Early Entrance Coproduction Plant
Quarterly Report No. 3

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Abstract:

The overall objective of this project is the three phase development of an Early Entrance Coproduction Plant (EECP) which produces at least one product from at least two of the following three categories: (1) electric power (or heat), (2) fuels, and (3) chemicals. The objective is to have these products produced by technologies capable of using synthesis gas derived from coal and/or other carbonaceous feedstock.

The objective of Phase I is to determine the feasibility and define the concept for the EECP located at a specific site and to develop a Research, Development, and Testing Plan (RD&T) for implementation in Phase II.

The objective of Phase II is to implement the RD&T as outlined in the Phase I RD&T Plan to enhance the development and commercial acceptance of coproduction technology that produces high-value products, particularly those that are critical to our domestic fuel and power requirements. The project will resolve critical knowledge and technology gaps on the integration of gasification and downstream processing to coproduce some combination of power, fuels, and chemicals from coal and other feedstocks.

The objective of Phase III is to develop an engineering design package and a financing plan for an EECP located at a specific site.

The project's intended result is to provide the necessary technical, economic, and environmental information that will be needed to move the EECP forward to detailed design, construction, and operation by industry.

Table of Contents

I. List of Figures and Tables

The following figures and diagrams were used in this report:

II. List of Acronyms

The following acronyms were used in this report:

AFDU .... Alternate Fuels Development Unit
AGR .... Acid gas removal
API .... American Petroleum Institute
ASU .... Air Separation Unit
BACT .... Best Available Control Technology
BPOD .... Barrels Per Operating Day
CCP .... Commercial Coproduction Plant
DCFROI .... Discounted Cash Flow Return On Investment
DOE .... United States Department of Energy
EECP .... Early Entrance Coproduction Plant
EPC .... Engineering-Procurement-Construction
FDEP .... Florida Department of Environmental Protection
FFBR .... Fixed-fluidized-bed reactor
F-T .... Fischer-Tropsch
GE .... General Electric Power Systems
GT .... Gas turbine
H_2SO_4 .... Sulfuric Acid
HCU .... Hydrocracking Unit
HRSG .... Heat Recovery Steam Generator
KBR .... Kellogg Brown & Root, Inc.
LPG .... Liquefied Petroleum Gas
LS .... Low sulfur
LS FO .... Low sulfur fuel oil
LS VGO .... Low sulfur vacuum gas oil
MACT .... Maximum Achievable Control Technology
MDEA .... Methyldiethanolamine
NPDES .... National Pollution Discharge Elimination System
NPV .... Net Present Value
PAR .... Motiva's Port Arthur Refinery
PARFW .... Port Arthur Refinery Finished Wax Case
PARHCU .... Port Arthur Refinery Hydrocracking Case
PUC .... Public Utilities Commission
PWI .... Present Worth Index
PWP .... Present Worth Payout
RD&T .... Research, Development & Test
SAP .... Sulfuric Acid Plant
SBCR .... Slurry Bubble Column Reactor
SIC .... Standard Industrial Code
SMR .... Steam Methane Reforming
SRU .... Sulfur Recovery Unit
ST .... Steam Turbine
STPD .... Short tons per day
TECO .... Tampa Electric Company
TFBR .... Tubular fixed bed reactor
TGTU .... Tail Gas Treating Unit
TSC .... Tampa Syncrude Case
THCU .... Tampa Hydrocracking Case
ULS .... Ultra low sulfur
USGC .... United States gulf coast
VGO .... Vacuum gas oil
WGS .... Water gas shift

III. Executive Summary

This is the third of five quarterly reports which summarize the progress of Phase I of the development of the Early Entrance Coproduction Plant (EECP) concept covered by DOE Cooperative Agreement No. DE-FC26-99FT40658. The Phase I objective is to determine the feasibility and define the concept for the EECP located at a specific site and to develop a Research, Development, and Test (RD&T) Plan. Phase I is scheduled for completion by the end of the year 2000. Phase II is to conduct the research as outlined in Phase I and is scheduled for two calendar years (2001 through 2002). Phase III is scheduled for the calendar year 2003 and is to develop an engineering design package and financing plan for the EECP. The overall project's intended result is to provide the necessary technical, economic, and environmental information needed to move the EECP forward to detailed design, construction, and operation by industry.

During this reporting period, process studies, cost estimates, proforma calculations, and environmental assessment activities were completed during the quarter to develop data for selection of the EECP host site. The Motiva Port Arthur Refinery (PAR) located at Port Arthur, Texas was selected as the EECP host site. This selection was based the most favorable economic indicators resulting from a model that provided financial return calculations for seventeen different scenarios. The indicators favored the Port Arthur "Finished Wax" case, primarily due to lower feedstock transportation costs, higher product value, and greater infrastructure compatibility. The Port Arthur Refinery Finished Wax case will now be used as the basis for further process design work during the upcoming quarter (3Q2000).

3Q2000 work will include completion of the preliminary process design for the selected EECP site, risk and technical assessment, initiation of capital and operating cost estimates, and continued market, economic, and environmental assessments. Also, RD&T planning will begin for work to be conducted in Phase II.

IV. Results, Discussion, and Preliminary Conclusions

Task 2 – Concept Definition, Development, and Technical Assessment

Introduction

The proposed Early Entrance Coproduction Plant (EECP) will coproduce electric power, steam, and clean fuels using petroleum coke as the source material. In the EECP concept, approximately 1,215 short tons per day (sTPD) of petroleum coke is fed into a Texaco gasifier along with oxygen produced from a Praxair Air Separation Unit (ASU). Inside the gasifier, reactions take place at very high temperatures, around 2500°F, which produce synthesis gas, also known as syngas, a mixture of mainly hydrogen and carbon monoxide, with lesser amounts of water vapor, carbon dioxide, hydrogen sulfide, methane, argon, and nitrogen. The syngas is sent to an Acid Gas Removal (AGR) unit, where virtually all the sulfur compounds are removed along with some carbon dioxide. Roughly 75% of the cleaned syngas is sent to a General Electric (GE) 6FA gas turbine for power generation. The remainder is sent to an 8-foot diameter Fischer-Tropsch (F-T) reactor, where syngas is converted into hydrocarbon liquids. Unconverted F-T feed gas along with light hydrocarbon products (F-T tail gas) is sent to the gas turbine as fuel for additional power generation. The hydrocarbon liquids are sent to the product upgrading section to make finished products.

Discussion Regarding Feedstock

While the original solicitation requested that coal be used as a feedstock, the analysis of the current available feedstocks resulted in our proposal premise that a petcoke feedstock would be the best feedstock to enable the EECP concept to become an actual project. The analysis results were that petcoke would be the lowest cost source of hydrogen and carbon for the future and the highest probable application of the EECP concept would be on petcoke and most probable at a refinery location due to the high cost of handling and transporting petcoke to another location. Therefore our proposal was that the project would be coal capable and therefore must demonstrate the design would be capable of converting coal to F-T fuel products. This decision was based on gasification pilot plant research and development results for over fifty years of using different feedstocks and their performance in the gasification process. Feedstocks have included petroleum products ranging from natural gas to the heaviest petroleum fractions, petroleum coke, and coal ranging from anthracite to lignite and many types of waste materials. All of these materials have been gasified successfully. Because of the severe operation conditions used in the gasification process, very high temperature and pressure, it has been shown that there are only minor, in many cases negligible, differences in the reactivities of the various feedstocks.

This universality of performance has been further demonstrated in the more than 130 commercial plants that have been built and run using the Texaco Gasification Process. These plants use the complete range of feedstocks, natural gas, all petroleum fractions, asphalt, petroleum coke, coal and several waste materials. Any differences in the results, such as variations in the composition of the product syngas or thermal efficiency, can be accounted for by the differences in atomic composition of the feedstocks. Currently, new plants are designed based only on the chemical composition of the feeds.

While this vast store of experience should demonstrate the validity of generalizing gasification performance across feedstocks, some interesting observations have been developed in the cases of petroleum coke and coal. In many other process uses, where operating conditions are less severe, there are significant performance differences. In these cases, coal is generally more reactive than coke because of the differences in the molecular structures. Higher volatility of coal, due to the relative ease of its thermal cracking, is perhaps the most obvious difference and is the source of many of the process differences seen. These processes are generally reaction rate limited at the lower temperatures and pressures used, and the volatiles generated in heating the coal react more rapidly than the solid portions of the material. But in gasification, reaction rates are extremely high, and primarily physical processes, heat, mass transfer and fluid mechanics determine the performance. When these processes are considered, coal and coke are quite similar and hence they perform the same in the Texaco Gasification Process.

Perform Location Specific Process Studies for Two Sites (Task 2.2.3)
Preliminary Block Flow Diagrams with mass and energy balances (Task 2.3)

Two facilities were evaluated as potential sites for the EECP. One is representative of a typical refinery application, the Motiva Port Arthur Refinery, and the other representative of a typical power generation facility, the Tampa Electric Company Polk Power Station. Two design basis were developed for each site, for a total of four cases studied. The four cases differed mainly in how F-T liquid products were upgraded, how sulfur was recovered, and how energy was exported.

For the Port Arthur site, two product upgrading options were developed. In the first case, PARFW, the F-T liquid is sent to a wax hydrotreating unit, which produces mainly high-grade finished wax, along with hydrotreated naphtha and diesel. In the second case, PARHCU, the F-T liquid is sent to a hydrocracker unit, which produces hydrocracked naphtha and diesel. The acid gas generated from the AGR unit is sent to a sulfur facility to make sulfur. For the Port Arthur site, steam is a valuable product, thus different levels of steam are exported as separate products.

For the Tampa site, two product upgrading options were developed as well. In the first case, TSC, the F-T liquid is sent to a Syncrude Dewaxing Unit, where the only hydroprocessing work done is to lower the pour point of the highly waxy F-T liquid. The final product is a single syncrude stream. In the second case, THCU, the F-T liquid is sent to a hydrocracker, which produces hydrocracked naphtha and diesel. Acid gas generated from AGR is sent to a sulfuric acid (H_2SO_4) facility to produce H_2SO_4 for the fertilizer market. Since there is no market for steam at the Tampa site, all steam is routed to a condensing steam turbine for additional power generation.

