventory of petroleum products in Puerto Rico. An analysis was conducted to determine whether access to these supplies in an emergency might benefit the insular areas. Discussions with the Department of Defense indicated that the military has petroleum storage capacity totalling 36,000 barrels on Puerto Rico. Actual inventories are reportedly maintained at about 70 percent of capacity. These quantities are clearly too small to be of any significant value during a global oil emergency. Puerto Rico's *daily* petroleum demand is nearly 170,000 barrels excluding refinery demand.

7.8 Guaranteed Insular Area Access to the SPR

During the last session of Congress, a bill was introduced in the House that would have guaranteed the insular areas access to SPR crude oil. Had it passed, this measure would have removed some of the uncertainty surrounding the bid process by guaranteeing that the insular areas would receive crude. However, because the crude would still be sold at the prevailing bid price, this option would not mitigate the price spike any more than without the guarantee. Thus, it would not substantially benefit Puerto Rico.

7.9 Island Component of U.S. Crude/Product SPR

Another option examined was the possibility of the Federal government establishing a crude oil or petroleum products reserve in Puerto Rico to serve both Puerto Rico and the U.S. Virgin Islands.⁴ As a component of the U.S. SPR, it would be subject to the same operational procedures. In particular, its release would require a Presidential decision, and the oil would be sold to the highest bidders. Under these conditions, the island reserve would be unlikely to benefit the islands much more than the status quo:

⁴If an island reserve were to be established, the U.S. Virgin Islands' government prefers that it be on Puerto Rico due to the more readily available land and storage capacity (i.e., at the CORCO refinery).

- The sales process may result in a 20 to 30 day period before oil could be delivered from the reserve. Additional time would be required for transportation, processing (for crude oil), and delivery to end users.
- The amount of the reserve would be too small to have any noticeable effect on world prices. Nor would it have much effect on island oil prices because the winning bids would likely be close to world prices except for transportation cost differences.
- The reserve may not produce much of a net increase in on-island inventories if island refiners and marketers reduce privately held inventories due to the availability of the reserve.
- The reserve may not significantly increase on-island supplies available during an emergency if some successful bidders take the supplies elsewhere.

Thus, the potential benefit to Puerto Rico and the U.S. Virgin Islands from an island component of the U.S. SPR in Puerto Rico appears to be small.

7.10 Special Waivers

Temporary environmental or other waivers could improve island supplies in a disruption:

- a Jones Act waiver (now likely to be integral with an SPR release) would increase tanker availability for Puerto Rico
- product quality relaxations – for instance, on diesel fuel or PREPA residual fuel oil – would allow temporary reversion to higher sulfur products, thereby tending to increase availability and lower cost

7.11 Concluding Comments

The options described above provide a range of alternatives for Puerto Rico to consider as additional responses to emergencies. This report does not presume to recommend a "best" option but has attempted to assess the strengths and weaknesses of each so that the island government can evaluate each one from its own perspectives. In addition, it should be noted that some of the options could be combined.

8 PREPAREDNESS AND VULNERABILITY REDUCTION STRATEGIES

The preceding section described response options that could be applied during an energy emergency. This section identifies strategies that could be followed to prepare more effectively for emergencies and to reduce vulnerability to emergencies. The following range of strategies is discussed:

- Enhanced Institutional Preparedness
- Increased Energy Conservation & Efficiency
- Fuel Diversification
- Definition of Potential Oil and Gas Reserves
- Petroleum Refining and Distribution System Enhancement
- Reduced Petroleum System Physical Vulnerability
- Reduced Electrical System Physical Vulnerability

Each is discussed in turn below.

8.1 Institutional Preparedness

At the time of preparation of this report, the Commonwealth of Puerto Rico was actively engaged in a reorganization of its energy functions. Set out below are supporting suggestions developed over the course of this study. The authors believe the institutions responsible for energy and energy emergencies could be materially strengthened through the following:

- Designating or re-establishing an organization with clear responsibility for energy emergency planning and response. To encourage industry cooperation, this organization should be separate from the institution responsible for gasoline price regulation if those regulations are continued.⁵
- Completing and adopting an energy emergency plan.
- Fostering coordination between government and the energy industry in energy emergency planning, testing and response.
- Developing an integrated energy planning capability.
- Developing and maintaining energy data sufficient to support plan development and implementation.

⁵In November 1993, the Puerto Rico legislature enacted a reorganization bill that would among other things establish an energy organization along these lines. The Governor signed the bill and his administration is now implementing the changes.

All of the above areas should fall under the wing of an expanded energy or natural resources department. This department should be established so that it has the capability to:

- develop comprehensive, accurate and timely island energy supply-demand balances
- understand and project island energy system supply and demand, economics, prospects and investment requirements; also broader market trends, opportunities and challenges
- advise and guide the Government toward establishing energy policies that optimally meet island needs, and maximize security and benefits to the island economy
- support and organize effective emergency plans and responses to actual emergencies

At present, the Government is reorganizing its energy policy and planning functions. This change responds to the prior absence of an agency responsible for energy policy and planning. With one or two notable exceptions, the Government also lacks personnel knowledgeable in the petroleum industry. Its energy data gathering is not fully comprehensive and is largely manual. It is suggested the impending reorganization consider the following actions:

8.1.1 *Personnel Resources and Training*

- assignment of sufficient personnel and systems resources to effectively execute department functions. A staff of even two to three capable, knowledgeable professionals, with a matching number of support personnel, should be able to accomplish a great deal.

The staff should (like their mainland counterparts in DOE and EIA) take full advantage of modern low-cost personal computer technology to gather and manage data, establish communication links and undertake analyses. (See below.)

- an early focus on training to improve departmental staff knowledge of the petroleum refining industry, petroleum economics, the electric power industry, electric power economics, the island refining, distribution and electric power sectors, the Caribbean (and ultimately global) petroleum markets, alternative energy options and conservation.

8.1.2 *Staged Development of Computer Systems*

Potential activities here could include:

- computerizing all currently obtained island petroleum and electric power data including: inventories, imports, exports, distributor sales, prices, generation and demand statistics
- extending this system to the point where it enables comprehensive and verifiable energy balances to be drawn up across the petroleum and electric power sectors, on both a monthly and annual basis.

In the petroleum sector, extensions should include:

- working with EIA to
 - a) routinely obtain refiners' submissions to the EIA
 - b) explore and rectify gaps and errors in EIA's data gathering on Puerto Rico (for instance, the EIA data do not appear to capture all imports to Puerto Rico that are to PREPA's account)
 - c) establish regular data communication with EIA to take advantage of the wealth of energy statistics EIA maintains, much of which is now available through a remote, on-line computer system (COGIS) as well as in hard copy form
 - d) encourage EIA to include explicit Puerto Rico petroleum statistics in its publications and data banks (These exist at present only to the extent of imports to and exports from the U.S. Mainland.)
- working with local refiners, PREPA, distributors, major consumers, and the Port Authority/U.S. Army Corps of Engineers to make sure available data, including crude and product flows into, out of and around the island, are captured

In the electric power and telecommunications sectors, extensions should include:

- working with PREPA and emergency service providers to ensure that critical backup power generators are in working order and will be able to obtain adequate supplies of fuel in the event of electric system emergencies
- working with telecommunications providers and private industry to:
 - a) establish emergency telephone restoration service priorities
 - b) update emergency telecommunications capabilities, including but not limited to providing expanded cellular telephone capability

In addition, the following extensions:

- incorporating into the system reasonable checks to maximize accuracy
- establishing a database on key energy personnel both within the island, on the U.S. mainland, and internationally
- establishing a database on key characteristics (location, function, capacities, etc.) of all significant energy installations on the island and their components
- potentially creating an analytical modelling capability (which could be relatively simple or highly sophisticated) that captures all the elements of the island energy system and enables them to be simulated so that the impacts and interactions of new developments (e.g. refinery closures or expansions, new electric power generation, changes in key product quality specifications, shifts to alternative fuels such as LNG) can all be evaluated and their consequences for security and the economy quantified

8.1.3 *Establishing Inter-organizational Links and Information Sources*

These could include:

- establishing/expanding firm links with key Federal energy and environmental personnel on the U.S. mainland
- establishing/expanding links with Caribbean regional and international organizations concerned with energy
- establishing links to data and information sources necessary to support and enhance departmental market understanding and intelligence (This could include subscriptions to a potentially wide range of publications.)

8.1.4 *Fostering Links with the Energy Industry*

This could include:

- establishing forums to communicate and review areas of common interest
- developing more formal links and undertaking test exercises related to energy emergency response planning
- creating response plans to cover specific identified potential emergencies, e.g. closure of San Juan Bay shipping channel, disruption of the Cataño to San Juan airport pipeline
- completing and adopting a comprehensive energy emergency plan
- working to resolve any issues outstanding between government and industry

8.1.5 *Developing an Integrated Energy Planning Capability*

The different energy sub-sectors on Puerto Rico interact with and affect each other. They are also impacted by international market developments, by new technologies, and by changes in the island's economy. To gain the maximum future benefit in terms of energy security, delivered energy cost, energy sector viability and efficiency, employment, balance of payments and tax revenue, it is essential to treat Puerto Rico's energy sector as a single system, with inter-connections both internally and internationally i.e. it is necessary to develop an integrated energy planning perspective and capability. This must encompass all energy sub-sectors currently active on the island – or potential – together with links to external markets. Such an integrated capability must be under-pinned by a comprehensive database, as discussed earlier, and would usually employ computer models of the island energy system.

8.2 Increased Energy Conservation and Efficiency

Electric power plants and motor vehicles consume 2/3 of the petroleum used in Puerto Rico. Increased energy conservation and efficiency in these uses could slow the growth in oil demand and, thus, contribute to reduced dependency on petroleum. Some options the islands may wish to consider are:

- *Electric power:*

- *Demand side management (DSM)* – is yielding measurable savings in *kW* and *kWh* among U.S. mainland electric utilities. PREPA may want consider implementing or expanding the following initiatives:
 - Customer load control, either by customers' voluntarily adjusting their loads in times of high demand or by PREPA, with customers' prior permission, remotely turning off appliances through an onsite or remote signal
 - Energy conservation, through encouraging the use of more energy-efficient lighting and appliances.
 - Cool energy storage, which shifts air conditioning electric load to off-peak hours. This technology is already being used in PREPA's executive offices, and PREPA is promoting it.
 - Heat pumps; the most advanced heat pumps provide efficiencies 30-40% greater than the average air conditioner
 - Pricing or rate design: PREPA has established Time-of-Use (TOU) rates for its larger commercial/industrial consumers.
- *Co-generation* – Co-generation offers increased energy efficiency compared to separate production of electricity and steam/heat. Puerto Rico's Generation Task Force is currently considering co-generation as well as other electric power options for PREPA.

- *Transportation:*

- *Mass transit* – The San Juan metropolitan area may be suitable for increased use of mass transit.
 - Mass transit would reduce petroleum use per passenger-mile.
 - Some mass transit options could also rely on non-petroleum energy sources such as electricity or natural gas.
 - Van pooling is a low cost option
- *Vehicle fuel economy* -- Puerto Rico may want to consider the following options to increase vehicle fuel economy:⁶
 - Higher fuel economy standards for new automobiles

⁶These options would also reduce vehicle emissions.

- Vehicle inspection programs
- Higher sales tax on new vehicles with lower fuel economy (widespread in Europe and adopted in Maryland but implementation delayed by the Bush Administration)
- "Clunker" buy-back program (used in California)
- Carburetor retrofit program for older cars

8.3 Fossil Fuel Diversification

Puerto Rico recognizes that it can best reduce petroleum dependency and vulnerability by following a long term program to diversify its energy supply. This section offers some suggestions on possible strategies involving diversification among fossil fuels. The next section discusses renewable energy. Elements of both strategies could also be combined.

PREPA's fuel mix heavily influences the future viability of Puerto Rico's refineries and the island's future petroleum dependency. PREPA fuel demand comprises over 45 percent of non-refinery petroleum consumption on Puerto Rico. To comply with tightening EPA emissions standards, PREPA is shifting to lower sulfur, lower metals residual fuel oil. This adversely impacts Puerto Rico refiners' economics. They are able to supply residual fuel at 2+ % sulfur but cannot do so at 1 % sulfur or lower without switching to high cost crude oils or blendstocks, or investing in new process facilities. The most likely outcome, already evident in island import-export data, is that island refiners will have to export high sulfur residual and import low sulfur to satisfy PREPA. The effect is two-fold: (1) an uneconomic double haul of residual fuel and (2) the investment to produce low sulfur residual or otherwise meet PREPA's emission goals is, effectively, exported elsewhere.

Recognizing the adverse impact on island refiners, PREPA could consider alternatives to residual fuel sulfur reduction. One option would be scrubbing of power station stack gasses to remove sulfur and nitrous oxides. This would enable local residual fuel supplies to be maintained and would lower the price paid for residual fuel under both business-as-usual and disruptions. Consideration should be given to the broadly projected widening of the gap between low and high sulfur residual fuel prices as shifts from high to low sulfur residual fuel are mandated in Europe, the Far East and elsewhere over the next five to ten years.⁷ While the energy sector and direct costs of stack gas scrubbing may be high, the net cost to the Puerto Rico economy may be lower than for fuel sulfur reduction.

Further steps, such as those for co-generation facilities already under consideration, would reduce Puerto Rico's dependency on petroleum through using coal, Orimulsion or liquefied natural gas (LNG) as fuels for power generation. All of these options reduce vulnerability to petroleum supply and price disruptions since prices of these three fuels are not so directly tied to crude oil prices and move less sharply in disruptions.

⁷Recent studies have suggested that the price differential between low and high sulfur residual fuel could widen to \$4-6 per barrel by the year 2000 compared to \$1-3 now.

Introduction of LNG in particular opens up a range of options for reducing vulnerability while maintaining island refinery economics and complying with environmental targets. Since LNG is a clean-burning fuel, PREPA could burn a 50/50 mix of LNG and 2% sulfur residual fuel and still generate emissions comparable to those from 100% use of 1% sulfur residual. Island refiners would be able to economically supply the 2% sulfur residual fuel and island vulnerability to petroleum price disruptions would be cut.

Puerto Rico could evaluate the benefits of expanding an initial LNG project - based, say, on the South Coast - to other markets in Puerto Rico. Construction of a trans-island pipeline (probably to move LNG in re-gasified form) would provide access to gas by power stations and industrial users in San Juan and potentially elsewhere. An island gas transmission system would also tie in to local gas supplies should any reserves be identified through future exploration on-shore or offshore Puerto Rico.

Additional potential for LNG could exist in the form of compressed natural gas for island busses, trucks, and potentially automobiles, reducing both petroleum dependency and also pollution, especially in the greater San Juan area. Fuel cells for dispersed electric power generation could represent a further application, reducing PREPA's need for investment in new central power stations.

Worldwide LNG trade is currently in a growth phase, increasing potential sources of supply. The recent announcement of a major LNG project on the coast of Venezuela, less than 500 miles from Puerto Rico, presents an opportunity for obtaining supplies at prices competitive with residual fuel on an environmental quality basis.

8.4 Renewable Energy

Renewable energy can play a role in the energy future of Puerto Rico. Renewables can reduce Puerto Rico's oil vulnerability and energy costs, and diversify its energy resources. Puerto Rico could use several renewable energy sources in the future. These sources include: OTEC, biomass, solar hot water heating, solar thermal electric, photovoltaics, and wind.

Ocean Thermal Energy Conversion (OTEC)

The OTEC process uses temperature differences between warm ocean surfaces and cold deep seawater to generate electricity. A temperature difference as small as 20 degrees Celsius can be exploited to generate electricity.⁸ The Center for Energy and Environmental Research (CEER) at the University of Puerto Rico has identified the southeast coast of Puerto Rico as the best location for potential OTEC facilities.

In addition, another type of OTEC technology pumps deep cold seawater to the surface for use in commercial air conditioning systems. Two facilities of this type are located in Hawaii at the Natural Energy Laboratory and in Halifax, Nova Scotia at Purdy's Wharf.⁹ This type of OTEC technology could also provide significant power savings for Puerto Rico.

⁸ Bath, Thomas D., et al. The Potential of Renewable Energy. National Renewable Energy Technologies, Golden CO., March 1990 at Appendix D-1.

⁹ Van Ryzin, Joseph and Tore Leraand. "Air Conditioning with Deep Seawater: A Cost-Effective Alternative," Sea Technology, September 1992, pp. 37-44.

Biomass

Biomass energy is derived from biological sources -- wood or wood wastes, residue of wood-processing industries, food processing wastes, agricultural processing wastes, organic, industrial and municipal solid waste (MSW), and the dedicated production of energy crops.

Potential for biomass in Puerto Rico. The three areas of potential growth for biomass in Puerto Rico are: 1) in crop residue combustion using multiple-use sugar cane; 2) in the direct combustion of forest products; and 3) in the direct combustion of MSW. According to the National Academy of Sciences, electricity generated by energy crops and residues could supply as much as 10 percent of Puerto Rico's energy needs by the year 2000.¹⁰

Solar Water Heating Systems

Solar water heating systems use sunshine to heat water either directly, by heating the water in a solar collector, or indirectly, by heating a circulating fluid-mixture that then releases the heat to the water through a heat exchanger. In 1990, 95 percent of low-and-medium-temperature solar thermal collector shipments in the U.S. were for the residential sector.

Potential for solar water heating systems in Puerto Rico. During the 1980's, more than 40,000 residential solar water heaters were installed in Puerto Rico. High purchasing and installation costs are the main constraints to greater utilization of solar water heating systems.¹¹ These costs should decline over time, however, with more experience in manufacturing technologies.¹²

Solar Thermal Electric Systems

Solar thermal electric systems use concentrated sunlight to generate heat for thermal conversion processes.

Potential for solar thermal electric systems in Puerto Rico. Assuming adequate solar insolation and improvements in current technologies, all types of solar thermal electric technologies have the chance at becoming fully competitive with fossil technologies. To do this, however, requires sustained orders, government investments, or other market signals.¹³

Photovoltaics

Photovoltaics (PVs) converts sunlight directly into electricity by means of a solid state device called a PV cell. In the United States, 31 percent of PVs sales are to the communications industry, 8

¹⁰ Southern States Energy Board, Energy Options for Puerto Rico, Norcross, Georgia, March 1990 at 26-27.

¹¹ Laitner, Skip, "Renewable Energy Resources in the U.S. Virgin Islands," Economic Research Associates, Alexandria, VA, August 1993 at 6.

¹² Conversation with Harvey Sachs, Ph.D., Director, Policy Research, Center for Global Change, University of Maryland at College Park, November 1, 1993.

¹³ *ibid.* at III-4-4.

percent are to the transportation industry, 7 percent are for water pumping, and 18 percent are directly to consumers.¹⁴

Potential for photovoltaic technology in Puerto Rico. Although there is a high level of solar insolation in Puerto Rico, PV use may be desirable only in remote areas that do not have access to electrical supply lines and that are removed from the island's electrical grid system.¹⁵ There is currently a 100 KW PV installation operating in the town of Juana Diaz.

Photovoltaic electricity is expensive when compared to alternative sources, but if markets grow as substantially as many observers agree they will, there is a potential for large price reductions.¹⁶

Wind Energy

Wind is converted into electricity with wind turbine generators or can be used to power mechanical processes, such as piston action water pumps. The quality of wind technology is improving. The best new turbines produce electricity at least 98 percent of the time if there is enough wind. Technical improvements are expected to continue and costs will decline if market growth is sustained. Experts have projected a cost of 3.5 cents/kWh within two decades.¹⁷

Potential for wind energy in Puerto Rico. More information is needed on wind patterns, such as velocities and durations, land use impacts, and environmental impacts before the feasibility of wind-based generating technologies can be determined.

8.5 Definition and Exploitation of Island Oil & Gas Resources

Between 1959 and the mid 1980's, Puerto Rico was the object of sporadic hydrocarbon exploration and production activity. At least three wells were drilled, all "dry." However, offshore geologic structures were identified and onshore gas pockets and oil seepages found.

A study commissioned in 1986 estimated 8 percent of Puerto Rico's onshore areas and 40 percent of its offshore areas up to 3,000 feet water depth had potential for oil and gas resources.¹⁸ The study also pointed to a dirth of exploration data and recommended a phased drilling program directed initially toward gathering data to confirm which specific areas could be prospective. Until 1994, PREPA holds an exclusive exploration license onshore and offshore Puerto Rico.

Puerto Rico may wish to consider options for re-establishing interest in its oil and gas potential, recognizing that :

¹⁴ Muller, Frank and Harvey M. Sachs, "Renewable Energy and Pollution Prevention in Southern California," Center for Global Change, University of Maryland, January 1993 at III-3-1.

¹⁵ Southern States Energy Board, Energy Options for Puerto Rico, Norcross, Georgia, March 1990 at 36.

¹⁶ Muller, Frank and Harvey M. Sachs, "Renewable Energy and Pollution Prevention in Southern California." Center for Global Change, University of Maryland, January 1993 at III-3-1.

¹⁷ *ibid.* at III-5-1.

¹⁸ De Golyer and MacNaughton, "Geological Investigation and Recommended Exploration Program for Hydrocarbons in Puerto Rico", June 1986.

- Private exploration and production (E&P) companies generally bear the primary risk and cost
- Exploration techniques have advanced substantially in the period since Puerto Rico's E&P program was active
- Improvements in offshore production techniques have greatly enhanced the economics of small, "marginal" fields.

The identification and development of even modest oil or gas reserves would reduce dependency on imported oil and enhance island balance of payments and employment. It would also support the viability of island refineries.

8.6 Refining Sector Enhancement

Puerto Rico's petroleum security is directly linked to the health of its refining sector. Numerous developments in the petroleum markets of North and Latin America present a rapidly changing scene for the island refineries. For instance:

- in Latin America:
 - privatization
 - high E&P activity, production expansion
 - demand growth
 - uncertain future export potential
 - refinery shortages, expansions & upgrading
 - gradual gas grid growth, LNG projects
 - environmental issues
- in the U.S. mainland
 - production decline
 - environmental mandates for refinery emissions reductions and fuels reformulation which are bringing about:
 - industry restructuring (including integration with foreign producers: Venezuela, Mexico, Saudi Arabia)
 - refinery reconfiguration, closures & sales
 - potential product import growth
 - possible product export growth
- regionally
 - growth activities of PdVSa dominate the scene
 - U.S. reformulated fuels program will have regional and global impacts.

For Puerto Rico and its refining sector, these developments represent both threats and opportunities:

- regional crude type/availability changes
- increased competition from regional & mainland refineries: Venezuela/Antilles, Trinidad, Hess VI, U.S. Gulf Coast
- new processing/export, feedstock supply, partnership opportunities

Ultimately, the island refineries will grow or decline based on their competitive economics. The authors' assessment is that the competitive outlook for the island refineries is not strong and that further decline may occur without effective support. (See discussion under Section 3.5, Energy Supply Outlook.)

Puerto Rico's refining outlook hinges on competitive advantages and disadvantages versus other regional refiners:

Advantages

- Petrochemicals and lubes boost value added
- Efficiently run (Mainland manning and service factors)
- Well depreciated (low capital carrying charge)
- Section 936 treatment of profits

Disadvantages

- Small, lack economies of scale
- Simple, limited upgrading capability
- Subject to full EPA environmental and safety standards
- No access to low-cost fuel
- High electric power cost (165% of Mainland)
- Ports are limited draft (no VLCC access)
- Jones Act constrains export trade to Mainland (*also provides potential protection against USGC exports*)
- Little/no local integration on unfinished products
- Limited local market

Puerto Rico faces the prospect that while its island refining sector might expand, with attendant increases in on-island sources and petroleum inventories up to 13 million bbls compared to 8-10 million bbls at present, it could easily decline further or even shut down totally in terms of fuels products operations. In the latter case, on-island inventories could halve to 4-5 million bbls.

Puerto Rico could benefit materially from pro-actively supporting its refining and petrochemicals sector to avoid potential further decline and maintain security, employment and government revenues.

Several options exist which between them could revitalize the sector, improve its efficiency and benefit consumers. These include:

- Seeking out and supporting new processing/supply/partnership arrangements
- Reviewing fiscal regimes and incentives for investment

- Maintaining/upgrading ports (hence access to larger lower-cost vessels)
- Minimizing costs of meeting environmental targets
- Promoting in-refinery steam/power generation
- Reducing refiners' cost of purchased power
- Reviewing refinery integration options
- Reducing intra-island distribution costs, e.g. through reactivation of the existing South-North petroleum products pipeline from Guayanilla to Cataño.
- Resolving any outstanding tax disputes and encouraging refining sector-government coordination.

Analysis of the factors influencing island refining competitiveness and of the costs and benefits of sector enhancement options, including their *combined* impacts, is a necessary first step.

8.7 Options for Reducing Petroleum System Physical Vulnerability

The study team had the opportunity to examine a number of the major petroleum facilities on Puerto Rico and to discuss operation of the petroleum systems with the operating companies. The following suggestions are offered as possible actions that could be taken to increase the physical security of petroleum supplies:

- The Ports Authority could enhance security at the oil terminals it owns and leases to the oil companies. This may require cooperation between the Ports Authority and the oil companies to modify the law on public access to certain docks.
- PREPA and the oil companies could formalize arrangements for priority restoration of electric power to petroleum facilities during an emergency.
- The oil companies could assess the adequacy of communications likely to be available during emergencies.
- The Ports Authority, in collaboration with island refiners and distributors could assess the logistics of supplying petroleum to the San Juan area in the event of blockage or closure of the San Juan Bay shipping channel as occurred a few years ago.
- The Department of Natural Resources and the oil companies could assess the feasibility of restoring and using the South-North petroleum products pipeline from Guayanilla to Cataño to provide additional capacity for moving products into the San Juan area during both normal and emergency conditions.
- The Ports Authority, in collaboration with island refiners and distributors could assess the logistics of supplying jet fuel to San Juan's Luis Muñoz Marín International Airport during emergencies, including a major disruption of the Cataño pipeline.

8.8 Options for Reducing Electric Power System Physical Vulnerability

Our study schedule did not allow a detailed assessment of options for reducing electric power system vulnerabilities. In lieu of such an assessment, we suggest below some emergency scenarios that PREPA may want consider as part of their normal emergency planning process. The draft Puerto Rico Energy Emergency Plan recognizes the value of testing emergency response procedures in advance (p.

9). We concur and suggest that testing include a variety of simulated electrical emergencies that will enable responses to be developed to reduce or mitigate potential electric power system vulnerabilities.

In this regard, we recommend that electric power emergency scenarios be considered in the areas described below.

8.8.1 Electric Generation

Puerto Rico has four major power generation plants connected by a high voltage grid. Loss of one or even two plants could still leave PREPA in a position to serve critical loads although perhaps at reduced levels.

However, a critical element in the power plants is the step-up transformer bank. We suggest that a scenario be considered which deals with loss of several of these banks and considers the spares situation. If it is determined that additional spare units should be obtained, we recommended that they *not* be stored in proximity to the existing units (as has often been done by utilities all over the world), but rather be housed in a secure location at some distance from the existing units.

One possible source of inexpensive spare capacity could be the surplus transformers which may become available during the military base closings in the U.S. mainland. Public agencies will have some priority rights to selection of such equipment when it is surplus, and *if* there are useful spares available, the Commonwealth would be well advised to explore the matter. (Surplus portable generators would be another asset to PREPA's preparedness program.)

Another possible source of transformers in an emergency could be spares located on the U.S. mainland. The North American Electric Reliability Council (NERC) maintains a "Spare Transformer Database." While we understand that PREPA is not now a member of NERC, PREPA may wish to consider an affiliate status such as Alaskan utilities have done.

8.8.2 Transmission

The comments made above for generating plant step-up transformers also apply to transformers located in transmission substations. The substation transformers could be *even more* critical assuming a multi-storm scenario or a sabotage scenario which affects a number of key substations simultaneously. It would be valuable to consider a scenario involving loss of these transformers and options for obtaining replacements.

8.8.3 Distribution

The Commonwealth has ample experience from Hurricane Hugo to develop scenarios that test whether it currently has sufficient spare power poles, distribution transformers, etc., available.

8.8.4 Communications and Control

As discussed in Section 3.2, PREPA has a state-of-the-art power management system in place. A scenario should be examined in which natural or man-induced damage occurs to the control center wherein back-up communications methods would be necessary. Also, the larger problem of communications among all concerned organizations such as the police, national guard, FEMA, etc., should be considered in concert with the control center loss scenario. Reports from other emergencies

clearly indicate that communications systems are often the most critical element in the success or failure of a response to a major emergency. Page 28 of the Puerto Rico Energy Emergency Plan commences a discussion of "Lines of Communication," the DOE "DIALCOM" system, and an "Operations and Coordination" center. This would be a good place to consider the entire array of communications tools such as FAX, cellular telephones, ham radio, walkie-talkies, etc., and consider their limitations and values. It may well be that an emergency communications system apart from the current commercial and utility systems may be appropriate. Again, with a reduced U.S. military establishment, there may surplus military mobile communications equipment available.

8.8.5 Customer Preparedness

Electric power customers can reduce their vulnerability to electric power outages by making provision for standby power. For example, a common problem during electrical emergencies is that gasoline service stations can't operate their pumps because the pumps are powered by electricity. As another example, it is apparent from recent major power outages in the mainland that telephone companies, in some instances, have not provided key equipment with sufficient standby power. This situation has been exacerbated in recent years with the requirement by EPA regarding fuel storage tanks. As utilities and business have removed their old "single-shell" buried tanks, they have often replaced the old tanks with new tanks of smaller capacity. This has reduced fuel storage for telephone system standby generators. An effective emergency plan should contain a program to encourage standby generation at critical service locations.

8.9 Concluding Comments

This section described a wide range of options for enhancing emergency preparedness and reducing energy system vulnerability. The options were based on an initial review of petroleum and electric power systems in Puerto Rico. A more detailed analysis is warranted. Puerto Rico may wish to undertake this analysis in connection with its currently on-going review of energy issues.