The following was developed for each of the four cases: block flow diagrams, overall heat and material balances, preliminary sized equipment lists, and budgetary capital and operating costs including utility and catalyst/chemical summaries. Gasification, acid gas removal, and sulfur recovery process block information was provided by Texaco, F-T synthesis by Texaco and Rentech, and F-T product upgrading sections by Kellogg Brown & Root, Inc. (KBR). Praxair provided information for the air separation unit and commercial pipeline hydrogen (for F-T product upgrading). GE provided the power turbine and heat recovery steam generator (HRSG) information. The H_2SO_4 process information was provided by Texaco based on an earlier quote from a vendor. Proforma calculations were made to determine which case had the best economic indicators as measured by Discounted Cash Flow Return On Investment (DCFROI), Net Present Value (NPV), Present Worth Index (PWI), and Present Worth Payout (PWP). (Refer to page 37 for definitions of these terms.)

Case Descriptions:

Case **PARFW:** Port Arthur Refinery Finished Wax. The hydrocarbon liquids produced from the F-T reactor are upgraded into three different products – hydrotreated naphtha, diesel, and finished wax.

Case **PARHCU** Port Arthur Refinery Hydrocracking Unit. The hydrocarbon liquids produced from the F-T reactor are sent to a hydrocracker, which produces diesel and naphtha.

Case **TSC** Tampa Syncrude. The hydrocarbon liquids produced from the F-T reactor are dewaxed to produce synthetic crude.

Case **THCU** Tampa Hydrocracking Unit. The hydrocarbon liquids produced from the F-T reactor are sent to a hydrocracker, which produces diesel and naphtha.

	PARFW	**PARHCU**	**TSC**	**THCU**
Feed	Petroleum Coke	Petroleum Coke	Petroleum Coke	Petroleum Coke
Stand-by Fuel – GT	Natural Gas	Natural Gas	Diesel	Diesel
Auxiliary Fuel – HRSG	Natural Gas	Natural Gas & HCU Offgas	Natural Gas	Natural Gas & HCU Offgas
Products	Power Naphtha Diesel Finished Wax Sulfur 6307 kPa steam (900 psig steam) 4238 kPa steam (600 psig steam) 1136 kPa steam (150 psig steam)	Power Naphtha Diesel - Sulfur 6307 kPa steam (900 psig steam) 4238 kPa steam (600 psig steam) 1136 kPa steam (150 psig steam)	Power Syncrude - - Sulfuric Acid - - -	Power Naphtha Diesel - Sulfuric Acid - - -

Block flow diagrams for each case are shown in Figures 1 through 4.