Insular Area Energy Vulnerability

Volume 3: U.S. Virgin Islands

Prepared for:

Office of Emergency Planning
U.S. Department of Energy
Washington, D.C. 20585

Prepared by:

Mathtech, Inc.
210 Carnegie Center, Suite 200
Princeton, N.J. 08540

With assistance from:

Ensys Energy & Systems, Inc.
P.O. Box 2320
Flemington, N.J. 08822

Mark Stern
Emmet E. Willard
Stanley Efferding

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TABLE OF CONTENTS

U.S. VIRGIN ISLANDS	1
1. INTRODUCTION.	1
1.1 <u>Geography</u>	1
1.2 <u>Demographics</u>	1
1.3 <u>Relationship with the United States</u>	2
1.4 <u>Government Structure</u>	2
2. ECONOMIC PROFILE	4
2.1 <u>Overview</u>	4
2.2 <u>Major Economic Sectors</u>	4
2.3 <u>Economic Development Incentives</u>	5
3. ENERGY PROFILE.	9
3.1 <u>Introduction</u>	9
3.2 <u>Electricity Demand, Supply and Distribution</u>	9
3.2.1 <i>Electricity Demand</i>	9
3.2.2 <i>Electricity Supply and Distribution</i>	12
3.2.3 <i>Fuel for Electric Power</i>	14
3.3 <u>Petroleum Demand, Supply and Distribution</u>	16
3.3.1 <i>Introduction to the Petroleum Sector</i>	16
3.3.2 <i>Petroleum Refining</i>	16
3.3.3 <i>Petroleum Supply and Demand</i>	17
3.3.4 <i>Petroleum Distribution, Storage and Logistics</i>	20
3.4 <u>Institutional and Regulatory Infrastructure</u>	20
3.4.1 <i>Electric Power</i>	21
3.4.2 <i>Petroleum</i>	21
3.5. <u>Energy Supply/Demand Outlook</u>	22
3.5.1 <i>Energy Demand Outlook</i>	22
3.5.2 <i>Energy Supply Outlook</i>	23
4. VULNERABILITY ASSESSMENT: INTRODUCTION AND SUMMARY	24
4.1 <u>Introduction</u>	24
4.2 <u>Factors That Contribute to Unique Energy Vulnerabilities</u>	24
4.2.1 <i>Petroleum Supply System Vulnerabilities</i>	24
4.2.2 <i>Electric Power System Vulnerabilities</i>	25
4.2.3 <i>Transportation System Vulnerabilities</i>	25
4.2.4 <i>Water Supply System Vulnerabilities</i>	25
4.2.5 <i>Economic Vulnerabilities</i>	26
4.3 <u>Methodology</u>	26
4.4 <u>Findings and Lessons Learned</u>	27

4.4.1	<i>Local Energy Supply Disruptions</i>	.27
4.4.2	<i>Global Oil Disruptions</i>	.28
5.	EXPERIENCE FROM PAST DISRUPTIONS	.31
5.1	<u>Global Disruptions</u>	.31
5.1.1	<i>Characteristics of Global Oil Supply Disruptions</i>	.31
5.1.2	<i>Middle East Crisis - Global Impacts</i>	.32
5.1.3	<i>Middle East Crisis - U.S.V.I. Petroleum Supply Impacts</i>	.34
5.1.4	<i>Impact on Electric System</i>	.35
5.1.5	<i>Economic Impact</i>	.36
5.2	<u>Local Disruptions - U.S. Virgin Islands</u>	.41
5.2.1	<i>Hurricane Hugo - U.S.V.I. Petroleum Supply Impacts</i>	.41
5.2.2	<i>Impact on the Electric System</i>	.41
5.2.3	<i>Economic Impact</i>	.44
6.	POTENTIAL IMPACTS OF FUTURE EMERGENCIES	.45
6.1	<u>Impacts of Postulated Global Oil Supply Disruptions</u>	.45
6.1.1	<i>Year 2000 BAU Base Case</i>	.47
6.1.2	<i>Year 2000 Disruption Cases</i>	.48
6.1.3	<i>Economic Impact</i>	.56
6.2	<u>Impacts of Postulated Local Energy Supply Disruptions</u>	.58
6.2.1	<i>Introduction</i>	.58
6.2.2	<i>Key Petroleum Facilities in the U.S. Virgin Islands</i>	.59
6.2.3	<i>Vulnerability of Key Petroleum Facilities</i>	.61
6.2.4	<i>Physical Characteristics of Key Electric Power Facilities</i>	.65
6.2.5	<i>Vulnerabilities of Key Electric Power Facilities to Local Disruptions</i>	.68
6.2.6	<i>Economic Impact</i>	.69
7	ACCESS TO VITAL OIL SUPPLIES IN AN EMERGENCY	.73
7.1	<u>Introduction: Scope of Response Options Evaluated</u>	.73
7.2	<u>U.S. Strategic Petroleum Reserve Policy</u>	.74
7.3	<u>Island-Owned Product Reserve</u>	.75
7.4	<u>Futures Market Hedging</u>	.82
7.5	<u>Standby Line of Credit</u>	.82
7.6	<u>Emergency Access to U.S. Military Petroleum Supplies</u>	.83
7.7	<u>Guaranteed Insular Area Access to the SPR</u>	.83
7.8	<u>Island Component of U.S. Crude/Product SPR</u>	.83
7.9	<u>Concluding Comments</u>	.84
8	PREPAREDNESS AND VULNERABILITY REDUCTION STRATEGIES	.85
8.1	<u>Institutional Preparedness</u>	.85
8.1.1	<i>Continuing Emergency Simulation</i>	.85
8.1.2	<i>Fostering Coordination</i>	.86
8.1.3	<i>Continuing to Develop and Maintain Energy Data and Models</i>	.86

8.1.4	<i>Enhancing Training and Resources</i>	.88
8.2	<u>Increased Energy Conservation and Efficiency</u>	.88
8.3	<u>Fuel Diversification -- Renewable Energy</u>	.89
8.4	<u>Options For Reducing Electric Power System Physical Vulnerability</u>	.93
8.4.1	<i>Electric Generation</i>	.93
8.4.2	<i>Transmission</i>	.94
8.4.3	<i>Distribution</i>	.94
8.4.4	<i>Communications and Control</i>	.94
8.4.5	<i>Customer Preparedness</i>	.94
8.5	<u>Concluding Comments</u>	.94

Section 1406 of the Energy Policy Act (EPACT) of 1992 required the Secretary of Energy to conduct a study of the energy vulnerability of the U.S. insular areas and their options for obtaining oil supplies during times of national emergency. The Department of Energy (DOE) contracted with Mathtech to perform the study of the Caribbean insular areas (Puerto Rico and the U.S. Virgin Islands) and with the East-West Center for the Pacific insular areas (American Samoa, Commonwealth of the Northern Marianas, Guam and Palau).

The Mathtech report is organized into three volumes. Volume 1 contains an executive summary, an introduction, and an overview of the Caribbean oil market. Volume 2 contains the report on Puerto Rico, and Volume 3 the report on the U.S. Virgin Islands.

U.S. VIRGIN ISLANDS

1. INTRODUCTION¹

1.1 Geography

The United States Virgin Islands are located in the Caribbean Sea approximately 1100 miles east-southeast of Miami, Florida and less than 500 miles east-northeast of Venezuela. Puerto Rico lies about 50 miles to the west. The largest of the U.S. Virgin Islands is St. Croix at 84 square miles. The next largest is St. Thomas (32 square miles), followed by St. John (28 square miles). Most of the other 65 islands are uninhabited. Charlotte Amalie, St. Thomas is the capital of the U.S. Virgin Islands. Other major towns include Christiansted and Fredriksted, St. Croix, and Cruz Bay, St. John. The British Virgin Islands are less than three miles northeast of St. John.

St. Croix has modest rolling hills and a central plain separating the relatively dry east end of the island from the more agricultural west end. St. Thomas is quite hilly and rocky with numerous sandy beaches and inlets. A substantial portion of St. John is set aside as a national park.

1.2 Demographics

The 1990 population of the U.S. Virgin Islands was 101,809 and 45 percent of the population was born in the territory. Major sources of immigration have been the West Indies, the U.S. mainland, and Puerto Rico. As shown in Table 1, the population of the U.S. Virgin Islands grew by 28.5 percent between 1970 and 1980. From 1980 to 1990 population grew by 5.4 percent. The rapid growth was a significant burden for the public and private providers of housing, water, electric power and other services. In 1990, the population density of the U.S. Virgin Islands exceeded that of all but three states.

The driving age population in the U.S. Virgin Islands is of particular interest. Approximately 21 percent of all petroleum consumed in the Virgin Islands is gasoline. This is due to the

¹Much of the data in this section is from: Virgin Islands Industrial Development Commission, *1992 United States Virgin Islands Business Guide*.

absence of a significant mass transit system and the heavy reliance on automobiles and vans for local transportation. The driving age population is approximated by the number of persons age 18 and older. Between 1980 and 1990, the age 18 and older population grew by 21.2 percent compared to 5.4 percent for the overall population.

The racial/ethnic composition of the population is 76.6 percent black, 13.5 percent white and 9.9 percent other. Persons of Hispanic origin of any race are 14.5 percent of the population.

Educational attainment in the U.S. Virgin Islands is less than the average in the U.S. mainland. Among persons 25 years of age and older in 1980, 50 percent completed 12 or more years of school. For the U.S. as a whole, the corresponding figures was 67 percent.

1.3 Relationship with the United States

The (U.S.) Virgin Islands were acquired by the United States from Denmark in 1917 and since 1954 have been an unincorporated territory of the United States. Under U.S. law, citizens of the Virgin Islands are also citizens of the United States. However, they do not vote for President, are not represented in the U.S. Senate, but are represented in the House of Representatives by a delegate who does not vote. The currency of the U.S. Virgin Islands is the U.S. dollar, and the official language is English. U.S. Virgin Island citizens are exempt from Federal taxes on income earned in the Virgin Islands, except Social Security taxes.

1.4 Government Structure

Under its constitution, the U.S. Virgin Islands has executive, legislative and judicial branches of government. The Governor is elected for a four-year term and the fifteen members of the unicameral legislature are elected to two-year terms. The government has powers similar to those of U.S. state governments and additionally has responsibility for local police and fire protection, education, public health and welfare programs and economic development.

Table 1

YEAR	GROSS TERRITORI- AL PRODUCT (\$ millions)	TOTAL EXPORTS (\$ millions)	TOTAL IMPORTS (\$ millions)	BALANCE OF TRADE (\$ millions)	RESIDENT POPULATION	CIVILIAN EMPLOY- MENT	UNEMPLOYMENT RATE (%)		PER CAPITA PERSONAL INCOME (\$)
							USVI	US	
1970		\$262.0	\$400.6	(\$138.6)	75,151	35,120	1.3	4.9	
1980	\$727.8	4,315.1	4,950.1	(\$635.0)	96,569	40,530	6.0	7.1	\$6,230
1983	916.9	3,649.3	4,663.7	(\$1,014.4)	103,700	40,370	8.2	9.6	7,370
1984	985.4	3,974.6	4,761.0	(\$786.4)	107,500	40,380	7.6	7.5	7,554
1985	990.4	3,357.0	3,710.6	(\$353.6)	110,800	40,960	6.0	7.2	7,404
1986	1,035.6	2,118.9	2,642.8	(\$523.9)	109,500	41,910	4.7	7.0	7,881
1987	1,147.8	2,195.5	3,370.4	(\$1,174.9)	106,100	43,600	3.0	6.2	9,024
1988	1,204.6	-	2,314.5		103,200	45,060	3.3	5.5	9,749
1989	1,343.9	2,402.8	3,169.7	(\$766.9)	-	44,360	3.7	5.3	11,052
1990	-	2,820.7	3,294.7	(\$474.0)	101,809	46,120	2.8	5.5	-
1991	-	2,518.4	3,118.0	(\$599.6)	-	46,760	2.8	6.7	-
1992	-	2,303.5	3,550.8	(\$1,247.3)	-	46,870	3.6	7.4	-
Annual % Change									
1970-80		32.3%	28.6%	16.4%	2.5%	1.4%	16.5%	3.8%	
1980-90		-4.2%	-4.0%	-2.9%	0.5%	1.3%	-7.3%	-2.5%	

Source: U.S. Virgin Islands Annual Economic Indicators, Bureau of Economic Research, U.S.V.I. Dept. of Economic Development and Agriculture, November 17, 1992, and June 1, 1993.

Economic Report of the President, February 1991, p.322., and Survey of Current Business, U.S. Department of Commerce, Bureau of Economic Analysis, May 1993.

2. ECONOMIC PROFILE²

2.1 Overview

Over the past two decades, the Virgin Islands economy grew considerably faster than the U.S. economy, aided in part by tax incentives and other development initiatives provided by the U.S. and Virgin Islands governments. The tourism sector has been the major engine of growth. Hurricane Hugo caused major devastation to the Virgin Islands, particularly St. Croix, in September 1989, and the physical destruction is still visible in some areas. Nonetheless, until very recently unemployment has been quite low. Although the Virgin Islands per capita income is considerably below the U.S. mainland, the median household income by race is comparable to the mainland.

Some general economic indicators were shown previously in Table 1. As the table shows, gross territorial product (GTP) in nominal dollars grew at an annual average rate of 7.1 percent (2.5% in constant dollars) between 1980 and 1989. During this same period, the U.S. gross domestic product expanded at an average annual rate of 7.6 percent (2.8% in constant dollars). Employment in Virgin Islands increased by an average of 1.0 percent per year while U.S. employment grew 1.9 percent per year over the same period. The unemployment rate was generally at or below the U.S. rate from 1984 to 1992. The 1989 per capita personal income of \$11,052 was 63 percent of the U.S. average.

The Virgin Islands had a trade deficit of \$1.2 billion in 1992. As shown in Table 2, their economy is highly integrated with the U.S. economy. In 1992, 86.1 percent of the Virgin Islands's exports went to the U.S., and 56.7 percent of its imports originated in the U.S. Thus, fluctuations in the mainland economy are felt quickly in U.S. Virgin Islands. Refined petroleum products (from the Hess Oil Virgin Islands Corporation refinery) dominate exports and comprised 77.0 percent of total Virgin Islands exports in 1992.

2.2 Major Economic Sectors

Table 3 provides a breakdown of Virgin Islands employment by major economic sectors. As can be seen in the table, the largest sectors of employment in 1992 were government (29.6%), wholesale and retail trade (21.0%), and services (19.9%). Overall civilian job growth averaged 1.7 percent per year between 1983 and 1992. The highest growth rates occurred in services (6.0%) which includes tourism; wholesale and retail trade (3.0%); and finance, insurance and real estate (2.7%).

The important role of tourism in the Virgin Islands economy is also shown in Table 4 which displays the total number of visitors and total visitor expenditures over the period 1970 to 1992. Tourism declined in both the early and late 1980s during the U.S. recessions, and it dipped further in 1989 following Hurricane Hugo.

The ten largest manufacturing employers in the Virgin Islands in 1990 were a newspaper publisher, Hess Oil Virgin Islands, four watch manufacturers, a construction materials firm, a

²Much of the data in this section is from U.S.V.I. Bureau of Economic Research, *U.S. Virgin Islands Annual Economic Indicators*, November 17, 1992 and June 1, 1993.

dairy, an electronics firm and an alumina processor. The ten largest private non-manufacturing employers were three resort hotels, a retail jewelry chain, a bank, two real estate organizations, a maintenance firm, a supermarket chain and the telephone company.

2.3 Economic Development Incentives

The U.S. and Virgin Islands governments provide a variety of economic incentives to promote economic growth in the Virgin Islands. The incentives include tax benefits from the Virgin Islands Industrial Development Commission (IDC), tax benefits under Sections 934 and 936 of the U.S. income tax code, U.S. tariff exemptions on certain exports, and others. In 1991, approximately 80 active companies employing nearly 5,500 persons were receiving tax benefits from the IDC. No figures were available on usage of the other incentives. However, Section 936, which is highly important to the economy of Puerto Rico, is apparently less widely used in the Virgin Islands. The recently enacted tax legislation included changes to Section 936.³

³The tax legislation recently enacted by the U.S. government included changes to Section 936. These changes are: (to be added).

Table 2

	1989		1990		1991		1992	
TOTAL EXPORTS	2,402.8		2,820.7		2,518.4		2,303.5	
		% of total		% of total		% of total		% of total
To United States	2,276.9	94.8%	2,644.8	93.8%	2,265.8	90.0%	2,167.6	86.1%
Refined petroleum	1,984.0	82.6%	2,346.3	83.2%	1,960.9	77.9%	1,939.3	77.0%
To Foreign Countries	125.9	5.2%	175.9	6.2%	252.6	10.0%	135.9	5.4%
TOTAL IMPORTS	3,169.7		3,294.7		3,118.0		3,550.8	
		% of total		% of total		% of total		% of total
From United States	1,562.9	49.3%	1,226.3	37.2%	1,420.8	45.6%	1,768.4	56.7%
Crude petroleum	984.7	31.1%	487.8	14.8%	782.8	25.1%	1,073.6	34.4%
From Foreign Countries	1,606.8	50.7%	2,068.4	62.8%	1,697.3	54.4%	1,782.4	57.2%
BALANCE OF TRADE	(766.9)		(474.0)		(599.6)		(1,247.3)	
United States	714.0		1,418.5		845.0		399.2	
Foreign Countries	(1,480.9)		(1,892.5)		(1,444.7)		(1,646.5)	

Source: U.S. Virgin Islands Annual Economic Indicators, Bureau of Economic Research, U.S.V.I. Dept. of Economic Development and Agriculture, November 17, 1992, and June 1, 1993.

Table 3

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	SHARE OF 1992 EMPLOY- MENT	1983-92 ANNUAL % CHA- NGE
CIVILIAN LABOR FORCE	43,970	43,680	43,580	43,990	44,960	46,590	46,050	47,430	48,120	48,260		1.0%
CIVILIAN EMPLOYMENT	40,370	40,380	40,960	41,910	43,600	45,060	44,360	46,120	46,760	46,870	100.0%	1.7%
Private Sector	22,350	22,740	23,340	24,570	26,810	28,240	28,430	29,560	28,740	29,520	63.0%	3.1%
Construction & Mining	2,400	2,270	1,880	2,350	1,990	2,330	2,730	3,750	2,620	2,960	6.3%	2.4%
Manufacturing	2,460	2,280	2,140	1,790	2,130	2,350	2,320	2,450	2,700	2,800	6.0%	1.4%
Transportation & Public Utilities	2,230	2,340	2,350	2,480	2,560	2,510	2,360	2,330	2,510	2,510	5.4%	1.3%
Wholesale & Retail Trade	7,540	7,900	8,030	8,640	9,310	9,550	9,500	9,660	9,960	9,850	21.0%	3.0%
Finance, Insurance and Real Estate	1,610	1,790	1,590	1,580	1,770	1,960	2,030	2,140	2,090	2,050	4.4%	2.7%
Services (tourism)	6,110	6,160	7,350	7,730	9,050	9,540	9,490	9,230	9,760	9,350	19.9%	6.0%
Federal Government	620	630	650	670	690	730	820	880	770	800	1.7%	2.7%
Territorial Government	13,410	13,230	12,900	12,480	12,120	12,500	12,760	12,700	12,610	13,080	27.9%	-0.8%
UNEMPLOYMENT RATE	8.2%	7.6%	6.0%	4.7%	3.0%	3.3%	3.7%	2.8%	2.8%	3.6%		

Source: U.S. Virgin Islands Annual Economic Indicators, Bureau of Economic Research, U.S.V.I. Dept. of Economic Development and Agriculture, November 17, 1992, and June 1, 1993.

Table 4

TOURISM INDICATORS: U.S. VIRGIN ISLANDS FISCAL YEARS: 1970 - 1992												
	1970	1980	1984	1985	1986	1987	1988	1989	1990	1991	1992	1984-92 ANNUAL % CHANGE
TOTAL VISITORS (thousands)	1,011.6	1,333.3	1,264.8	1,315.6	1,654.4	1,917.8	1,881.4	1,764.1	1,865.0	1,949.7	1,963.8	5.7%
Tourists	372.4	380.0	369.5	411.6	463.1	541.8	555.5	450.0	462.5	470.3	487.3	3.5%
Excursionists	639.2	953.3	895.3	903.9	1,191.3	1,376.0	1,325.9	1,314.1	1,402.5	1,479.4	1,476.5	6.5%
TOTAL EXPENDITURES (\$ millions)	129.6	304.3	440.1	507.4	510.9	614.4	659.6	625.1	704.9	750.3	791.5	7.6%
Tourists	103.6	221.9	308.8	365.4	318.3	385.7	411.6	441.9	498.8	522.7	556.0	7.6%
Excursionists	26.0	82.4	131.3	142.0	192.5	228.7	248.0	183.2	206.1	227.6	235.4	7.6%
TOTAL TOURISM- RELATED EMPLOY- MENT (number of jobs)		7,200	7,190	7,620	8,390	9,480	9,800	9,320	8,640	8,830	8,510	2.1%

Source: U.S. Virgin Islands Annual Tourism Indicators, Bureau of Economic Research, U.S.V.I. Dept. of Economic Development and Agriculture, March 10, 1993.

3. ENERGY PROFILE

3.1 Introduction

U.S. Virgin Islands's economy is nearly totally dependent on petroleum, and all crude oil and refined petroleum products are imported. The importing, refining, and marketing of petroleum in U.S. Virgin Islands is accomplished by private companies, principally subsidiaries or affiliates of multinational oil companies. Amerada Hess, which operates one of the world's largest petroleum refineries, on St. Croix, is the dominant supplier. The petroleum sector is profiled in Section 3.3 below.

The Virgin Islands Water and Power Authority (WAPA), an instrumentality of the Virgin Islands government, is the only electric utility serving the islands. A limited number of industrial facilities generate some or all of their electric power requirements, and others have emergency backup generators. Otherwise, WAPA provides all electric power for the territory. The electric power sector is profiled in Section 3.2 below.

Aside from some coal used by the Virgin Islands Alumina Company (VIALCO) and small amounts of propane/butane and limited solar energy facilities, no other sources of energy are currently used in U.S. Virgin Islands. Other energy sources are under active consideration but have not been adopted to date.

3.2 Electricity Demand, Supply and Distribution⁴

3.2.1 *Electricity Demand*

In the fiscal year ending June 30, 1993 WAPA had about 45,000 customers, sold 539 million kilowatt hours (kWh) of electricity, and had a system peak demand of about 102 megawatts (MW). Table 5 shows the historical trend in peak demand, sales, number of customers, and the breakdown of sales by customer class for the period 1988 to 1992. As the table shows, annual sales have grown at an average rate of 3.9 percent per year on St. Thomas and 2.2 percent per year on St. Croix. Industrial sector sales are the largest sales category on St. Thomas and represented 43.9 percent of total sales in 1992. The residential sector is the largest on St. Croix (Hess generates all its own power) and accounted for 42.9 percent of sales. The Virgin Islands government is a large WAPA electricity customer. The government's consumption in fiscal year 1992 was 82.159 million kWh.⁵

⁴Except where noted otherwise, the data in this section came from the Official Statement of the July 1, 1991 Electric System Revenue Bonds of the Virgin Islands Water and Power Authority (hereinafter "1991 WAPA OS") or was provided directly by WAPA.

⁵Economic Research Associates, *Energy Consumption Patterns in the U.S. Virgin Islands Government*, May 1993, p. 4, based on data supplied by WAPA. Note: the figure in the text is for the V.I. government's fiscal year which runs from October 1 to September 30.

ELECTRIC POWER DEMAND AND SUPPLY: U.S. VIRGIN ISLANDS (FISCAL YEARS 1988 -1992)							
St. Thomas and St. John	1988	1989	1990	1991	1992	Average Annual Growth (%/Year)	Share of Total 1992 Sales (%)
Dependable generating capacity (MW)				103.7			
Peak demand (MW)	55.2	57.0	59.8				
Reserve margin (%)							
Average load (MW)	40.0	40.8	38.5				
Load factor (%)	72.4%	71.6%	64.4%				
Electric energy sales (million kWh)							
Residential	99,210	101,055	89,424		112,008	3.1%	34.1%
Commercial	60,773	62,069	57,938		67,082	2.5%	20.4%
Industrial	118,320	122,104	110,580		144,130	5.1%	43.9%
Other	2,940	2,911	2,921		5,076	14.6%	1.5%
Total sales	281,243	288,139	260,863		328,296	3.9%	100.0%
St. Croix	1988	1989	1990	1991	1992	Average Annual Growth (%/Year)	Share of Total 1992 Sales (%)
Dependable generating capacity (MW)				66.7			
Peak demand (MW)	38.5	39.8	42.4				
Reserve margin (%)							
Average load (MW)	27.3	28.9	20.1				
Load factor (%)	71.0%	72.5%	47.3%				
Electric energy sales (million kWh)		83,602	60,279		90,348	3.4%	27.5%
Residential	79,149	36,341	28,020		40,284	5.8%	12.3%
Commercial	32,205	77,649	53,905		72,630	-1.3%	22.1%
Industrial	76,600	4,964	2,005		7,410	10.5%	2.3%
Other	4,967						
Total sales	192,921	202,556	144,209		210,672	2.2%	64.2%

Source: Official Statement of the July 1, 1991 Electric System Revenue Bonds of the Virgin Islands Water and Power Authority, pp. 22, 23, B-4, B-15.
WAPA Energy Production Summary, July 1, 1993.

Source: Official Statement of the July 1, 1991 Electric System Revenue Bonds of the Virgin Islands Water and Power Authority, pp. 22, 23, B-4, B-15. WAPA Energy Production Summary, July 1, 1993.

Residential customers in U.S. Virgin Islands generally use less electricity than residential customers in the mainland. As shown in Table 6, annual demand per home in 1992 was 5,738 kWh on St. Thomas and 4,981 on St. Croix vs. 9,660 kWh in the U.S. mainland. Part of this difference is related to the lower per capita incomes in U.S. Virgin Islands compared to the mainland, as noted earlier, which leads to lower prevalence and usage of electricity using equipment in the home. The high cost of electricity also reduces demand. The average residential customer in 1991 used about 400 kWh per month and had an electric bill of about \$50.00 or 12.5 cents per kWh. That cost per kWh would be comparable to the highest cost mainland states.

Table 6

RESIDENTIAL SECTOR ELECTRIC DEMAND CHARACTERISTICS: U.S. VIRGIN ISLANDS (FISCAL YEAR 1992)				
Residential Sector	St. Thomas	St. Croix	Virgin Islands	United States
Average sales per customer (kWh)	5,738	4,981	5,373	9,620
Per capita personal income (\$)				\$19,805
Average revenue per kWh (\$)				\$0.0816
<p>Note: All data are for the WAPA fiscal year ended June 30, 1992 except U.S. per capita income which is for calendar year 1992.</p> <p>Sources: Official Statement of the July 1, 1991 Electric System Revenue Bonds of the Virgin Islands Water and Power Authority. U.S. Department of Energy, Energy Information Administration, April 1992 and June 1993 Electric Power Monthly, Table 51; 1991 Electric Power Annual, February 1993, Table 27. U.S. Department of Commerce, Bureau of Economic Analysis, Survey of Current Business, p. 15.</p>				

Table 7 compares average revenue per kWh by customer class in U.S. Virgin Islands and the U.S. for the year ending June 30, 1992. As can be seen, over all customer classes combined, average revenue per kWh is 13.3 cents in U.S. Virgin Islands and 6.79 cents in the U.S.

Table 7

AVERAGE REVENUE PER KWH, BY CUSTOMER CLASS: U.S. VIRGIN ISLANDS (FISCAL YEAR 1992)		
Average Revenue per kWh (\$)	Virgin Islands	United States
Residential	N/A	\$0.0816
Commercial	N/A	0.0756
Industrial	N/A	0.0485
All Customers (incl. other)	\$0.133	0.0679
Sources:	U.S. Department of Energy, Energy Information Administration, April 1992 and June 1993 Electric Power Monthly, Table 51.	

3.2.2 Electricity Supply and Distribution

The Virgin Islands Electric Power Authority (WAPA) is the only electric power utility in the U.S. Virgin Islands. Although a few industrial users generate some or all of their own electric power,⁶ the remainder of the Virgin Islands economy depends upon the electric power generated and distributed by WAPA. WAPA is governed by a nine member Board appointed by the Governor of the U.S. Virgin Islands.

WAPA is empowered by the Virgin Islands government to construct, operate, and maintain an electric system to serve the residential, commercial, industrial, and street lighting needs of the islands. In 1987, WAPA was authorized to perform the same functions for the potable water system. Previously it had merely produced desalinated water and sold it to another agency.

WAPA is unusual among electric utility systems of the United States in that all of its generating energy comes from burning oil. In the 48 contiguous states only three percent of all electricity is generated from oil. Any disruption in WAPA's oil supply which retards generation can produce, at the very least, a ripple effect throughout the entire economy. Also, unlike most other mainland electric utilities, there is no interconnected neighboring power system which can come to WAPA's assistance in time of trouble.

As a result of WAPA's unusual circumstances as an oil-based, island electric system, the Virgin Island's economy is far more subject to variations in fuel oil prices and supply disruptions than the U.S. mainland. In addition, because the electric system is essential for operating water and sewage systems, street lighting, signal lights, etc., the economic well-being, health, and safety of the populace depends on WAPA's operations.

⁶The Hess oil refinery, the VIALCO alumina plant, and several hotels operate their own power plants. Many other businesses have standby generators. (1992 V.I. Business Guide, p. 16)

The three major components of a modern electric power system are: (1) the generating facilities, (2) the delivery system (transmission and distribution), and (3) the dispatching, control and data acquisition system.

WAPA's generating facilities are 100 percent oil fired and had a total capacity of 170.4 MW at the end of June, 1991. There are two major power plant sites. One site, on St. Thomas (Drum Bay), has 101.2 MW of capacity which serves St. Thomas, and via underwater cable, St. John and two other islands. St. John also has a 2.5 MW diesel generator for emergency power. The second site, on St. Croix (Richmond), has 66.7 MW of capacity which serves only St. Croix. Due to the depth and topography of the ocean floor, engineering firms such as R.W. Beck and Associates have determined that it is not feasible to interconnect the islands by electric cable. Therefore, the two islands operate as separate systems for purposes of determining generator sizes and reserve requirements.

Approximately one half of the generating capacity on St. Thomas is steam capacity that burns No. 6 fuel oil. The balance is combustion turbines that burn No. 2 fuel oil. On St. Croix the fossil steam units comprise about one-third of total capacity and combustion turbines are two-thirds. The fuels used are the same as on St. Thomas. Because of the relatively small size of its system, WAPA must install small generators (the largest unit is 35 MW on St. Thomas and 22 MW on St. Croix) to assure a reliable grade of service. The small units substantially reduce economies of scale and contribute to the high cost of electricity.

Because WAPA has no neighboring electric power systems with which it can interconnect,⁷ it must have generating reserves far in excess of the electric systems of the continental U.S. Mainland systems have assistance agreements and transmission interties which provide support in emergency situations and economic exchange of power and energy at other times. Because WAPA stands alone, it must have sufficient generating capacity available to provide for scheduled maintenance, emergency outages, system operating requirements, and unforeseen customer demands. Additionally, WAPA's annual load factor is 70 percent (for comparison, the U.S. mainland average is 61 percent per NERC data), which means that average electrical demand is 70 percent of the peak annual demand. This high load factor makes it more difficult to take units out of service for scheduled maintenance or to deal with emergency outages.

The excess of generating reserves over system peak demand is known as reserve margin or capacity margin. Interconnected utility systems in the mainland U.S. can operate safely with capacity margins on the order of 15 percent to 30 percent, depending on the situation (see North American Electric Reliability Council report, "Electricity Supply and Demand, 1993-2002."). Because of the "stand-alone" nature of WAPA's operation, without interconnections to neighbors, WAPA must keep enough spinning reserve and other standby generation available to prevent black-outs in case one or more operating units goes off line. This is a common burden borne by all the insular electric systems. WAPA follows a policy of trying to maintain enough excess capacity that it can continue to supply all loads even if the two largest units are out of service. WAPA and its

⁷WAPA currently has no interconnection to the electric power generation facilities on St. Croix at the Hess oil refinery and the VIALCO alumina plant.

engineering consultant have determined that they require a capacity margin of at least 45% at St. Thomas and 52% at St. Croix at the 1993 load level.⁸

WAPA delivers power and energy to customers via a network of distribution feeders ranging in voltage from 4.16 kilovolts (kV) to 24.9 kV, with one 34.5 kV sub-transmission line on St. Thomas. The combined mileage of the system totals 845 miles, including a submarine cable between St. Thomas and St. John. In the wake of Hurricane Hugo, a major rebuilding effort was launched, especially on St. Croix which received the brunt of the storm. In the 1991 WAPA Revenue Bond Official Statement (OS), the consulting engineer states that "the restoration of the storm damaged facilities resulted in a significant improvement to the general condition of the Authority's transmission and distribution facilities."

WAPA's Dispatching and System Control facilities are appropriate for the size and complexity of the system. It is capable of controlling the major feeders and monitoring system loads and system disturbances.

WAPA management is keenly aware of its heavy reliance on fuel oil and is continuing an active inquiry into practical alternatives. Because of the relatively small size of its system, nuclear and coal fuels are impractical. Liquefied Natural Gas (LNG) may, in the future, merit consideration; but current costs of transportation and storage make it non-competitive on the Virgin Islands with current oil prices. Wind and solar electric generators require considerable acreage which is an expensive commodity on the Islands. However, demand-side installations of small wind turbines and solar collectors could be helpful in reducing load growth.

Other energy alternatives are waste-to-energy (WTE) systems, methane produced in landfills, and Ocean Thermal Energy Conversion (OTEC). WAPA's engineering consultant concluded that a 150-250 ton per day WTE facility could be feasible in 5 to 7 years, but would require a restructuring of WAPA. Methane gas is being used in approximately 80 U.S. projects under 5 MW and is being studied by the City of Seattle, among others, for larger feasibility. OTEC is promising, though only proven in small sizes (less than 5 MW). If there is any "energy resource" indigenous to the Virgin Islands, it could well be the temperature differentials which may be present in the deep water trenches near the Islands. WAPA is currently reviewing proposals from two organizations offering to build 5 MW OTEC systems.

3.2.3 Fuel for Electric Power

All of the net electric energy generated by WAPA in 1992 was produced by burning oil. The steam-electric plants burn No. 6 residual fuel oil, and the combustion turbines burn No. 2 distillate fuel oil. WAPA annually solicits bids for fuel oil from fuel oil suppliers.

As a result of a 1965 agreement between the government of the Virgin Islands and Hess Oil Virgin Islands Corporation (an affiliate of Amerada Hess Corporation), which operates one of the world's largest refineries on St. Croix, WAPA receives fuel oil from Hess at prices below those submitted by other potential fuel oil suppliers. This agreement was last amended in 1990 and expires in 2013. Under the agreement, Hess must annually submit bids containing a maximum

⁸See Table IV, page B-39, of the 1991 WAPA OS.

price which shall not exceed the lower of (1) Hess' average landed monthly crude oil costs or (ii) the published Exxon New York Contract Cargo prices per barrel, less \$2.00 per barrel.

As part of the above agreement, Hess agrees to maintain sufficient fuel in its storage facilities to ensure that there are adequate supplies to meet local fuel needs of the U.S. Virgin Islands, including WAPA. (WAPA's average fuel oil consumption in fiscal year 1992 was 4,630 barrels per day) In addition, WAPA has storage capacity at its St. Thomas plant for over a month's supply of No. 2 and No. 6 fuel oil. As a general rule, because of Hess's proximity, only about two week's supply is kept on hand with more storage utilized during the storm season.

The fuel oil is delivered to the St. Thomas power plant site by barge from the Hess oil refinery on St. Croix. Under the 1965 agreement, as amended, Hess operates the barges and annually bids on transporting the fuel from the Hess refinery to WAPA. Currently, Hess receives \$1.50 per barrel for transportation. WAPA has comparable storage facilities at its St. Croix plant which also receives its fuel by barge from the Hess refinery. WAPA has proposed in its budget to add further storage at both plants.

The quantity of fuel oil used by WAPA in recent years is shown in Table 8. WAPA's dependence on petroleum greatly increases the cost of fuel for electric power generation compared to the rest of the U.S. which relies more heavily on less expensive fuels: coal (56.3%), nuclear (22.1%), gas (9.4%), hydro (8.6%) and other (0.4%), compared to petroleum (3.2%) for electric generation.⁹ In addition, the inability to substitute fuels during an oil disruption causes WAPA and its customers to bear the full brunt of escalating oil prices, except for the temporary price dampening effect of the supply agreement with Hess.

Table 8

QUANTITY OF FUEL USED FOR ELECTRIC POWER: U.S. VIRGIN ISLANDS (FISCAL YEARS 1988 -1993)						
	1988	1989	1990	1991	1992	1993
Quantity of fuel oil used (million barrels)		1.54	1.27	1.54	1.69	1.63
Sources: WAPA Annual Reports, 1989-91. WAPA Energy Production Summary, July 1993.						

⁹Data on U.S. electric generation by source are from U.S. Department of Energy, Energy Information Administration, *Electric Power Monthly*, June 1993, Table 3.

3.3 Petroleum Demand, Supply and Distribution

3.3.1 *Introduction to the Petroleum Sector*

The USVI petroleum sector comprises two distinct parts:

- a simple distribution system supplying products to a set of small islands
- a large and essentially self-contained refinery (i.e. Hess St. Croix) that supplies fuel to the local electric utility (WAPA) and other components of the island economy on a wholesale basis but otherwise participates in U.S. and international markets.

3.3.2 *Petroleum Refining*

The Hess U.S. Virgin Islands refinery has a rated capacity of 545,000 bpd and typical throughput of 400,000 bpd in recent years. These levels are lower than the refinery's earlier recorded peak capacity of 700,000 bpd, but are still very substantial by Caribbean, U.S. and global standards. The Hess refinery represents one of the primary Caribbean Island refineries (the others being at Curacao, Aruba and Trinidad, all off the Venezuelan coast).

While very large by world standards, the Hess refinery has limited upgrading capability when compared to the norm for large U.S. Mainland refineries. This is in part because the Hess refinery has traditionally produced substantial gas oil and residuum "unfinished oils" that feed the Hess cracking refinery at Port Reading in New Jersey. Currently underway at Hess Saint Croix is a major project to build a 75,000 bpd cat cracker plus ancillary units. This will significantly raise the proportion of light products output by the refinery, notably of gasoline, including reformulated gasoline destined for the U.S. Mainland market. Box 1 describes the Hess refinery processing configuration.

Traditionally, the Hess refinery has run about 100,000 bpd Alaskan North Slope crude (although this may decline in the future as ANS production itself declines). The balance of the refinery's intake has typically been comprised of primarily lighter to medium sour crudes from Persian Gulf countries and, secondarily, medium to heavy sweet crudes from West Africa.

The Hess U.S. Virgin Islands refinery has the benefit of a deepwater port which can accommodate several VLCC¹⁰ crude oil tankers at one time, together with smaller intermediates and product tankers. The Hess dock facility incorporates several tanker berths and a large cargo dock. This latter is used to offload all refinery construction equipment and operating supplies.

The Hess refinery has an additional benefit in that it is not subject to the Jones Act rules for shipments to/from the U.S. Mainland. The refinery operates under Section 934 of U.S. federal tax regulations, which provide favorable tax terms. The refinery also operates under a 20-year re-negotiable agreement with the U.S. Virgin Islands government. As detailed in *Section 3.2.3*, this agreement covers terms for supplies to WAPA and requires Hess to maintain inventory dedicated to island needs.

¹⁰VLCC typically designates tankers around 250,000 DWT capacity.

The Hess refinery operates essentially as a self-contained system. All electrical power for consumption in refinery process units, off-site storage facilities, docks, and staff housing compounds is generated within the refinery. Similarly, all cooling, process and potable water requirements are met from in-refinery units which de-salinate sea water. There is no apparent connection between the island's and the refinery's electrical power or water supply systems. Employment at the refinery is reported as 600 full time employees plus around 750 contract maintenance workers. The cat cracker project has swollen the refinery's temporary workforce.

PROCESSING CONFIGURATION HESS OIL

	<u>bpcd</u>	
Crude	545000	(approx. 150,000 idle)
Vacuum	215000	
Visbreaker	80000	
Cat Reforming	125000 *	semi regen - bimetallic catalyst
Cat Hydrotreating	150000	heavy gas oil desulfurization/ mild hydrocracking
Cat Hydrotreating	125000	reformer feed
Cat Hydrotreating	165000	straight run distillate
BTX	30000	
C ₅ /C ₆ Isomerization	15000	
Sulfur tpd	580	
Construction:		
FCC cat cracker	75000	
MTBE/TAME	N/A	
Visbreaker	N/A	

BOX 1

3.3.3 Petroleum Supply and Demand

The U.S. Virgin Islands are 99% dependent on petroleum for primary energy. Total consumption comprises the sum of (a) consumption by the island's population and economy plus (b) fuel consumption and losses internal to the Hess refinery on Saint Croix. Because of the large scale of the Hess refinery and the small total population of the U.S. Virgin Islands, Hess refinery consumption exceeds non-refinery consumption. (This situation is unusual and highlights the smallness by world standards of U.S. Virgin Islands energy needs.) In examining U.S. Virgin Islands

petroleum statistics, a distinction has therefore been made between "Hess Refinery" and "Island Economy" consumptions.

Refinery fuel and loss consumption internal to the Hess refinery is almost entirely dependent upon that refinery's throughput, processing patterns and process unit additions/shutdowns. This, in turn, is a function of regional and global petroleum market conditions, and corporate Hess decisions, and is essentially independent of the state of the U.S. Virgin Islands economy.

Figure 1 illustrates the wide variability in total USVI petroleum consumption in recent years. Although definitive historical breakdowns have not been developed, it must be recognized that a significant part of this variation could stem from fluctuations in Hess refinery, not island economy, demand.

Figure 1

Current Hess Refinery fuel and loss consumption has been estimated at approximately 24,000 bpd, based on current refinery configuration and throughput of close to 400,000 bpd. Generally, fuels consumed in such a refinery comprise process gases and residual fuel, with minor amounts of other refinery streams. Construction projects currently underway at Hess to build a

75,000 bpd cat cracker and related units will increase Hess Refinery fuel and loss. The level of increase depends upon a variety of process specifications but may be on the order of 1,000 to 3,000 bpd.

Island economy petroleum consumption in the U.S. Virgin Islands has expanded significantly in recent years, in line with a growing population and increasing standard of living. Demand for transport fuels (motor gasoline and diesel) is reported to have increased by 79% between 1981 and 1991. Similarly, non-refinery electricity consumption - and hence demand for power generation fuel oils - grew by over 50% between 1980 and 1991. These represent annual demand growth rates in the range of 4% to 6%.

Table 9 indicates estimated USVI petroleum demand for 1992, taken from EIA data and USVI EEMIS data and WAPA reports. WAPA consumption of 4,500 bpd of residual fuel and distillate constitutes half total island economy consumption. Non WAPA economy demand is dominated by gasoline and aviation fuel.

Table 9

ESTIMATED DEMAND - 1992 1,000 bpd					
product	refinery		island economy		total
	fuel	bunkers	WAPA	other	
LPG	4.7			0.4	5.1
gasoline				1.9	1.9
aviation fuel & kerosene				1.5	1.5
distillate (diesel/No. 2)		2.0	1.6	0.5	4.1
residual	12.1	1.0	2.9		16.0
lubes				0.1	0.1
refinery gas	7.2				7.2
total	24.0	3.0	4.5	4.4	35.9
Note: 1. Data taken from several sources including: EIA, EEMIS, Economic Research Associates reports. 2. Discrepancies exist between these sources, e.g. 1991 EIA International Energy Annual indicates total USVI demand at 55,000 bpd.					

3.3.4 *Petroleum Distribution, Storage and Logistics*

The USVI petroleum product distribution system comprises marine barge movements to WAPA and distributor storage terminals, principally on the two major islands, St. Thomas and St. Croix, together with limited truck distribution to local island consumers and retail outlets. Although Hess is not allowed to participate in retail operations on USVI, the bulk of island supplies come from the Hess St. Croix refinery. According to a *Virgin Islands Energy Office* survey, some 80 - 85% of island wholesalers' motor gasoline and diesel supplies come from Hess and essentially 100% of LPG, jet fuel and marine fuels. In addition, Hess supplies 100% of WAPA's requirements for No. 6 and No. 2 fuels. Other oil companies actively market on the USVI, including Esso and Texaco. It is understood that Esso, Texaco and other marketers obtain supplies by barge, mainly from Puerto Rico.

Hess refinery inventory is estimated to average 12-15 million bbls. (In addition it is understood that Hess uses several million barrels of storage available on St. Lucia as an integral part of its St. Croix operations.) The current Hess cat cracker project will likely increase total refinery inventories, possibly to 15-20 million barrels, since additional tankage is reported to be under construction. The effect of the project will be to shift the inventory mix towards a higher proportion of gasoline and other light products.

According to the agreement between Hess Oil Virgin Islands Corp. and the Government of the Virgin Islands, Hess *"will maintain in its storage facilities sufficient fuel to ensure that there are adequate supplies to meet local fuel needs of the United States Virgin Islands"*. Based on estimated inventories of 15 million bbls and island economy demand of 9,000 bpd, the U.S. Virgin Islands have on hand petroleum stocks equivalent to over 4.5 years' supply. 3% of Hess' inventory corresponds to 50 days' supply. This supply is over and above supply in non-refinery island storage.

Comprehensive data were not readily available for non-refinery stocks on the island. WAPA is reported to have 129,000 barrels of diesel tankage and 176,000 for residual fuel. The utility has announced plans to expand storage for diesel fuel by 36,000 barrels on St. Croix and 28,500 barrels on St. Thomas. WAPA was reported to hold about two weeks' supply in its own tankage, indicating total stocks of around 75,000 barrels. Applying the same level of up to 15 days' storage to non-WAPA island consumption as well¹¹, indicates total non-refinery stocks of around 130,000 barrels.

3.4 Institutional and Regulatory Infrastructure

As in most mainland states, the institutional and regulatory infrastructure affecting energy in the Virgin Islands is complex, with authority and responsibility shared among numerous organizations.

Overall responsibility for energy issues in the Virgin Islands is vested in the Virgin Islands Energy Office (VIEO). VIEO has prepared the Virgin Islands' energy emergency plan and

¹¹10 to 15 days' consumption was a typical stock level for the major distributors on Puerto Rico.

sponsored the development of an Energy Emergency Management Information System (EEMIS). VIEO coordinates with the Virgin Islands Territorial Emergency Management Agency (VITEMA) on emergency planning issues related to energy. VIEO also acts as an advocate and financial supporter of conservation and renewable energy activities in the Virgin Islands. While VIEO has good communications with WAPA, contact with the Hess oil refinery is more limited, although VIEO would like more interaction.

Other elements of the institutional and regulatory infrastructure for electric power and petroleum are described in the two sections below.

3.4.1 Electric Power¹²

As noted earlier, most electric power users in the U.S. Virgin Islands rely on power generated and distributed by the Virgin Islands Water and Power Authority, which is an instrumentality of the Virgin Islands government. Under the 1964 authorizing legislation, as amended, WAPA has broad powers to construct, reconstruct and improve water supply and distribution systems, and electric supply and distribution systems; to issue bonds and make repayments of principal and interest; and to determine, charge and collect reasonable rates for water and electric service. In 1973 the Virgin Islands government placed WAPA's rates under the jurisdiction of the Virgin Islands Public Services Commission (PSC). As a result, WAPA's electric rates are now subject to PSC regulation and approval.

WAPA's rates for electric service include a fixed charge for each customer class, energy charges, demand charges for large power customers, and a levelized energy adjustment charge which is adjusted every six months to reflect increases (or decreases) in the price of fuel oil. An additional maintenance and capital fund surcharge was discontinued and made part of the base rate following a 1991 PSC order.

As a small, oil-based municipal utility, WAPA can experience a cash flow problem during periods of sudden, large increases in oil prices. This problem can arise because fuel oil costs are such a large part of WAPA's total costs, and because the levelized energy adjustment charge is adjusted only every six months.

WAPA is subject to all environmental regulations of the U.S. Environmental Protection Agency, environmental regulations of the Virgin Islands Department of Planning and Natural Resources, and construction permitting by the U.S. Virgin Islands Coastal Zone Management Agency.

3.4.2 Petroleum

Activities in the petroleum industry in the Virgin Islands are subject to all environmental regulations of the U.S. Environmental Protection Agency and environmental regulations of the U.S. Virgin Islands Department of Planning and Natural Resources.

¹²All data in this section is from the 1992 WAPA OS.

The Virgin Islands does not regulate prices of refined petroleum products. The Virgin Islands has a standby petroleum set-aside program, and the Virgin Islands Energy Office (VIEO) is currently studying how the program would operate during an emergency.

Hess Oil Virgin Islands Corporation, which operates the oil refinery on St. Croix, sells refined petroleum products to the wholesale market in the Virgin Islands but is prohibited by the government from retail sales of gasoline and other motor fuels.

Transportation of crude oil and petroleum products between U.S. Virgin Islands and the U.S. mainland is exempt from Jones Act provisions requiring the use of U.S. built and registered tankers.

3.5. Energy Supply/Demand Outlook

3.5.1 *Energy Demand Outlook*

Almost all of the Virgin Islands' primary energy needs are provided by petroleum products. This should continue to be the case through the year 2000, although other energy resources are being considered for electric generation, including renewables and DSM options. Through the year 2000, however, forecasting energy demand is almost equivalent to forecasting petroleum demand.

We were able to obtain historical total petroleum¹³ demand figures as well as WAPA's petroleum demand. WAPA's demand is for electric generation and desalinization plants. WAPA demand was about 8% of total petroleum demand in the latter part of the eighties. Total demand and WAPA demand for petroleum fluctuate greatly over the period; no trend was apparent.

The only projections of petroleum demand currently available were obtained from WAPA. WAPA demand projections were available to FY¹⁴ 2000. These projections and the average ratio of WAPA demand to total petroleum demand were the basis for forecasting total petroleum demand.

The Virgin Islands' petroleum demand was forecast in the following manner. Actual WAPA petroleum consumption was compared to actual total consumption from FY 1988 through FY 1991. The ratio of WAPA consumption to total consumption was calculated and averaged.

The average total petroleum demand forecast was estimated by dividing projected WAPA consumption by the average ratio of WAPA consumption to total consumption described above. The *low* total petroleum demand forecast was obtained in the following manner. First, the 90% one-tailed¹⁵ *high* confidence bound of the average WAPA to total petroleum consumption ratio was calculated. Second, estimated total consumption was obtained by dividing WAPA consumption by the high WAPA to total petroleum consumption ratio. The high forecast was estimated in the same

¹³Total petroleum demand includes refinery consumption as well.

¹⁴WAPA's fiscal year, which is the one we are using, runs from July 1 to June 30.

¹⁵The interpretation for using the one tailed test is this: given that the total petroleum demand will be lower than average, the lower confidence bound shows how much it will be lower than average.

manner as the low petroleum demand forecast, except the 90% one-tailed *low* confidence bound of the WAPA to total petroleum consumption was used. The forecasts are shown in Table 10.

Table 10

FORECAST PETROLEUM DEMAND (Millions of bbls annually)									
TYPE/FY	1993	1994	1995	1996	1997	1998	1999	2000	Annual Growth Rate
LOW	17.3	19.4	19.8	20.2	20.5	20.9	21.3	24.5	3.14%
MEDIUM	21.0	23.4	23.9	24.5	24.8	25.2	25.7	29.6	3.14%
HIGH	26.5	29.6	30.3	30.9	31.4	31.9	32.5	37.4	3.14%

3.5.2 Energy Supply Outlook

Petroleum products consumed in the USVI island economy come overwhelmingly from the St. Croix Hess refinery, with minor volumes imported from Puerto Rico. The petroleum supply outlook for the USVI is thus primarily dependent on the status of the Hess refinery. Given:

- a. the scale of the refinery
- b. its high degree of integration with Mainland Hess refineries
- c. Hess' financial commitment to the FCC project and the improvement in the refinery's economic viability that should result from bringing the project on stream,

it appears highly unlikely that processing activity at Hess St. Croix will decline. Product availability to the USVI should therefore be maintained. The FCC project will in fact increase the availability - and stocks - of gasoline and distillate from the Hess refinery.

Secondary supplies of petroleum products could be adversely affected if the Puerto Rican refining sector were to further decline. However, large refinery investment projects in Venezuela and Trinidad would more than offset a Puerto Rican decline and will anyway bring significant new volumes of clean products onto the Caribbean market. These will increase the supply sources available to USVI marketers and government consumers.

4 VULNERABILITY ASSESSMENT: INTRODUCTION AND SUMMARY

4.1 Introduction

Assessing the unique energy vulnerabilities of the insular areas was one of the core tasks of this study. This section first delineates the U.S. Virgin Islands' unique vulnerabilities, essentially the factors in their energy and economy make-up that indicate a potentially greater risk versus the mainland of interruptions in physical oil supplies and/or susceptibility to a higher level of economic damage from oil supply disruptions. The methodologies used by the study team to assess the implications of the island's unique vulnerabilities are then outlined; in brief, a combination of approaches to analyze both the island's past record in global and local disruptions and their prospects under potential future disruptions. A primary goal here was to ascertain whether, in fact, the existence of additional vulnerabilities relative to the mainland does lead to greater loss of oil supplies and/or impacts on the island economies. The section concludes by summarizing the key findings from the vulnerability assessment, notably that, while concerns are most often raised over access to physical oil supplies, it is actual and potential damage to the island economy that is the primary consequence of their unique energy/economy vulnerability.

Sections 5 and 6 provide further details. Section 5 assesses the U.S. Virgin Island's energy vulnerability based on experience with past disruptions, and Section 6 considers the possible impacts of a range of future disruptions.

4.2 Factors That Contribute to Unique Energy Vulnerabilities

The insular areas have energy-related vulnerabilities that are unique or more severe than exist on the U.S. mainland. In the U.S. Virgin Islands these vulnerabilities affect the petroleum supply system, electric power system, transportation system, and the water supply system. Ultimately, these vulnerabilities become vulnerabilities of the island economy. Each vulnerability category is described below.

4.2.1 *Petroleum Supply System Vulnerabilities*

The petroleum supply systems have the following unique vulnerabilities:

- The U.S. Virgin Islands relies on petroleum for virtually all of its energy needs, whereas in the U.S. mainland, oil supplies only 40.6 percent of total energy needs.¹
- In the U.S. Virgin Islands 100 percent of all petroleum supplies must be imported (vs. 40.7% in the U.S. mainland²).
- All petroleum entering the islands must arrive by sea in tankers and barges. Unlike the U.S. mainland, the islands have no land access to petroleum supplies.

¹EIA, *Annual Energy Review*, 1992.

²EIA, *Petroleum Supply Annual*, 1992.

- The docks in the U.S. Virgin Islands are a critical link in the islands' petroleum supply system. The docks are essential for receiving all petroleum imports, and they are important for intra-island petroleum distribution via barges. In contrast, the U.S. mainland has an extensive petroleum pipeline network to distribute petroleum. An accident at the docks could inhibit petroleum resupply. As in many mainland areas, policies that allow public access to the docks compromise dock security.

4.2.2 Electric Power System Vulnerabilities

The electric power system on the U.S. Virgin Islands has the following unique vulnerabilities.

- WAPA relies 100 percent on petroleum. It cannot switch fuels during an emergency. In comparison, in the 48 contiguous states only three percent of all electricity is generated from oil. Most areas of the mainland have a wider range of energy sources available, such as coal, nuclear energy, natural gas and hydro which provide lower, more stable electricity prices and greater ability to switch fuels when needed.
- All petroleum used for electric power generation must be imported. There are no known resources of crude oil on the islands.
- WAPA is an island electric system. It does not have neighboring electric systems that can supply electric power during an emergency. As a result, to achieve levels of reliability comparable to the U.S. mainland, it must strive to maintain larger capacity margins than U.S. mainland utilities, which increases electricity costs.
- In comparison with U.S. mainland utilities, most of WAPA's electric load is served by a distribution system that is above ground where it is more vulnerable to disturbances such as hurricanes. Limited financial resources have prevented more rapid implementation of underground distribution.

4.2.3 Transportation System Vulnerabilities

Transportation in the U.S. Virgin Islands is totally dependent on petroleum. Thus, any petroleum supply disruption or price spike has an immediate impact on island transportation. In particular:

- Ground transportation is highly dependent on gasoline and the automobile.
- Public ground transportation options are limited.
- The airports in the U.S. Virgin Islands are vital transportation links. The U.S. Virgin Islands government relies heavily on inter-island air travel for day-to-day operations. In addition, the economy, which is heavily dependent on tourism, would be adversely affected by disruption of jet fuel supplies or prices.

4.2.4 Water Supply System Vulnerabilities

The U.S. Virgin Islands has very limited water resources. The predominant source of water supply is desalinization of sea water by WAPA, which supplies approximately 65 percent of total water used in the U.S. Virgin Islands. WAPA's desalinization facilities and electric generation facilities are co-located and rely exclusively upon petroleum. Thus, a substantial portion of the water supply is vulnerable to petroleum disruptions and price spikes.

4.2.5 *Economic Vulnerabilities*

The U.S. Virgin Islands economy, like that of the Pacific islands, is dramatically smaller, simpler, and less diversified than the economy of the U.S. mainland. For instance, they are heavily reliant on tourism, which is subject to wide fluctuations in activity, especially to declines during and after global oil emergencies.

Petroleum imports also play a much larger role in the U.S. Virgin Islands' economy than they do in the mainland economy. The mainland's petroleum imports bill has a value equivalent to 0.8% of GDP. For the U.S. Virgin Islands the corresponding figure is 6.5%. As a result, the U.S. Virgin Islands is vulnerable to greater wealth losses during oil supply disruptions than the U.S. mainland.

4.3 Methodology

The previous subsection identified the factors that contribute to the U.S. Virgin Islands' energy vulnerabilities. In order to identify and assess the implications of these factors, a combination of approaches was employed:

- Detailed historical data on petroleum and electricity supply, demand, flows, inventories and pricing were examined and compared with mainland data for periods covering recent oil supply disruptions.
- Island economy data were similarly evaluated and compared with mainland data.
- Reports prepared by island government agencies on the impacts of *past* global and local emergencies were examined.
- Scenarios were developed for possible *future* global oil disruptions of different magnitudes and locations. The impact of these disruptions on the islands was estimated.
- Scenarios were developed for possible *future* local energy disruptions of different types and locations. The impacts of these disruptions were estimated.
- Island energy emergency response plans were reviewed.
- The physical vulnerabilities of the island petroleum and electricity supply systems were assessed principally through discussion with relevant personnel.
- Extensive interviews were conducted with island government personnel responsible for energy and emergency planning, and with industry personnel in the islands' refining,

distribution, petroleum storage and electric utility sectors. These interviews served several purposes including:

- relating first hand knowledge of experiences in prior emergencies
- gaining perspectives on energy/economy outlooks, plans and potential for enhancing energy security
- gaining insights into the adequacy of island government's energy and emergency institutions.

During the course of the study, substantial amounts of energy and economy data were obtained from island governments, energy organizations and from the Energy Information Administration. The reader should be aware however that complete data were not available for any of the islands. The assessment therefore had to be completed in the face of data gaps which were minor only in the case of Puerto Rico. These gaps related principally to detailed petroleum supply, demand and price data and to selected economic statistics. Where "hard" data were not available, either estimates were developed or reliance was placed on island reports, on the views of island officials and on the experience and judgement of the study team.

4.4 Findings and Lessons Learned

4.4.1 *Local Energy Supply Disruptions*

Historical experience and this analysis indicate that following the types of local emergencies studied, the petroleum industry on the U.S. Virgin Islands can restore product flows to consumers in 30 days or less. This is done by:

- Restoring damaged facilities
- Drawing down on-island commercial inventories
- Acquiring products from other areas.

There is no history of prolonged shortages of petroleum products in any previous on-island emergency. Even after Hurricane Hugo, which devastated St. Croix and caused the Hess St. Croix refinery to be shut down for 30 days, Hess reportedly maintained its supply commitments for delivery of petroleum products in the islands and the mainland.

The principal vulnerabilities associated with local emergencies are not petroleum supplies. They are:

- Logistical problems in transporting products around the islands, including loading or off-loading crude oil and refined products in the event of damage to the docks or blockage of shipping channels.
- Damage to island electric power distribution systems from hurricanes and other causes.

WAPA depends on petroleum for all of its generation facilities. They can obtain petroleum supplies in a local emergency by:

- Using commercial oil inventories (their own and the oil industry's, particularly those held by Hess)
- Acquiring fuel off-island from various suppliers.

In addition, during local emergencies such as hurricanes, electric demand declines due to damage at homes and businesses, which further reduces the utilities' need for petroleum.

The U.S. Virgin Island's long-term contractual relationship with Amerada Hess provides a unique level of oil supply security to the territory that is not available in other insular areas. This relationship offers the equivalent of a commercial strategic products reserve.

- The size of the Hess operation relative to U.S. Virgin Islands' oil demand insures a large on-island petroleum products inventory.
- Hess is contractually committed to meeting the U.S. Virgin Islands' essential petroleum requirements in an emergency.
- Hess has consistently met these commitments.
- Products are supplied on advantageous price terms.

4.4.2 Global Oil Disruptions

Several common themes are evident from examination of actual past and potential future global oil disruptions:

- *A major disruption among Latin American oil suppliers will have severe impacts on the Caribbean, with a sustained fall-off in refinery throughputs of 25 percent compared to 5 to 15 percent for the U.S. mainland.*

Of the insular areas, Puerto Rico would initially feel the greatest impact because of its near total reliance on Latin American oil.

- *A major disruption among Pacific and Middle Eastern suppliers will impact the Pacific islands more than the Caribbean islands.*

Simulations indicate that the Far East and U.S. west coast would be more severely disrupted than other regions.

- *Gasoline and distillate inventories are most likely to drop sharply in local disruptions.*

This phenomenon may be due to temporary panic purchasing and hoarding and to the island power authority needing to consume a higher proportion of distillate/diesel fuel under unstable load conditions.

- *Residual fuel inventories tend to be maintained or rise in both global and local disruptions (high sulfur resid tends to surplus).*

In both local and global disruptions, island electricity consumption tends to decline and, with it, demand for residual fuel for power generation. Consequently, residual fuel inventories tend to rise. In addition, evidence from the 1990-91 Persian Gulf Crisis and from simulations of potential disruptions indicates that high sulfur residual fuel tends to become an unwanted product in disruptions and therefore tends to surplus.

- *Inventory drops are short-lived because the U.S. Virgin Islands have multiple sources of supply.*

In both Hurricane Hugo and the 1990-91 Persian Gulf Crisis, inventories that dropped sharply were generally restored to near normal levels in a month or less.

- *Today's oil market is highly integrated and responds very rapidly: local price dislocations are short-lived.*

Today, the petroleum crude and products market functions as a fast-moving, open commodities market with real-time computer-based trading and information systems linking several market centers and virtually all market players worldwide, including Hess and the distributors on the U.S. Virgin Islands. Under this situation, the market reacts rapidly. Consequently, any local supply and price dislocations, such as might occur on the islands, would be transmitted to the market and resolved quickly.

- *Petroleum prices in the U.S. Virgin Islands will move with the market, barring special supply relationships (e.g. the Hess-WAPA arrangement).*

The U.S. Virgin Islands will find their petroleum product prices inevitably move with the market over the long term. However, the special supply relationship between Hess and WAPA will dampen short term price fluctuations somewhat, compared to the mainland.

- *High oil prices that accompany global oil disruptions do more harm to the insular economies than to the U.S. mainland.*

Historical evidence from past disruptions and economic model simulations of future disruptions both show that the percentage loss in Gross Domestic Product (GDP) is generally larger in the insular economies than in the overall U.S. economy. For example, in the scenario Global I (with inventory build) described earlier, the annual GDP loss in the overall U.S. economy is 1.2 percent, compared to a 2.3 percent loss in Puerto Rico and a 3.0 percent loss in the U.S. Virgin Islands. This result is not surprising in view of the insular areas' heavier dependence on petroleum fuels. The islands also experience a double blow from oil disruptions. First, they suffer the direct impact of higher oil prices on their economies. Second, because their economies are so closely linked to the mainland economy, they suffer again when the higher oil prices cause a downturn in the mainland economy.

- *Higher oil prices, not the lack of oil supplies, are the major problem facing the U.S. Virgin Islands during a global oil emergency.*

The availability of multiple sources of oil supply, the islands' location along major shipping lanes in the greater Caribbean oil market, and the proximity of Hess' massive inventories minimize the likelihood that the U.S. Virgin Islands would be without petroleum supplies any longer than would U.S. mainland areas. However, the islands' total dependence on petroleum means that their economies would be more severely affected than the mainland by the price spikes that accompany an oil disruption.

5. EXPERIENCE FROM PAST DISRUPTIONS

5.1 Global Disruptions

Since October of 1973, the world supply of crude oil has been interrupted four times by political and economic forces with their origins in the Middle East. In addition, the Alaskan Valdez oil spill and the Caribbean Hurricane Hugo provided examples of the effects of localized short duration accidental and natural calamities. This section reviews the characteristics of these global disruptions, their broad impacts and their specific effects on Puerto Rico/USVI.

5.1.1 *Characteristics of Global Oil Supply Disruptions*

The major global oil supply disruptions that have occurred since 1973 have entailed supply losses of up to 5 million bpd of crude and have lasted an average of six months. Future disruptions of as much as 10 million bpd are considered plausible, given the world's dependency on Middle Eastern crude oil.

All disruptions are accompanied by an initial price shock (at times exacerbated by consumer hoarding) and a period of hectic market activity. Underlying this activity and volatility are intense trading activity generally directed to securing replacement crude oil and product supplies, together with intense supply planning activity as oil companies re-allocate crude oil shipments, re-balance refinery operations and adjust product distribution patterns. This initial period appears to last 1-3 months. Assuming no follow-on disruption shocks, what emerges is the beginnings of a new – if jittery – market equilibrium where supply and demand have begun adjusting to the new circumstances. Prices are still generally high – and volatile – but stabilizing, and even subsiding, as elasticity effects begin to curb demand.

The disruption's second phase, which may be short or long lived depending on the circumstances, generally entails a subsidence of demand as elasticity effects spread through economies. By the end of the crisis, petroleum prices may be close to or even below pre-crisis levels.

The intensity of the price and supply impacts of the disruption depend on several factors, not just on the initial supply loss. These factors include:

- the quality of the crude lost Loss of light, sweet crude has a more serious market impact than loss of heavy, sour crude, since the former creates increased difficulty in producing light clean products (gasoline, jet fuel, diesel/heating oil) and thus leads to wider light-heavy product price differentials.
- the quantity and quality of replacement surge crude production
- the degree of pre-crisis slackness or tightness in the world refining system, especially as regards capability to upgrade residual cuts to light, clean products.
- the extent and type of any loss of refinery capacity, either as an element of the disruption itself or through some unrelated incident. Loss of sophisticated refineries

with a high degree of upgrading capability will have a bigger impact than loss of simple "topping" refineries.

- the extent of military action, politically-inspired embargoes, or threat of war These can have several effects from raised demand for military jet and other fuels to curtailing commercial jet traffic to disrupting or raising the costs of petroleum transportation. A threat of impending war (as was the case in the Middle East Crisis) can elevate crude and products prices to levels higher than are justified by the underlying supply situation. This, in turn, leads to an offset whereby demand is suppressed below the level of supply. As a consequence, commercial supplies of crude oil build up for as long as the "threat of war" situation obtains
- the season of the year A disruption occurring in the third and fourth quarters is likely to put maximum pressure on jet fuel and distillate prices. Jet demand is not at its peak at this time of year, but demand for premium distillate components (as used in kerojet) to meet high volume and tightened quality for winter heating oil and residual fuel is peaking.

A disruption starting during the first quarter and leading into the second quarter is likely to have relatively less severe impact, since the second quarter is a time when seasonal demand is at a minimum. In addition, many refinery process unit shut-downs and turnarounds are normally timed for the second quarter. In an emergency, many of these can be curtailed or postponed, increasing available refining capacity.

A disruption starting in the second quarter and leading into the summer is likely to put maximum pressure on gasoline supply and pricing.

- the response measures taken, notably at the national and international levels Several nations possess crude and product reserves which they may decide to draw down (the most important being the U.S. SPR). In addition, nations may implement rationing or a variety of other measures to force conservation and constrain demand. The International Energy Agency and its member countries constitute the primary international organization for instituting and coordinating response measures.

5.1.2 Middle East Crisis - Global Impacts

Appendix B describes the main disruptions that have occurred since 1973 and discusses in detail the characteristics of the 1990-91 Middle East Crisis, including its impacts on the U.S. petroleum sector. This section discusses those characteristics in order to use the Middle East Crisis to set a context for gauging the scale of impact of potential future disruptions.