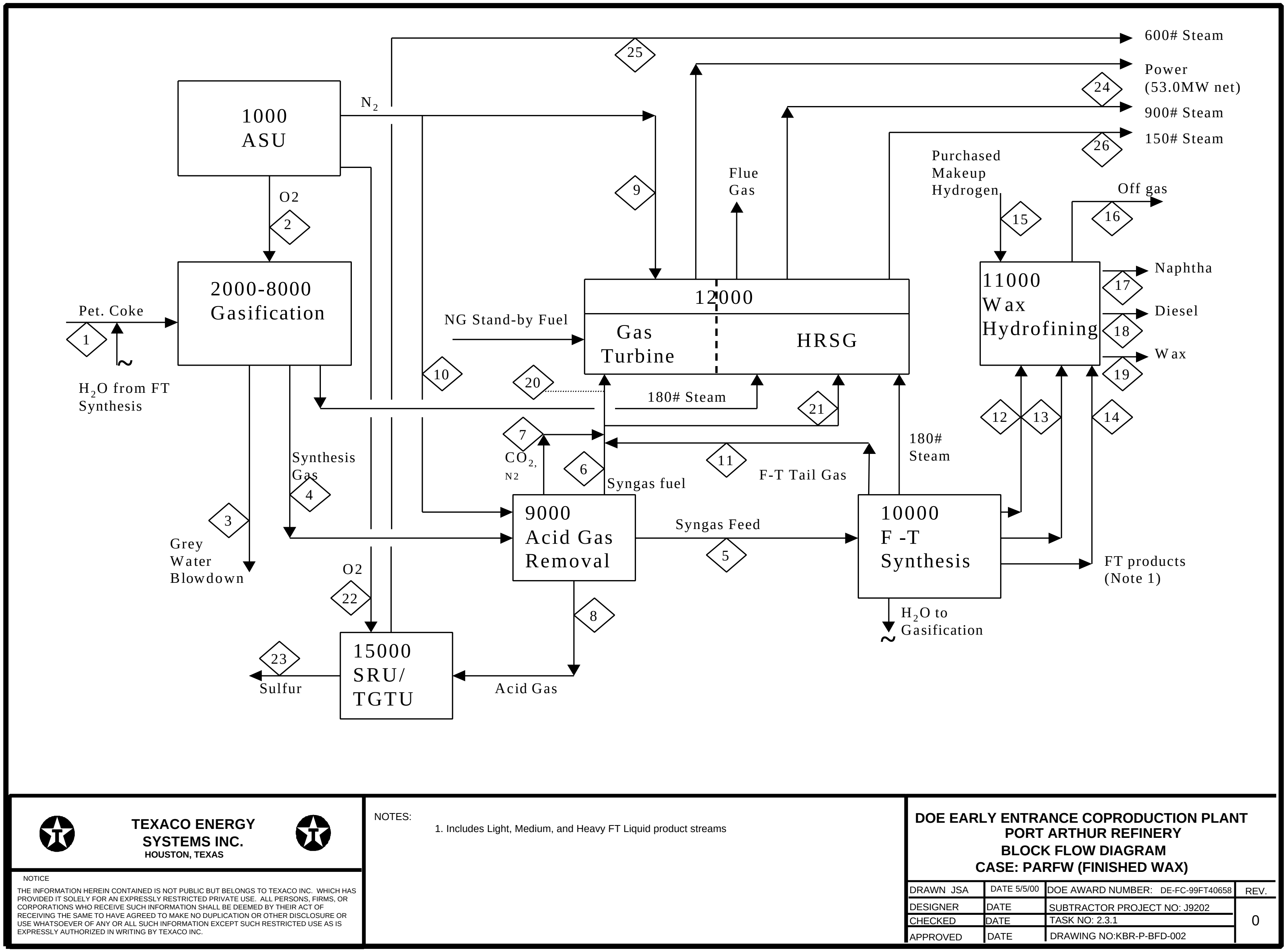


Figure 1 – PAR Finished Wax Case

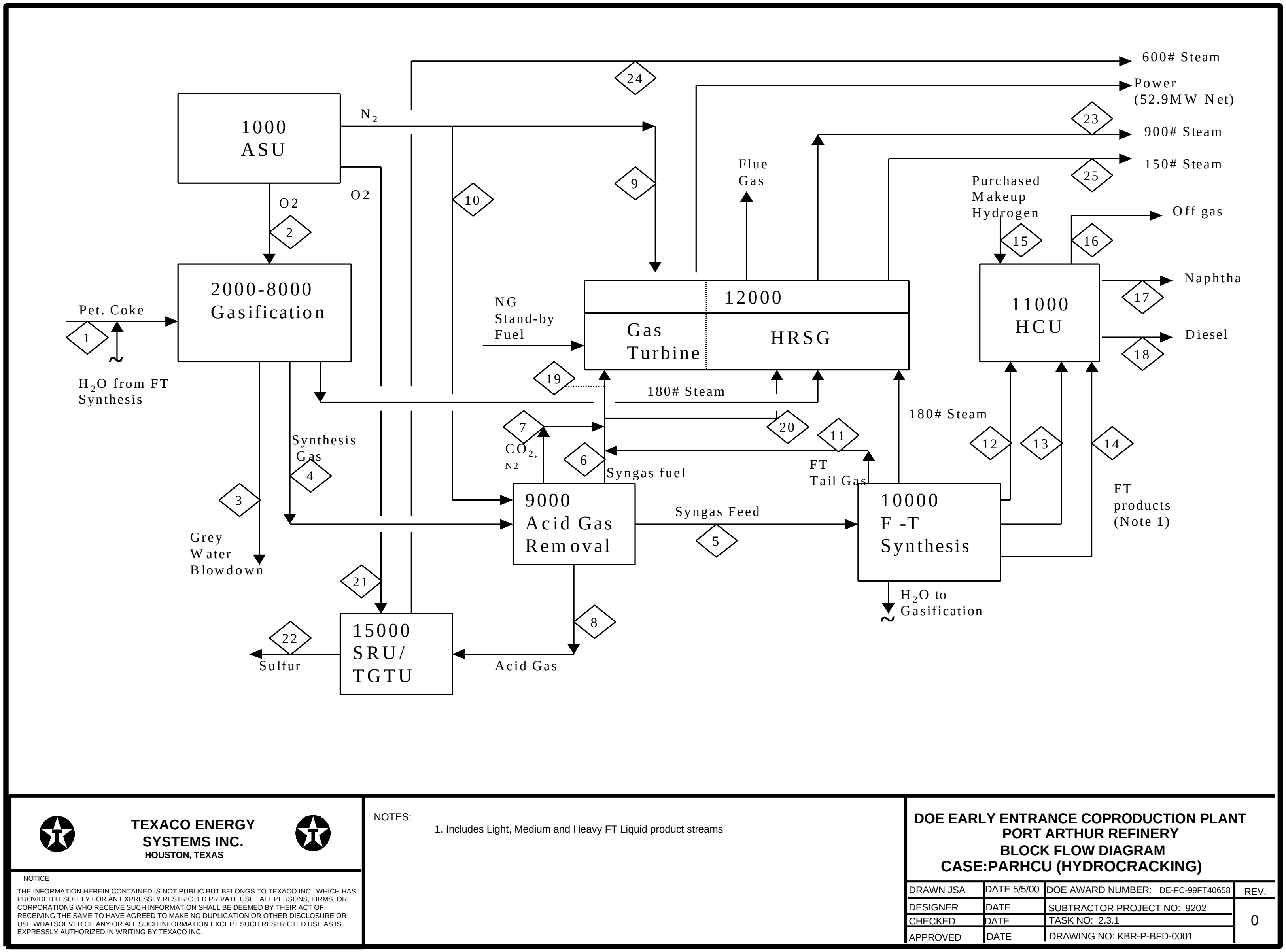


Figure 2 – PAR Hydrocracking Case

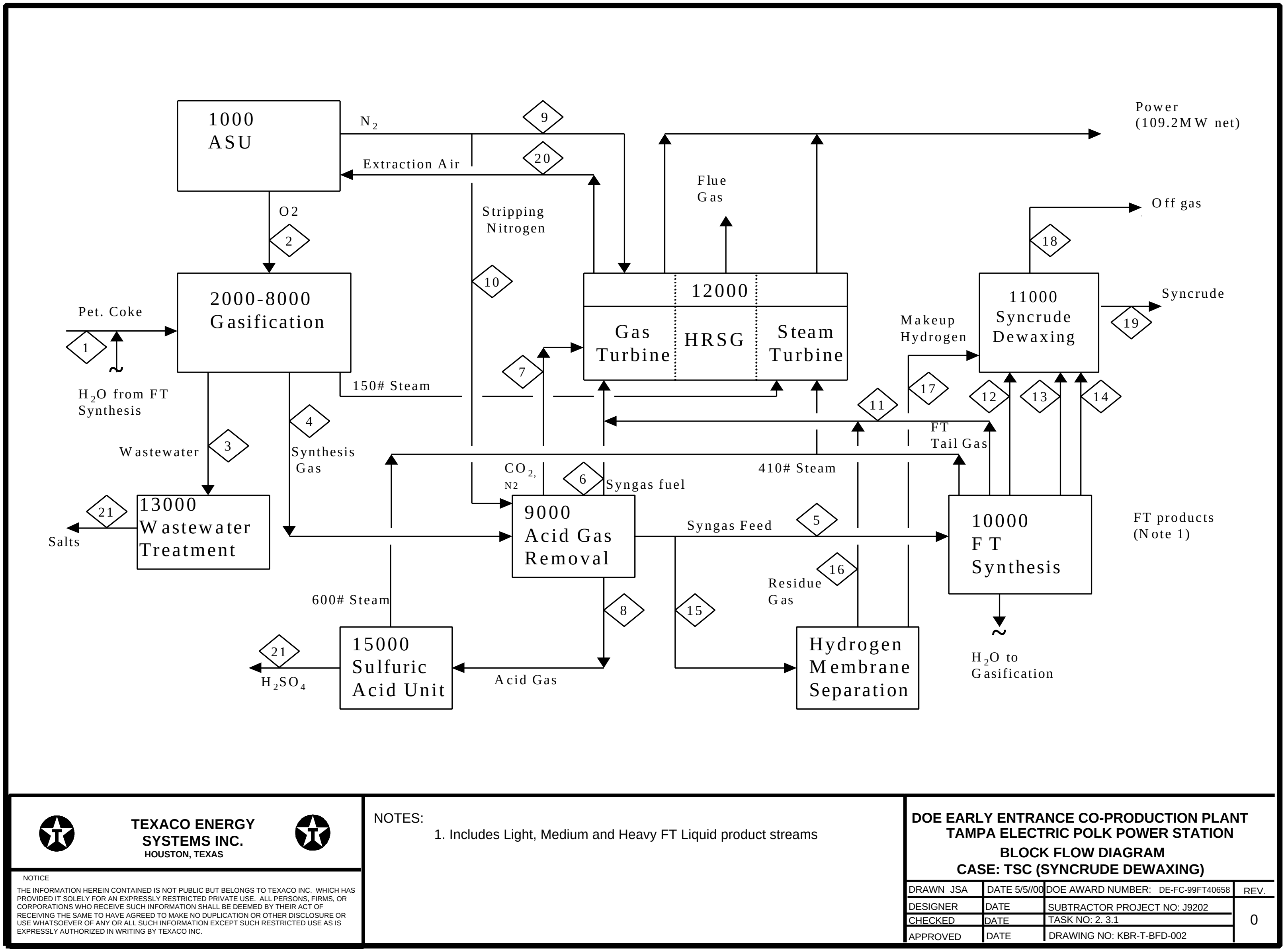
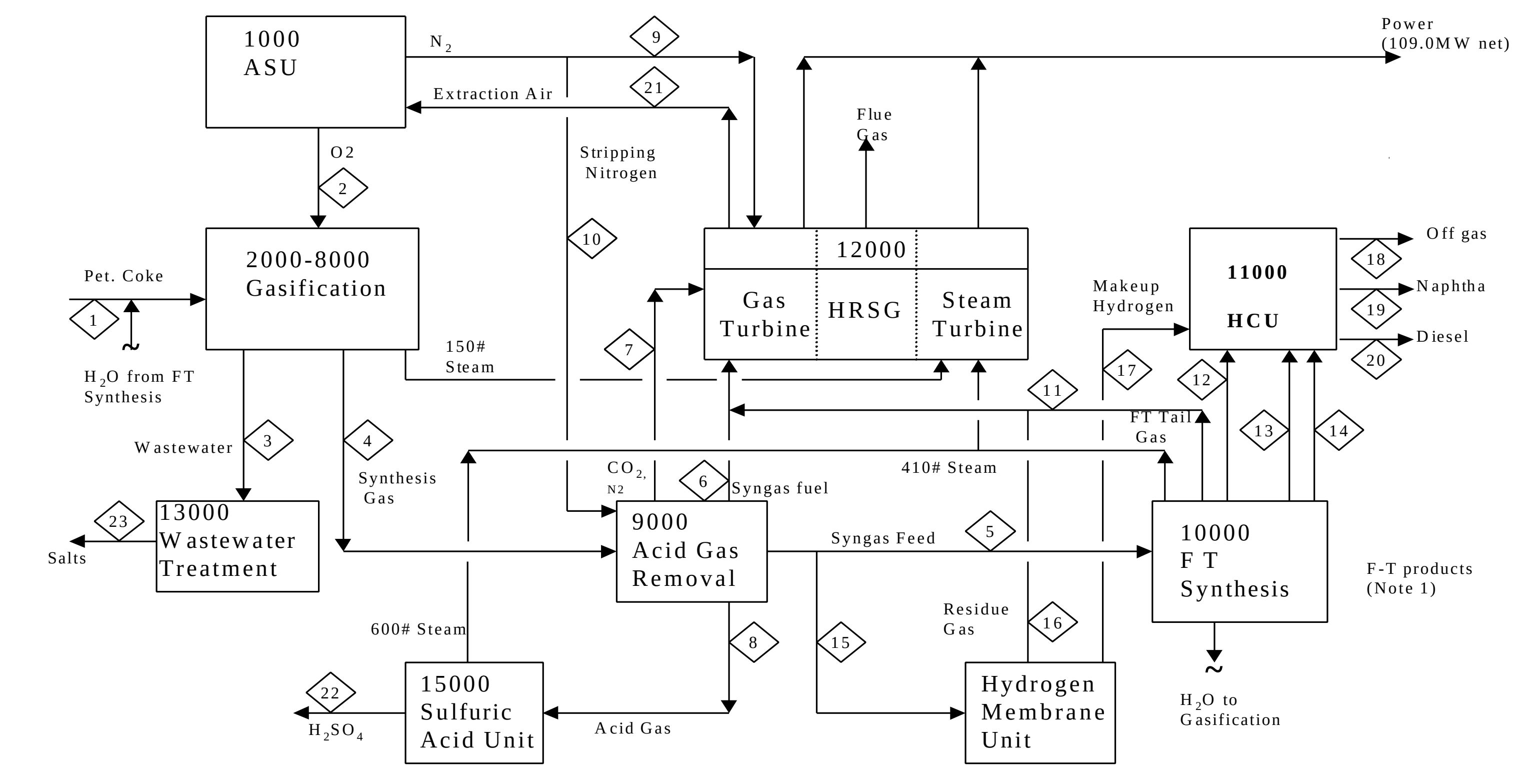


Figure 3 – Tampa Syncrude Case



TEXACO ENERGY SYSTEMS INC. HOUSTON, TEXAS	NOTES: 1. Includes Light, Medium and Heavy FT Liquid product streams	DOE EARLY ENTRANCE COPRODUCTION PLANT TAMPA ELECTRIC POLK POWER STATION BLOCK FLOW DIAGRAM CASE: THCU (HYDROCRACKING)

NOTICE

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DRAWN JSA	DATE 5/5/00	DOE AWARD NUMBER: DE-FC-99FT40658	REV.
DESIGNER	DATE	SUBTRACTOR PROJECT NO J9202:	0
CHECKED	DATE	TASK NO: 2.3.1	
APPROVED	DATE	DRAWING NO: KBR-T-BFD-001	

Figure 4 – Tampa Hydrocracking Case

Environmental Considerations (Task 2.2.4)

An environmental review was performed in support of Task 2.2, Alternatives and Options Assessment and Selection. The environmental differentiators between the Motiva Port Arthur Texas Refinery and Tampa Electric Company's Polk Station near Tampa, Florida are subtle and were not found to be substantive. The environmental review methodology consisted of a 5 step process: 1) site selection, 2) applicability of regulations, 3) identification of compliance issues, 4) establishing status of existing environmental control facilities, and 5) status of future regulatory frameworks. Steps 1-4 are passed through in a serial fashion and integrated with Step 5 into a master compliance plan view. This review process ensures that potential issues will be addressed in a comprehensive fashion.

If one assumes that the EECP site will be owned/managed by an independent entity and not fall under the same Standard Industry Code (SIC) as either of the host site's prime activities, the environmental requirements trend towards almost being independent of location. The applicability of federal and state regulations at either site are nearly the same, with some bias towards location in Texas because of their more pragmatic approach to air permitting, i.e., separation of New Source Review (NSR) requirements from the operating permit requirements imposed under Title V of the Clear Air Act Amendments of 1990. In Florida, simple cycle projects or those less than 75 MW are not required to go through the Florida Department of Environmental Protection (FDEP) Power Plant Siting Act (a 14-month minimum permitting process).

In regards to air issues, while the Port Arthur area has serious non-attainment status for ozone, it has attainment status for all other criteria pollutants and emission credits or sources of offset are available to enable construction permit approvals. A case in point is that the Best Available Control Technology (BACT) levels being applied by the FDEP for the EECP's major point source emissions (i.e., the gas turbine exhaust) would be comparable to expected requirements in Port Arthur, though credits would not be needed for permitting.

In regards to wastewater issues, a zero discharge approach was considered necessary at the Polk site, whereas discharges at Port Arthur would be reduced to a minimum and integrated into the refinery's current National Pollution Discharge Elimination System (NPDES) treatment system. Water supply is more adequate at the Port Arthur site than the Tampa site. Also, the need for a large cooling pond at the Polk site may be problematic due to increased capital expenditure and a long-term operating expense, related to groundwater monitoring and protection requirements to minimize potential leakage. In regards to solid waste management issues, the sites were considered fairly equal.