The Middle East crisis represents a more appropriate model for future disruptions than do the earlier major crises. By 1990:

- the world refining sector had grown in processing sophistication and geographical diversity

- certain OPEC crude producers had become integrated into the downstream operations of consuming nations, a trend that is continuing
- the world petroleum market had changed in that most transactions had become linked to the spot market, active futures markets had evolved, and – thanks to electronics – the many players in the market were highly inter-linked so that price signals were transmitted to the market rapidly and globally

In addition, the magnitude and duration of the Middle East crisis were relatively "typical".

Each of the factors described in *Section 5.1.1* played a role in shaping the petroleum supply and market effects of the 1990-91 Middle East Crisis:

- An initial loss of 4.3 million bpd of Iraqi and Kuwaiti crudes in August 1990 was eliminated within four months by surge production from Saudi Arabia and other OPEC and non-OPEC countries. As a result, the average supply loss over the course of the disruption was closer to 450,000 bpd.
- The quality of the crude lost was close to the world average and similar to the quality of replacement crude from surge production.
- The pre-crisis global refinery upgrading situation was already tight. The timing of the disruption (third quarter leading into fourth quarter) allied to loss of sophisticated Kuwaiti export refining capacity, panic purchasing of kerosene and naphtha in the Far East, elevated demands for military jet, and the onset of winter product requirements all combined to create severe light-heavy product price differentials in the first few months of the crisis, with kero-jet price peaking at \$60/bbl.
- The elasticity effects of high light product prices, the crude supply over-run caused by the fear of war, and then the activation of simultaneous IEA measures and SPR drawdown led to a subsidence of demand and prices by the mid-January 1991 onset of Operation Desert Storm. The threat of war, in suppressing demand, had led to the build-up of some 80-100 million bbls of heavier Saudi and Iranian crudes in temporary storage or tankers.
- By the end of the crisis in April 1991, crude and product prices were back to pre-crisis levels.

The 1990-91 Middle East Crisis thus had all the attributes of a major crisis. In considering how it should be regarded in planning for future crises, however, several factors need to be considered:

1. Despite the crisis occurring in the Persian Gulf, no production from regional suppliers other than Iraq and Kuwait was seriously affected. If Saudi surge capacity had been constrained or Middle East production otherwise interfered with, the crisis would have been much more difficult to cope with.

2. The Allies were fortunate; things that could have gone wrong did not:

- initial commercial stocks were high
- replacement crude supply exceeded expectations
- outside of Kuwait, Iraq and the fire at the Aramco, Ras Tanura, refinery, there was a general lack of refinery outages. This was in marked contrast to Winter 1989-90 when several outages at large U.S. refineries created significant product supply problems.
- versus 1989-90, the Winter weather was milder (outside Europe)
- civilian jet traffic dropped, offsetting increased military jet/distillate demand
- the threat of impending war existed long enough to sustain damagingly high oil prices but also to allow creation of an extra 80-100 million bbl "reserve" of crude oil¹
- the U.S. economy was already moving toward recession in the Summer of 1990, easing petroleum demand.

The bulk of the world's proven oil reserves lie in the Middle East and the general projection is that the U.S.A., Europe and Pacific regions will become increasingly dependent on Middle Eastern oil supplies. Given this prospect, together with the "what if's" surrounding the Middle East Crisis, it is clear that Crisis provides a solid reference point for future disruptions, but does not correspond to a "worst case" for planning purposes.

5.1.3 Middle East Crisis - U.S.V.I. Petroleum Supply Impacts

As a market economy, the U.S.V.I. was subject to the full impact of the Middle East Crisis. Examination of available data, together with feedback from industry and island officials, indicates that the Crisis did not cause any physical petroleum supply difficulties.

- The U.S.V.I. (Hess refinery) appears to have had no difficulty obtaining crude oil supplies.
- Crude oil imports and refinery runs are believed to have followed the general industry pattern of initially rising and then falling back in late 1990/early 1991, in line with a universal decline in product demand. Hess VI is known to have supplied large volumes of military fuels in support of Desert Storm and this may have helped support its refinery crude runs. (These are estimated to have been 200,000 to 300,000 bpd over the period 1991-91.)
- Refinery stocks are estimated not to have varied much from seasonal business-as-usual levels (on the order of 15 million bbls).

Even with significant variations, these levels of refinery throughputs and stocks far outweigh the U.S.V.I. island economy petroleum consumption of approximately 9,500 bpd.

¹ This consisted mainly of heavier Saudi and Iranian crude oils that could not readily be sold because of their poorer quality.

5.1.4 Impact on Electric System

The Persian Gulf crisis had little or no impact upon the electric system in the Virgin Islands. The crisis had no measurable effect on electric demand and no adverse impact upon electric supply.² Both island electric systems were recovering from the effects of Hurricane Hugo, and these recovery efforts were not hampered by the Persian Gulf crisis.

Electric Demand

The Persian Gulf crisis had no discernible effect on Virgin Islands electric demand. During FY 1991, the time of the crisis, extensive rebuilding was occurring. Table 11 shows electricity sales in FY 1989 and FY 1991 for the combined electric systems. Sales for FY 1990 are excluded because they are distorted by Hurricane Hugo.

Table 11

U.S.V.I Electric Sales		
Fiscal Year ending June 30	1989	1991
Aggregate Electric Sales in mWh	482820	511680
Source: U.S.V.I. Bureau of Economic Research, "U.S. Virgin Islands Annual Economic Indicators."		

Electric sales had rebounded considerably in FY 1991 from their FY 1989 pre-Hugo levels. Considerable sales growth continued in subsequent years: FY 1992 and FY 1993 annual electric sales growth rates were respectively 5.2% and 5.16%. This suggests that the Persian Gulf crisis had little, if any, effect on electric demand.

Electric Supply

The electric system rebuilding continued unabated during the Persian Gulf crisis in FY 1991. WAPA had considered generation upgrades before Hurricane Hugo, and was forced to rebuild much of the transmission and distribution system after Hugo. These rebuilding efforts were unaffected by the Persian Gulf crisis.

Electricity prices did increase slightly during the Persian Gulf crisis, as indicated by average revenue per kWh of electricity. Average revenue per kWh of electricity sold was approximately 12¢ in

²Electric rates increased significantly one year before the Persian Gulf crisis, but increased only slightly in FY 1991, the year of the crisis. While consumers are worse off as a result of higher electric rates, electricity sales increased both in FY 1990 and FY 1991. This suggests that the adverse economic welfare impact of higher rates was not great.

both FY 1989 and FY 1990, but increased to approximately 13¢ in FY 1991.³ This increase can best be explained by the increase in oil prices that occurred during the Persian Gulf crisis during FY 1991.⁴ This rate increase would lead to a very small increase in electric bills; for example, a customer using 500 kWh per month would see a \$5 increase in FY 1991 monthly electric bills.

The Persian Gulf crisis may have had a small, negative impact on WAPA profitability. However, any effect cannot be identified because WAPA profit in FY 1991 was still negatively affected by the Hugo aftermath. For example, line losses were higher after Hugo because some meter records were destroyed, and many meters were not properly calibrated and sealed in the rebuilding effort.⁵ Approximately \$300,000 was earmarked in FY 1991 to calibrate and seal meters. WAPA operating profit in FY 1989, the year before Hugo, was approximately \$6.2 million;⁶ projected⁷ FY 1991 operating profits were approximately \$5.5 million. The meter sealing effort explains almost half the difference in profitability.

5.1.5 *Economic Impact*

Measurement of Economic Impact

Global oil supply disruptions adversely affect the economies of oil consuming areas such as the U.S. territories. Losses in GDP and terms of trade are widely used measures of economic impact. Other indicators are changes in inflation and unemployment rates.

Global oil disruptions generally cause GDP losses because the sudden increase in oil prices pushes the production cost of many goods and services higher than the price many consumers are willing to pay, which causes a decline in real consumption expenditures. The disruption usually also creates a more unfavorable investment climate, which leads to a decline in investment expenditures. This process occurs worldwide. Hence, foreign demand for goods and services produced in the U.S. mainland and insular areas declines. Consumption expenditures, investment expenditures and sales of goods to other countries are all major components of GDP. As these fall, so does GDP.

GDP losses tend to be larger in the insular areas because of their total dependence on imported petroleum. In addition, most of the insular areas' economies (except American Samoa's and Puerto

³The FY 1991 figure is based on projected revenues from sales of electricity. The projected '91 revenues were above annualized electric sales revenues as of March 31, 1991. However, the continued rebuilding of the system and sales growth suggests that the projected figures are reasonable.

⁴The relative proportion of each customer class--residential, commercial, and industrial--did not change over this period. Hence the increase cannot be explained by shifts in customer composition.

⁵Virgin Islands Water and Power Authority, *Electric System Revenue Bonds 1991 Series A Offering Statement*, July 1991, p. 38.

⁶Source: WAPA 1991 Series A electric revenue bonds offering statement, Appendix A, p. 5.

⁷The projection was calculated by annualizing operating profits for the first three quarters of FY 1991. Figures for FY 1991 were obtained from the 1991 WAPA electric revenue bonds offering statement, Appendix A-1 p. 3.

Rico's) are heavily tourism based, and tourism is disproportionately affected in the worldwide recessions that result from global oil supply disruptions.

Oil disruptions also generally cause a transfer of wealth from net oil consuming economies to net oil producing economies. This loss is measured by the terms of trade loss. When oil consumers pay more for petroleum products in an oil disruption, they have less money to spend on other items. Hence, the oil price increase is equivalent to a wealth loss for oil consumers. This wealth that oil consumers lose is transferred to oil producers, who are receiving higher prices for their oil. Roughly, the terms of trade loss can be measured by changes in an economy's oil import bill. An economy that is relatively more dependent upon imports for oil consumption will suffer a relatively greater terms of trade loss in global oil supply disruptions.

Terms of trade losses resulting from a global oil supply disruption are proportionally larger in the insular areas than the U.S. mainland for two reasons. First, the insular areas cannot currently use other forms of energy in place of oil during a global oil supply disruption, hence their oil consumption will decrease proportionately less than will the U.S. mainland's. This fact as well as the fact that oil demand is generally inelastic implies that the insular areas' oil expenditures increase proportionately more than does the U.S. mainland's, during a global oil supply disruption. Second, unlike the U.S. mainland, all insular area oil must be imported, which means that oil import expenditures will increase proportionately more than the U.S. mainland's.

Where data were available, we calculated several indicators of the economic effect of past and potential global oil disruptions: GDP losses, proportionate terms of trade losses, inflationary effects, and unemployment changes.

The economic effects in the U.S. Virgin Islands from past oil supply disruptions are shown in Table 12. The data capture what occurred in the recessions that resulted after the oil supply disruption. Data shown are average annual compounded growth rates, change in the growth rates, peak unemployment rates and changes from the pre-disruption unemployment rates. Following the table, each prior disruption is reviewed individually.

Table 12

Economic Effects of Past Global Oil Supply Disruptions			
	Disruption		
	1973-74	1979-80	1990-91
GDP Growth Rate			
U.S. mainland	-0.72%	-2.18%	0.72%
U.S.V.I.	2.79%	-4.72%	-18.51%
Change from Pre-Crisis GDP Growth Rate			
U.S. mainland	-5.8%	-4.7%	-1.8%
U.S.V.I.	-4.51%	-6.94%	-23.9%
Peak Unemployment Rate			
U.S. mainland	8.5%	9.7%	7.4%
U.S.V.I.	10.8%	8.2%	2.8%
Change from Pre-Crisis Unemployment Rate			
U.S. mainland	2.9%	3.9%	1.9%
U.S.V.I.	6.2%	2.6%	0%

The Virgin Islands economy appears to have suffered sharper impacts from past global oil crises than the U.S. mainland. Economic activity is affected later than on the U.S. mainland, and recovery appears to be somewhat faster. Tourism, the most important industry in the Virgin Islands, declines contemporaneously with U.S. economic recessions, but the overall economy tends to show the effects a year later. This is a result of incidental employment declines and large increases in inflation. The economic effects of the Persian Gulf crisis are obscured by the economic aftereffects of the post-Hurricane Hugo rebuilding effort. The U.S.V.I. economy expanded greatly in 1990 as a result of extensive rebuilding, and slowed when these rebuilding efforts contracted in 1991.

The 1973-74 Oil Crisis

The 1973-74 oil crisis initiated a worldwide recession, which in the U.S. mainland began in November 1973 and ended in March 1975.⁸ At that time, it was the longest and worst recession that

⁸Source : *Survey of Current Business*, August 1993, p. C-7.

the mainland⁹ U.S. had experienced since the end of World War II. The oil crisis also precipitated an economic slowdown in the Virgin Islands that began and ended later than the U.S. recession.

The Virgin Islands economic slowdown was sharp and slightly more severe than the U.S., but it appears to have reversed itself relatively quickly. The economic indicators are mixed. While GTP figures show negative growth from 1976 through 1979, tourism went through a decline contemporaneous with the U.S. recession, recovering by 1977. Employment growth was positive during the U.S. mainland recession, and a decline in employment that occurred in 1976 had more than reversed itself by 1977.

The economic slowdown in the Virgin Islands did not begin until 1975, about the time the recession ended in the U.S. mainland. Part of this slowdown was undoubtedly a result of declining real tourist expenditures, which fell at about a 10% compounded annual rate in 1974 and 1975. The decline in tourist expenditures continued into 1976, but real tourist expenditures rebounded strongly in 1977 to about their 1973 level. In spite of a rebound in tourism, real GTP experienced negative growth until 1979. While GTP figures indicate economic slowdown during this period, employment growth was fairly strong. Employment growth was positive during the oil crisis: it grew at an average annual compounded rate of 2.79% over the FY 1972-75 period.¹⁰ Total employment fell in FY 1976, but rebounded sharply in FY 1977. There was a similar decline in nonagricultural wage and salary employment in 1976, but it too rebounded in 1977. The unemployment rate peaked at a high of 10.8% in 1976, considerably higher than the U.S. rate, but had fallen to a lower level than the U.S. unemployment rate by 1979. Although specific local price data are unavailable, the effects of an oil disruption on the Virgin Islands' price level should be expected to be more severe in the Virgin Islands than on the mainland because of the Virgin Islands' dependence upon petroleum and imports for its most basic needs.

The oil crisis affected the Virgin Islands economy with a lag, and the severity of the economic slowdown appears to have been slightly greater than that in the U.S. mainland. However, it appears that the economy recovered more quickly than the U.S. mainland economy as a result of tourism growth.

The 1979-80 Oil Crisis

The 1979-80 oil crisis precipitated a worldwide recession beginning in July 1981 and ending in November 1982.¹¹ In the U.S., the recession was the worst since the Great Depression. The Virgin Islands did undergo an economic slowdown in 1982, but this slowdown was shorter and shallower than the U.S. recession. Economic activity had completely rebounded by 1983. The economic slowdown in the Virgin Islands began later and ended earlier than the U.S. mainland recession.

⁹"Mainland" U.S. means all 50 states, including Alaska and Hawaii.

¹⁰U.S.V.I. Department of Economic Development and Agriculture, *Comparative Growth Statistics*. Employment growth represented is *all* employment, instead of the more common nonagricultural wage and salary employment.

¹¹The oil crisis also sparked a short, relatively mild U.S. recession beginning in January 1980 and ending in July the same year.

Virgin Islands real GTP declined by 4.72% in 1982, but this decline had completely reversed in 1983, when GTP had returned to better than its 1981 level. Tourism declined contemporaneously with the U.S. mainland recession, declining about 5% in both 1981 and 1982. Tourism recovered strongly in subsequent years, posting a 7% gain in 1983 and an almost 18% gain in 1984. Nonagricultural wage and salary employment growth was negative in 1982 and 1983, and while positive in 1984 and 1985, was quite sluggish.¹² The unemployment rate peaked at 8.2% in 1983, declining in subsequent years. The unemployment rate declined to very low levels in the latter part of the 1980s, largely as a result of outmigration. Although specific local price data are unavailable, the effects of an oil disruption on the Virgin Islands' price level should be expected to be more severe in the Virgin Islands than on the mainland because of the Virgin Islands' dependence upon petroleum and imports for its most basic needs.

While the Virgin Islands economy experienced a slowdown as a result of the U.S. mainland recession, it was shorter and appears to have been shallower.

The Persian Gulf Crisis

The Persian Gulf crisis was limited in duration, which limited the economic impact worldwide and in the Virgin Islands. The U.S. had independently entered a recession starting in the third quarter of FY 1990. The U.S. recession also affected the Virgin Islands economy for the worse, because the Virgin Islands is heavily tourist dependent, and tourism is strongly procyclical. Although the recession officially ended in April 1991, the subsequent recovery has been weak, limiting tourism growth. Also in 1991, the Virgin Islands economy contracted strongly as a result of reduced intensity of the post Hurricane Hugo rebuilding effort. The effects of the U.S. recession and the slowdown of the post-Hugo rebuilding dominate any effect of the Persian Gulf crisis on Virgin Islands economic activity and unemployment.

Virgin Islands economic data from 1991 are negative. Real GTP shrank by 18.51% in 1991; real per capita GTP fell by 16.72%. The large fall in 1991 GTP was caused by the slowing of post-Hugo rebuilding efforts and anemic tourist expenditure growth, which in turn was caused by the U.S. mainland recession. Construction employment fell by nearly one-third from its record 1990 levels, and tourism-related employment grew slowly. However, unemployment remained low in 1991 at 2.8% and even total employment grew modestly.

There is some sign of economic rebound in 1992. In 1992, GTP grew by 2.98% and per capita GTP grew by 3.98%. However, because GTP and per capita GTP fell so precipitously in 1991, 1992 per capita GTP is only slightly above its 1988 level. Real tourist expenditures grew by 2.85%, which is low by historic standards. Employment in 1992 grew by only 0.98%; the unemployment rate increased to 3.6%. Although this is higher than its 1991 level, it is low by recent historic standards and is not a recessionary level.

Substantial outmigration has been occurring in the Virgin Islands since 1986. This trend continued in 1991 and 1992, although at not as fast a pace as in the mid-1980s. Outmigration has been instrumental in reducing the Virgin Islands' unemployment rate; as the labor force ages and becomes

¹²A similar pattern exists for total employment.

more skilled, outmigration will become a less attractive option in the future, which could lead to higher unemployment rates in future economic slowdowns.

The Persian Gulf crisis *per se* had little impact on the Virgin Islands economy. Although the Virgin Islands economy shrank markedly in 1991, this was more a result of the U.S. recession and a slowdown in post-Hugo rebuilding efforts than any effect of the Persian Gulf crisis.

Summary

The Virgin Islands economy appears to have suffered a sharper impact from the global oil crises than the U.S. mainland. Economic activity is affected later than on the U.S. mainland, and recovery appears to be somewhat faster. Tourism, the most important industry in the Virgin Islands, declines contemporaneously with U.S. economic recessions, but the entire economy tends to show the effects a year later. This is a result of incidental employment declines and large increases in inflation. The economic effects of the Persian Gulf crisis are obscured by the economic aftereffects of the post-Hurricane Hugo rebuilding effort.

5.2 Local Disruptions - U.S. Virgin Islands

The U.S. Virgin Islands must contend with the risk of natural disasters and accidents which impact petroleum supply. Hurricanes constitute the more persistent and frequent threat, although earthquakes are also a possibility. In addition, accidents can disrupt island petroleum supplies.

5.2.1 *Hurricane Hugo - U.S.V.I. Petroleum Supply Impacts*

Hurricane Hugo struck the U.S.V.I. in September 1989. The island of St. Croix took the full force of the storm, which caused significant damage to the Hess refinery. (This had already been shut down and emergency measures taken before the hurricane's arrival.) The following specific impacts were felt:

- The Hess refinery was shut down for about 30 days with the effect that monthly output was cut in half in September and October 1989 (i.e., fell from approximately 7.5 million bbls per month to nearer 4 million bbl).
- Total refinery stocks are understood to have dropped significantly (from business-as-usual levels estimated at approximately 15 million bbl) but to have recovered sharply.
- By rearranging supplies, Hess was able to meet its delivery commitments. This enabled exports from Hess to be cut, maintaining substantial stocks on U.S.V.I.
- Recovery was rapid. Normal refinery operations were re-established by November.

5.2.2 *Impact on the Electric System*

Hurricane Hugo devastated the Virgin Islands electric system in September 1989. St. Croix was particularly hard hit. While there was less damage to the St. Thomas electric system, damage was still severe. There was a total loss of WAPA power on all three islands; however, the Amerada Hess

Figure 2

refinery, which is located on St. Croix and generates all of its own power, did not lose power during the storm.¹³ Power was restored on an emergency basis to all St. Thomas residents by December 1989 and all St. Croix residents by January 1990. Full restoration took considerably longer. The remainder of this section will describe the impact of Hugo on electric power demand, electric supply, including the generation, transmission, and distribution sub-systems, and secondary impacts of electric system failure.

Electricity Demand

Hurricane Hugo had a large short-term effect on electricity demand but little long-term effect. The magnitude of Hugo's damage can be appreciated fully by examining its effects on peak loads, as shown in Figure 2. The fall in peak loads is particularly dramatic in St. Croix. Although the St. Thomas system appears to have recovered by spring of 1990, as evidenced by peak loads, the St. Croix system does not appear to have fully recovered from Hugo until the second quarter of 1991. There was some out-migration and many businesses either temporarily or permanently ceased operations as a result of storm damage.¹⁴ However, any decreases in demand were not long-term: by FY 1992, the number of customers of all types on both St. Croix and St. Thomas exceeded their pre-Hugo levels.

¹³Source: U.S.V.I. Department of Economic Development and Agriculture, *Damage Assessment Report of Hurricane Hugo*, undated draft.

¹⁴Source: U.S.V.I. Department of Economic Development and Agriculture, *Damage Assessment Report of Hurricane Hugo*, date unknown.

A post-Hugo rebuilding effort has boosted recent electric sales growth rates, particularly on St. Croix. For example, St. Croix electric sales increased by 7.38% in FY 1993. This growth rate is considerably above the 5% annual growth rate experienced in the 1980s economic boom and is especially significant in light of the less favorable recent economic conditions.

Electricity Supply

All aspects of the Virgin Islands' electric systems were damaged: generation facilities, fuel handling facilities, the St. Thomas-St. John submarine transmission cable, and distribution facilities. However, it appears that damage to items other than the distribution system did not impede the electric systems' ability to generate electricity. The critical part of the electric systems that was damaged was distribution plant. Approximately 60% of St. Croix distribution system poles and approximately 13% of the St. Thomas distribution system poles were destroyed or damaged.

Restoration on an emergency basis was completed to almost all St. Thomas customers by December 1989 and to all St. Croix customers by January 1990. Complete restoration took considerably longer. Partially as a result of Hugo, WAPA is undertaking several capital improvements to its system. These are being made primarily to the distribution system and include, among other things, stronger replacement distribution poles, self-protected transformers, and high efficiency streetlighting. Distribution system improvements are already contributing to lower line losses.¹⁵ A generation expansion plan study had been initiated by WAPA before Hugo, which recommended additions to the generating capacity on both systems. Hence, any expansions to base generation cannot be explained by Hugo.

Secondary Effects

The severe effects on the electric system also produced severe secondary effects on the telecommunications and water systems. The water system is particularly dependent on electricity, because most of the Virgin Islands' potable water supply is obtained from desalinization plants, and the island system's isolation means that water cannot be easily transported from other sources in emergencies. Water service was not restored to pre-Hugo levels until December 1990.

Communication between St. Thomas and St. Croix was completely cut off as a result of Hugo, and no communication took place for four days after the hurricane. The first post-Hugo communication between the two islands was hand-carried by messenger. An HF radio located in a local Health and Human services office was the only inter-island communications service available for three weeks as a result of the storm. Subsequent restoration of service was slow because of the lack of WAPA power; relatively unreliable private generators had to be used to provide electricity. As of mid-February 1990, 90% of St. Thomas and 50% of St. Croix telephone service was restored.¹⁶ One impediment to the restoration of service was the scarcity of contract labor, which was occupied restoring communication service to the Carolinas; adequate labor was not available until almost two months after the storm.

¹⁵R. W. Beck and Associates, *Long Range Generation Plan for St. Croix*, December 1990, page 1-2.

¹⁶Office of the Manager, National Communications System, *Hurricane Hugo and Loma Prieta Earthquake Telecommunications Impacts*, May 1990, p. 2-15.

As a result of the storm, the Virgin Islands Telephone Company, which provides local service, plans to bury as much of its cable as possible.

Water rationing was in effect in the Virgin Islands for at least two to three months following Hugo. In addition, there were also food shortages.¹⁷ These factors also served to impede the restoration process.

There were no reports of the effect on other critical services such as hospitals. However, there were only six deaths on the Virgin Islands attributable to the storm. This suggests that the commercial power loss did not have a major impact on critical hospital services or lead to epidemics.

5.2.3 Economic Impact

After Hurricane Hugo devastated the Virgin Islands in September 1989, the local economy initially grew strongly as a result of the post-Hugo rebuilding effort. However, the economy contracted strongly in 1991 when these rebuilding efforts slowed; the U.S. mainland recession also contributed to the 1991 contraction. Hugo caused temporary intersectoral employment shifts, and possibly permanent interisland employment and economic activity shifts as well. In particular, there was a surge in 1990 construction employment, which more than offset the decline in 1990 tourism-related employment. In addition, it appears that St. Croix has had more trouble recovering from Hugo than St. Thomas and St. John. Increases in economic activity in St. Thomas and St. John have more than offset declines in St. Croix economic activity.

Tourism comprises the major part of U.S.V.I. economic activity, contributing approximately 50% to real GTP in the 1980s. Real tourist expenditures fell by almost 10% in 1989 as a result of Hugo. Tourism recovered quickly in 1990, as evidenced by 8% growth in real tourist expenditures; Tourism expenditures in 1990 almost reached their then-record 1988 levels. Most tourist expenditure growth appears to have occurred in St. Thomas/St. John. The number of tourists visiting St. Croix declined precipitously in 1990, largely as a result of the destruction of the Fredericksted cruise ship dock.

Even though tourist expenditures fell so precipitously in 1989, the U.S.V.I. economy and employment grew strongly through 1989 and 1990. Real GTP grew at a rate of 6.58% in 1989 and 5.33% in 1990. This period was near the end of the U.S. mainland economic recovery. Total employment grew by 1.29% in 1989 and 2.65% in 1990, which was lower than in previous years and was at least in part a result of Hugo. Tourism related employment fell and construction employment rose. The unemployment rate increased slightly in 1989 to 3.7% from its 3.3% 1988 level, and this was likely a result of Hugo. Unemployment was down to 2.8% in 1990.

While Hugo undoubtedly had a very deleterious immediate effect on the U.S.V.I. economy, especially in St. Croix, rebuilding efforts boosted total U.S.V.I. economic growth in 1990. The economy contracted strongly in 1991, partly as a result of the rebuilding slowdown and partly as a result of the U.S. mainland recession. While it appears that St. Thomas has recovered from the effects of Hugo, St. Croix still appears to be struggling.

¹⁷Office of the Manager, National Communications System, *Hurricane Hugo and Loma Prieta Earthquake Telecommunications Impacts*, May 1990, p. 2-15.

6. POTENTIAL IMPACTS OF FUTURE EMERGENCIES

The impacts of past global and local disruptions were examined in *Section 5*. In *Sections 6.1* and *6.2* below, the potential impacts of possible future disruptions are explored.

6.1 Impacts of Postulated Global Oil Supply Disruptions

Potential future global oil disruption scenarios were developed to examine the impacts on Puerto Rico and the U.S. Virgin Islands of different levels and types of crude loss and refining capacity loss. The scenarios are summarized in Table 13 and described further below.

- **Global I** represents a geographically widespread loss of medium and higher quality crude oils affecting producers in the Middle East, North Africa and the Pacific. PR/USVI refiners would be impacted directly by the lost Middle Eastern crudes and indirectly (through crude oil diversion) by the loss of high quality African and Pacific crudes.
- **Global II** represents a loss of crude oil supplies from regions on which the U.S. Virgin Islands and, especially, Puerto Rico refineries are heavily dependent, namely Latin America and secondarily West Africa. Impacts on PR/USVI refining throughputs would be expected to be substantial.
- **Global III** represents a situation akin to the 1990-91 Persian Gulf Crisis, but with the net loss of crude supply after production surges remaining larger than was the case in 1990/91. Impacts on PR/USVI refineries would be expected to be limited.

Variants of **Global I** and **II** incorporating refinery capacity losses were designed to examine the impacts on light product supply of loss of sophisticated capacity in the Middle East and Europe. In **Global III**, the variant was designed to explore the impact of an essentially total simultaneous loss of Puerto Rico and U.S. Virgin Islands refineries, e.g., through accidents and natural disaster. The implication of this variant is that petroleum product may have to be supplied entirely from off-island sources.

The analysis of the impacts of the global oil disruption scenarios was based in part on several models, including:

- DOE/EIA's Disruption Impact Simulator (DIS) Model. This projects overall market conditions, including world oil price, for a postulated disruption away from an underlying business as usual scenario. The model also projects impacts on the U.S. economy.
- EnSys' World Oil Refining Logistics and Supply (WORLD) Model. This model integrates and simulates the activities and economics of the world-regional petroleum supply system. It outputs projected regional crude and product flows, refinery utilizations and detailed crude and product prices from base assumptions regarding disrupted supply, demand, refining capacity, transportation and the "marker" crude price.

- The Puerto Rico Planning Board Macroeconomic Model. This model consists of an econometric model linked to an input-output model. The model was used to simulate specific impacts on the Puerto Rico economy of the same global disruption scenarios simulated using DIS and WORLD. No macroeconomic model was available for any of the other insular areas. The Puerto Rico Planning Board model captures key effects needed for vulnerability analysis including impacts of world oil price level, interactions between the energy sector and other economy sectors and interactions between the Puerto Rico economy and the (disrupted) U.S. mainland economy.
- The Virgin Islands Energy Office (VIEO) Jobs Impact Model. This model, maintained for VIEO by the Amercian Council for an Energy Efficient Economy, simulates the effect of various developments in the U.S. Virgin Island economy on island employment. GDP effects were estimated outside the model based on the predicted employment changes.

EIA, the Puerto Rico Planning Board and the VIEO assisted in this effort.

The prime purpose behind the analysis of potential year 2000 disruption scenarios was to gain a sense of how the Caribbean and Pacific insular areas could be impacted (relative to the Mainland) in disruptions of a world regional petroleum supply system that will have changed significantly from that obtaining today; also to explore disruptions of high severity by historical standards, as well as lesser disruptions similar to the 1990-91 Middle East crisis.

Table 13

Potential Global Energy Disruptions			
Cases Examined (all Year 2000)			
Case (MMbpd)	I	II	III
Crisis Duration Months	6	6	6
Crude Loss Regions	Mid East, N. Africa Far East	Latin Am., W. Africa	Similar to 1990-91 Persian Gulf Crisis
Crude Loss Volume	9	6	4.3
U.S. SPR Draw	3.5	1.5	0
Foreign SPR Draw	1	0	0
Net Supply Loss	4.5	4.5	2.3 (2.0 Saudi surge production)
Crude Price (BAU \$22.90)			
- High Stock Build (\$/Bbl)	\$50	\$50	\$36
- Low Stock Build (\$/Bbl)	\$35	\$35	\$26
Case Variants			
- Refining Loss MMbpd	.5 Europe .5 P.G.	.5 Europe .5 P.G.	PR+USVI total loss

6.1.1 Year 2000 BAU Base Case

In constructing a basis for evaluating potential disruptions, EIA first developed a Year 2000 business-as-usual (BAU) case using EIA supply/demand projections and the EnSys *WORLD* Model. The base case BAU 2000 results included the following features of particular interest to Puerto Rico and the Virgin Islands:

- A significant growth of refining in the Caribbean Basin region is projected by 2000 directed towards the production of reformulated gasoline for the U.S. market. The cost edge attributable to refiners in this region for reformulated gasoline production stems in part from presumed advantages in re-blending on the basis that (a) reformulated gasoline would constitute only a portion of total gasoline output and (b) the absence of "anti-dumping" constraints would enable disposition of environmentally poor quality blendstocks into conventional foreign grades. Additional factors are the closer proximity to the U.S. as compared to Europe and the Middle East, and the more stringent U.S. environmental restrictions associated with the requirements of the Clean air act and other environmental legislation. The latter could make it cost-prohibitive for U.S. refiners to upgrade their facilities.

While much of the expansion will occur in Venezuela (with several projects already underway) due to its indigenous supply of crude oil and natural gas, Puerto Rico and the Virgin Islands may also be well positioned to share in this expansion of U.S. offshore refining.

- While residual fuel oil was the Caribbean Basin's prevalent export to the East Coast of the United States up through the early 1990's, a significant swing towards lighter products is expected by the year 2000 with reformulated gasoline encompassing more than a third of the export volume.
- Most of the crude oil refined in the Caribbean Basin is indigenous to that region. The insular areas of Puerto Rico and the Virgin Islands have no production of their own and must import all of their crude oil. Traditionally, Puerto Rico has imported most of its crude oil from Caribbean neighbors (mainly Colombia, Ecuador, Mexico, and Venezuela). The Virgin Islands on the other hand has imported more than half of their crude volume from West African and Middle Eastern sources. These trade patterns are not expected to significantly change by the Year 2000.

6.1.2 Year 2000 Disruption Cases

The following sections provide a description of the EIA disruption cases and their variants. Comparisons to the 1990/91 Mid-East Crisis are made throughout since the impacts of the Mid-East Crisis described in *Section 5* provide a useful benchmark for attempting to predict the effects of the various disruptions on Puerto Rico and the Virgin Islands.

The simulations undertaken using the EnSys *WORLD* Model provide a "snap-shot" of the postulated disruption under average disruption conditions. The results obtained, therefore, most closely represent the situation where the disruption has been underway for some time and a new market equilibrium has been reached. It should therefore be borne in mind that conditions early in the disruption would likely be worse than the situations presented here, especially as regards the severity of crude and product price spikes and light-heavy product differentials.

Global I (Large)

This case showed that the sustained falloff in refinery operations in the different world regions varied between 5% and 15%. Refinery runs were down slightly more than 10% in Puerto Rico and the Virgin Islands, not disproportionately worse than the rest of the world.

Refinery output did not drop measurably in Puerto Rico during the Mid-East Crisis and rose by about 10% on the average in the Virgin Islands. Although Puerto Rico emerged from that crisis with their inventories intact and having met Island demands, a key to their successful management of the crisis was an early build-up of crude oil and gasoline stocks. The Global I case had a net sustained world crude supply shortfall of 4.5 million barrels per day as opposed to an average world shortfall of 450 thousand barrels per day in the Mid-East Crisis, with production losses being erased less than half way into the crisis.

It is not unreasonable to assume that Puerto Rico will be unable to sequester sufficient early crude oil and product supplies to ride out a crisis of the magnitude of Global I. If this be the case, an analysis of the impacts of the Mid-East Crisis on Puerto Rico indicates that their product inventories could reach an untenable position early in the course of a Global I crisis. The consequences would be that Puerto Rico may either have to be supplied from the outside, have sufficient on-island or dedicated

strategic reserves, or curtail Island product sales. If supplied from the outside, the indications are that the Virgin Islands would be a favored source for supplying Puerto Rico with products.

The Global I results showed that among the most vulnerable areas were the U.S. West Coast, Southern Europe, and the Far East. The West Coast made up over one half of its shortfall from Latin American producers and additional cargoes were imported from Latin America to replace Far East oil. These indicated crude oil flow patterns would tend to bring additional pressure to bear on Puerto Rico, but to a much lesser extent on the Virgin Islands.

Crude oil and product prices between the U.S. and Puerto Rico were found to track closely during the Mid-East crisis. For Global I and its variant case, the Year 2000 U.S. East Coast prices (in 1991 dollars per barrel) were found to be:

	Base Case	Global I	Global I Variant
World Oil Price	\$22.90	\$48.20	\$48.20
Refinery Gate Prices			
- Gasoline	\$31.37	\$58.00	\$58.67
- Distillate	\$28.21	\$54.12	\$54.73
- Residual	\$14.89	\$39.20	\$39.75
- Jet Fuel	\$28.25	\$54.67	\$54.93
- LPG	\$19.23	\$43.60	\$42.68

Some of the crude oils lost in Global I were of high quality (light, low sulfur). Because of this, the price differentials between the lighter refined products and crude oil were higher than those exhibited in the pre-disruption environment. This was a result of the increased downstream processing requirements needed to enhance the yields of the heavier crude oils (despite the lowered average refinery throughputs).

The above price structure suggests that the economic viability under disruptions of Puerto Rico and Virgin Islands refineries would be improved if their facilities were upgraded and expanded to provide complex, flexible, high conversion refineries capable of producing light products from heavy crude oils, including reformulated gasoline.¹⁸

¹⁸The Hess VI upgrade moves that refinery in that direction.

Table 14

**YEAR 2000 REFINERY OPERATIONS - GLOBAL I
PERCENT UTILIZATION OF DISTILLATION CAPACITY**

<u>Refinery Region</u>	<u>Base Case</u>	<u>Global I</u>	<u>Global I Variant</u>
North America			
- East	92.0	92.0	92.0
- Mid	92.0	81.7	81.6
- West	91.5	85.2	85.2
Caribbean Basin	90.0	72.5	72.7
Northern Europe	90.0	90.0	83.9
Southern Europe	90.0	74.9	78.1
North Africa	90.0	78.4	83.3
Persian Gulf	90.0	85.3	75.3
Pacific High Growth	90.0	83.9	85.2
Rest of World	90.0	84.4	86.7

Global I Variant

The loss of 500,000 barrels per day Middle East/Pacific refining capacity and 500,000 barrels per day of sophisticated U.S./European refining capacity was assumed and superimposed on Global I. The approximate current regional crude oil distillation capacities are given below:

	Year 2000 BAU	
	Million Barrels per Calendar Day	Refinery Percent Utilization
U.S.	15.2	92
Middle East	6.4	90
Europe	14.3 (excluding Turkey and C.I.S)	90
Pacific	7.3 (including China)	90

The refining capacity losses for this variant case therefore correspond to 3.6% of the total Middle East/Pacific capacity and 1.7% of the U.S./European capacity. Given the approximate 90% BAU capacity utilizations in the affected regions, and in light of an approximate 10% net world crude loss associated with Global I, no significant variant case impact was found. The average refinery utilization in the Global I case was 83.0%, and 83.6% for the variant case. Other than slight changes in worldwide trade flows, there was no evidence of any tight market conditions.

As was expected, light product prices were slightly higher in the variant case due to the small decline in worldwide refining flexibility.

Global II (Medium)

This case showed that the sustained falloff in refinery operations in the U.S. Gulf Coast was between 5% and 15% and by more than 25% in the Caribbean Basin. The refining areas most dependent on Latin America and/or West African crude oil in the pre-disruption environment were the Gulf Coast of the U.S. and the Caribbean Basin. The Gulf Coast was able to replace large quantities of its disrupted supply with oil from the SPR, while the Caribbean Basin partly replaced its crude oil supply with increased imports from the Middle East. Of the insular areas, Puerto Rican refiners would initially feel the greatest impact due to their almost complete dependence on Latin American oil.

As with Global I, it is not unreasonable to assume that Puerto Rico will be unable to obtain sufficient early crude oil and product supplies to ride out a crisis of the magnitude and locale of Global II as smoothly as it rode out the Middle East Crisis. Although most of the supply sources for the Virgin Islands remained secure during Global II, the Virgin Islands would be more poorly positioned than in Global I to provide the Puerto Rico with emergency product supply in the face of unforeseen events.

Global II shows the East Coast of the United States as still the primary export destination for Caribbean Basin products, but with the East Coast probably increasing their light product imports from European refiners under Global II. The average drop off in exports from Puerto Rico during the Mid-East Crisis was 25% of the export products normally flowing to the U.S. and 20% for their other export products. The average drop off in exports from the Virgin Islands was a marginal 4%, however the exports to other areas from the Virgin Islands greatly increased during the Mid-East Crisis. Therefore the ability of the U.S., particularly the Puerto Rico and the Virgin islands, to cope with the effects of Global II may be heavily dependent on the sustained ability of Europe and the Middle East to export products and crude oil during the course of Global II.

In Global II and its variant case, the Year 2000 U.S. East Coast prices (in 1991 dollars per barrel) were found to be:

	Base Case	Global II	Global II Variant
World Oil Price	\$22.90	\$48.20	\$48.20
Refinery Gate Prices			
- Gasoline	\$31.37	\$57.55	\$59.31
- Distillate	\$28.21	\$53.76	\$54.01
- Residual	\$14.89	\$39.90	\$39.61
- Jet Fuel	\$28.25	\$54.22	\$54.29
- LPG	\$19.23	\$44.17	\$43.99

The prices for refined products mirrored the increase in the world oil price without any dramatic widening of light-heavy product price differentials (once market conditions under the

disruption have stabilized). This was largely due to the fact that the Global II severe disruption in Latin American petroleum supplies did not take large quantities of high quality crude oil (light, low sulfur) off of the world crude market.

The Global II reliance on the SPR (and no reliance assumed on the other IEA inventories) does not approach that of Global I. However, a 1.5 million barrels per day draw over six months will effectively reduce the present SPR crude oil inventory to 55% of its present capacity, or 65% if the crude inventory is increased to 750 million barrels.

Latin America and Mexico provided only about 5% of the OPEC and non-OPEC surge production during the Mid-East Crisis. This leaves most of the peak surge production of 5.2 million barrels per day provided during the Mid-East Crisis potentially available. Also, since the Kuwaiti refineries are not down in Global II, and the Saudi products are not diverted to war purposes, the Middle East is a potential product supply region for the U.S. On the other hand, since Venezuela is anticipated to be producing significant quantities of reformulated gasoline for export to the U.S., this source of supply for the U.S. (and potentially for Puerto Rico in an emergency) is withdrawn during Global II. This argues that U.S. refining security would be enhanced by the expansion of Puerto Rico's refining facilities as a hedge against possible future world crude oil disruptions, a hedge which potentially benefits both Puerto Rico and the U.S.

Global II Variant

As is the case for Global I, the loss of 500,000 barrels per day Middle East/Pacific refining capacity and 500,000 barrels per day of sophisticated U.S./European refining capacity has little impact on the Global II case. However, as shown in *Table 15*, the loss of Latin American crude oil and products (and hence refining capability) translates into higher refinery utilizations elsewhere to compensate for the losses in the Caribbean Basin. Utilizations are up 6% in Northern Europe and 10% to 13% in the Middle-East. Since there is anticipated greater U.S. and Caribbean Basin reliance on product imports from these regions, the U.S., Puerto Rico and the Virgin Islands stand at greater potential risk under Variant II.

Table 15

YEAR 2000 REFINERY OPERATIONS - GLOBAL II
PERCENT UTILIZATION OF DISTILLATION CAPACITY

<u>Refinery Region</u>	<u>Base Case</u>	<u>Global II</u>	<u>Global II Variant</u>
North America			
- East	92.0	92.0	92.0
- Mid	92.0	81.6	81.5
- West	91.5	87.6	87.5
Caribbean Basin	90.0	63.3	50.1
Northern Europe	90.0	90.0	90.0
Southern Europe	90.0	75.1	75.1
North Africa	90.0	82.5	82.4
Persian Gulf	90.0	86.9	86.9
Pacific High Growth	90.0	84.4	84.3
Rest of World	90.0	86.4	86.3

Global III (Small)

This disruption is similar to the recent Mid-East Crisis, with a 4.3 million barrel per day disruption, Saudi Arabia making up 2.0 million barrels per day, but no U.S. SPR/IEA draw. The net supply loss is thus 2.3 million bpd. Although the fact is that the Middle East Crisis was well managed from U.S., Caribbean Basin and global perspectives, Global III assumes a sustained 2.3 million bpd global shortfall in crude supply versus an average net shortfall of 450,000 bpd during the Middle East Crisis.

Except for Southern European and the Pacific High-Growth Region refiners, world refinery utilizations were only marginally off. Because Persian Gulf crude oils are processed in significant volumes in most refining centers of the world, Global III had a major impact on the worldwide flow of crude oils and refined products. Refiners in Europe competed with the U.S. for the choice North African and West African crude oils and kept a larger percentage of their own North Sea production (as happened in the 1990-91 Middle East Crisis). The Persian Gulf production that was not disrupted ended up for the most part in Northern European and Far Eastern refineries. Refineries in Northern Europe and the East Coast of the U.S. continued to operate at capacity.

The Virgin Islands were the most adversely affected in the Caribbean Basin because they traditionally import appreciable volumes of Middle Eastern crude oils. However, they were still able to replace most of their lost crude oil with imports from their Caribbean Basin neighbors (primarily

Mexico and Venezuela) such that refinery runs were less than 5% below pre-disruption levels. Light product cargoes destined for the East Coast of the U.S. still represented the primary flow out of the Caribbean Basin, although product flows to both the U.S. Gulf Coast and the West Coast increased under this disruption.

It bears repeating that many of the events that occurred during the recent Middle East Crisis fell into place fortuitously. Therefore, it is not inconceivable that Puerto Rico will be unable to sequester sufficient early crude oil and product supplies to ride out the Global III disruption as smoothly as it did the Middle East Crisis.

In the Global III and its variant case, the Year 2000 U.S. East Coast prices (in 1991 dollars per barrel) were found to be:

	Base Case	Global III	Global III Variant
World Oil Price	\$22.90	\$33.10	\$33.10
Refinery Gate Prices			
- Gasoline	\$31.37	\$42.39	\$43.62
- Distillate	\$28.21	\$39.37	\$40.34
- Residual	\$14.89	\$24.40	\$24.05
- Jet Fuel	\$28.25	\$40.03	\$41.01
- LPG	\$19.23	\$28.60	\$28.39

The crude oil price rise agrees reasonably well with that experienced during the Mid-East Crisis. For Global III, because the disrupted Middle East crude oils were of intermediate quality, the price differentials between lighter refined products were not significantly different than those of the Year 2000 BAU case. However, the recent Mid-East Crisis experienced wider product differentials for the lighter products as shown below:

	Price Ratio to Crude Oil	
	Global III	Mid-East Crisis Nov 1990
Gasoline	1.28	1.59
Distillate	1.18	1.39
Residual Fuel Oil	0.74	0.87
Jet Fuel	1.21	1.61

The Mid-East Crisis ratios are based on U.S. refiner prices to end users, excluding taxes. The above differences may be the result of the Gulf War demand for jet and other military fuels and the tendency in that crisis for gasoline prices to hold up longer than crude oil prices.

Global III Variant

The loss of all of the refining and storage facilities in Puerto Rico and the Virgin Islands in conjunction with the approximate 5% net world crude loss associated with Global III can be accommodated on a global basis. However, Hurricane Hugo reduced Puerto Rico's refinery output by one third for one month and that of the Virgin Islands by almost one half for two months. A loss of the magnitude postulated for Variant III will result in the need to supply virtually all products for Puerto Rico and the Virgin Islands from the outside, principally from Venezuela, the United States and Europe, in a reversal of normal export patterns.

Table 16

**YEAR 2000 REFINERY OPERATIONS - GLOBAL III
PERCENT UTILIZATION OF DISTILLATION CAPACITY**

<u>Refinery Region</u>	<u>Base Case</u>	<u>Global III</u>	<u>Global III Variant</u>
North America			
- East	92.0	92.0	92.0
- Mid	92.0	81.6	81.5
- West	91.5	87.6	87.5
Caribbean Basin	90.0	63.3	50.1
Northern Europe	90.0	90.0	90.0
Southern Europe	90.0	75.1	75.1
North Africa	90.0	82.5	82.4
Persian Gulf	90.0	86.9	86.9
Pacific High Growth	90.0	84.4	84.3
Rest of World	90.0	86.4	86.3

6.1.3 Economic Impact

As noted previously in Section 2, the Virgin Islands economy is highly interrelated with the U.S. mainland economy. Thus, the impact of a global oil supply disruption on the Virgin Islands economy will depend mostly upon its impact upon the U.S. mainland economy. The Virgin Islands economy is extremely vulnerable to U.S. mainland recessions. Approximately 60% of economic activity and employment¹⁹ are tourism related; most tourists are from the U.S. mainland; and tourism is a heavily cyclical industry.

Table 17 presents the impacts upon U.S. mainland and U.S. Virgin Islands GDP and U.S. mainland inflation relative to a business as usual base case for the year 2000. Information on the terms of trade loss²⁰ and consequently, total economic loss²¹ was also available for the U.S. mainland. The effects on U.S. mainland GDP, terms of trade loss, and total economic loss were calculated by the Energy Information Administration's DIS model for CY 2000. The effects on U.S. Virgin Islands GDP were calculated by the American Council for an Energy Efficient Economy, which adapted the VIEO Jobs Impact Model for this purpose. The effects presented are GDP levels and percent changes relative to a year 2000 business as usual base case. The Global I scenario is most serious and corresponds to a 6-month net loss of 4.5 million bbls/day of crude oil from the world market.²² The Global III scenario corresponds to a 6-month net loss of 2 million bbls/day of crude oil from the world market and is comparable to the recent Persian Gulf crisis.²³ The Low and High subscenarios reflect different behavior of private inventories. In the Low subscenario, 1 million bbls/day of private crude inventories are released, buffering price increases. In the High subscenario, private crude inventories increase by 1 million bbls/day, amplifying price increases.

¹⁹U.S.V.I. Industrial Development Commission, 1992 *United States Virgin Islands Business Guide*.

²⁰Terms of trade loss is the loss in consumer surplus from a change in the price of oil. This is a rough indicator of the loss in consumer well being as a result of an oil price increase.

²¹Total economic loss is defined as the GDP loss plus terms of trade loss minus of SPR revenues.

²²The gross loss of Global I is 9 million bbls/day production cutback in export crude oil. This cutback is partially offset by combined US and allied SPR drawdowns of 4.5 million barrels a day. This results in a net loss of 4.5 million bbls/day of oil supplies in the world market.

²³The gross loss of the Global III scenario is a 4.3 million bbls/day cutback in production by some producing countries, which is partially offset by a 2.3 million bbls/day production increase by other producing countries.

Table 17

Relative Effects of Global Oil Supply Disruptions					
Scenario	Base Case	Global I		Global III	
		Low	High	Low	High
Effect on GDP					
U.S. mainland GDP (trillions of 1987 dollars) ²⁴	6.051	6.01	5.979	6.038	6.007
Change Relative to Base Case		-0.68%	-1.19%	-0.22%	-0.72%
U.S.V.I. GDP (billions of 1987 dollars)	1.480	1.459	1.436	1.474	1.457
Change Relative to Base Case		-1.43%	-2.97%	-0.40%	-1.54%
Terms of Trade Loss					
U.S. mainland (billions of 1987 dollars)		35.51	81.8	12.61	53.42
Total Economic Loss (GDP loss + Terms of Trade Loss Less SPR revenues)					
U.S. mainland (billions of 1987 dollars)	0	86.09	182.09	33.63	53.42
Effect on U.S. mainland inflation ²⁵	0	+1.01%	+1.79%	+0.33%	+1.08%

The Global III Low scenario would have little effect the on U.S. mainland economy. In this case, there will be little effect on tourism and the Virgin Islands economy. The other scenarios would indicate a more adverse economic impact. The Global III High and the Global I low scenario, which may only lead to a lower rate of economic growth in the U.S. mainland, could reduce tourism to the point of inducing an economic slowdown in the Virgin Islands. The most severe disruption, Global I High, could induce a moderate recession in the U.S. mainland. This would in turn cause a moderate to severe economic slowdown in the Virgin Islands. Other sectors of the economy, such as the

²⁴This is the impact on GDP in 1987 dollars relative to the base case.

²⁵Although 0% is entered into the base case column, this is not to imply that inflation is zero in the base case. The inflation effects are increases in the rate of inflation above base case inflation. U.S. mainland inflation is the additional change in the CPI-U caused by the disruptions. The base period of the CPI-U is set equal to the 1982 through 1984 period.

manufacturing sector, are also sensitive to U.S. economic activity, although less so than in tourism. A U.S. recession could also lead to production declines in these sectors.

Effects of global oil supply disruptions on employment were also calculated by the American Council for an Energy Efficient Economy. Employment loss ranged from a low of 0.13% in the Global III Low Scenario to 1.05% in the Global I High scenario. The impact on unemployment rates may be greater in the future, because outmigration has kept the U.S.V.I. unemployment rate extremely low. Incomes are expected to increase considerably and the labor force is expected to age and become more skilled between now and the year 2000. Under these conditions, outmigration will become less attractive. Consequently, future economic slowdowns may have a greater adverse impact on the Virgin Islands unemployment rate than they do today.

Although inflation caused by a global oil supply disruption may be higher in the Virgin Islands than on the U.S. mainland, it may have little economic impact because the economy is heavily tourism driven. The impact of local inflation on tourism may be small compared to the impact of a U.S. mainland recession on tourism.

6.2 Impacts of Postulated Local Energy Supply Disruptions

6.2.1 *Introduction*

Energy security on the U.S. Virgin Islands is almost totally tied to its unimpeded access to petroleum products. Petroleum accounts for 99 percent of primary energy use in the territory. The Virgin Islands have no indigenous sources, and the territory is totally import dependent on oil.

The largest volume of petroleum products for local consumption is derived from the operations of Amerada Hess, which (through its Hess Oil Virgin Islands Corporation or HOVIC) operates a world class export refinery on the south coast of St. Croix. The refinery capacity is presently estimated at 545,000 b/d and its throughput has typically run approximately 400,000 b/d in recent years. These volumes dwarf the total consumption of petroleum products in the territory, which is estimated to be on the order of 9,500 b/d (not including internal consumption of refinery fuel by HOVIC itself).

Under existing laws intended to limit vertical integration and to protect independent retail dealers, Amerada Hess is prevented from engaging in retail business. HOVIC exports most of its refinery output, largely to the U.S. East Coast markets. It also meets most of the petroleum products requirements of the U.S. Virgin Islands by wholesale sales of refinery products to a number of companies engaged in local marketing. These companies include Exxon, Texaco, Shell, Sun Oil, Antilles Gas, and others. Some of those other operators also import small volumes of products for their own local operations.

A local survey conducted in early 1993 for the Virgin Islands Energy Office to update data on wholesale and retail operations in the territory showed that Hess was the wholesale source for 85 percent of the motor gasoline, 81 percent of the diesel fuel, 98 percent of the motor oil, 100 percent of the aviation fuel, 99 percent of the lubricants and 99 percent of the LPG in the territory. While these statistics have some upward bias because not all firms responded to the survey, it indicates the pre-eminent position of HOVIC in the Virgin Islands petroleum market.

In addition, the Virgin Islands Water and Power Authority (WAPA), which is the only electric power utility in the territory, is 100 percent dependent on oil fired plants for electricity generation. It receives its No. 6 residual fuel and No. 2 distillate fuel exclusively from HOVIC under a long term agreement which expires in the year 2013. Under that agreement, WAPA receives advantageous price terms through annual bids; and Hess is responsible for transporting the products by barge from the refinery to WAPA power plants on St. Croix and St. Thomas. (Fuel oil for St. John is trucked by WAPA to the eastern end of St. Thomas, from where it is barged to storage facilities on St. John.)

WAPA estimates its average fuel consumption in FY 1992 at 4,630 b/d, making it the largest consumer of petroleum products in the territory (excluding fuel use in the Hess refinery).

As part of its original agreement with the United States Virgin Islands to construct the refinery (as signed in 1965 and amended in 1990), Amerada Hess agreed to maintain in its storage facilities sufficient fuel to insure that there are adequate supplies to meet local fuel needs of the United States Virgin Islands, including the fuel needs of WAPA. Given the comparative size of its operation, HOVIC had no difficulty consistently meeting that commitment to the Virgin Islands, including the immediate aftermath of Hurricane Hugo in September 1989.

The oil product supply network supporting the U.S. Virgin Islands is vulnerable to certain types of disruption to service. We have analyzed the extent to which those disruptions might impede access of consumers to essential products, and what solutions might exist to mitigate or remedy such problems.

On balance, the existing arrangements maintained between the government of the U.S. Virgin Islands and the petroleum industry operating in the territory appear to offer a relatively high degree of reliability of supply. The major problems likely to be encountered tend to relate more to distribution of products to end users than to oil product inflow to the territory.

6.2.2 Key Petroleum Facilities in the U.S. Virgin Islands

The predominant petroleum facility in the U.S. Virgin Islands is the Amerada Hess (HOVIC) refining complex on the south coast of St. Croix. The complex has been designed to operate as a totally self-contained system, and it is not dependent on utilities outside its own perimeter.

All electric power for consumption in refinery process units, off-site storage facilities, docks, and staff housing compounds is generated within the refining complex. Built and expanded over a period of time, the complex consists of an east and west refinery. Each refinery has two zones; therefore, four operating zones each have separate power systems. Steam and power are generated by the same units in each zone. The system is designed so that there is back-up in the grid through interconnections and redundancies, including power to the tank farms and piers. All cooling, process, and potable water requirements are met from in-refinery desalination units. The HOVIC power and water systems are completely distinct from the WAPA facilities on St. Croix.

The facility maintains its own long distance communications network with Amerada Hess headquarters in New York, as well as its facilities in Woodbridge (New Jersey), Tulsa and with other Hess refineries.

Control systems are operated through master control at a central tower, which can monitor and control all operations. Emergency shutdown can be effected from this master control center or by operators within the respective zones.

The processing units include approximately 130 towers. Amerada Hess currently is in the construction phase of a major project that will add a 75,000 b/d catalytic cracker and ancillary units.

Petroleum storage capacity in the HOVIC complex is estimated to be a minimum of 15 million barrels. This includes roughly 230 tanks of varying sizes to handle crude oil and products. An estimated 59 more tanks reportedly will be added adjacent to the east end of the refinery as part of the catalytic cracker project. Amerada Hess also maintains additional crude oil storage on the island of St. Lucia to support the HOVIC operation on St. Croix.

HOVIC Marine Terminal Operations

The Amerada Hess Virgin Islands (HOVIC) marine terminal is a major deepwater port, capable of handling multiple VLCC operations simultaneously. The terminal is located in Limetree Bay on St. Croix. (Limetree Bay also contains a separate containerized cargo port called Third Port, and a bauxite terminal at Port Alucroix to serve an alumina plant adjacent to the Hess refinery.) The Hess tanker terminal can take vessels up to 292,641 deadweight tons (dwt), with a 347.2 meter length, and 16.76 meter beam (diameter). The terminal also has a large cargo dock, capable of unloading all refinery construction equipment and operating supplies from two berths.

According to the Lloyd's of London Database, the HOVIC terminal serviced 688 vessels, totaling 36,111,916 dwt in 1987.

WAPA Fuel Oil Storage

The Virgin Islands Water and Power Authority maintains on-site storage on St. Croix, St. Thomas and St. John to support its electric power and water operations.

On St. Thomas, the storage facilities are above ground and consist of eight tanks. Three of these have a combined nominal capacity of 119,800 barrels, and are used to store No. 6 fuel oil. The remaining five tanks, having a combined nominal capacity of 43,200 barrels, are used to store No. 2 fuel oil. One of these five, with a capacity of 13,600 barrels, is capable of storing either type of fuel oil. Fuel oil is delivered to this storage by barge under a contract with Amerada Hess, which operates the barges.

On St. Croix, fuel oil storage is contained in six above ground tanks. Half of these, with a combined nominal capacity of 64,100 barrels, store No. 6 fuel oil. The remaining three, with a combined nominal capacity of 29,700 barrels, store No. 2 fuel oil. According to a 1991 report by a consulting engineer for WAPA, the need for large fuel oil storage facilities on St. Croix "is obviated" because of the proximity to the Amerada Hess refinery. Hess makes oil delivery by barge to the WAPA power generation facilities.

On St. John, WAPA maintains two 5,000 gallon storage tanks to provide fuel for its 2.6 MW diesel unit. This fuel is transported to St. John from the east end of St. Thomas by barge as part of the WAPA operation.

WAPA maintains an average fuel oil storage equivalent to 25 days consumption. This may drop to 20 days equivalent during certain times of the year, but climbs to 30 days equivalent during hurricane season. It should be noted that this storage/daily consumption ratio is based on normal draw-downs. In the event of an emergency which disrupts the electricity distribution system and/or final demand for electricity (as occurred after Hurricane Hugo), the result would be a curtailment of power generation, and the ratio of storage/daily consumption would climb sharply. This would provide additional cushion to WAPA in terms of its immediate requirements for fuel oil acquisitions.

According to WAPA documents prepared in 1991 relating to the issuance of revenue bonds, the funds obtained are intended for certain improvements in the power generation and distribution system, including fuel handling and storage improvements. The bond issue was prepared as part of WAPA's post Hurricane Hugo long term recovery plan.

6.2.3 Vulnerability of Key Petroleum Facilities

This study has analyzed several types of potential emergencies to determine the vulnerabilities faced by the U.S. Virgin Islands in maintaining essential supplies of petroleum products. The types of emergencies we examined include natural disasters, industrial accidents, and organized sabotage and terrorism.

We have found that petroleum systems on the U.S. Virgin Islands are vulnerable to various types of unanticipated disruptions. However, given the relatively small volumes of oil product supply required to meet final demand (compared with the volume of products typically located on the islands), the territory faces significantly less risk of petroleum shortages than of electric power outages.

The security of petroleum supply on the U.S. Virgin Islands rests on several factors:

- The presence of the large HOVIC export refining facilities on St. Croix; the ability and experience of Amerada Hess in supporting the petroleum market in the territory, and the long-term contractual commitment of Amerada Hess to assure adequate supplies to the U.S. Virgin Islands. Amerada Hess appears to have consistently met these commitments, even following the large scale damage caused by Hurricane Hugo.
- The presence of other international oil companies in the wholesale and retail petroleum products business in the U.S. Virgin Islands. These firms have the capability and experience of delivering products to this market from outside the territory, as necessary to meet their business requirements.
- The proximity of the U.S. Virgin Islands to major supply sources of crude oil and petroleum products in the Caribbean area. The territory is situated relatively close to large refineries in Venezuela, Curacao, Aruba and Trinidad & Tobago. In the event of emergency in the Virgin Islands, it is possible to procure the small product cargoes needed from these sources. The length of time required to procure and deliver these

cargoes is not significant, given the product inventories generally held in the Virgin Islands. The petroleum industry is capable of handling this procurement and product movement without government intervention.

The major risks faced by the U.S. Virgin Islands in maintaining an adequate supply of petroleum products relate to the disruption of receiving and distribution points, most particularly on St. Thomas and St. John. For example, the loss of WAPA fuel oil barge unloading facilities or product storage for a protracted period of time (one month or more) probably would necessitate imposing restraints on fuel oil consumption, and would result in scheduled brown outs for electric power consumers.

Speculatively, it is possible in the future that one or more companies engaged in the wholesale or retail petroleum products business might opt to leave the U.S. Virgin Islands market for economic reasons (no such reasons are foreseen at present). In all probability, such operations would be taken over by other companies. However, the Amerada Hess refining operation on St. Croix, which is organized to support that company's international markets, has little or no economic sensitivity to local oil market conditions in the Virgin Islands. Therefore, assuming no drastic changes in the cost of engaging in business on the U.S. Virgin Islands, the Hess presence should be viewed as permanent, within the future timeframe of this study.

The Lessons of Hurricane Hugo

Hurricane Hugo, a devastating Category 5 storm, struck the U.S. Virgin Islands in September 1989. The largest volume of damage occurred to the island of St. Croix, including the HOVIC refining complex which took the full brunt of the storm. WAPA electric power transmission and distribution suffered massive damage on St. Croix and major damage on St. Thomas. Widespread losses to residential and commercial buildings and the closing of business resulted in a sharp, short-term decline in demand for petroleum products. The most critical services requiring priority restoration were: (1) water; (2) sanitation; (3) electric power, and (4) communications.

The HOVIC refining complex suffered damage in several locations, including its tank farm (with several storage tanks destroyed). The refinery was forced to shut down processing operations for one month. Nevertheless, Hess was able to meet all of its product delivery commitments in the Virgin Islands. We have no indication that the territory experienced any shortages of petroleum products, although accessing the products (e.g., pumping gasoline at retail outlets in the absence of electric power) may have posed some difficulties.

The Amerada Hess emergency response program was initiated before the storm had passed. During the ensuing week, HOVIC dispatched bulldozers to assist in clearing debris at the airport on St. Croix. Among the first relief flights were five aircraft brought into the island by Hess with food supplies to its workforce. Hess also brought in five satellite communications stations, at least two of which were kept at the refinery, with the remainder loaned to other users including at the adjacent aluminum plant. Hess also supplied personnel to assist in sewerage cleanup on St. Croix.

WAPA electric power services were totally out on the island of St. Croix and Hess assisted in the re-start effort by use of its personnel and generating equipment. The Amerada Hess cargo facilities were used to bring in emergency supplies for the island recovery.

The U.S. Virgin Islands are not likely to face a natural disaster of substantially greater threat to the resident petroleum facilities than presented by Hurricane Hugo. Given the size of these facilities in comparison with the needs of the territory, the islands should not face any overall shortage. Even when operating at relatively low levels of refinery operation, Hess storage is more than sufficient to meet almost all equivalent petroleum requirements for the territory for some time.

Hess has certain redundancy built into its processing operation. There are separate processing trains which are self-contained. Therefore, damage to one section of the processing complex will not necessarily impair the long-term ability of the remainder of the refinery to process oil at a reduced capacity. Even though Hess may be constrained from performing some types of processing operations, there should be no long-term impediment to processing volumes sufficient for the needs of the Virgin Islands.

Outside the HOVIC processing facilities, the essential petroleum installations obviously are the product storage tank and barge terminal facilities, including the pipelines and pumping capacity between storage sites and docks. The availability of barges also is important. The petroleum transportation system operates no long distance product pipelines. Unlike the electric power sector, the absence of fixed transmission pipelines minimizes the number of critical facilities necessary to maintain service.

We have obtained no specific information on damage, if any, and cleanup to the HOVIC marine terminal. We assume that with multiple loading berths, the marine terminal could have restored some operation fairly readily after the hurricane.