Finally in considering what a master compliance plan would encompass, the Port Arthur site has several advantages in its existing facility capacities (emission credits and wastewater treatment) which make it a more "flexible" location for considering engineering design options. Additionally, the Texas regulators have tended to review the broader picture of what a facility installation can mean. Thus, they may view a facility not just in terms of its emissions, but also what the facility can mean in terms of advancing technology relevant to the area's industrial base. The future regulatory frameworks impacting the Port Arthur site related to NO_x control, refinery Maximum Achievable Control Technology (MACT) and sulfur in fuels also create opportunities for integrating environmental emission reduction projects allowing for greater site benefits.

Cost Estimating Plan (Task 2.2.6)

Purpose and Scope
This project is to determine the feasibility of an Early Entrance Coproduction Plant (EECP) to produce electric power, fuels and/or chemicals from synthesis gas derived from petroleum coke.

This phase of the project is to determine the comparable capital cost for two cases at the Port Arthur and Tampa sites as a part of an economic evaluation to select a site for further study.

This estimate basis is written to describe the methodology that was used to develop the capital cost estimates for each of the cases and locations. Each estimate has a projected accuracy of +/-35% inclusive of contingency.

Approach
The cost estimating plan served as the basis for capital cost estimates that have been prepared. The objective was to provide related differential costs for the two locations being considered as one of the factors in selecting a site to proceed with a detailed study for the EECP concept. The capital cost estimates for the different cases at the two sites, along with feedstock and product pricing and operating cost estimates, will be used in economic proforma calculations to aid in site selection.

Estimate structure
Four (4) Capital Cost Estimates were prepared. Two (2) cases for the Port Arthur, Texas facility and two cases (2) for the Tampa, Florida facility. The two cases for the Port Arthur facility are PARFW and PARHCW. The two cases for the Tampa facility are TSC and THCU.

Case **PARFW:** Port Arthur Refinery Finished Wax. The hydrocarbon liquids produced from the F-T reactor are upgraded into three different products – hydrotreated naphtha, diesel, and finished wax.

Case **PARHCU** Port Arthur Refinery Hydrocracking Unit. The hydrocarbon liquids produced from the F-T reactor are sent to a hydrocracker, which produces diesel and naphtha.

Case **TSC** Tampa Syncrude. The hydrocarbon liquids produced from the F-T reactor are dewaxed to produce synthetic crude.

Case **THCU** Tampa Hydrocracking Unit. The hydrocarbon liquids produced from the F-T reactor are sent to a hydrocracker, which produces diesel and naphtha.

The estimates for each case and location were segregated into sections or areas. A Total Installed Cost (TIC) has been prepared for each area inclusive of materials, construction, engineering, owner's costs, etc. The accuracy of the TIC for each individual area may not be within the accuracy of the overall estimate of ±35%.

The areas into which the estimates have been segregated as applicable to each case are as follows.

- Air Separation Unit
- Gasification
- Acid Gas Removal
- Fischer-Tropsch Synthesis
- Fischer-Tropsch Product Upgrading
- GasTurbine / Heat Recovery Steam Generator / Steam Turbine
- Sulfur Recovery Unit / Tail Gas Treating Unit
- H_2SO_4 Plant
- Hydrogen Separation by Membrane Technology
- Offsites

Methodology
Equipment
Sized preliminary equipment lists were prepared for each area or section. Equipment lists specified Tag ID's, equipment descriptions, sizes, type, metallurgy, internals, design pressures and temperatures, special requirements, etc.

Texaco prepared the equipment list for the Gasifier section of the Gasification area. Texaco also prepared the equipment lists for the Acid Gas Removal, F-T Synthesis, and SRU/TGTU areas.

The H_2SO_4 section costs were based on a vendor quote received by Texaco.

KBR prepared the equipment lists for the HCU, HF, and SC sections of the Product Upgrading section. KBR also prepared the equipment lists for the hydrogen membrane separation unit and offsites areas. Texaco provided KBR with the tankage requirements for each case and location for inclusion on the offsites equipment list.

Praxair provided a "Turnkey" cost estimate for the Air Separation Unit.

GE provided a "Turnkey" cost estimate for the GT/HRSG/ST area.

Equipment costs were developed internally from the sized equipment lists by KBR using "Questimate" estimating software or factored from like equipment from similar projects. Exceptions to this are as noted below.

- Texaco provided a budget cost for the Cat/Wax Separation units in the F-T Synthesis area.

- KBR costed the gasifier vessel shell only. Texaco provided costs for gasifier ancillary items such as refractory, spare refractory, feed injectors, quench rings, thermocouples, control/safety shutdown system, etc.
- Praxair included equipment costs for the Air Separation Unit in their "Turnkey" cost for that area.
- GE included equipment costs for the GT/HRSG/ST in their "Turnkey" cost for that area.
- Texaco provided catalyst/chemical requirements and costs.

Bulk Materials
KBR factored the bulk material costs for the Process Areas (except the H_2S0_4, ASU and GT/HRSG/ST areas) using its own internal proprietary "Cap Cost" program. Adjustments to the bulk material costs calculated by "Cap Cost" were made for known special considerations such as the gasifier structure using historical information from similar projects.

Praxair and GE included the bulk material costs for ASU and GT/HRSG/ST in their "Turnkey" estimates for these areas respectively.

Offsites bulk materials were factored by KBR using historical data from similar projects adjusted as necessary for the specific size and scope of this project. Exceptions to this approach for offsites are as follows:

- Texaco defined power equipment requirements for each case and location.
- Number, type, and size of buildings were defined. Buildings were costed on a $ per square foot basis.

Material Related Costs
Costs for material related costs such as spares, freight, storage, vendor servicemen, etc. were estimated using historical percentages. Texaco provided sales tax rates to be used for each location. Praxair and GE included these costs in their "Turnkey" estimates for their respective units.

Construction
Construction man-hours for the process units were estimated using KBR's "Cap Cost" program. Adjustments to these man-hours were made for known specific considerations such as the gasifier structure, productivities at both location, etc. Offsites man-hours were factored using historical data from similar projects and adjusted based upon the scope, size, and location of this project.

An "all-in" construction cost per man-hour was developed and used to cost construction. The "all-in" rate and productivity adjustments for both locations were determined in conjunction with KBR's construction department using historical data from the two areas.

Praxair and GE included the construction costs for their respective units in their "Turnkey" estimates.

Home Office Services
Project management, engineering, and procurement man-hours for the process units were estimated using KBR's "Cap Cost" program. The man-hours for offsites work were factored using historical data from similar projects. These man-hours were costed using an average "all-in" rate for these services.

Praxair and GE included these costs in their "Turnkey" estimates for their respective units.

Owner’s Costs
Owner's costs were included as 5% of the TIC.

Contingency / Process Design Allowance
A Process Design Allowance has been included for each area to cover possible design problems due to unproven technology. A contingency has also been included to bring the overall accuracy of the estimate to +/-35%.

Cost Summary:

UNIT	**Case PARFW**	**Case PARHCU**	**Case TSC**	**Case THCU**
	Base $	Delta MM$	Delta MM$	Delta MM$
AIR SEPARATION UNIT	Base	0	(1.05)	(1.05)
GASIFICATION	Base	0	11.53	11.53
ACID GAS REMOVAL	Base	0	2.17	2.17
F-T SYNTHESIS	Base	0	1.06	1.06
F-T PRODUCT UPGRADING	Base	1.2	(3.76)	2.20
GT / HRSG / ST	Base	0	13.86	13.86
SRU / TGTU	Base	0	N/A	N/A
H_2SO_4	N/A	N/A	Base	0
H_2 MEMBRANE	N/A	N/A	Base	0.06
OFFSITES	Base	(.42)	0	3.2
TOTALS	**Base**	**.79**	**30.60**	**36.63**

The information was used for site selection only, i.e. the deltas between the estimates for individual process units were considered to be more significant than the absolute value of each component of the estimate or the overall estimate.

Operating and Maintenance Costs

Operating and maintenance costs, which included operations and maintenance labor, long-term service agreements, and catalyst/chemical costs, were estimated for each case. The table below summarizes the costs for the first full year of operation:

	Case	**Case**	**Case**	**Case**
	PARFW	**PARHCU**	**TSC**	**THCU**
	Base $	**Delta MM$**	**Delta MM$**	**Delta MM$**
O & M COSTS	**0**	**(0.11)**	**30.76**	**30.76**

Qualifications / Exclusions

The estimate was developed subject to the following qualifications, and exclusions:

Qualifications:

- Battery Limit Process units with limited offsites as agreed
- 1st Quarter 2000 Investment Cost - USGC Basis
- Nonbinding +/- 35% Order of Magnitude Cost
- Quotes on Air Separation, GT/HRSG/ST, and H_2SO_4 facility of equal or better quality
- Clear & level site and free of underground obstructions, minimal site prep
- Open shop, direct hire construction on standard 40-hour workweek
- Adequate local workforce
- Reasonable site access
- Worldwide purchase of materials and equipment
- Soil conditions assumed to require pilings at both sites (lack actual soil surveys)

Exclusions:

- Cost of land and roadways
- Additional Costs for demolition or relocation of and minimal tie-ins to existing facilities
- Spare Parts other than as agreed
- License Fees / Royalties for gasification, hydroprocessing, etc.
- Forward Escalation
- Client costs other than 5% of TIC as agreed
- Fees or Permits
- Site Survey, soils investigation, or site preparation
- Startup and Commissioning costs
- Cathodic protection
- Firewater loop around process unit
- Contingency for GE and Praxair scope of supply
- Owner’s contingency

Determine Commercial Viability of EECP for both Sites (Task 2.2.7)

To determine the economic viability of each site the following economic cases were developed to obtain the necessary data to run an economic analysis of each site:

Refinery Finished Wax Case: The hydrocarbon liquids produced from the F-T reactor were upgraded into three different products – hydrotreated naphtha & diesel, and finished wax at a refinery location. With the following economic parameters:

- Pet coke cost: $0/ton-no inflation
- Electrical power price-current basis: $27.50/MW-hr
- Steam value at natural gas equivalent: DOE/EIA 1998 report
- Operating, maintenance and capital costs: as previously reported
- F-T product prices: as reported in Task 5 of the 1Q2000 report

Refinery Hydrocracking Unit Case: The hydrocarbon liquids produced from the F-T reactor were processed through a Hydrocracker to produce diesel and naphtha at a refinery location. With the following economic parameters:

- Pet coke cost: $0/ton-no inflation
- Electrical power price-current basis: $27.50/MW-hr
- Steam value at natural gas equivalent: DOE/EIA 1998 report
- Operating, maintenance and capital costs: as previously reported
- F-T product prices: as reported in Task 5 of the 1Q2000 report.