WAPA documents relating to a bond issuance in 1991 state that hurricane-related damage to its facilities on both St. Thomas and St. Croix included fuel handling, in particular, storage tanks and fuel unloading piers. However, damage reportedly was limited to one tank (leak) and relatively minor damage at the docks, which, in the opinion of WAPA officials, did not affect the fuel oil unloading operations, nor the critical time path to recovery.

Other Types of Emergencies

We have reviewed the impact that other forms of natural disaster, such as earthquakes, would have on petroleum operations. We have not examined tectonic information to assess the likelihood of earthquakes in the territory of the U.S. Virgin Islands. However, for purposes of this study, we have assumed that the area of St. Croix would be subjected to a large magnitude (e.g., 7.5 on the Richter Scale) seismic event. Based on experience elsewhere, the level of destruction of a large magnitude earthquake probably would be insufficient to eliminate all of the essential refining functions at HOVIC. Although the refining complex might have to be closed for post-event cleanup operations, there should be sufficient functionality after a short-term closure - either from processing or storage - to meet the requirements of the U.S. Virgin Islands.

The analysis also examined the prospect for major accidents which could render the plant inoperable. The models used were the Phillips ethylene plant accident, and the ARCO chemical plant accident in the Houston area. The analysis also did a comparative assessment of other incidents, including the Shell Norco, Louisiana refinery fire, and the Exxon Baytown and Baton Rouge accidents. While an accident at the HOVIC complex on St. Croix potentially could be of a magnitude to damage much processing capability (albeit a very low probability), there should be sufficient product storage,

and some processing capability remaining to sustain limited operation adequate to meet the commitments of HOVIC to the U.S. Virgin Islands. Even in the event of a total closure temporarily, it would be possible for HOVIC to meet its contractual commitments by arranging small volume product shipments into the U.S. Virgin Islands.

There is a greater risk to the survivability of product receiving terminals and local storage facilities at the wholesale, distribution, and end-user levels. A major loss stemming from an accident is assumed to have the same approximate level of risk as it would at HOVIC, but there is less redundancy built into those systems than at HOVIC. (Our analysis did not have the benefit of assessing operator practices and strategies).

In the event of damage that would require a long time path to complete recovery (e.g., long lead times to order, install and commission capital equipment, and undertake capital construction) it might be possible to develop temporary makeshift facilities to restore some degree of functionality. But even such temporary solutions might require weeks or months to implement. This would have a serious impact on end use in the areas served by the damaged facility if in-place bypass capability was not available.

The study also examined the prospect for sabotage and terrorism against the petroleum systems of the U.S. Virgin Islands. The study team did not have the benefit of a detailed internal review of those security systems. However, the team was able to obtain a limited amount of information on security from interviews and some observations on-site.

The HOVIC facility on St. Croix is essentially a self-contained operation, which is not dependent on outside utility and support services. Based on discussions and observations, it appears that HOVIC operates at a higher level of security than do the refinery operations on Puerto Rico. In addition to its resident staff, HOVIC has a large number of contractor personnel that have access to the grounds of the refining and terminal complex, including those presently involved in the construction of the new catalytic cracking unit. There is a higher degree of security monitoring along the perimeter than inside the facility itself.

For purposes of this analysis, we did not attempt to develop individual gaming scenarios on strategies to attack the facility. What has been done, instead, is to compare this facility to others worldwide that have actually experienced major incidents, and analyze the impact of the same level of applied force. The incidents we have used as benchmarks include:

- Damage to the North and South Tank Farms, central pipeline manifolds, and terminal loading facilities in Ahmadi (Kuwait, 1986-87).
- Damage to the onshore metering station at Convnas terminal (Colombia, 1989).
- War damage to the Abadan refinery at the beginning of the Iran-Iraq war (Iran, 1980-81).
- Sabotage attempts at the Juaymah and Ras Tanura refineries (Saudi Arabia 1987-89).

Each of the above incidents involved perpetrators with knowledge of the system targets.

The analysis concludes that sabotage directed against the HOVIC complex would have a reasonable prospect of causing major damage. However, there is a low probability that one incident will render the facility incapable of meeting product supply commitments to the U.S. Virgin Islands.

Sabotage directed against other key petroleum related facilities on the U.S. Virgin Islands (the same level of force as above) is likely to have a more deleterious impact on deliverability to those segments of the territory serviced by the affected facilities.

Emergency Planning and Response

The Amerada Hess contingency planning strategy is totally disassociated from energy emergency planning activities of the Virgin Islands government. As it does in the operation of its facilities, Amerada Hess emergency planning is largely self-contained, and assumes that it must service essentially all of its own requirements to function at a high standard.

Amerada Hess maintains its own security force to protect inside the perimeter of the operating facility and the company housing complex. The company also maintains its own fire fighting capability; we understand that this capability is available to support certain non-refinery related civil emergencies on St. Croix. As demonstrated by its response to the Hurricane Hugo disaster, Hess has the capability to provide emergency communications, and to mobilize necessary logistical support. The company also is the operator of the HOVIC marine terminal.

Although Amerada Hess maintains an official liaison with civil authorities in the territory, government officials apparently have little knowledge of the details of the refinery operations and the refinery's emergency response plans. For its part, the Virgin Islands Energy Emergency Plan, in terms of capability to implement at this time, appears to be in a relatively embryonic stage. Therefore, the territory has a heavy reliance on the response capability of Amerada Hess in the event of an emergency.

6.2.4 Physical Characteristics of Key Electric Power Facilities

The electric power systems of the U.S. Virgin Islands have clearly demonstrated the consequences of catastrophic forces of nature applied against the energy infrastructure. In September 1989, Hurricane Hugo pummeled the Virgin Islands as a Category V storm. The event was devastating not only to the electric power industry on the islands, but to the economy as a whole. A high percentage of residential structures and commercial businesses were destroyed or significantly damaged. Losses were sustained in communications, transportation, sanitation, water supply, and to the tourist infrastructure.

Recovery for the electric power industry took months, and the Virgin Islands Water and Power Authority (WAPA) has since adopted remedial measures not only to repair its damaged physical assets, but also to reduce future vulnerabilities. Nevertheless, the WAPA system remains relatively highly vulnerable to similar disasters in the future.

The general economic recovery also was slow and, therefore, demand for electricity only gradually was restored to previous trend lines. As shown in the accompanying graphics on peak loads for electric power in the pre- and post-Hugo periods (prepared by WAPA), Hurricane Hugo essentially

shut-down electric power service on St. Croix, and sharply constrained electricity utilization on St. Thomas.

These losses are not related to, nor had a direct impact on the electric power operations of the large Amerada Hess (HOVIC) refining facilities on St. Croix, which are totally separate and independent of the WAPA generation and transmission system. The HOVIC facilities (without responsibility for delivering electric power to local distribution) fared significantly better than those of WAPA. HOVIC refining operations were fully back onstream within 30 days.

System Description

The Water and Power Authority, as in most small insular areas, operates one principal power plant on St. Thomas, and a second on St. Croix. Because of the subsea topography between the two islands, it is not feasible to interconnect the two systems; nor can either of the systems be interconnected with other outside electric power grids. Therefore, each system operates with very restricted emergency backup capability in the event units are taken out of service on a routine or emergency basis.

The WAPA generating facilities on St. Thomas are located at Krum Bay. They consist of steam and combustion turbine units with a total net continuous capability of 101.2 MW. This system also serves the island of St. John through a 34.5 kV submarine cable that is operated at 13.2 kV. Additional submarine cables connect St. Thomas to Hassel Island and Water Island. WAPA maintains a 2.5 MW diesel generator on St. John to provide emergency backup. The distribution system on St. Thomas consists of nine distribution feeders, and had a total of 355 nominal line miles (including St. John) immediately prior to Hurricane Hugo.

The facilities on St. Croix consist of one power generation station located at Estate Richmond on the north coast. Its steam and combustion turbine units total 66.7 MW of net continuous capability. The distribution system is in a radial configuration from the power plant, consisting of seven feeders. The system included 490 nominal miles of transmission and distribution lines immediately prior to Hurricane Hugo. This description does not include the Amerada Hess (HOVIC) electric power system.

There are a number of emergency generators of varying sizes in the Virgin Islands, which are held by private businesses and individuals. We were not able to determine the precise number of units, sizes, or ownership during our investigation.

Hurricane Hugo

In September 1989, Hurricane Hugo struck the U.S. Virgin Islands. According to the U.S. Department of the Interior, winds on St. Croix reached a sustained speed of 220 mph for over a 12-hour period. St. Croix experienced the destruction of 16 percent of housing on the island, and up to 40 percent of housing throughout the islands sustained some damage.

WAPA's electric power distribution system was devastated on St. Croix, while St. Thomas suffered less extensive damage.

- On St. Croix, about 9,600 poles (about 60 percent of the total) were damaged or destroyed, with a corresponding percentage of distribution transformers damaged and circuit miles of distribution lines down.
- On St. Thomas, about 1,300 poles (about 13 percent of the total) were damaged or destroyed, with a corresponding percentage of distribution transformers damaged and distribution lines down.

According to WAPA (which is the source for the above damage statistics), service was restored to essentially all customers on St. Thomas by December 1989 and St. Croix by January 1990. The lead time to effect this emergency restoration was 3 to 4 months. Full restoration required considerable additional time.

According to information supplied by WAPA for its 1991 revenue bond issue:

"Hurricane related damage was not limited to the Authority's distribution systems. Generation, fuel handling and general facilities on the islands suffered storm damage, including damage to buildings, inventory, equipment, storage tanks, the fuel unloading pier and the St. John underwater cable."

The WAPA consultant's report (R.W. Beck and Associates) contains the same above quotation, except no reference is made to the underwater cable to St. John. It is the impression of the study team members that this damage to the power generation facilities, storage tanks, and fuel unloading pier, was not sufficiently severe so as to restrict WAPA's ability to generate electricity from its plants.

Information we obtained indicated that only one storage tank was damaged (a one inch hole in its wall lining) producing a leak. Moreover, no damage to generators was experienced, and the switch yards suffered slight damage, mainly from wind-borne debris. Oil was available, and generators were ready to provide power. In no case was there a shortage of fuel oil availability to the power plants, and WAPA's fuel oil supplier (HOVIC) was able to meet all delivery requirements after the emergency.

System Improvements

The WAPA response to Hurricane Hugo was to develop a capital improvements restoration and upgrading plan that would reduce vulnerabilities in its system. Some features of the proposed upgrades include:

- installation of new, completely self-protected transformers for improved lighting and transformer overload protection and heavier conductors with greater current-carrying capabilities for future load growth, better voltage regulation, and reduced line losses;
- replacement of a substantial portion of the distribution lines;
- replacement of poles with heavier class poles dug deeper for better wind resistance;
- new line extensions to form a distribution loop and provide an alternate supply path for hazard mitigation;

- installation of new high pressure sodium street lights for durability, public safety, and conservation;
- construction of a new generation station on the south coast of St. Croix at Krause Lagoon, with two simple cycle combustion turbine units, each with net capability of 15 MW;
- reinforced fuel tanks;
- development of a new 34.5 kV to 13.2 kV substation on the east end of St. Thomas, and acquisition and installation of a second submarine cable to interconnect St. Thomas and St. John.

WAPA Fuel Oil Requirements

The discussion of WAPA's fuel oil handling capability, inventories, and acquisitions is contained in the petroleum vulnerability section of this study.

6.2.5 Vulnerabilities of Key Electric Power Facilities to Local Disruptions

The study team evaluated the vulnerability of the WAPA electric power system to four types of disruptions: hurricanes, earthquakes, accidents, and sabotage.

The effects of such disruptions on the Virgin Islands can be somewhat different from Puerto Rico, principally because:

- The Virgin Islands Water and Power Authority has a different fuel oil supply relationship than does PREPA on Puerto Rico; fuel oil supply is not a critical vulnerability for WAPA except for bottlenecks that may arise at its generating plant dock and fuel storage facilities;
- WAPA does not provide power to the HOVIC refinery on St. Croix and, therefore, its functioning is not critical to crude oil imports and oil product production;
- The Virgin Islands' generating plants are not dispersed as are PREPA's, leaving WAPA subject to more devastating and pervasive blackouts from a single localized disruption.

Because each of the two major islands, at the present time, has only one central station power plant, a "direct hit" by a hurricane, or an earthquake, or well planned sabotage could seriously impair the delivery of power. Each plant has one barge unloading area, and a limited number of fuel storage tanks. While we do not necessarily assign a high probability to the loss of these various functions at the power plants, multiple failures could seriously reduce the amount of available fuel oil from inventory, as well as the ability to rapidly bring in sufficient volumes of replacement fuel oil. This would lead to a requirement for rationing and reduced power generation.

In the event of long term damage to fuel handling, temporary or makeshift fuel unloading and storage schemes could allow for oil to be brought in until repairs were completed. How rapidly this could be set up would depend on how much pre-planning and pre-positioning of equipment were done.

As the WAPA system is comprised of distribution voltage equipment, some replacement parts are stocked with which to begin early restoration. Also, supplies are readily available from the mainland on short notice, so long as necessary airport and dock services on the islands are available. Even if a generator would be severely damaged, new portable generation units could be airlifted from the mainland to meet its urgent generation needs. This could be accomplished while the distribution system is being repaired.

On balance, the major vulnerabilities to the electric power supply in the Virgin Islands are:

- (1) the concentration of the infrastructure in one generation plant on each of the two largest islands, and
- (2) the continued exposure of the distribution system. Because it is an insular area, the system cannot draw on outside power resources for emergency backup. And even where the probabilities of loss are low, if major damage is inflicted, there is little redundancy that allows the system to maintain its ability to deliver electric power to consumers.

In this environment, sabotage poses a more significant risk to maintaining system integrity, because it becomes possible to bring the system down for a protracted period with less applied force. This analysis is based on the assumption of such a threat, without assigning any weight to the probability that such action will actually take place. Unlike a catastrophic hurricane or earthquake, in the event of sabotage to power supply, the demand base for electric power will not necessarily be diminished. In such cases, the mitigation of economic losses to the community is directly and exclusively tied to the critical path of electric power restoration.

6.2.6 Economic Impact

This section will discuss the economic impact of potential *local* energy supply disruptions in the Virgin Islands. The types of local disruptions that could occur are natural disasters, specifically hurricanes and earthquakes; accidents, such as fires, ship collisions, and oil spills; and acts of sabotage and terrorism. Economic impact will be similar for different types of disasters because physical destruction of facilities will be similar in different disasters. A discussion of vulnerabilities and disruption scenarios is included elsewhere in this report.

Petroleum Supply Disruptions

Virgin Islands petroleum facilities include the gargantuan Hess refinery and terminal on St. Croix and local WAPA oil terminals and storage facilities located near the generating plants on St. Croix, St. Thomas and St. John. Petroleum facilities²⁶ are vulnerable to the following events.

- Natural disasters, such as hurricanes or earthquakes. All petroleum handling facilities are vulnerable to hurricanes. The Virgin Islands has had recent experience with Hurricane Hugo, a Category V storm that scored a direct hit on the Hess refinery and

²⁶Although WAPA, the sole Virgin Islands electric utility, has substantial petroleum storage facilities, these will be considered separately under electrical supply disruptions.

devastated the Virgin Islands. Natural disasters of Hurricane Hugo's magnitude disrupt the economy even in the absence of petroleum disruptions. This section will discuss only those economic impacts that can be traced *specifically* to the petroleum disruptions.

- Accidents, such as fires, explosions, ship collisions and oil spills. These accidents are more localized than the natural disasters and are assumed to affect one site only. These accidents can disrupt dock operations, refinery operations, and may damage storage capacity.
- Acts of sabotage or terrorism. Sabotage and terrorism could be perpetrated on WAPA storage sites or the Hess refinery.

Different disasters can lead to similar damage to petroleum facilities. The disruption scenarios discussed above can cause the following physical disruptions to vital petroleum facilities.

- Shutdown of the Hess refinery.
- Shutdown of oil terminal and docking operations. These could last for between 10 days to several weeks in the case of oil spills.

Hurricane Hugo showed how Virgin Islands petroleum facilities performed in the face of a major natural disaster. Hugo forced Hess refining operations to shut down for one month. However, it was able to keep its delivery commitments not only to the Virgin Islands, but also to the U.S. East Coast. The refinery is one of the largest in the world, and its production and storage capacity dwarf Virgin Islands consumption. Damage to WAPA petroleum handling facilities was relatively minor, and petroleum handling operations were able to continue. Petroleum facility damage did nothing to impede Hugo recovery operations, nor were there any shortages of petroleum as a result of Hugo. Hess did not lay off any workers as a result of Hurricane Hugo.

Hess provides between 80% and 100% of all refined petroleum products to the Virgin Islands and 100% of WAPA fuel, used for electricity generation and water production. Even if the refinery were to shut down, refined petroleum products may be obtained from Hess stocks and other Caribbean sources. If spot market prices are higher than contractual prices, prices for gasoline and other refined petroleum products may increase.²⁷ However, such increases would be temporary and would likely have little economic impact.

Electric Supply Disruptions

WAPA is the only utility in the Virgin Islands. WAPA depends upon petroleum for 100% of its electricity generation, and it keeps approximately a 25-day supply²⁸ of fuel at its generating stations. Hess generates all its own electricity for its refinery and is completely independent from WAPA for

²⁷Hess supplies WAPA with fuel oil under contract at a price which is the lesser of Hess's average inventory cost or the New York market price less \$2. Electricity prices would not increase as a result of a local disruption.

²⁸Under normal demand conditions.

electric services. In addition, a number of hotels and the VIALCO alumina plant have their own power plants, and several businesses have backup generators on hand.

The electric system is vulnerable to hurricanes, earthquakes, floods, accidents, and sabotage/terrorist activity. Unlike mainland utilities, WAPA is also potentially vulnerable to disruptions in petroleum supply through physical damage to its petroleum handling and storage facilities.

The most vulnerable parts of an electric system tend to be the transmission and distribution networks.²⁹ An outage affecting the entire island system and lasting three to four months will lead to short-term impedance of economic activity, but even a major outage such as this is not a critical impediment to long term economic growth. This is borne out by the Hurricane Hugo experience, where power was lost throughout both island systems. Electricity was completely restored to St. Thomas three months and St. Croix four months after Hugo. There was little long term economic impact as a result of the outage: economic growth was boosted in 1990 by a post-Hugo rebuilding effort.

Unlike in the mainland, the generating units for both island electric systems are located in one area. A devastating earthquake or well-directed sabotage could devastate the generation facilities. Some replacement parts are kept on hand, and generators can be obtained from the mainland to provide urgent power service.

An outage lasting more than a few months could seriously impede the tourist industry, thereby devastating the economy. Moreover, the Virgin Islands is following mainland trends and computerizing; an extended outage now could wreak more long-term damage than one in the past. Financial services are an emerging industry within the islands; extended outages could impede this industry's growth. A long term outage could also impede the Virgin Islands attempts to diversify the economy. Hess and the VIALCO alumina plant operate their own generating facilities and would be unaffected by extended outages; these plants are major employers and their products comprise the bulk of Virgin Islands exports.

In the event of a refinery disruption, WAPA could still receive deliveries from Hess from its extensive supplies. Hess is contractually obliged to keep sufficient supplies to meet petroleum needs for the Virgin Islands, including WAPA. In the extremely unlikely event that Hess could not deliver WAPA petroleum from its own inventories, refined petroleum supplies could be shipped in from other sources in the Caribbean with little or no effect. In the meantime, WAPA could draw on its inventories kept at each generating plant.

Physical damage to WAPA petroleum handling facilities could occur through damage to its docks and terminals by a hurricane, an accident, or by sabotage. If seaborne petroleum handling facilities were disabled, WAPA can draw down on its inventories. In most cases, repairs can be made and deliveries can resume within a month. Damage from Hugo was repaired easily and not critical to restoration of power. In the unlikely event that petroleum handling facilities are completely disabled for more a month, electric generation would have to be shut down. A long outage could have

²⁹Although generating facilities can also be damaged, there is enough backup capacity to keep generators from being a critical factor in an emergency.

devastating long-term effects on the economy by curtailing tourism and impeding development and diversification of the economy.

Over the past ten years, WAPA has had no problems securing and delivering petroleum supplies to its electric plants.³⁰

Summary

The Virgin Islands should be able to weather almost all local petroleum supply disruptions with little economic impact, thanks to the presence of the Hess refinery and storage operation. Electric systems are more vulnerable and critical. Although the Virgin Islands economy was not damaged in the long term as a result of outages caused by Hurricane Hugo, an outage lasting more than three months could have devastating long-term effects on the economy by impeding tourism and hindering computerization and diversification.

³⁰Virgin Islands Water and Power Authority, *Electric System Revenue Bonds 1991 Series A Offering Statement* July 1, 1991.

7 ACCESS TO VITAL OIL SUPPLIES IN AN EMERGENCY

7.1 Introduction: Scope of Response Options Evaluated

Experience has shown that *local* emergencies are unlikely to cause a sustained major oil supply disruption in the islands. The most likely effect of hurricanes, typhoons and earthquakes on oil supply systems is damage to docks and oil storage facilities and to electric power facilities that serve them. This damage would create problems for distributing available oil supplies. However, island dock and storage facilities have survived severe storms relatively unscathed.

The analysis of *past global* disruptions has shown that the islands have consistently maintained continuous supplies. Analysis of possible future global disruptions does indicate that the islands could suffer supply interruptions under severe conditions, particularly early on in a disruption. The principal negative consequence of oil supply disruptions is, however, that the islands suffer heavy economic losses from the high oil prices obtaining during the disruption.

Given these impacts of possible local emergencies and global disruptions, efforts to increase energy security in the U.S. insular areas need to focus on: (1) methods for coping with temporary shortages that can occur until local petroleum distribution problems are resolved, or new regional supply-demand balances are established; and (2) ways to mitigate the price increases from global oil disruptions.

In recognition of the requirements of the Energy Policy Act 1992, this section concentrates on options to enhance "access to vital oil supplies". Section 8 focusses on means to improve energy emergency preparedness and to reduce energy vulnerability over the longer term.

Several of the options considered would improve physical "wet barrel" oil supplies without alleviating oil price – and therefore economy – impacts. Others, such as conservation and fuel diversification, would restructure energy demand so as to reduce the role of petroleum on the islands. Further options, notably an island-owned oil reserve and revolving oil futures contracts, would secure additional physical supplies and help mitigate disruption price effects.

It should be noted that both Puerto Rico and the U.S. Virgin Islands have energy emergency response plans approved or under development. These plans contain a variety of response measures, such as demand management, that the island governments could implement in an energy emergency. It should also be noted that the options considered here are incremental to SPR drawdown, IEA response measures and possible additional actions such as relaxation of monetary policy. The islands would all benefit from the supply and prices impacts of these national/international measures.

The following options were identified and assessed:

- Puerto Rico, together with the U.S. Virgin Islands, establishes an island-owned product SPR.
- The U.S. Virgin Islands employ the futures market to hedge against sudden oil price increases.
- U.S. Virgin Islands establishes a standby line of credit.

- Federal government provides the U.S. Virgin Islands with emergency access to military petroleum supplies on the islands. Federal government guarantees the U.S. Virgin Islands priority access to crude oil from the U.S. SPR.
- Federal government establishes a crude/product SPR on Puerto Rico that serves both Puerto Rico and the U.S. Virgin Islands.
- The U.S. Virgin Islands establish temporary product quality waivers to be invoked during emergencies.

Each option is reviewed below.

7.2 U.S. Strategic Petroleum Reserve Policy

The U.S. currently maintains approximately 580 million barrels of crude oil for use during oil crises. The policy of the U.S. regarding the release of SPR oil is to rely primarily on market forces to allocate supply, and, in an emergency, to supplement oil supply by the early drawdown of SPR oil in large volumes, in coordination with our allies and trading partners. The main objective of the policy is to remove pressures on oil prices, thereby limiting economic losses resulting from a sudden large increase in oil prices in an emergency.

During a global oil emergency, the Hess refinery in the U.S. Virgin Islands can bid on crude oil from the U.S. SPR on the same basis as mainland refineries. This option is the status quo. Accordingly, it is important to understand how the SPR would affect the islands. Access to SPR crude is subject to the following major procedures: the President must decide to release SPR crude, the crude is sold on the basis of sealed bids to the highest eligible bidders, and successful bidders must transport their oil. (A detailed discussion of SPR drawdown procedure and experience is contained in *Appendix C*.) Each of these procedures has important consequences for the islands.

The need for a Presidential decision to release the SPR means that the timing of an SPR release will depend on political as well as market factors. These may lead to an early draw. However, during the 1990-91 Persian Gulf Crisis, over five months elapsed between the onset of the Crisis and the Presidential order to release the SPR. In short, from the islands' perspective, the timing and probability of an SPR draw are both uncertain and outside the island's control.

In addition, the time taken for the SPR bid process, selection of winning bids, arrangement of liftings, crude shipping, refining, and distribution means there is a minimum 30-45 day period from release order to availability of product at the retail level. Announcement of an SPR draw will, however, tend to have an immediate downward effect on oil prices, easing market conditions even before physical product deliveries improve.

The sale of SPR crude to the highest bidders means that island refineries are not guaranteed SPR crude supplies. In addition, the bidding process ensures that the oil will sell at the prevailing market price, although the act of releasing the SPR will tend to depress the market price. Thus, if island refineries are among the successful bidders, the crude would be obtained at prices which may still be substantially higher than pre-disruption prices. Hence, although SPR crude could provide additional supplies for the islands, it would not mitigate the price spike in the islands any more than it would do so for the U.S. Mainland areas.

The need for successful bidders to provide their own means of oil transport puts a premium on the availability of suitable tankers during an emergency.

7.3 Island-Owned Product Reserve

Another option examined was the concept of an on-island strategic products reserve that would be owned and controlled by the islands. Such a reserve could be developed by Puerto Rico and the U.S. Virgin Islands together. This would require that the two governments agree on procedures for financing and managing the reserve and for distributing oil supplies in an emergency.

The concept could be implemented in several ways. One possible implementation includes the following elements:

- **Financing**
 - A Puerto Rico government authority (for example, PRIDCO) would issue tax-exempt revenue bonds to pay for the reserve.
 - A dedicated tax would be levied on all island oil consumption to pay the principal and interest on the bonds, i.e. to fund the costs of establishing and maintaining the reserve. Over a period of, say, five years, the cost of the reserve – barring ongoing leasing costs – would have been fully recouped through the tax levy.
- **Storage**
 - Storage capacity would be leased from private companies on the basis of lowest bid cost for storage and inventory turnover.
 - The CORCO refinery on Puerto Rico's south coast has tankage available, and CORCO officials have expressed serious interest in the concept.
- **Operation**
 - The reserve would be operated by a petroleum company under contract to the Puerto Rico government.
 - Clean products in the reserve would be turned over (i.e. sold off and replaced) at intervals to prevent product deterioration. Market hedging methods would be used by the reserve operator to buy and sell at the same price.
 - In an emergency, the reserve would be released upon order of the Governor. If the product in the reserve had been fully paid for via the oil tax by the time of the disruption, the reserve would be released into the island market at effectively zero cost. Its effect would be to partially offset the high oil product prices obtaining because of the disruption. The mechanism for administering the release would require further study but at least two alternatives are apparent:

1. Zero Price Release

Under this mechanism,

- Oil from the reserve would be released at *zero* price into island markets. Reserve oil would combine with other oil supplies purchased at market prices so that the effective price to oil users would be a weighted average below the market price.
- An allocation or set-aside system would be used to distribute the reserve among interested parties.
- Price controls would be applied to prevent the reserve oil from rising to market prices and to prevent windfall profits by oil companies
- Export controls would be applied to prevent reserve oil from being exported and re-imported as market oil.

2. Full Price Release

Under this mechanism,

- Reserve oil would be sold into the market at market price. In fact, the intent would be to sell at peak disrupted prices to gain the maximum benefit.
- The revenue gained from the sale would be applied as an immediate rebate or tax reduction against island prices of petroleum products. For any reserve oil used by PREP, this would take the form of a downward adjustment to the otherwise increased fuel charge. For other products, this may take the form of a sales tax reduction or negative sales tax.
- A physical allocation or set-aside system would probably not be necessary but price and export controls may still be needed.

As mentioned above, either mechanism would require more analysis to assess its administrative feasibility and market impacts.

- **Benefits**

- During an oil disruption, product prices would reflect a weighted average of (effectively) zero-priced supplies from the reserve and market-priced supplies from the open market. This would mitigate the impact of the usual price

spike on the island economies (although not the impact of a slowdown in the U.S. mainland economy).

- During the period of reserve build-up or replacement, the tax on oil consumption would encourage further conservation efforts by oil users.
- Issues
 - Operation of the reserve would require a complex administrative system that may prove unworkable. In particular, it could require standby emergency price controls, allocation, and export controls. All of these elements would need to be available only on a standby basis, i.e., the Governor could still proceed with previously announced intentions to dismantle Puerto Rico's current system of gasoline price controls.
 - Although preliminary indications are positive, detailed analysis is required to assess whether the beneficial impact of the reserve in a disruption would exceed the cost of creating and maintaining the reserve.
 - Environmental risks associated with a local reserve, and liabilities assumed by the Puerto Rico government, would need to be assessed.

The economics of an island-owned products reserve depends on numerous factors, including: the size of the reserve, the number of years the reserve is in place before a disruption, the magnitude and duration of the oil price increases during the disruption, the price of oil when the reserve is being filled, interest rates, annual costs for leasing storage capacity, the rate of growth in real oil prices over time, the administrative cost burden of price controls and allocation during the disruption, and the economic benefit to the insular economies from mitigating oil price spikes.

As part of this study, numerous cases were examined involving a range of values for the above factors.¹ For illustrative purposes, costs and benefits were estimated for Puerto Rico (but not the U.S. Virgin Islands) due to the ready availability of macroeconomic data. It was found that for a 5 million barrel reserve, benefits exceeded costs under a wide range of reasonable parameter values. This finding appears to be due to the following factors:

- The ready availability of a large amount of existing storage tanks that could be leased on a long term basis for 15 to 20 cents per barrel per month including inventory turnover. This is at the low end of storage costs estimated in earlier studies.
- The relatively low current price of oil.
- The presumed use of tax-exempt revenue bonds to finance the reserve. This lowers the real discount rate for Puerto Rico to about 3 percent, compared to a 10 percent real discount rate for a Federal SPR.
- Use of a comprehensive measure of economic benefits that includes both the improvement in GDP and the improvement in the terms of trade that result from

¹Environmental risks and administrative costs were not assessed as part of the study.

lower island oil prices. This is the approach adopted by a Federal interagency working group for estimating the economic benefits of the U.S. SPR.

The tax on island oil consumption required to finance the reserve would be on the order of 0.7 to 1.5 cents per gallon depending on the reserve size and the other factors mentioned earlier. Environmental risks and administrative costs were not considered in the above analysis.

Tables 18 and 19 summarize cost and benefits results designed to bracket the likely range of scenarios; from a large disruption (\$50/bbl) occurring after five years with a monthly storage cost of 15¢/bbl to a small disruption (\$35/bbl) occurring fifteen years after the reserve has been in operation with a monthly storage cost of 25¢/bbl.² In the one extreme (large, early disruption, low cost storage), the indicated future value net benefit to Puerto Rico is approximately \$325 million. In the opposite extreme (small, late disruption, higher cost storage), the indicated net benefit is essentially zero. Should the period to disruption be extended beyond fifteen years, and only a small disruption then occur, the indicated net benefit would be negative.

The degree of impact from the reserve, how visible that impact is, and where it falls in the economy depends primarily on the size and mix of the reserve. In the analysis conducted for this study, drawing down a 5 million bbl reserve fully over the course of a six-month disruption resulted in roughly 15% of Puerto Rico's petroleum demand being met from reserve oil, the balance from market sources.

The product mix contained in the reserve could, of course, be varied – both initially and over time – as could the size of the reserve. In the analysis conducted for the study, the reserve was focussed primarily on gasoline (60%) and secondarily on light and middle distillates (total 30%) and residual fuel (10%). The largest impact was, therefore, on gasoline prices. Price increases were, respectively:

<u>Disruption</u>	<u>With reserve</u>	<u>Without reserve</u>
small	10.2%	47.5%
large	43.0%	94.9%

Impacts on distillate and residual fuel increases were far smaller. A different reserve mix would have re-allocated the price impact and the reserve's effects on different segments of the economy.

Table 20 sets out key assumptions used in constructing the analysis. Any of these assumptions could be varied to examine their impacts.

²The monthly storage costs represent an "all-in" fee, including periodic product turnover as well as fill, draw and physical tankage lease costs.

Table 18

ISLAND-FUNDED PRODUCT RESERVE DIFFERENTIAL IMPACTS OF DISRUPTION ON PR RESERVE VERSUS NO RESERVE			
Large Six-Month Disruption \$50.22/bbl Monthly Storage Cost 15 ¢/bbl Future Value Basis Costs and Benefits for Puerto Rico Only			
\$mm (1991)	Disruption Occurs		
BAU Crude Price \$22.90	after 5 years	after 10 years	after 15 years
Cumulative Reserve Cost	195.4	243.9	290.5
Benefits vs No Reserve:			
- Terms of Trade Improvement	240.0	240.0	240.0
- GDP Improvement	280.1	280.1	280.1
Total Benefits	520.1	520.1	520.1
Net (Cost)/Benefit	324.7	276.1	229.5
Average Tax Cost Spread Across Total Non-Refinery Demand (assumes inventory cost of reserve fully paid off just before disruption occurs)	1.28 ¢/gal	0.85 ¢/gal	0.71 ¢/gal

Table 19

ISLAND-FUNDED PRODUCT RESERVE DIFFERENTIAL IMPACTS OF DISRUPTION ON PUERTO RICO RESERVE VERSUS NO RESERVE			
Small Six-Month Disruption \$35.10/bbl Monthly Storage Cost 25¢/bbl Future Value Basis Costs and Benefits for Puerto Rico Only			
\$mm (1991)	Disruption Occurs		
	after 5 years	after 10 years	after 15 years
BAU Crude Price \$22.90			
Cumulative Reserve Cost	225.4	303.9	380.5
Benefits vs No Reserve:			
- Terms of Trade Improvement	199.5	199.5	199.5
- GDP Improvement	182.2	182.2	182.2
Total Benefits	381.7	381.7	381.7
Net (Cost)/Benefit	156.3	77.8	1.2
Average Tax Cost Spread Across Total Non-Refinery Demand (assumes inventory cost of reserve fully paid off just before disruption occurs)	1.48 ¢/gal	1.05 ¢/gal	0.93 ¢/gal

Table 20

ISLAND FUNDED PRODUCT RESERVE - ASSUMPTIONS

BAU world crude price prior to disruption (\$1990)	\$22.90/bbl
real annual discount rate/carrying charge	3%
annual oil price gain over inflation	2%
disruption duration (months)	6
price elasticity of demand	- 0.15 ¹
size and composition of product reserve (mmbbls)	
- LPG	0.0
- gasoline	3.0
- jet fuel	0.75
- distillate (diesel/No.2)	0.75
- residual fuel	0.5
- total	5.0
recovery via tax of	
- initial cost	yes
- carrying charge	yes
- storage facilities cost	yes

Notes:

1. Price elasticities of -0.10 and -0.20 were also tested but had little impact on the results.

The general approach to the analysis was as follow:

1. Set assumptions for financial parameters, reserve size and mix, period reserve in place before disruption, length of disruption, price elasticities of demand, demand BAU growth rates.
2. Utilize results from EIA's Year 2000 analyses using EnSys' **WORLD** Model to give market prices for crude and major products for BAU and two levels of disruption ("large" and "small").
3. Select either "large" or "small" disruption.
4. From projected BAU demands, establish disrupted demands, without reserve, using price elasticities.

5. Establish adjusted island petroleum product prices resulting from injecting zero cost (i.e. fully paid for) reserve oil into the island supply. Adjust demands for these prices using price elasticities.
6. Compute an effective island oil price based on the impacts of the reserve oil.
7. Compute the oil terms-of-trade loss versus BAU for the disruption, with and without the reserve.
8. Using results from the Puerto Rico planning board model, compute the GNP loss versus BAU, again with and without the reserve's impact on island petroleum prices.³
9. Compute the total cost of the reserve assuming its inventory cost is fully paid off just before the disruption. Reserve costs include product acquisition and carrying costs together with storage facilities costs.
10. Compare the cumulative reserve cost at the time of the disruption with the combined reductions in terms-of-trade and GNP losses because of the reserve to arrive at a net benefit to the economy at the time of the disruption.

7.4 Futures Market Hedging

The petroleum futures markets that have evolved in the last ten to fifteen years provide oil producers, processors, traders and consumers with a variety of "paper barrel" mechanisms to hedge against the uncertainty inherent in the market. For consumers in particular, they provide a way to lock in future supplies at a known cost.

It is conceivable that the Virgin Islands' Government could establish and maintain a set of rolling futures contracts covering designated volumes of gasoline and other products. Futures contracts generally run out a maximum of twelve months into the future and the timing of disruptions is, by their nature, uncertain. Therefore, the total volume of each product to be covered would have to be divided into, say, 6 or 12 contracts, each expiring in a different month. This would provide coverage of 10/12 or 11/12 of the product volume at undisrupted prices at all points in time.

The value of this option would depend on the level of transaction costs associated with maintaining and turning over multiple futures contracts.

7.5 Standby Line of Credit

The U.S. Virgin Islands reported that one difficulty they experience during oil disruptions is a cash flow problem at their electric power authority (WAPA), which suddenly may need to pay considerably more for petroleum but which requires a longer period of time to raise electric rates to recover the higher costs. Nor apparently is WAPA able to maintain large enough cash reserves to resolve the problem.

³The Planning Board cases for island reserve drawdown assumed that Puerto Rico would operate at a lower oil price because of the reserve but that the U.S. economy would still be operating at the global disrupted oil price. Therefore, the negative impact of U.S. Mainland economic down-turn on the Puerto Rico economy was not altered by use of the island reserve.

One option that might be explored to deal with this problem would be to negotiate a standby line of credit with a financial institution. The line of credit may (or may not) carry a monthly fee, in addition to interest costs, but would provide additional liquidity in times of emergency.

7.6 Emergency Access to U.S. Military Petroleum Supplies

The U.S. military maintains an inventory of petroleum products in the U.S. Virgin Islands. An analysis was conducted to determine whether access to these supplies in an emergency might benefit the insular areas. Discussions with the Department of Defense indicated that the military has only 500 barrels of petroleum storage capacity in the U.S. Virgin Islands. Actual inventories are reportedly maintained at about 70 percent of capacity. This quantity is clearly too small to be of any significant value during a global oil emergency.

7.7 Guaranteed Insular Area Access to the SPR

During the last session of Congress, a bill was introduced in the House that would have guaranteed the insular areas access to SPR crude oil. Had it passed, this measure would have removed some of the uncertainty surrounding the bid process by guaranteeing that the insular areas would receive crude. However, because the crude would still be sold at the prevailing bid price, this option would not mitigate the price spike any more than without the guarantee. Thus, it would not substantially benefit the U.S. Virgin Islands.

7.8 Island Component of U.S. Crude/Product SPR

Another option examined was the possibility of the Federal government establishing a crude oil or petroleum products reserve in Puerto Rico to serve both Puerto Rico and the U.S. Virgin Islands.⁴ As a component of the U.S. SPR, it would be subject to the same operational procedures. In particular, its release would require a Presidential decision, and the oil would be sold to the highest bidders. Under these conditions, the island reserve would be unlikely to benefit the islands much more than the status quo:

- The sales process may result in a 20-30 day period before oil could be delivered from the reserve. Additional time would be required for transportation, processing (for crude oil), and delivery to end users.
- The amount of the reserve would be too small to have any noticeable effect on world prices. Nor would it have much effect on island oil prices because the winning bids would likely be close to world prices except for transportation cost differences.
- The reserve may not produce much of a net increase in on-island inventories if island refiners and marketers reduce privately held inventories due to the availability of the reserve.
- The reserve may not significantly increase on-island supplies available during an emergency if some successful bidders take the supplies elsewhere.

⁴If an island reserve were to be established, the U.S. Virgin Islands' government prefers that it be on Puerto Rico due to the more readily available land and storage capacity (i.e., at the CORCO refinery).

Thus, the potential benefit to Puerto Rico and the U.S. Virgin Islands from an island component of the U.S. SPR in Puerto Rico appears to be small.

7.9 Concluding Comments

The options described above provide a range of alternatives for the U.S. Virgin Islands to consider as additional responses to emergencies. This report does not presume to recommend a "best" option but has attempted to assess the strengths and weaknesses of each so that the island governments can evaluate each one from their own perspectives. In addition, it should be noted that some of the options could be combined.

8 PREPAREDNESS AND VULNERABILITY REDUCTION STRATEGIES

The preceding section described response options that could be applied during an energy emergency. This section identifies strategies that could be followed to prepare more effectively for emergencies and to reduce vulnerability to emergencies. The following range of strategies is discussed:

- Enhanced Institutional Preparedness
- Increased Energy Conservation & Efficiency
- Fuel Diversification
- Reduced Electrical System Physical Vulnerability

Each is discussed in turn below.

8.1 Institutional Preparedness

The U.S. Virgin Islands Government is actively pursuing leadership initiatives to establish renewable energy as a viable alternative for island energy supplies. Set out below are supporting suggestions designed to strengthen the institutions responsible for energy and energy emergencies.

- Continuing to develop and conduct simulation exercises for their energy emergency plan.
- Fostering increased coordination between the government and Amerada Hess in energy emergency planning, testing and response.
- Continuing to develop and maintain energy data sufficient to support energy emergency planning and plan implementation.
- Enhancing training and resources.

Each area is discussed below in more detail.

8.1.1 *Continuing Emergency Simulation*

The VIEO has been testing its emergency operation capabilities as part of overall VITEMA simulation exercises. Although we believe that this integrated approach is beneficial because it addresses essential emergency coordination issues, we also recommend that the VIEO prepare one or more of its own simulation exercises. Ideally, energy industry personnel and selected government officials would participate in these simulation exercises. The purpose of the latter approach is to specifically determine unique constraints that exist within VIEO's own plan and response mechanisms, to ascertain more clearly the internal resources (manpower, communications, etc.) that may be required in an emergency, and to clarify what information bottlenecks exist.

8.1.2 *Fostering Coordination*

Successful emergency plan implementation will depend on coordination with and the response of the operating companies from the private sector. The most significant of these companies from the perspective of the Virgin Islands is Amerada Hess (HOVIC), whose refinery operations and petroleum storage capabilities dwarf the requirements of the Virgin Islands. Its response capabilities were demonstrated in the aftermath of Hurricane Hugo in 1989. Moreover, as discussed previously, Amerada Hess has made a long term contractual commitment to the U.S. Virgin Islands to meet the petroleum requirements of the Territory in an emergency and has consistently met these commitments.

Existing formalized coordination between the VIEO and Amerada Hess executive management is insufficient to allow the Energy Office to meet its plan obligations; indeed, effective coordination is almost non-existent. Cooperation of Amerada Hess is an essential step toward effective emergency planning by the VIEO. We recommend that the Office of the Governor formulate a request to the senior executive management of Amerada Hess Corporation requesting this cooperation, specifically by having Amerada Hess designate an experienced executive to consult with and advise the VIEO a voluntary basis.

In the electric power and telecommunications sectors, extensions should include:

- working with WAPA and emergency service providers to:
 - a) ensure that critical backup power generators are in working order and will be able to obtain adequate supplies of fuel in the event of electric system emergencies
 - b) ensure that sufficient potable water supplies are available during and after electric system emergencies
- working with the telecommunications providers and private industry to
 - a) establish emergency telephone restoration service priorities
 - b) to update emergency telecommunications capabilities, including but not limited to providing expanded cellular telephone capability
 - c) to assure that communications between St. Croix and St. Thomas can be maintained during and after emergencies

8.1.3 *Continuing to Develop and Maintain Energy Data and Models*

The VIEO has developed a computerized energy emergency management information system (EEMIS). This contains a range of energy data specific to the USVI energy system. However, comprehensive data on island energy imports, exports, distribution, consumption, stocks, and pricing appear to be lacking. During the course of this study, no proven annual or monthly data on petroleum consumption were made available. A U.S. Virgin Islands petroleum supply-demand balance was constructed, but using a combination of EIA data, limited local data, and judgement.

To effectively plan for energy developments and emergencies, the U.S. Virgin Islands Government must have a comprehensive, accurate and timely computer-based system containing all relevant island energy data (principally petroleum and electric power). This should make a clear distinction between in-refinery (Hess V.I.) and island economy flows and consumption. The data system should take advantage of data submitted to the EIA and other Federal agencies. It should also be extended to incorporate data submissions from island sources (such as local distributors) in order to fill out the complete energy picture.

The database should contain monthly data which give a complete and reconciled picture of island economy supplies, flows, stocks, power generation, consumption, and pricing. This will in turn provide a sound basis for island energy analyses and planning. EEMIS provides a good starting point for this effort.

Some extensions of this effort would include:

- working with EIA to
 - a) routinely obtain refiners' submissions to the EIA
 - b) explore and rectify gaps and errors in EIA's data gathering on the U.S. Virgin Islands.
 - c) establish regular data communication with EIA to take advantage of the wealth of energy statistics EIA maintains, much of which is now available through a remote, on-line computer system (COGIS) as well as in hard copy form
 - d) encourage EIA to include explicit U.S. Virgin Islands petroleum statistics in its publications and data banks (These exist at present only to the extent of imports to and exports from the U.S. Mainland.)
- working with Hess, WAPA, distributors, major consumers, and the Port Authority/U.S. Army Corps of Engineers to make sure available data, including crude and product flows into, out of and around the island, are captured

In addition, the following extensions:

- incorporating into the system reasonable checks to maximize accuracy
- establishing a database on key energy personnel both within the island, on the U.S. Mainland, and internationally
- establishing a database on key characteristics (location, function, capacities, etc.) of all significant energy installations on the island and their components
- potentially creating an analytical modelling capability (which could be relatively simple or highly sophisticated) that captures all the elements of the island energy system and enables them to be simulated so that the impacts and interactions of new developments (e.g. new electric power generation) can all be evaluated and their consequences for security and the economy quantified

8.1.4 Enhancing Training and Resources

The U.S. Virgin Islands Government energy personnel contacted during this study had a competent grasp of many energy issues. However, they do reside with one of the largest oil refineries in the western hemisphere and the island is confronted by continuing, often complex, developments in energy markets and technologies.

Investment in personnel training, selected market information sources, strong personal links to Federal and international energy organizations, and the effective use of modern, low-cost personal computers and data links could all pay dividends in terms of increased energy planning effectiveness. An early focus on training to improve departmental staff knowledge of the petroleum refining industry, petroleum economics, the electric power industry, electric power economics, the island refining, distribution and electric power sectors, the Caribbean (and ultimately global) petroleum markets, alternative energy options and conservation.

8.2 Increased Energy Conservation and Efficiency

Electric power plants and motor vehicles consume over 2/3 of the petroleum used in the U.S. Virgin Islands. Increased energy conservation and efficiency in these uses could slow the growth in oil demand and, thus, contribute to reduced dependency on petroleum. Some options the islands may wish to consider are:

- **Electric power:**
 - **Demand side management (DSM)** – is yielding measurable savings in *kW* and *kWh* among U.S. mainland electric utilities. WAPA may want consider implementing or expanding the following initiatives:
 - Customer load control, either by customers' voluntarily adjusting their loads in times of high demand or by WAPA, with customers' prior permission, remotely turning off appliances through an onsite or remote signal
 - Energy conservation, through encouraging the use of more energy-efficient lighting and appliances. WAPA used the post-Hurricane Hugo rebuilding effort to install higher efficiency streetlighting.
 - Cool energy storage, which shifts air conditioning electric load to off-peak hours.
 - Heat pumps; the most advanced heat pumps provide efficiencies 30-40% greater than the average air conditioner
 - Pricing or rate design: WAPA has established Time-of-Use (TOU) rates
 - **Co-generation** – Co-generation offers increased energy efficiency compared to separate production of electricity and steam/heat. WAPA's co-production of electricity and desalinized water is an existing form of co-generation.

- **Transportation:**

- *Mass transit*

- Mass transit would reduce petroleum use per passenger-mile.
- Some mass transit options could also rely on non-petroleum energy sources such as electricity or natural gas.
- Van pooling is a low cost option

- *Vehicle fuel economy* -- The U.S. Virgin Islands may want to consider the following options to increase vehicle fuel economy:⁵

- Higher fuel economy standards for new automobiles
- Vehicle inspection programs
- Higher sales tax on new vehicles with lower fuel economy (widespread in Europe and adopted in Maryland but implementation delayed by the Bush Administration)
- "Clunker" buy-back program (used in California)
- Carburetor retrofit program for older cars

8.3 **Fuel Diversification -- Renewable Energy**

The U.S. Virgin Islands Energy Office recognizes that the Territory can best reduce its petroleum dependency and vulnerability by following a long term program to diversify its energy supply. This section offers some suggestions on possible strategies, relying on renewable energy forms.

Renewable energy can play a role in the energy future of the U.S. Virgin Islands. Renewables can reduce the U.S. Virgin Islands's oil vulnerability and energy costs, and diversify its energy resources. the U.S. Virgin Islands could use several renewable energy sources in the future. These sources include: OTEC, biomass, solar electric and solar hot water heating, photovoltaics, and wind.

Ocean Thermal Energy Conversion (OTEC)

The OTEC process uses temperature differences between warm ocean surfaces and cold deep seawater to generate electricity. A temperature difference as small as 20 degrees Celsius can be ex-

⁵These options would also reduce vehicle emissions.

ploited to generate electricity.⁶ The U.S. Virgin Islands are located close to deep ocean areas with significant temperature differentials, which are promising OTEC sites.

Private U.S. companies have been soliciting WAPA to participate in an OTEC project (in the range of 5 MW) off the shore of St. Croix. Although WAPA is not in the position to assume the entire risk of such a project, WAPA might participate if private companies assume the development risk of the OTEC facility and WAPA only agrees to buy the electricity and water that it generates.⁷

WAPA also would be very interested in an OTEC plant that could produce potable water from seawater. If an OTEC plant can produce both electricity *and* distilled water, the OTEC facility's high capital costs might be justified.⁸

In addition, another type of OTEC technology pumps deep cold seawater to the surface for use in commercial air conditioning systems. Two facilities of this type are located in Hawaii at the Natural Energy Laboratory and in Halifax, Nova Scotia at Purdy's Wharf.⁹ This type of OTEC technology could also provide significant power savings for the U.S. Virgin Islands.

Biomass

Biomass energy is derived from biological sources -- wood or wood wastes, residue of wood-processing industries, food processing wastes, agricultural processing wastes, organic, industrial and municipal solid waste (MSW), and the dedicated production of energy crops.

Potential for biomass in the U.S. Virgin Islands. There is a relatively small amount of MSW on St. Thomas and St. Croix -- below 250 tons per day per island. MSW from the U.S. Virgin Islands has the potential to produce 1 to 2 megawatts of electricity on each island.¹⁰ Although WAPA has no plans to develop waste-to-energy technology, a group of private developers has offered to build two \$30 million waste-to-energy facilities -- one on St. Thomas and one on St. Croix.¹¹

⁶ Bath, Thomas D., et al., The Potential of Renewable Energy, National Renewable Energy Technologies, Golden CO., March 1990 at Appendix D-1.

⁷ Hill, Lawrence J., et al., *An Integrated Assessment of Electric Power Resource Options in the U.S. Virgin Islands* (Final Draft), Oak Ridge National Laboratory, Oak Ridge, Tennessee, August 1993 at 19.

⁸ *ibid.* at 19.

⁹ Van Ryzin, Joseph and Tore Leraand, "Air Conditioning with Deep Seawater: A Cost-Effective Alternative," Sea Technology, September 1992, pp. 37-44.

¹⁰ Hill, Lawrence J., et al., *An Integrated Assessment of Electric Power Resource Options in the U.S. Virgin Islands* (Final Draft), Oak Ridge National Laboratory, Oak Ridge, Tennessee, August 1993 at 18.

¹¹ The contract prices to WAPA of 9.0 cents per kWh and \$11 per thousand gallons of water "appear" higher than WAPA's short run marginal costs of production. The offer was presented in April 1993 and WAPA has not yet taken action. Laitner, Skip, "Renewable Energy Resources in the U.S. Virgin Islands," Economic Research Associates, Alexandria, VA, November 1993 at 4.

Solar Water Heating Systems

Solar water heating systems use sunshine to heat water either directly, by heating the water in a solar collector, or indirectly, by heating a circulating fluid-mixture that then releases the heat to the water through a heat exchanger. In 1990, 95 percent of low-and-medium-temperature solar thermal collector shipments in the U.S. were for the residential sector.

Potential for solar water heating systems in the U.S. Virgin Islands. More monitoring of solar insolation (the rate of solar energy falling to the earth) is necessary before the potential for solar water heating systems in the U.S. Virgin Islands can be evaluated. Data for Puerto Rico show an average of more than 1,600 BTU per square foot per day -- an "excellent" source of daytime solar energy.¹²

High purchasing and installation costs are the main constraints to greater utilization of solar water heating systems.¹³ These costs will decline over time, however, with more experience in manufacturing technologies.¹⁴

The Energy Office's Energy Financial Incentive Program provided 330 rebates (through 1992) to customers who use solar hot water heaters.¹⁵ This program has saved WAPA about 587,000 KW hours of electricity or 1500 barrels of fuel oil.

In addition, a "large-scale" hot water system that should provide 5,000 to 6,000 gallons of hot water per day is planned for the St. Croix Hospital. Also, a 16-unit resort on St. John will be built with solar water heaters. The resort, called Harmony: A Center for the Study of Sustainable Resort Development, will utilize other types of renewables and will attempt to be independent of utility grid power. The Energy Office is assisting Maho Bay Camps, Inc. in this project.¹⁶

Photovoltaics

Photovoltaics (PVs) converts sunlight directly into electricity. In the United States, 31 percent of PVs sales are to the communications industry, 8 percent are to the transportation industry, 7 percent are for water pumping, and 18 percent are directly to consumers.¹⁷

¹² Laitner, Skip, "Renewable Energy Resources in the U.S. Virgin Islands," Economic Research Associates, Alexandria, VA, November 1993 at 7.

¹³ Laitner, Skip, "Renewable Energy Resources in the U.S. Virgin Islands," Economic Research Associates, Alexandria, VA, August 1993 at 6.

¹⁴ Conversation with Harvey Sachs, Ph.D., Director, Policy Research, Center for Global Change, University of Maryland at College Park, November 1, 1993.

¹⁵ Laitner, Skip, "Renewable Energy Resources in the U.S. Virgin Islands," Economic Research Associates, Alexandria, VA, November 1993 at 6.

¹⁶ Laitner, Skip, "Renewable Energy Resources in the U.S. Virgin Islands," Economic Research Associates, Alexandria, VA, November 1993 at 8.

¹⁷ Muller, Frank and Harvey M. Sachs, "Renewable Energy and Pollution Prevention in Southern California," Center for Global Change, University of Maryland, January 1993 at III-3-1.

Potential for photovoltaic technology in the U.S. Virgin Islands. Several private homes already use PVs for their electricity needs. A modest PV program would yield 8,746 MWh of savings per year and 1.2 MW of reduced load.¹⁸

A large roof-top system has been installed at a housing project at Harrigan Court in Frederiksted and began testing in June 1993. The system provides the electricity for pumping 20,000 gallons of brackish water and powering a "reverse osmosis system" to supply the residents' daily water requirements.¹⁹

In addition, the Energy Office has launched the *Farmer's Energy Conservation Program* to demonstrate the feasibility of using renewables in agriculture. Nine photovoltaic pumps have been installed between St. Croix and St. Thomas to provide electricity for the pumping of irrigation water. The systems are designed to supply more than 25,000 gallons of water per day.²⁰

Photovoltaic electricity is expensive when compared to alternative sources, but if markets grow as substantially as many observers agree they will, there is a potential for large price reductions.²¹

Solar Thermal Electric Systems

Currently WAPA has no solar thermal systems or plans to incorporate them into the grid system in the near future. According to Hill, et al., *An Integrated Assessment of Electric Power Resource Options in the U.S. Virgin Islands*, 1993, electricity demand is too low to consider solar thermal technology.

However, assuming adequate solar insolation and improvements in current technologies, all types of solar thermal electric technologies have the chance at becoming fully competitive with fossil technologies. To do this requires sustained orders, government investments, or other market signals.²²

Wind Energy

Wind is converted into electricity with wind turbine generators or can be used to power mechanical processes, such as piston action water pumps. The quality of wind technology is improving. The best new turbines produce electricity at least 98 percent of the time there is enough

¹⁸ Laitner, Skip, "Renewable Energy Resources in the U.S. Virgin Islands," Economic Research Associates, Alexandria, VA, August 1993 at 7.

¹⁹ Two more Renewable Energy Districts are being planned by the Energy Office. Laitner, Skip, "Renewable Energy Resources in the U.S. Virgin Islands," Economic Research Associates, Alexandria, VA, November 1993 at 7.

²⁰ *ibid.* at 9.

²¹ Muller, Frank and Harvey M. Sachs, "Renewable Energy and Pollution Prevention in Southern California," Center for Global Change, University of Maryland, January 1993 at III-3-1.

²² *ibid.* at III-4-4.

wind. Technical improvements are expected to continue and costs will decline if market growth is sustained. Experts have projected a cost of 3.5 cents/kWh within two decades.²³

Potential for wind energy in the U.S. Virgin Islands. More information is needed on wind patterns, such as velocities and durations, land use impacts, and environmental impacts before the feasibility of wind-based generating technologies can be determined.

8.4 Options For Reducing Electric Power System Physical Vulnerability

Our study schedule did not allow a detailed assessment of options for reducing electric power system vulnerabilities. In lieu of such an assessment, we suggest below some emergency scenarios that VIEO and WAPA may want consider as part of their normal emergency planning process. The Virgin Islands Energy Emergency Plan recognizes the value of testing emergency response procedures in advance (Chapter V, pp. 39-40). We concur and suggest that testing include a variety of simulated electrical emergencies that will enable responses to be developed to reduce or mitigate potential electric power system vulnerabilities.

In this regard, we recommend that electric power emergency scenarios be considered in the areas described below.

8.4.1 *Electric Generation*

St. Thomas and St. Croix each have but one generating plant. There is no interconnection possible between them or back-up available.²⁴ This makes certain components at the plants extremely critical. One critical element is the step-up transformer bank. We suggest that a scenario be considered which deals with loss of several of these banks and considers the spares situation. If it is determined that additional spare units should be obtained, we recommended that they *not* be stored in proximity to the existing units (as has often been done by utilities all over the world), but rather be housed in a secure location at some distance from the existing units. Given the lower voltages that the WAPA system uses, there may be quicker access to replacements. However, it may be valuable to explore the availability of spare transformer capacity and spare combustion turbines.

One possible source of inexpensive spare capacity could be the surplus transformers and other equipment which may become available during the military base closings in the U.S. mainland. Public agencies will have some priority rights to selection of such equipment when it is surplus, and if there are useful spares available, WAPA would be well advised to explore the matter. (Surplus portable generators would be another asset to WAPA's preparedness program.)

Another possible source of transformers in an emergency could be spares located on the U.S. mainland. The North American Electric Reliability Council (NERC) maintains a "Spare Transformer Database."

²³ *ibid.* at III-5-1.

²⁴ As noted previously in Section 3.2, discussions are currently underway with Hess regarding the provision of emergency power by the Hess refinery during electrical emergencies. However, this option would only benefit St. Croix and is not yet in place.

8.4.2 *Transmission*

The comments made above for generating plant step-up transformers also apply to the transformers in WAPA's sub-transmission system. These transformers could be *even more* critical assuming a multi-storm scenario or a sabotage scenario which affects a number of key substations simultaneously. It would be valuable to consider a scenario involving loss of these transformers and options for obtaining replacements.

8.4.3 *Distribution*

WAPA has ample experience from Hurricane Hugo to develop scenarios that test whether it currently has sufficient spare power poles, distribution transformers, etc., available.

8.4.4 *Communications and Control*

Because of the relatively small size of the power system, and because of the small size of the territory involved, difficulties with emergency communications should not be as big a factor as in Puerto Rico. However, DIALCOM is important and is discussed on page 33 of the plan. The discussion omits reference to FAX and to ham operators and their potential roles in an emergency.

8.4.5 *Customer Preparedness*

Electric power customers can reduce their vulnerability to electric power outages by making provision for standby power. For example, a common problem during electrical emergencies is that gasoline service stations can't operate their pumps because the pumps are powered by electricity. As another example, it is apparent from recent major power outages in the mainland that telephone companies, in some instances, have not provided key equipment with sufficient standby power. This situation has been exacerbated in recent years with the requirement by EPA regarding fuel storage tanks. As utilities and business have removed their old "single-shell" buried tanks, they have often replaced the old tanks with new tanks of smaller capacity. This has reduced fuel storage for telephone system standby generators. An effective emergency plan should contain a program to encourage standby generation at critical service locations. In addition, it should be observed that the Preparatory Emergency Measures and the Energy Emergency Measures outlined in the Plan are excellent, and will serve the Islands in good stead if they are implemented as recommended.

8.5 Concluding Comments

This section described a wide range of options for enhancing emergency preparedness and reducing energy system vulnerability. The options were based on an initial review of petroleum and electric power systems in the U.S. Virgin Islands. A more detailed analysis is warranted. The islands may wish to undertake this analysis in connection with their currently on-going review of energy issues.

APPENDIX A
LIST OF OFFICIALS INTERVIEWED

PUERTO RICO

Department of Natural Resources

Mr. Pedro Gelabert, Secretary
Mr. Juan A. Mendez, Under Secretary
Ms. Carmen Reveron, Special Technical Assistant to the Secretary

Planning Board

Ms. Norma E. Burgos Andújar, M.P.A., President
Eng. José R. Caballero Mercado, Associate Member
Dr. Wanda I. Marrero, Director, Economic and Social Planning Area
Mr. José M. Velez Alicea, Executive Director, Economic Planning and Evaluation

Department of Consumer Affairs

Ms. Nitzia Amadeo, Director, Division of Planning and Economic Studies

Economic Development Administration

Dr. Leonard Shapiro, Assistant Administrator

State Civil Defense Agency

Mr. Epifanio Jimenez Melendez, State Director

Puerto Rico Electric Power Authority

Eng. Angel L. Rivera, Director, Planning and Environmental Protection
Mr. Luis Cruz, Head, Planning & Research Division
Ms. Magdalena Rodriguez, Civil Defense Coordinator

Ports Authority

Ms. Barbara Colon, Chief, Administrative Division
Mr. Miguel A. Maldonado Rodriguez, Chief, Tariff & Rates Department

Petroleum Industry

Caribbean Petroleum Corporation

Mr. Wilfredo Rodriguez, Managing Director

Commonwealth Oil Refining Company

Mr. Roberto Graticas, Senior Vice President
Mr. Farid Chehab, Vice President, Marketing and Business Development

Esso Standard Oil Company (Puerto Rico)

Mr. Juan A. Juanet R., Vice President & Operations and Administration Manager, Central Caribbean Division
Mr. Otto M. Bustelo Carriga, Esq., Manager, Law Department, Central Caribbean Division

Gulf Chemical Corporation

Mr. J. Richard Perkins, Managing Director & Chief Operating Officer

Peerless Oil & Chemicals

Mr. Edward A. Maciula, Manager, Caribbean Operations

Phillips Petroleum

Mr. Alberto Sola, Operations Manager

Shell Oil Company-- Puerto Rico

Mr. Wilhelm J. Thate, President

Sun Oil--Puerto Rico

Mr. John Shea, Refinery Manager
Mr. Jose Antonio Morales, Operations Manager
Mr. X. F. McLeod Matos, Manager, Health, Safety and Emergency Response

Local Consultants

Dr. Fernando Zalacain, President, Econometrica, Inc.
Dr. Juan J. Rigau, Director, Juan J. Rigau & Associates

U.S. VIRGIN ISLANDS

Virgin Islands Energy Office

Ms. Claudette Young-Hinds, Director
Ms. Rena Francis, Program Monitor
Mr. Alphonse Javois, EEMIS

Virgin Islands Territory Emergency Management Agency

Mr. Elroy D. Harrison, Acting Director

Department of Economic Development and Agriculture

Mr. Dan Inveen, Chief Economist, Bureau of Economic Research

Virgin Islands Water and Power Authority

Mr. Alberto Bruno-Vega, Executive Director
Mr. Donald C. Francois, Chief Operating Officer, Director, Planning, Engineering and Environmental Affairs
Mr. Glenn Rothgeb, Director of Plant Production and Maintenance
Mr. Seymour Blackman, Chief Engineer

Petroleum Industry

Amerada Hess

Mr. Leon Hess, Chairman

APPENDIX B

REVIEW OF MAJOR OIL DISRUPTIONS

Since October of 1973, the world supply of crude oil has been interrupted four times by political and economic forces with their origins in the Middle East. In addition, the Alaskan Valdez oil spill and the Caribbean Hurricane Hugo provided examples of the effects of localized short duration accidental and natural calamities.

Set out below are brief summaries of these disruptions followed by a more in-depth review of the 1990-91 Persian Gulf crisis.

1. GLOBAL DISRUPTIONS

The Arab Oil Embargo (1973-74), Iranian Revolution (1978-79), Iran/Iraq War (1980), and Iraq Invasion of Kuwait (1990-91) all had substantial disruptive impacts on world oil supplies and prices. They all took place in the Middle East, led to peak free world supply losses of 3 to 5 million bpd and lasted at least six months.

Set out below are summaries of the "statistics" of these disruptions.