Power Generation Syncrude Case: The hydrocarbon liquids produced from the F-T reactor were dewaxed to produce synthetic crude for sale from a power generation site. With the following economic parameters:

- Pet coke cost: $18/ton-with transportation and no inflation
- Electrical power price-current basis: $28/MW-hr
- Steam value at natural gas equivalent: DOE/EIA 1998 report
- Operating, maintenance and capital costs: as previously reported
- F-T product prices: as reported in Task 5 of the 1Q2000 report

Power Generation Hydrocracking Unit Case: The hydrocarbon liquids produced from the F-T reactor were sent to a Hydrocracker, which produced diesel and naphtha for internal consumption at the power generation facility. With the following economic parameters:

- Pet coke cost: $18/ton-with transportation and no inflation
- Electrical power price-current basis: $28/MW-hr
- Steam value at natural gas equivalent: DOE/EIA 1998 report
- Operating, maintenance and capital costs: as previously reported
- F-T product prices: as reported in Task 5 of the 1Q2000 report

Evaluate Two Sites and Select a Site (Task 2.2.8)

Shortly after award of the DOE Cooperative Agreement, efforts to identify potential EECP host sites began. A site selection team was formed to develop specific site criteria. This team was comprised of representatives from Texaco, Kellogg Brown & Root, General Electric, and Praxair. Contacts for potential host sites were also identified and asked to provide liaison with the team. The criteria developed, with relative weighting factors, are shown in Table 1.

After preliminary discussions with several possible sites, two were identified as having the potential to match up well with the necessary site criteria. One site, Motiva's Port Arthur, Texas Refinery was considered representative of a typical petroleum refinery application. The other, Tampa Electric Company's Polk Power Station near Tampa, Florida was representative of a typical power generation facility. The site selection team traveled to these two sites to gain a better understanding of the facilities, available infrastructure, and local conditions. Trips were made to Polk Power Station on December 2, 1999 and to the Port Arthur, Texas Refinery on December 7, 1999. These trips confirmed that both sites were suitable for further consideration as the host EECP site. Each facility satisfied many of the criteria considered important to the EECP concept, such as synergy with existing infrastructure, good construction capabilities and site access, similar environmental requirements, good community relations, etc. Further, both sites exhibited a strong commitment to the EECP concept and were willing to provide the information necessary to the consortium for the conceptual process engineering studies that were to follow.

Table 1 – Site Selection Criteria

Site Characteristics (5%)
- Size (20%)
- Elevation (10%)
- Geometry (15%)
- Building and Zoning (10%)
- Flood potential (15%)
- Soil data (10%)
- Seismic Zone (10%)
- Climatic conditions (10%)
Transportation access (5%)
- River Barges (15%)
- Oceangoing Barges (15%)
- Railroad (20%)
- Highway (20%)
- Pipeline (20%)
-Airport (10%)
Pollution Control Regulations (8%)
- Air Emissions (20%)
- Liquid Effluents (20%)
- Water Discharge (20%)
- Solid Waste Disposal (20%)
- Hazardous Waste, Toxic Emissions (20%)
Conservation, Community Factors (6%)
- Terrestrial & Aquatic Ecology (20%)
*** -- Wetlands
*** -- Endangered species
- Obstructions (20%)
*** -- Historical Importance
*** -- Archeological Importance
-- Corridor Effects
- Local Laws (Noise levels, etc.) (20%)
- Proximity to neighborhoods (20%)
- Proximity to existing reservoir (20%)
Market Factors (28%)
A. Product Values & Marketability (Revenue) (35%)
-- Electricity (25%)
-- Steam (25%)
-- F/T Liquid Fuels (25%)
-- Syngas, Hydrogen (15%)
-- Oxygen (10%)
B. Existing Infrastructure to supply: (35%)
-- Pet coke or coal (60%)
-- Hydrogen (5%)
-- Oxygen (5%)

-- Nitrogen (2%)
-- Treated (demineralized) water (3%)
-- Cooling water (5%)
-- Existing facilities (bldgs, warehouse, control room, lab, maintenance shops, storage) (5%)
-- Existing process facilities (5%)
-- Existing fire protection, medical (5%)
-- Existing utilities availability (5%)
C. Existing Infrastructure to export: (30%)
-- Electricity (40%)
-- Steam (10%)
-- F/T Liquid Fuels (15%)
-- Syngas, Hydrogen (25%)
-- Oxygen (10%)
Economic Factors (28%)
A. Capital Cost Factors (50%)
- Land (5%)
- Product pipelines (5%)
- Site Preparation (5%)
-- Foundations
-- Grading
-- Drainage & Flood Control
-- Dredging
- Transportation (rail, road, barges) Access (5%)
- Electric Power Connection (5%)
- Water Supply Treatment (5%)
- Liquid Effluent Disposal (5%)
- Site obstructions removal/relocation (10%)
- Materials Handling/Constructibility (15%)
-Skilled construction labor availability & cost (40%)
B. Operating Cost Factors (50%)
- Raw materials (feedstock, NG, H2) (50%)
- Utilities (power, cooling water, steam, BFW, condensate) (10%)
- Products distribution (5%)
- Raw Water, catalyst, chemicals, other supplies (5%)
- Labor – operations, maintenance (15%)
- Transportation access maintenance (5%)
- Taxes – property, etc. (5%)
- Tax Incentives (5%)
***** Site Commitment to Project (20%)**

* Rating: Site Disqualified (0), Poor (1), Fair (2), Average (3), Good (4), Preferred (5)
** Value = (Weight)*(Rating)
******* Possible site elimination category.

The criteria is described below.

Synergy with Existing Infrastructure

The team gave high importance to the possibility of sharing infrastructure, which included facilities and personnel, with the host facility. Infrastructure was divided into two categories: (1) infrastructure to supply items such as feedstock, hydrogen, oxygen, nitrogen, treated water, cooling water, buildings, warehouse, control room, laboratory, maintenance shops, fire protection, medical facilities, utilities, and (2) infrastructure to export products such as electricity, steam, F-T liquid products, syngas, hydrogen, oxygen, etc. The host site's ability to provide infrastructure was considered vital to the success of the EECP concept.

Construction Requirements

Construction requirements were addressed by the team and included consideration for skilled labor availability and cost, site clearance/preparation, drainage and flood control, material handling costs, as well as transportation access. These items would be reflected in the overall facility capital cost estimate.

Site Access

The team considered feedstock and product shipping requirements as well as site accessibility for delivery of construction equipment and materials. This included consideration of barge, rail, highway, pipeline, and airport accessibility.

Environmental Requirements

Environmental engineers considered Federal, state, and local environmental regulations for the potential sites. Air emissions, liquid effluents, water discharge, and solid waste disposal were considered. Refer to Task 2.2.4 for a description of the environmental considerations.

Community

The team considered the communities associated with the potential sites including the proximity and type of adjacent neighborhoods, zoning requirements, and the host site's relationship with the community. The team also considered the environmental impact on the community in regard to potential wetlands, endangered species issues, historical or archeological significant areas and noise levels.

Geotechnic and Topographic Investigation

Consideration for the site included items such as the space available, geometry, elevation, zoning, flood potential, geotechnical and topographical data, seismic zone, and climatic data.

Economic Factors

Another area considered vital to the success of the concept was capital and operating costs of the EECP. For capital costs, the team made judgements regarding the cost of land, site preparation work, electric power connection, water supply treatment, materials handling, skilled labor availability and cost, and other factors which would ultimately be reflected in total installed cost estimates. Operating costs were also important and consideration was given to feedstock costs, utilities, catalyst/chemicals, product distribution, operating and maintenance labor, taxes, etc.

Site commitment to Project
The host site's commitment to the EECP project, by both management and operating personnel, were also judged by the site selection team as vital to successful implementation of the concept.

Design Consideration For Advanced Subsystems (Task 2.4)

The EECP concept contains four major technology elements: the oxygen-based gasifier, the F-T Synthesis Unit, the power plant, and the F-T products upgrading section, which have not been previously integrated. The F-T Synthesis Unit, operation of the GE combustion turbine on low-Btu feed gas, and F-T products upgrading requires more development. The following describes the technical approach for the further development of these three subsystems.

Fischer-Tropsch Synthesis

The Fischer-Tropsch Synthesis subsystem is the one section of the EECP concept where considerable technical and economic developments have occurred recently and are constantly being evaluated for further improvement. The Fischer-Tropsch synthesis section is based on Rentech, Inc. technology. During the concept definition of the Phase I of the EECP, the technical team will make assumptions for the design of the Fischer-Tropsch synthesis section based on Rentech's past work. At the end of Phase I of the EECP, the area that requires further development will be identified for investigation in Phase II. The following describes the technical design consideration for the Fischer-Tropsch synthesis subsystem.

- REACTOR CONFIGURATION – There are four types of Fischer-Tropsch (F-T) reactors which are being used commercially:

  1) tubular fixed-bed reactors (TFBR) by SASOL and Royal Dutch Shell
  2) entrained-bed reactors (the SYNTHOL reactors) at SASOL
  3) fixed-fluidized-bed reactors (FFBR) at SASOL
  4) slurry bubble column reactor (SBCR) at SASOL

The SYNTHOL and FFBR reactors can be used only for F-T reactions that do not produce heavy wax since fluidization becomes impaired when the catalyst particles become laden with wax.

During the past several years, considerable development work has been carried out by the Department of Energy and in the private sector on the fourth type of reactor– the slurry bubble column reactor (SBCR). Herbert Koelbel pioneered development of the SBCR in Germany in the early 1950's. Professor Koelbel recognized that efficient coal gasifiers of the future would produce a synthesis gas having a low hydrogen to carbon monoxide (H_2:COmailto:H@CO) ratio, i.e. < 1. This synthesis gas would require the use of a catalyst possessing some water-gas-shift activity to supply the H_2:CO ratio necessary for the F-T reaction, i.e. about 2:1. An iron-based catalyst was selected by Professor Koelbel to operate in low H_2:CO ratio synthesis gas environments. The SBCR was also ideal for handling any carbon formation on the catalyst surface, since the carbon could "sluff" off into the slurry.

Studies comparing the slurry reactor against the tubular fixed-bed reactor have shown several advantages for the SBCR. Due to the relatively high slurry side heat transfer coefficient and good axial and radial mixing, the SBCR operates isothermally thereby eliminating hot spots and coking of the catalyst. Both the SBCR and the TFBR are configured like large shell and tube heat exchangers. But the reaction takes place in the slurry on the shell side in the SBCR whereas the reaction takes place within tubes in the TFBR. Therefore the SBCR offers higher reactor capacity, superior heat removal, and easier catalyst addition and removal.

In the concept definition of Phase I, Texaco has selected the slurry bubble column reactor (SBCR) reactor configuration and the F-T Synthesis process as developed by Rentech. Rentech has been working on slurry bubble column reactor technology using a precipitated iron catalyst since 1982, primarily for natural gas applications. The design of Rentech's 6-foot diameter SBCR used at their Synhytech demonstration project was assisted by SBCR experts Y. T. Shah, W. D. Deckwer, and H. Koelbel.

- CATALYST – Feed gas composition and the desired products must be taken into account when selecting a catalyst. Depending on the H_2:CO ratio of the feed, the F-T catalyst will need to have water-gas-shift (WGS) activity. Cobalt-based catalysts have low activity for the WGS reaction and would therefore be optimal for H_2:CO ratios around 2. Iron-based catalysts, on the other hand, have higher WGS activity and can be used for H_2:CO ratios between 0.5 to 2. The addition of promoters will also have an impact on the WGS activity of the catalyst.

  The desired product slate must also be considered when choosing a catalyst. Low-alpha catalysts tend to make lighter products, while catalysts with high alpha will make heavier products.

  This EECP Project is investigating the integration of the gasification of hydrocarbon solids with Fischer-Tropsch to produce transportation fuels and with a gas turbine for generation of electric power and steam. In the case of coal or coke gasification, the H_2:CO ratio of synthesis gas without any shift section is approximately 0.5 to 0.8; therefore, an iron-based catalyst would be the preferred synthesis catalyst. The optimum H_2:CO ratio study has shown that for the Rentech iron-based F-T catalyst, a low H_2:CO ratio is more economical than adjusting the feed gas to a higher H_2:CO ratio. Higher yields of middle distillates and/or finished wax are expected from upgrading the heavier material that is characteristic of high alpha catalyst. Therefore high alpha catalyst is preferred.

- CATALYST ACTIVATION – The fresh catalyst requires activation by reduction of iron oxide to iron carbide. The reduction occurs at conditions different from the F-T operating conditions. The initial load of fresh catalyst can be activated in the F-T reaction vessel. Periodic addition of fresh catalyst is provided to make up for the losses due to physical attrition and removal in the catalyst/wax separation system and the losses in catalyst activity. The periodic addition of fresh catalyst is provided through a separate catalyst activation system. Contacting the catalyst with reducing gas (gasification synthesis gas or modified synthesis gas composition) activates the catalyst under controlled conditions of time, temperature, pressure, and composition. A careful evaluation of catalyst deactivation rate, catalyst addition rate, and catalyst withdrawal rate will define the catalyst handling section of the Fischer Tropsch synthesis section.

- REACTOR OPERATING CONDITIONS – Reactor temperature and pressure have an impact on the hydrocarbon product selectivity. Although the catalyst activity increases with the reaction temperature, the selectivity will shift towards higher methane and light hydrocarbon production. The harsher conditions will also adversely affect the life of the catalyst. Lowering the reactor temperature, on the other hand, will tend to favor the longer paraffin chains and will be less severe on the catalyst. Pressure has a less pronounced effect on selectivity, but has a large impact on reactor design. At high pressures, the flow through the reactor can be high due to the high density of gases in the reactor. The required space velocity to attain the desired CO conversion forces the height of the reactor to be large at high pressures due to the higher mass flow rate. The higher reactor pressure is also required to route the F-T tail gas to the combustion chamber of gas turbine without the use of mechanical compression. The optimal reactor operating condition will be confirmed further in the Phase II of this EECP. F-T tail gas recycle also has an impact on the hydrocarbon selectivity and productivity. Since for the coproduction plant, F-T tail gas will be sent to the gas turbine to produce additional electricity, the recycle of F-T tail gas to F-T reactor will not be considered.

- CATALYST/WAX SEPARATION – When the SBCR is operated to produce heavier hydrocarbon products, the quantity of slurry will increase with time. Therefore it is necessary to remove wax continually to keep the slurry height constant without removing catalyst from the reactor. This is a critical issue that must be resolved. Currently, various separation methods are being evaluated outside DOE EECP Project funding. Prior to the detailed design and construction of the EECP Project, sufficient work will have identified an effective means to separate catalyst and wax. Texaco will demonstrate the effectiveness of the separation on a stand-alone system, and a small SBCR outside of DOE funding. Texaco will also privately fund construction and testing of a demonstration separator for catalyst/wax separation on the DOE's Alternate Fuels Development Unit (AFDU) at LaPorte, Texas scheduled for 4th quarter 2000.

- SPACE VELOCITY – Space velocity, defined as the flow rate of synthesis gas at normal conditions per unit weight of catalyst, is an important reactor design consideration. Conversion is inversely related to space velocities, being higher at lower space velocities, and lower at high space velocities. Although there is a range of space velocities that result in conversions in an acceptable range, the actual correlation between space velocity and conversion is dependent on reactor type, catalyst properties, and scale. The effect of space velocity on conversion with the Rentech catalyst will be determined in work outside of the scope of the EECP, and confirmed in Phase II.

- SUPERFICIAL VAPOR VELOCITY – Superficial vapor velocity is defined as the actual flow rate of syngas into the reactor divided by the effective cross sectional area of the reactor. In effect it is the speed at which a unit volume of feed gas moves up the column, and consequently it has a large effect on conversion and product yields. Generally a high superficial vapor velocity is desired because the rate of mass transfer from the gas phase to the liquid phase is higher for larger superficial vapor velocities. However given its relationship to space velocity, the superficial vapor velocity must be balanced with space velocity to achieve optimal conversion and yield for a given reactor size. The relationship between space velocity, superficial vapor velocity and reactor yields will be investigated in work outside the scope of the EECP project, and confirmed in Phase II of the EECP project.

- EFFECT OF FEED IMPURITIES – The main feed impurity of concern is sulfur. Sulfur deactivates the iron catalyst, and reduces conversion and product yields. Essentially sulfur impurities in the feed gas will increase the catalyst replacement rate. The effect of different sulfur concentrations on conversion and yield will be studied in autoclave reactor tests outside the scope of the EECP project. These results will be used in conjunction with the design of the AGR to determine the required catalyst replacement rate.

- F-T TAIL GAS RECYCLE – The tail gas composition of the Fischer-Tropsch synthesis is made up primarily of unconverted synthesis gas and CO_2, and smaller quantities of light hydrocarbons. Recycle of the F-T tail gas may be especially advantageous where there is no viable method to dispose of the tail gas and maximum hydrocarbon liquid production is desired. The tail gas may be recycled as feed to either the Fischer-Tropsch Synthesis unit or the syngas generation unit. For the EECP, F-T tail gas will be routed to the gas turbine as fuel for additional electricity production, and recycle will not be considered.

Gas Turbine

The GE gas turbine is configured with the same hardware as if the machine was used with natural gas fuel except for the combustion system. A multi-nozzle diffusion combustor is utilized, with NO_x generation controlled by injecting low-purity nitrogen from the ASU into the reaction zone. The combustor will also be modified to provide the capability for power augmentation beyond that obtained as a result of using diluents for NO_x control .

The combustion system will need to be configured for operation on start up fuel, gasification clean syngas, and various mixtures of clean syngas, carbon dioxide from the AGR unit, and the F-T synthesis tail gas. Purge air from the compressor discharge will be used to purge the unused fuel nozzle opening when operating on a single fuel. The combustion system design including appropriate fuel nozzles will require new design testing and validation.

The oxygen and nitrogen product requirements defined for the project's air separation unit will dictate how much nitrogen is available for injection. The gas turbine and fuel characteristics will determine what quantities of nitrogen are required to meet NO_X targets and power output requirements. The compressor operating pressure ratio limit must not be exceeded at any injection condition. The maximum amount of diluent that can be added is limited by the minimum equivalent heating value of the resultant fuel gas/diluent mixture, staying within the compressor operating range, and maintaining rated component life within the turbine hot gas path.

- NITROGEN INJECTION – Nitrogen is introduced into the head-end of the combustor and injected into the combustion reaction zone. Additional nitrogen required for power augmentation will be added downstream into the post-combustion zone.

- AIR EXTRACTION – For the Tampa site case, the air compressors for the combustion turbine and ASU are integrated so that air extracted for the turbine compressor supplies the ASU with compressed air. The use of air for cooling the combustion components results in some additional air pressure drop relative to compressor discharge pressure and also causes the extracted air temperature to be higher than compressor discharge conditions. The machine air extraction is limited to a maximum allowable value, while still providing adequate cooling.

- START-UP FUELS – An additional fuel (natural gas for Port Arthur site and distillate oil for Tampa Electric site) is required for starting up the gas turbine and can be utilized as a backup fuel. This results in safer operation during start-up, as the turbine is designed for normal operation on fuels containing significant quantities of hydrogen.

- MATERIAL ISSUES – Syngas is cleaned prior to combustion to insure that its sulfur content is less than 50 ppm. Similarly, it is essential to operate within the limitations of the gas turbine fuel specification GEI-41040 for any particulate (size ≤10 microns and quantity ≤5 ppmvw) present in the syngas.

  The combustion system will be designed to accommodate syngas flame which burns in very close proximity to the fuel nozzle compared to traditional natural gas or oil burning units.

- SAFETY ISSUES – It is critically important that the combustion system hardware be leak-free to prevent unintended exposure of the syngas to facility operators during normal turbine operation.

  There also exists appropriate measures for the plant maintenance personnel during turbine shut down to protect against any residual syngas which may linger in confined spaces of the turbine housing and assembly. Since the syngas possesses wide flammability levels, if the safety system is not designed properly, then only a minor ignition source would pose potential risk to maintenance personnel during a unit shut down.

Another safety concern that has been observed at some field locations, is the possible accumulation of toxic mineral and metal oxides that are potentially harmful to human health. These deposits have been found on combustion fuel nozzles and turbine section 1st stage nozzles. Exposure to these deposits could occur during turbine maintenance events. The source of these contaminants is believed to be from off-spec syngas.