TABLE B-1
COMPARISON OF PAST GLOBAL DISRUPTIONS

Arab Oil Embargo

	Crude Oil Production	Free World Supply Losses	Gross Supply Increase	Net Shortfall	Imported U.S. Oil Price
Sep 1973	47.7	--	--	--	\$4.78
Oct 1973	46.4	1.47	0.19	1.27	\$5.60
Nov 1973	43.6	4.34	0.25	4.09	\$5.84
Dec 1973	43.7	4.20	0.20	4.00	\$7.84
Jan 1974	45.1	2.56	0.05	2.51	\$9.59
Feb 1974	45.7	2.23	0.20	1.94	\$12.54
Mar 1974	46.0	1.73	0.12	1.61	\$12.73

Iranian Revolution

	Crude Oil Production	Free World Supply Losses	Gross Supply Increase	Net Shortfall	Imported U.S. Oil Price
Oct 1978	48.9	--	--	--	\$14.63
Nov 1978	49.0	2.01	2.11	-0.10	\$14.74
Dec 1978	47.7	3.14	1.91	1.23	\$14.94
Jan 1979	46.3	4.80	2.13	2.67	\$15.50
Feb 1979	46.6	4.80	2.51	2.29	\$15.88
Mar 1979	47.8	3.08	1.95	1.13	\$16.41
Apr 1979	48.9	1.36	1.34	0.02	\$17.59

Iran/Iraq War

	Crude Oil Production	Free World Supply Losses	Gross Supply Increase	Net Shortfall	Imported U.S. Oil Price
Sep 1980	43.9	--	--	--	\$34.46
Oct 1980	41.5	3.36	0.96	2.40	\$34.63
Nov 1980	42.4	2.93	1.44	1.49	\$35.09
Dec 1980	43.8	2.13	2.05	0.08	\$35.63

Iraqi Invasion of Kuwait - The Persian Gulf crisis

	Crude Oil Production	Free World Supply Losses	Gross Supply Increase	Net Shortfall	Imported U.S. Oil Price
Jul 1990	60.1	--	--	--	\$17.65
Aug 1990	56.6	2.15	0.00	2.15	\$24.63
Sep 1990	59.2	4.30	0.93	3.37	\$29.48
Oct 1990	59.5	4.30	3.58	0.72	\$31.47
Nov 1990	60.4	4.30	4.37	-.07	\$28.34
Dec 1990	60.6	4.30	4.74	-.44	\$24.05
Jan 1991	60.2	4.30	4.82	-.52	\$20.86
Feb 1991	59.9	4.30	4.96	-.66	\$17.26
Mar 1991	60.2	4.30	5.23	-.93	\$17.16

All crude oil prices are dollars per barrel average landed cost of crude oil imports, except those prior to January 1974, where they are U. S. refinery gate prices. Crude oil volumes are in millions of barrels per day.

Crude oil production is world total for the Iraqi Invasion of Kuwait disruption and the free world supply for the prior disruptions. The delivery of surge production is lagged 30 days for the August 1990 to March 1991 period corresponding to the Mid-East Crisis.

2. VALDEZ OIL SPILL

The Exxon Valdez ran aground on March 24, 1989 resulting in the loss of 240,000 barrels of crude oil and initiated an intense cleanup effort in Alaska's Prince William Sound. Subsequent tanker transport restrictions and flow reductions in the Alaskan North Slope (ANS) pipeline resulted in a 13 million barrel supply disruption extending over 13 days.

This was a rather minor disruption compared to those described above, corresponding to approximately 3.5 days supply for the West Coast or about two-thirds of one day's supply based on total U.S. consumption. Although the crude and product supply disruption effects were relatively small, the price effects were significant. Gasoline prices, which were already on the rise because of seasonal factors, peaked at \$1.18 per gallon in the Los Angeles spot market after rising \$0.50 per gallon, while the New York Harbor spot price peaked a week and a half after the spill at \$0.69 per gallon, up \$0.12 above the pre-spill level.

In retrospect, it appears that the temporary disruption in ANS supplies resulted in rapid price rises due to the perception of tight markets rather than actual changes in the underlying supply and demand factors. Once the ANS production returned to normal this anxiety evaporated and the California and U.S. markets quickly returned to normal.

3. HURRICANE HUGO

Hurricane Hugo struck St. Croix in the Virgin Islands in September of 1989 and hit the eastern shores of Puerto Rico at approximately 130 miles per hour with wind gusts of 145 to 225 mph. Private housing, public buildings, tourist facilities and the Hess oil refinery were extensively damaged in St. Croix. This was accompanied by the general loss of water and electricity. National Guard troops transported from the U.S. were required to ensure public order and to aid the population in obtaining food and water.

Approximately 25,000 homes were severely damaged or destroyed in Puerto Rico, with over half a million people being left without electricity for several days or weeks.

The hurricane seriously affected economies throughout the Caribbean.

4. THE 1990-91 PERSIAN GULF CRISIS IN DETAIL

Gross production losses during the Persian Gulf crisis of 1990-91 were comparable to those which occurred during the Arab Oil Embargo of 1973 and the Iranian revolution of 1978-79, and greater than during the Iran/Iraq war of 1980. While the Mid-East disruption was of a relatively long eight months duration, the crisis proved manageable.

The characteristics of magnitude, duration and recency make the Persian Gulf crisis a creditable model for assessing the effects of future possible disruptions. However, it is also true that approximately 75% of the shortfall in production during the Persian Gulf crisis was made up by OPEC countries located near the Persian Gulf and in North Africa. This region has the largest potential surge production capacity in the world and therefore the effects of a comparable disruption which interrupts Middle East production would be considerably more difficult to cope with. A mitigating factor is that the OECD nations now possess considerable commercial and strategic stocks in place. Also, the IEA has formulated emergency plans to cope with future oil supply disruptions.

The Persian Gulf crisis is examined in considerable detail in the following sections. Recency is an important factor. Compared with previous disruptions, the global refinery configuration is considerably more advanced towards large flexible complex refineries capable of converting the heavier crude slate being produced. Also, the establishment of refining centers in the Middle East, the Far East, Venezuela and elsewhere, the end of the Cold War, the nearly complete integration of the global energy markets and the increase in U.S. and OECD strategic and dedicated stocks all serve to limit the utility of analyzing the effects of prior crude oil disruptions. However, this is not to say that the root causes and magnitude of prior disruptions do not merit examination.

The Persian Gulf crisis commenced on August 2, 1990 with the Iraqi invasion of Kuwait. The loss of Kuwaiti oil production and the subsequent boycott of Iraqi oil removed 8 percent of the world's oil supply (4.3 million bpd). The crude oil supply shortfall was redressed primarily by increased OPEC production. The Saudi production surge of 2.7 million barrels per day was key to eliminating the shortfall by November of 1990. This surge erased 60% of the shortfall. It was supplemented by 30% from the other OPEC countries with a balance of 20% coming from non-OPEC countries, for a net 10% increase in crude supply versus pre-Crisis levels (see *Table B-1*). On the other hand, product sales from the Middle East decreased due to the complete halt in Kuwaiti and Iraqi refined product exports, the diversion of Saudi product sales to cover military needs and a loss of refining capacity due to a fire at the Ras Tanura refinery in December of 1990.

U.S. and OECD strategic stocks represented a potential defense for resisting the effects of the disruption. Total stocks (including strategic stocks) held by the OECD countries at the time of the disruption stood at approximately 93 days of forward consumption. These were high compared to the 1973 and 1978 disruptions, both in terms of reserves and the number of days of usage represented by those stocks. Approximately 20 days more of forward consumption was in storage at the beginning of the Persian Gulf crisis as compared to the prior disruptions.

Puerto Rico, the Virgin Islands and the U.S. oil markets do not function in isolation from the rest of the world. Oil and product prices are determined more by the international supply and demand picture than by regional imbalances and local oil company pricing practices. The effects of the Persian Gulf crisis on the U.S. and on Puerto Rico and the Virgin Islands were therefore closely related. These

inter-relationships are examined in the body of the report. Detailed impacts on the U.S. Mainland are discussed below.

4.1 Effects on the U.S. Mainland

As shown in *Table B-4*, U.S. crude oil imports and refinery throughput dropped in the fall of 1990 and left gasoline stocks at an unusually low point at the start of the 1991. This trend continued and gasoline stocks fell to the Minimum Operating Inventory (MOI) level to a low point of 169 million barrels in April of 1991, recovering in May and June with increased U.S. imports and refinery production. U.S. distillate and residual fuel oil inventories were at normal seasonal levels coming out of the crisis, aided by a mild U.S. winter.

Distillate markets and traditional supply patterns were profoundly affected by the loss of exports from Kuwait and Iraq and the military buildup in the fall and winter of 1990-1991. The impact on U.S. markets was manifested by reduced imports, lower inventories and higher prices. Fortunately, the U.S. winter was mild and the situation was managed. As shown in *Table B-2*, U.S. product exports rose during the Persian Gulf crisis with products comprising approximately 90% of total U.S. petroleum exports. Demand increased in Asian markets, particularly for distillate, jet fuel, and naphtha, as a consequence of the loss of a major supplier with the shutdown of the refineries in Kuwait. Also, the military demands of Operation Desert Storm diverted Saudi exports, another key supply source. Also contributing to tighter global product supplies were a cold European winter, refinery outages in Brazil, Mexico and Venezuela and increased fuel oil demands in Japan due to outages in their nuclear power generation facilities.

The combined surge production from the various OPEC and non-OPEC sources which replaced the lost Kuwaiti and Iraqi production closely matched the quality of the interrupted crude oil supply. However, U.S. sweet crude oil imports fell from approximately 40% of total crude oil imports to 33%, comparing August to March 90-91 to the same period for the previous year. *Table B-2* shows a significant drop in API gravity and a rise in sulfur content as evidence of the poorer U.S. imported crude oil quality. The explanation for the decrease in U.S. sweet crude oil imports is linked to market forces rather than to any global physical shortage of sweet crude oils. Other nations were willing to pay a higher price for sweet crude oil as a hedge because the foreign refinery centers do not have the complexity and flexibility that the U.S. refineries do. With U.S. refinery throughput down (affording additional product yield flexibility) and reduced domestic demand, the U.S. refiners were able to produce the required product slate with a heavier crude oil mix, albeit with pressure on the gasoline inventory at the end of the crisis.

Demands were down in all major product categories comparing the period August/90 to March/91 with August/89 to March/90. On this basis, motor gasoline demand was down 0.7%, kero-jet demand off by 2.6%, distillate demand down by 1.9%. Residual fuel oil demand fell by 16.4%, tied in large part to the warm 1990/91 U.S. winter. The weighted demand of the above major product categories was off by 2.4% with refinery input down by approximately the same percentage on the seasonally adjusted basis.

All demands were met with normal seasonal inventories at the end of the crisis, except for low gasoline inventory. This was the result of reduced U.S. product imports, increased exports and possibly the heavier U.S. crude oil slate processed during the Persian Gulf crisis.

Iraq's August 2, 1990, invasion of Kuwait de-stabilized world oil markets and sent crude oil and product prices sharply upwards. The monthly average landed cost of crude oil delivered to the U.S. averaged \$31.47 per barrel for the peak month of October, nearly double that of the pre-invasion level. By November, surge production had replaced the 4.3 million barrel per day shortfall, demand was receding under price elasticity effects, and prices began their decline. However, uncertainties concerning the impending war and the ability to sustain replacement oil supplies held prices up into December. As the allies began to prevail, launched their successful first offensive under Desert Storm, crude oil prices fell. They reached pre-invasion levels during February of 1991. Product prices in general held up longer than crude oil prices and reached pre-invasion seasonal norms in March of 1991.

As *Table B-9* shows, the Persian Gulf crisis affected the return on equity of the upstream and downstream petroleum segment in opposite ways. The rapid rise in crude oil price sharply increased the profits of the independent producers at the expense of the independent refiners holding inadequate crude oil supplies of their own. Since the major petroleum companies operate both oil and gas production and refining/marketing facilities, these offsetting industry segments made their profitability changes less volatile.

The profitability of the independent refiners increased in the first quarter of 1991, due primarily to the fact that gasoline prices declined less rapidly than crude oil prices as shown in *Table B-8*. U.S. product price declines were slowed by increased European product demands which reduced U.S. gasoline imports and increased U.S. product exports. There was a particularly high foreign demand for jet fuel in the Middle East and Europe.

As shown in *Table B-9*, gross composite refining margins in the U.S. declined after the Persian Gulf crisis commenced and recovered partially in the first quarter of 1991. This response corresponded to the effect of crude oil and product prices on the profitability of the independent refiners, as described above.

As shown in *Table B-11*, foreign refining margins (and profits) increased markedly in contrast to the weak U.S. refining sector performance. Increased refining throughput in Singapore to replace Kuwaiti losses and Saudi refined products diverted to supply the needs of Desert Shield/Storm bolstered the Singapore refining margins. The improved Rotterdam refining margins reflected the strong European product demands, particularly for jet fuel and distillates. Depressed demand for residual fuel also helped maintain light-heavy product differentials and thus cracking refinery margins.

The SPR contained 590 million barrels of crude oil at the onset of the Persian Gulf crisis and was subsequently reduced to 569 million barrels as the result of a test sale and then a drawdown conducted during January of 1991. DOE concluded from the test that a maximum drawdown rate of 3.9 million barrels per day could be maintained for 60 days. After that, the maximum draw rate could be progressively reduced to 300,000 barrels per day over an additional period of 180 days. DOE is presently attempting to enhance its off-site commercial distribution capability so that the SPR can be drawn down at a rate of 4.5 million barrels per day. The SPR storage sites are currently capable of holding 750 million barrels of crude oil.

The U.S. and the other IEA members have agreed to maintain sufficient oil inventory to replace 90 days' of net imports as well as to develop emergency contingency plans to restrain oil

demand in the event of an energy emergency. In January of 1991, the IEA approved a contingency plan to provide the equivalent of 2.5 million barrels per day of crude oil supply through a combination of stock drawdowns, demand restraint and fuel switching. The total of 2.5 million barrels included the following commitments:

United States	1.125
Japan	0.350
Germany	0.187
Italy	0.130
France	0.126 (as a participating non-member of IEA)
United Kingdom	0.120
Canada	0.115
Spain	0.062
Netherlands	0.032
Others	0.253

Of the above, 2.0 million barrels per day was from stock drawdown, 0.4 from demand restraint and 0.1 from fuel switching.

The only actual crude oil drawdowns which occurred during the Persian Gulf crisis were a U.S. SPR test sale in September/October 1990 and the SPR draw in January 1991 as part of the IEA plan. Under the test sale, 4 million bbls of oil was purchased. Under the January release, 17.2 million barrels were purchased by 13 U.S. oil companies, with the demand for sour oil being weak. The decision to draw down the SPR was based on a presidential finding of "the existence of a potential national energy supply shortage constituting a severe supply interruption". In addition to testing the SPR drawdown capabilities, the stated purpose was to minimize price increases and inventory buildup as Desert Storm approached by signalling the oil markets that adequate supplies of crude oil could be made available if required. Between January 16, 1991, when the drawdown commenced, and the following day, the spot price of crude oil dropped from \$32 to \$21.45 a barrel, the largest one day decline since the start of the Crisis. However, it proved impossible to isolate the effect of the drawdown because of the simultaneous influence of the early allied successes in their air war against Iraq.

In assessing the overall impacts of the Persian Gulf crisis, it is important to emphasize that the world and the U.S. managed the disruption better than the raw probabilities might have suggested at the onset. A warm U.S. winter (although Europe experienced an abnormally cold winter), damage of oil producing and refining facilities being confined to the fire at Ras Tanura, North Sea production gains in the face of operating difficulties, international cooperation (due in large part to the fact that the producing and consuming nations were involved in a joint military venture) and a quick military victory ending the Crisis after eight months were all mitigating factors. Considering them all together, matters could well have been worse. Sustained higher crude and product prices and much tighter gasoline and distillate markets and supplies could have resulted if developments had been more negative.

Table B-2

**U.S. CRUDE OIL AND PRODUCT IMPORTS AND EXPORTS
DURING THE PERSIAN GULF CRISIS (MBPD)**

	Total Crude Oil Imported	Total Product Imports	Product Exports	Average API	Crude Import Wt. % Sulfur
Jul 1990	6855	2193	606	31.7	1.37
Aug 1990	6452	2192	785	31.7	1.37
Sep 1990	5664	1698	779	30.9	1.44
Oct 1990	5132	1585	844	30.2	1.52
Nov 1990	5085	1918	948	30.1	1.49
Dec 1990	4611	1828	1026	30.6	1.48
Jan 1991	5296	1808	1149	30.4	1.59
Feb 1991	5485	1380	1288	30.4	1.49
Mar 1991	5166	1480	807	30.3	1.56

Sources:

EIA/Petroleum Supply Annual 1991, volume 1, p3.

1/9/92 Fax from Budd Gray to Martin Tallett, entitled U.S. Crude Oil Imports, August to March 1988-91

TABLE B-3**U.S. IMPORT SOURCES DURING THE PERSIAN GULF CRISIS (MBPD)**

	Saudi Arabian Imports	Arab-OPEC Imports	Other OPEC	Non-OPEC Imports
Crude plus Product				
Jul 1990	1182	2853	2139	4057
Aug 1990	1316	2757	2164	3722
Sep 1990	1109	1915	2029	3417
Oct 1990	1158	1792	1725	3199
Nov 1990	1342	1758	1871	3374
Dec 1990	1115	1843	1585	3011
Jan 1991	1214	2261	1637	3205
Feb 1991	1557	1812	2003	3051
Mar 1991	1157	1905	1718	3023

Source: EIA/Petroleum Supply Annual 1991, volume 1, p9, 11 and 16.

TABLE B-4**U.S. PETROLEUM REFINERY INPUT AND CRUDE OIL INVENTORY
DURING THE PERSIAN GULF CRISIS (MBPD)**

	Total Refinery Input	Refinery Capacity Utilization	Total Crude Inventory	SPR Crude Inventory
Jul 1990	14212		966	587
Aug 1990	14142		959	590
Sep 1990	14104		932	590
Oct 1990	12825		936	589
Nov 1990	12953		925	586
Dec 1990	12708		908	586
Jan 1991	12735		906	586
Feb 1991	13046		913	582
Mar 1991	12839		905	568

Sources:

EIA/Petroleum Supply Annual 1991, volume 1, p7.

Refinery Capacity Utilization from EIA or ?? back issues of OGJ??

TABLE B-5**U.S. REFINER SALES DURING THE PERSIAN GULF CRISIS**

	Motor Gasoline	Kerojet	Distillate Fuel Oil	Residual Fuel Oil
Jul 1990	341.7	49.5	119.1	48.1
Aug 1990	349.4	50.5	129.9	48.0
Sep 1990	319.3	51.1	123.8	41.0
Oct 1990	322.0	50.6	126.3	35.9
Nov 1990	322.5	49.8	125.0	36.8
Dec 1990	310.6	45.9	119.6	40.5
Jan 1991	296.8	46.2	136.9	43.2
Feb 1991	304.0	45.1	126.0	42.5
Mar 1991	317.5	44.1	125.1	40.8

Sales are in million gallons per day.

Source: EIA/Petroleum Marketing Annual 1991, p. 7, 16 and 20.

TABLE B-6

**U.S. PETROLEUM PRODUCT INVENTORIES
DURING THE PERSIAN GULF CRISIS**

	Motor Gasoline	Kerojet	Distillate Fuel Oil	Residual Fuel Oil
Jul 1990	180	45	125	49
Aug 1990	172	43	130	49
Sep 1990	188	44	136	49
Oct 1990	180	45	136	49
Nov 1990	177	45	132	50
Dec 1990	181	46	132	49
Jan 1991	186	44	112	48
Feb 1991	179	41	102	46
Mar 1991	171	38	98	43
Apr 1991	169			

Inventories are end of the month stocks in millions of barrels.

Source: EIA/Petroleum Supply Annual 1991, volume 1, p 17, 19, 21 and 23.

TABLE B-7

**U.S. CRUDE OIL COST AND PRODUCT PRICES
DURING THE PERSIAN GULF CRISIS**

	Crude Oil Average Landed Cost	Motor Gasoline Price	Kerojet Price	No.2 Distillate Price	No. 6 Fuel Oil Price
Jul 1990	17.65	80.8	55.4	53.6	31.9
Aug 1990	24.63	92.4	70.7	74.2	44.1
Sep 1990	29.48	101.2	92.1	87.3	50.7
Oct 1990	31.47	108.7	116.8	99.4	60.5
Nov 1990	28.34	107.2	108.4	93.5	58.7
Dec 1990	24.05	98.4	90.9	86.8	55.5
Jan 1991	20.86	88.8	81.1	84.3	53.4
Feb 1991	17.26	79.5	73.7	75.2	39.8
Mar 1991	17.16	74.0	62.1	64.5	32.3

Crude oil costs are in dollars per barrel and product prices are the refiner prices to end users in cents per gallon (excluding taxes).

Source: EIA/Petroleum Marketing Annual 1991, p14.

TABLE B-8**AVERAGE CENTS PER GALLON INCREASE SINCE JULY 24, 1990**

	Crude Oil Spot Price	Retail Gasoline	Spot Gasoline
Jul 1990	0	0	0
Aug 1990	4	2	4
Sep 1990	14	20	10
Oct 1990	19	30	3
Nov 1990	7	29	-9
Dec 1990	0	27	-23
Jan 1991	-3	16	-22
Feb 1991	-21	5	-26
Mar 1991	-18	0	-18

Prices are mid-month prices.

Source: EIA/Petroleum/U.S. Energy Industry Financial Developments, 1991 First Quarter, p 15.

TABLE B-9**QUARTERLY RETURN ON EQUITY FOR U.S. COMPANIES
DURING THE PERSIAN GULF CRISIS**

	Independent Producers	Major Refiners	Independent Refiners	Composite Gross Refinery Margins
1990 Q2	0	12	28	10.00
1990 Q3	10	13	29	8.80
1990 Q4	36	17	15	6.70
1991 Q1	13	15	11	7.90

Notes:

1. The percentage return on equity is calculated on an annualized basis.

Source: EIA/Petroleum/U.S. Energy Industry Financial Developments, 1991 First Quarter, p 16.

2. Refinery margins are the difference between the composite wholesale product price and the composite refiner acquisition cost of crude oil.

Source: Ibid, p12.

TABLE B-10

U.S. VS. OVERSEAS SPOT MARKET PRICES

	Rotterdam Unleaded Regular	N.Y. Unleaded Regular	Rotterdam Distillate No. 2	N.Y. Distillate No. 2	Rotterdam No. 6 Fuel Oil	N.Y. No. 6 Fuel Oil
Jul 1990	26.85	27.24	22.52	23.25	15.02	16.00
Aug 1990	36.34	37.91	31.23	31.12	19.37	21.50
Sep 1990	42.97	42.53	35.7	34.17	23.05	23.00
Oct 1990	45.02	40.95	47.05	43.09	24.92	26.25
Nov 1990	34.99	34.88	39.81	37.34	22.67	24.75
Dec 1990	27.78	27.43	34.45	32.42	21.62	23.25
Jan 1991	26.67	25.78	34.72	30.66	18.09	19.75
Feb 1991	26.98	27.80	36.66	30.95	13.81	14.25
Mar 1991	27.90	29.91	22.79	26.04	15.54	15.50

All prices in dollars per barrel and are mid-month spot prices.

Rotterdam gasoline RON of 91 is approximately equivalent to a U.S. Antiknock Index of 87. Rotterdam distillate is 0.3% Sulfur, N. Y. Distillate is 0.2 % Sulfur and both residual fuel oils are 1% Sulfur.

N.Y. Distillate prices are New York Harbor barge prices. Prices to end users in cents per gallon (excluding taxes).

Source: EIA Weekly Petroleum Status Report, DOE/EIA-0208(91-47), Week Ended November 8, 1991, Tables S1 and 13.

TABLE B-11**DIFFERENCE BETWEEN FOREIGN AND U.S. REFINING MARGINS
DURING THE PERSIAN GULF CRISIS**

	Rotterdam	Singapore
Jul 1990	-0.80	-0.80
Aug 1990	-1.00	1.00
Sep 1990	0.00	2.00
Oct 1990	1.50	6.20
Nov 1990	1.30	2.20
Dec 1990	3.90	4.00
Jan 1991	3.90	4.00
Feb 1991	4.00	7.70
Mar 1991	-1.00	-0.50

The above differences are calculated by subtracting the U.S. Gulf Coast margin from the refining margin in the foreign market. The calculation assumes that Arab Light crude oil is used in the refinery.

Source: EIA/Petroleum /U.S. Energy Industry Financial Developments, 1991 First Quarter, p 10.

SUMMARY OF SOURCES

- (1) EIA Service Report, "Petroleum Prices and Profits in the 90 Days Following the Invasion of Kuwait", SR/OA/90-01, November 1990.
- (2) *EIA Petroleum Marketing Annual 1989.*
- (3) *EIA Petroleum Marketing Annual 1991.*
- (4) *EIA/Petroleum Supply Annual 1991*, volume 1, p3.
- (5) 1/9/92 communication from OSPR to EnSys entitled "U.S. Crude Oil Imports, August to March 1988-91". (References DOE/EIA 0520)
- (6) *EIA/Petroleum /U.S. Energy Industry Financial Developments*, 1991 First Quarter, p 15.
- (7) *EIA Weekly Petroleum Status Report*, DOE/EIA-0208(91-47), Week Ended November 8, 1991, Tables S1 and 13.
- (8) *Oil Industry Developments 1/1991.*
- (9) *EIA Petroleum Profits in the Fourth Quarter of 1990*, SR/OA/91-01, February 1991.
- (10) *EIA International Energy Outlook. "A Post-War Review of Energy Markets"*, DOE/EIA-0484(91), June 1991.
- (11) *Analysis of Oil Pricing. "Federal Authorities to Respond to Oil Supply Disruptions"*, GAO/RCED-93-17, p 77.

APPENDIX C

1. GENERAL BACKGROUND AND THE CONDITIONS FOR RELEASING AN SPR DRAW

The creation of the SPR and the requirements governing the release of crude oil to reduce the impact of severe supply reductions were established by the 1975 Energy Policy and Conservation Act, as amended, in response to the 1973 OPEC oil embargo.

The current U.S. policy is to first rely on free market forces to react to a crude oil disruption. The EPCA permits the President to authorize a SPR release when there is an actual or imminent "severe energy supply interruption". This is defined in the Act as an interruption of likely significant scope and duration with the potential to cause major adverse impact on the national safety or economy and involving a likely interruption in imported crude oil and petroleum products, or sabotage, or an act of God.

The above conditions contained in the original Act do not provide specific guidance on how long market forces should be permitted to operate without a SPR draw and when the President should act. The Energy Policy Act of 1992 amends the EPCA to allow the President to release SPR oil if a disruption has caused a severe increase in the price of petroleum products and if the price increases are likely to have a major adverse impact on the national economy. Although the 1992 legislation explicitly links price increase with the decision to release SPR crude oil, the current DOE policy is opposed to establishing a price trigger for using the SPR. The DOE's approach remains supply-oriented and stresses Presidential discretion and decision to assess the many potential ramifications of a supply disruption, rather than on relying on an impersonal "trigger" or price related formula to decide the timing and extent of an SPR release.

2. TIMING OF THE DECISION FOR AN SPR RELEASE

The general U.S. policy is to allow free market forces to determine crude oil and product prices to balance supply and demand at the onset of an oil supply crisis. However, the federal government also considers "early use" of the SPR as the best means for combatting the negative economic effects of an oil market shock. These two considerations may be at odds and there is no precise definition assigned to "early use". While the U.S. may act alone in releasing crude oil from the SPR, the U.S. is also bound by its commitments as one of the participating countries in the IEA's contingency plans for managing the impacts of an oil supply disruption. Securing joint agreement with the other IEA members may slow the process. The timing of U.S. SPR drawdown during the recent Mid-East Crisis was decided in cooperation with the other IEA members. The chronology of events leading to and following this drawdown is given below.

CHRONOLOGY OF SPR DRAW AND OTHER KEY EVENTS 1990-91 MIDDLE EAST CRISIS

1990

- August 2 Iraq invades Kuwait
- August 24 N.Y. Harbor No. 6 Fuel Oil price peaks at \$27.00
- September 26 President orders 5 mmb SPR test sale.
- October 12 N.Y. W.T.I. spot price peaks at \$41.07
- October 12 N.Y. Harbor No. 2 Fuel Oil price peaks at \$43.09
- October 26 N.Y. Harbor Gasoline price peaks at \$42.57
- November World crude oil shortfall erased by surge production early in November 1990.
- December 11 Notice of Standard Sales Provisions for SPR crude appears in the Federal Register.

1991

- January 11 IEA Governing Board approves contingency plan to increase world oil supply by 2.5 mmbpd
- January 16 The President orders the first sustained SPR drawdown of 33.75 mmb, equivalent to 1.125 mmbpd for 30 days. Of this amount, 17.2 mmb was ultimately purchased by 13 U.S. companies.
- January 17 DOE issues a Notice of Sale for SPR crude oil.
- January 17 Spot price of W.T.I. crude oil drops from \$32 to \$21.45 per barrel, the largest 1 day drop since the beginning of the crisis.
- January 25 Final Bids for SPR crude oil due in New Orleans, La.
- February 15 Earliest pickup date allowed for SPR crude oil.
- March 31 Latest pickup date allowed for SPR crude oil.

As shown above, the first major U.S. drawdown occurred over 5 months after the beginning of the crisis and 3 months after oil and product prices peaked in October 1990. While a sharp drop in crude oil prices coincided with the U.S. drawdown, the DOE has acknowledged that other factors may have acted in concert, including the early success of the allied air force against Iraq.

As a result of the standard sales provisions applied by DOE, SPR crude oil deliveries did not impact on end-use customers until late February through early April 1991, or one month away from the end of the crisis.

The federal government's decision to rely on market forces for two-thirds of the crisis span was determined by shortage assessment and risk appraisal. Shortly after the invasion, DOE concluded that there was no significant shortfall in the U.S. markets at the time and that world surge production capacity (which had already reached close to 1 mmbpd during August 1990) and high levels of world inventories would be capable of coping with the loss of Iraqi and Kuwaiti production and refining. Fear of losing Saudi Arabian oil also influenced in favor of delay, the idea being to hold off on SPR release until absolutely required in the face of a calamity. At the time, DOE was also encouraging increased domestic oil production, voluntary energy conservation, fuel switching and intensified its collection and analysis of data relevant to the operation of the oil markets.

The drawdown decision was based on a Presidential finding of "the existence of a potential national energy supply shortage constituting a severe energy supply disruption". The Secretary of Energy further stated that an ancillary purpose was to signal the oil markets that adequate oil supplies could be made available during the course of the war, with the intent to minimize price increases and to prevent a run-up in inventories at the onset of the Mid-East Crisis land war.

Actually, there was no crude oil shortfall in mid-January of 1991. The SPR draw proved to be more of a cautionary move which quelled anxieties concerning the adequacy of future oil supplies and insured stability in the oil markets. DOE feared that unbridled negative speculation could push the oil price as high as \$90 per barrel.

3. THE SPR CRUDE OIL SALE PROCEDURE

The Mid-East Crisis SPR crude oil sale provided for price competitive bidding with certain price adjustments. Key elements of the DOE SPRPMO "Notice of Sale" are summarized below:

Bid responses were due in 7 days. Offers to purchase SPR crude had to be guaranteed at most by 10 million dollars or 5% of the maximum potential contract value. The purchaser's offered price was adjustable by current crude oil spot market price indices and quality differentials based on API.

- Minimum delivery lot sizes were 200,000 barrels for tankers, 40,000 barrels for barges and 100,000 barrels for pipelines.
- The successful offerers were required to submit a proposed lifting program 15 days prior to the earliest delivery date offered by the Notice of Sale. Vessel nominations were required 7 days in advance of the 3 day loading window allowed.
- Pipeline, tanker and barge points at which SPR crude oil was available were specified. Allowance was made for 15 day pickup periods. Continued storage of

purchaser's oil in the SPR facilities after the end of the delivery periods was not permitted. The "Jones Act" which requires crude transport in U.S. Flagship Vessels was waived for the marine delivery of SPR crude oil.

Depending on the mode of SPR crude oil delivery and the delivery point, SPR crude oil was made available to refiners at the pickup point from February 15 through March 31, 1991, at the latest. Therefore, allowing for transport, refining and product delivery time requirements, the end user effects of the January 16, 1991 SPR release decision were not realized until late February through mid-April 1991.

SOURCES:

- (1) "EIA Weekly Petroleum Status Report", DOE/EIA-0208(91-47), Week Ended November 8, 1991, Tables S1 and 13.
- (2) "EIA Petroleum Profits in the Fourth Quarter of 1990", SR/OA/91-01, February 1991.
- (3) "Analysis of Oil Pricing. Federal Authorities to Respond to Oil Supply Disruptions", GAO/RCED-93-17, p 77.
- (4) Federal Register, DOE Strategic Petroleum Reserve; Standard Sales Provisions; Notice, Friday, December 11, 1992, pp 58872-58928.
- (5) DOE Strategic Petroleum Reserve Project Management Office, Strategic Petroleum Reserve, Crude Oil Sale 91-1, Notice of Sale, DE-NS96-91PO51012.

UNITED STATES DEPARTMENT OF ENERGY
PO-9
WASHINGTON, DC 20585

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