- LOW PRESSURE DROP FUEL SYSTEM – This gas turbine application may require a "low pressure drop fuel system", also referred to as the "low delta P" fuel system. This system uses oversized fuel system components to minimize pressure drops and uses special control algorithms to further minimize fuel system pressure drops.
- SYNGAS MANIFOLD/COMPRESSOR DISCHARGE BACKFLOW PROTECTION – During normal gas fuel system operation, a positive pressure ratio is maintained across the gas fuel nozzle in the combustor. For gas turbines with high hydrogen fuel content, it is required that protective algorithms be included in the control system to prevent possible backflow from occurring. Avoidance of reverse flow through the nozzle into a manifold containing high hydrogen fuel will prevent an unplanned ignition event in the manifold and fuel gas piping upstream of the nozzle.
- FUEL TRANSFERS – As discussed above, gas turbines require start-up on a non-hydrogen "standard" fuel such as natural gas or distillate fuel oil. Based on this requirement, the gas turbines will be equipped with a "dual fuel' control system which will allow operation at base load on either or both fuel streams. In addition to start-up, the standard back-up fuel is typically used for shutdowns and during trips. Transfers to and from syngas typically occur above 20% gas turbine load and normally can be done (non-emergency) as fast as 30 seconds for standard fuel control and 2 to 5 minutes for the low pressure drop fuel control system.
- FUEL GAS LINE PURGING AND BUFFERING – Gas turbine fuels with greater than 5% hydrogen content, on a percent volume basis, require an inert gas purge/blocking system. Due to the lower auto ignition temperatures of hydrogen, it is necessary to separate the gas fuel containing hydrogen and ignition sources within the gas fuel control/delivery system.

  A "High Hydrogen Fuel Purge System" will be provided to maintain separation of air and fuel within the fuel piping system, regardless of the temperature of the fuel. Nitrogen is used to displace air/fuel from piping prior to and after passing high hydrogen fuel. It is also used to provide a "block" in cavities that separate fuel and hot air.
- HAZARDOUS GAS PROTECTION – The gas turbine operating procedures include additional hazardous gas monitoring and protection. The hazardous gas detection

system senses combustible gases within the turbine and applicable accessory compartments. Alarms are annunciated with detection of a combustible gas so that appropriate operator action can be taken. The fire protection system will release carbon dioxide and initiate a gas turbine trip with the detection of fire within the turbine and appropriate accessory compartments.

- HIGH HYDROGEN FUEL PROTECTION – Due to the close proximity of gas fuel piping to hot surfaces in the turbine and gas fuel compartments, any small localized leak of high hydrogen fuel which could easily be ignited, should be detected. Such a leak, turned into a flame, may be small enough so as not to set off the heat detectors of the fire protection system. However, it may not be detected by the hazardous gas detectors, since the hydrogen is consumed in the flame. Therefore, special ultraviolet (UV) detectors will be supplied to detect such a leak.

- SYNGAS FUEL MODULE – A separate fuel module will be supplied to control the flow of syngas to the combustion system. The volume flow of syngas is considerably higher than natural gas and requires larger piping and valves than what is typically required for natural gas only fuel systems. The natural gas fuel delivery system used for start-up, back-up, and co-fired operation will be part of the gas turbine accessory base. The syngas fuel module consists of an enclosed skid containing the syngas auxiliary stop, stop/ratio, and fuel control valves, an air purge system, a nitrogen purge/buffer system, a fuel gas strainer, and explosion proofing. A separate syngas flow meter will be supplied for installation in the customer's syngas piping outside the skid.

- ENCLOSURE – The skid enclosure will require all-weather protective housings with Class I, Group B, Division 2 hazardous area classification. The enclosure shall allow access to equipment for routine inspections and maintenance and will be lighted and ventilated. Hot surfaces within the enclosure are also tagged for personnel protection.

- AIR PURGE – An air purge system will be utilized to prevent combustible products from backing up through the fuel nozzle openings when that fuel is not in operation. This system utilizes compressor discharge air and contains the necessary piping and valving to deliver the air to the fuel nozzle.

- NITROGEN INJECTION MODULE – A separate module will be needed for the nitrogen injection control valve. This skid will include the injection stop and control valves as well as the necessary vents and drains. The module will be enclosed with adequate lighting, ventilation, and personnel protection, if necessary. Separate flow meters will be supplied for installation in the nitrogen and steam piping outside the skid.

- AIR EXTRACTION SKID – In cases using air extraction, an air extraction manifold in the turbine compartment collects air from each combustion can casing. The air is routed through pipes to a single manifold, which interconnects to the off base air extraction compartment. The air extraction compartment contains the system components, which provide for control of the air extraction flow and protection of the gas turbine compressor.

- COMBUSTION CAN/PIPING – Individual combustion cans contain a casing air extraction port which is connected to the air extraction manifold via a flexible pipe (pigtail). Extraction air is therefore increased in temperature and lower in pressure than actual compressor discharge air. The pigtails and piping within the turbine compartment are sized to minimize pressure drop. Often, the piping is large enough to require that the manifold be mounted off the gas turbine base, therefore increasing the size of the turbine compartment. A single flange located on the side of the turbine compartment allows for connection to the air extraction compartment.
- TURBINE ENCLOSURE MODIFICATIONS – The large size of the syngas piping, diluent injection piping, and air extraction piping will require special enclosure provisions. The gas turbine enclosures will include special provisions to provide enough room for the larger piping manifold(s) and flex pigtails. The turbine enclosure will have Class I, Group D, Division 2 hazardous area classification in the turbine, accessory, and gas compartments.

Fischer-Tropsch Product Upgrading

The upgrading design considerations deal with ways to upgrade, on site, the three highly paraffinic product streams generated by the Fischer-Tropsch (F-T) synthesis process plant. The available technologies vary from a simple stabilization column to a complete finished product upgrading plant. If simple stabilization is used, pipeline quality syncrude can be produced for shipment to an existing plant, capable of making the desired products such as fuels, lubricants, waxes, and chemicals. The alternative is to build a finished products facility to produce one or more products at the site of the F-T facility. Design considerations for a typical commercial catalytic (such as hydrocracking, hydrotreating, hydroisomerization, etc.) and non-catalytic (such as stabilization) upgrading facility will be examined.

Commercial catalytic hydroprocessing of the three highly paraffinic product streams generated by the F-T synthesis is one set of technologies being considered for the Upgrading Plant. Hydrocracking, hydroisomerization, and hydrofinishing are well proven licensed hydroprocessing technologies. Commercial units are available to upgrade waxy feedstocks (from crude oil) to distillate fuels, lubricant base oils, and waxes. These technologies are also well suited to process F-T synthesis liquids, based on patent literature and the experience of various F-T plants and F-T pilot operation. Open literature test engine results suggest that hydroprocessing is an ideal way to produce a premium “environmental friendly” diesel fuel and/or other specialty products such as lubricant base oils, and wax. Texaco plans to select licensors with extensive experience to define the process design conditions for F-T product upgrading. These licensors will then confirm the hydrogen consumption requirements, desired product yield slates, product qualities, operating parameters, and if required, perform additional testing during Phase II.

Texaco, together with licensors, will investigate and address the following upgrader design concerns during Phase I:

- UPGRADER FEED CHARACTERIZATION – The light, medium, and heavy liquid products streams from F-T synthesis need to be properly characterized in order to provide accurate input for a pipeline quality stabilized syncrude, a non-catalytic thermal cracking furnace design or catalytic reactor design, hydrogen consumption, product yield slate estimates, and product qualities. This characterization also includes the paraffins, entrained syngas impurities (i.e. CO and CO_2), and byproducts of olefins and oxygenates, so as to properly design the upgrading plant. Estimates of F-T liquid stream gravities, boiling point temperatures, viscosities, distillate octane and cetane numbers, wax oil content, wax viscosities, wax melt points, pour wax points, and other key feed quality information also need to be confirmed.

- HIGH F-T CATALYST METALS IN UPGRADER FEED – To reduce the technical risk to the Upgrader, it was assumed that there is no more than 10 ppmw F-T catalyst metals (primarily iron) in the heavy F-T liquid (wax) stream. The economics for recovery and recycled use of the F-T catalyst mandates that the metals be removed within the F-T synthesis process to reduce losses from 200 to 10 ppmw in the F-T liquid product streams. Entrained F-T catalyst solid particles raise design concerns for fouling of catalyst beds or plugging of cracking furnace tubes, subsequent reactor catalyst bed pressure drop problems and heater tube failures, followed by reduced upgrader feed throughput, and possible contamination of finished products for outside sales.

- HIGH CO AND CO_2 IN UPGRADER FEED – There is a concern for the degree and impact of the build-up of syngas impurities in the hydrogen recycle gas loop common to typical commercial catalytic upgrading plants. High CO and CO_2 amounts may be detrimental to the reactor catalyst performance and life (i.e. Hydroisomerization) and these impurities need to be either stripped from the feed and/or adequately purged from the hydrogen recycle gas loop. The presence of CO in the recycle gas loop could potentially favor the formation of carbonyls which may raise safety design concerns associated with potential exposure during upgrader maintenance turnarounds. Disposal of the upgrader vent offgas streams could present challenges if CO was present.

- PRODUCT PROCESSING CONFIGURATION – F-T synthesis utilizing an iron catalyst produces olefins and oxygenates which tend to concentrate in the naphtha and diesel boiling ranges of the light and medium F-T liquid product streams. The CO and CO_2 gas impurities are also concentrated in the light F-T liquid product stream. Once quantified by assay, the olefins and oxygenates may need to be saturated or recovered as products in the Upgrading Plant. The degree of processing needed for the three F-T liquid streams will be dictated by the end use of the products. Processing needs impact a non-catalytic thermal cracking furnace design or a catalytic reactor design, hydrogen consumption, and hydrogen recycle gas loop purge requirements. If all three F-T liquid streams are hydroprocessed together, they will inherently be of premium quality, compared to typical naphtha refinery or petrochemical feedstocks or compared to refinery diesel product pool quality.

- COMBINED FEED TO UPGRADER – We will need to resolve whether light and medium F-T liquid streams should be combined and hydroprocessed together with the heavy F-T liquid (wax) stream. There is incentive to combine these from an operational standpoint; putting all the feed, especially the low volumes of light and medium F-T liquid streams into one feed surge drum. Both streams (with high olefin and oxygenate contents) can be hydrogenated and sold as fuels. However, in a combined feed slate their impact on the conversion of the heavy F-T liquid (wax) stream, overall product yield slate, and product specifications needs to be evaluated.

- KEY OPERATING CONDITIONS – Non-catalytic thermal cracking furnace process parameters and product fractionation requirements are to be specified by licensors, based on the required operating severity and desired purity of the alpha olefin product streams. The catalytic upgrader operating reactor pressure, temperatures, and hydrogen treat gas rates are to be specified by licensors, based on the required operating severity and desired catalyst cycle life. The operating severity is set by the quality of the feed, H_2 availability, and the required product yield slate and specifications.

- UPGRADER REACTOR DESIGN – The licensor will develop a basis for design, given the properties of the F-T liquid streams to be catalytically upgraded and the desired product yield slate and qualities. The reactor design will then be set by the licensor, including hydrogen consumption/quench, catalyst type(s) and catalyst volume(s), and liquid (wax) recycle requirements when hydrocracking the heavy F-T liquid to extinction.

- UPGRADER HEAT INTEGRATION - Heat integration of the upgrader with that of the F-T synthesis unit needs to be checked and developed. There is some logic to try to utilize the F-T synthesis heat source, especially since the upgrader is small. There is a potential to replace small hydroprocessing furnaces with a common hot oil system.

- MAKEUP H_2 - If pipeline H_2 is not available, using H_2 membrane separation to upgrade the syngas appears to be the preferred route over a Pressure Swing Absorption Unit. However, this needs to be confirmed, and it will be necessary to check if the low H_2 content of syngas (~40% mol) requires special provisions. It may be necessary to also investigate the benefit of using a membrane in the hydroprocessing recycle gas.

- RECYCLE GAS LOOP – Due to the small capacity (~ 500 barrels per operating day) of the hydroprocessing facility there may be a tendency to go with once through hydrogen and avoid the use of a hydrogen gas recycle compressor loop. While a once through hydrogen flow scheme may prove economically attractive at this unit capacity, process and catalyst performance concerns with CO and CO_2 buildup would not be addressed, especially when scaling-up to a higher capacity unit which has a gas recycle loop. The degree of purge required, and build-up of impurities is an important process consideration. Validation of known design parameters will be checked during Phase II.

- UPGRADER PRODUCT SLATE – There are a number of options available regarding the degree of separation and products to make. The question of producing liquefied petroleum gas (LPG) in conjunction with naphtha and diesel products, or slack wax vs. finished wax (low/high melt point waxes) have been reviewed and will be addressed. Presently there does not appear to be enough incentives for extensive fractionation of the LPG, due to small yield and product end-use uncertainty. The present plan calls for the propane and butanes to be collected with the offgas and consumed as fuel in the gas turbine.

- ALPHA OLEFIN PRODUCT PURITY - There is another option to produce high value products, which does not include hydroprocessing but utilizes thermal cracking technology to produce a broad range of alpha olefins for use as a detergent intermediate feedstock. The highly paraffinic heavy F-T liquid (wax) is an ideal thermal cracking feedstock. Both the light and medium F-T liquids contain approximately 60%v olefins and could be sent directly to fractionation. Additional effort is required to test and verify this concept as well as the need to determine operating conditions and alpha olefin purity.

- UPGRADER EQUIPMENT SIZE, DESIGN, AND FABRICATION COSTS – Since the facility is small, a unique design philosophy and special equipment will be required. This would include small furnaces, high head/small capacity pumps and compressors, small diameter reactor and columns, integration of exchangers, and the use of air coolers and/or a tempered water system. Modularization, maximizing shop fabrication, and utilizing process structures within other units needs to be considered as possible and less costly construction alternatives.

Economic Model (Task 5.3)

Upon completion of process engineering studies for each of the two sites, the final site selection was based primarily on financial return calculations produced by an economic model. This model was developed using Microsoft Excel software and provided the ability to change various input parameters and note their affect on the financial calculations. The process studies were conducted first however, in order to provide the necessary inputs to the model such as product quantities, utility requirements, and capital and operating cost estimates. Prior determination of the site selection criteria helped provide objective supporting information for development of the cost estimates, product market values, transportation costs, inflation rates, etc. which were incorporated in the model.
The inputs used in the economic model included:

- feedstock prices on an annual basis
- any product price on an annual basis or an inflator basis
- capital cost (leveraged and unleveraged)

- natural gas prices on a yearly basis or by varying inflators
- maintenance costs on an annual basis to allow for required turn-around periods
- process availability
- separate on-stream reliability factors for gasification, F-T synthesis, and power generation
- inflation factors for operation and maintenance costs
- independent electrical inflation rates
- independent labor rate inflation factors

The model provided the following financial calculations:

- Net Present Value (NPV) – Defined as the current dollar value today of the annual future net cash flows discounted by the cost of capital.
- Present Worth Index (PWI) – Defined as the ratio of the present value of cash inflows to the present value of the cash outflows. PWI measures the relative attractiveness of projects per dollar of investment.
- Present Worth Payout (PWP) – Defined as the time it takes to recover an investment in terms of present value dollars. It represents the elapsed time (expressed in years) it takes for the present value of the net cash inflows to equal the present value of the net cash outflows. It is measured from the initial outflow of funds.
- Discounted Cash Flow Return On Investment (DCFROI) – Defined as the discount rate which equates the project's discounted net cash inflows with its discounted net cash outflows. It can also be interpreted as the return on investment that allows the project's net cash inflows to reduce the present value of the investment to zero.

A total of 17 economic analyses of the refinery and power generation station cases were run with various inputs varied. Table 2 summarizes the results of these calculations. As can be seen, the Port Arthur "Finished Wax" (PARFW) base case resulted in the best financial indicators over the other three base cases for PARHCU, TSC, and THCU. As a result, the PARFW case was considered to have the greatest economic opportunity for deployment of the EECP concept. Subsequently, inputs were varied for this case in order to examine the financial results under different conditions such as; higher rates for electricity sales, reduced capital cost, reduced operating cost, a combination of these assumptions, and various oil prices. The table also shows additional variations run for the THCU case.

Table 2 – Summary of EECP Economic Model Results

	NPV	PWI	PWP	DCFROI
PARFW Cases:				
• Economic Model Base Case	(49,071,775)	-0.77	NA	6.17%
• Electric sales @ $35/mw	(28,868,309)	0.86	NA	8.04%
• Investment reduction of $30MM	(28,785,101)	-0.84	NA	7.70%
• Operating expense reduction of $5MM	(23,749,572)	-0.89	NA	8.48%
• Investment reduction ($30MM), OPEX reduction ($5MM), and sales @ $35/mw	16,740,567	1.09	13.96	12.03%
• Best case with petcoke @ -$10/ton	32,262,309	1.18	12.29	13.41%
• Best case with oil @ $30/barrel	31,604,405	1.18	12.41	13.33%
• Best case with oil @ $20/barrel	1,876,730	1.01	15.97	10.67%
PARHCU Economic Model Base Case	**(98,286,943)**	**-0.54**	**NA**	**0.82%**
TSC Economic Model Base Case	**(158,700,398)**	**-0.35**	**NA**	**-5.75%**
THCU Cases:				
• Economic Model Base Case	**(150,949,319)**	**-0.39**	**NA**	**-4.01%**
• Electric sales @ $35/mw	**(114,017,914)**	**-0.54**	**NA**	**0.64%**
• Electric sales @ $40/mw	**(87,677,831)**	**-0.64**	**NA**	**3.33%**
• Electric sales @ $45/mw	**(61,337,748)**	**-0.75**	**NA**	**5.71%**
• Investment reduction ($30MM), OPEX reduction ($5MM), Electric sales @ $40/mw	**(42,068,955)**	**-0.80**	**NA**	**6.90%**
• Investment reduction ($30MM), OPEX reduction ($5MM), Electric sales @ $45/mw	**(15,728,871)**	**-0.93**	**NA**	**9.21%**
• Investment reduction ($45MM), OPEX reduction ($5MM), Electric sales @ $40/mw	**(31,925,618)**	**-0.84**	**NA**	**7.64%**

Site Selection Summary

With reference to sections for Tasks 2.2.8 (Evaluate Two Sites and Select a Site) and 5.3 (Economic Model), the Port Arthur Finished Wax case was selected as the host site and configuration based on the most favorable economic indicators resulting from an economic model. This model provided financial calculations for Net Present Value, Present Worth Index, Present Worth Payout, and Discounted Cash Flow Return On Investment (terms are defined on page 37) for seventeen different scenarios shown on page 38. The process studies were conducted first however, in order to provide the necessary inputs to the model such as product quantities, utility requirements, and capital and operating costs. Prior determination of the site selection criteria helped provide objective supporting information for development of the cost estimates, product market values, transportation costs, inflation rates, etc. which were also incorporated in the model. Overall, the factors having the greatest impact on the selection were:

- The location differentials for petcoke was substantial with the petcoke having a $0/ton cost at the refinery location but an $18/ton cost at the power plant due to transportation and handling costs. Electric power prices were surveyed at the two locations and were higher at the power generation site, but were not sufficient to offset the petcoke transportation cost. In fact, this difference resulted in substantial economic disadvantage to the EECP concept being located at the power generation site.
- Electric power, steam, and F-T products can be more effectively integrated into a refinery operation than a power generation operation due to greater infrastructure compatibility for the refinery application.
- The typical refinery application has a greater degree of similar type of unit operations and the core competencies to incorporate the processes and operations associated with the EECP concept.
- Economies of scale required for a power generation site are larger than the EECP concept design basis. The power generation station application would require a facility at least twice the EECP concept design basis to have similar economic criteria indicators.
- There is an increased thermal efficiency for the EECP concept in a refinery location since the heat from the F-T process can be used directly without any reduction in mechanical efficiency due to conversion to another form of energy.
- Sulfuric acid manufacture required at the power generation site was not economic for the EECP concept design size.

Based on these results, the PARFW case was selected for further development for the EECP concept.

V. List of Major Activities Accomplished in 2Q2000

The following list is provided as a brief summary of the work performed during this reporting period:

- Completed process studies for site selection work
- Completed cost estimates for the two sites
- Performed pro-forma calculations for each site
- Reviewed basis of design with selected site
- Selected Port Arthur Refinery (PAR) for further EECP process studies
- Began process design for selected site
- Issued 1Q2000 quarterly report to DOE

VI. List of Planned Activities for 3Q2000

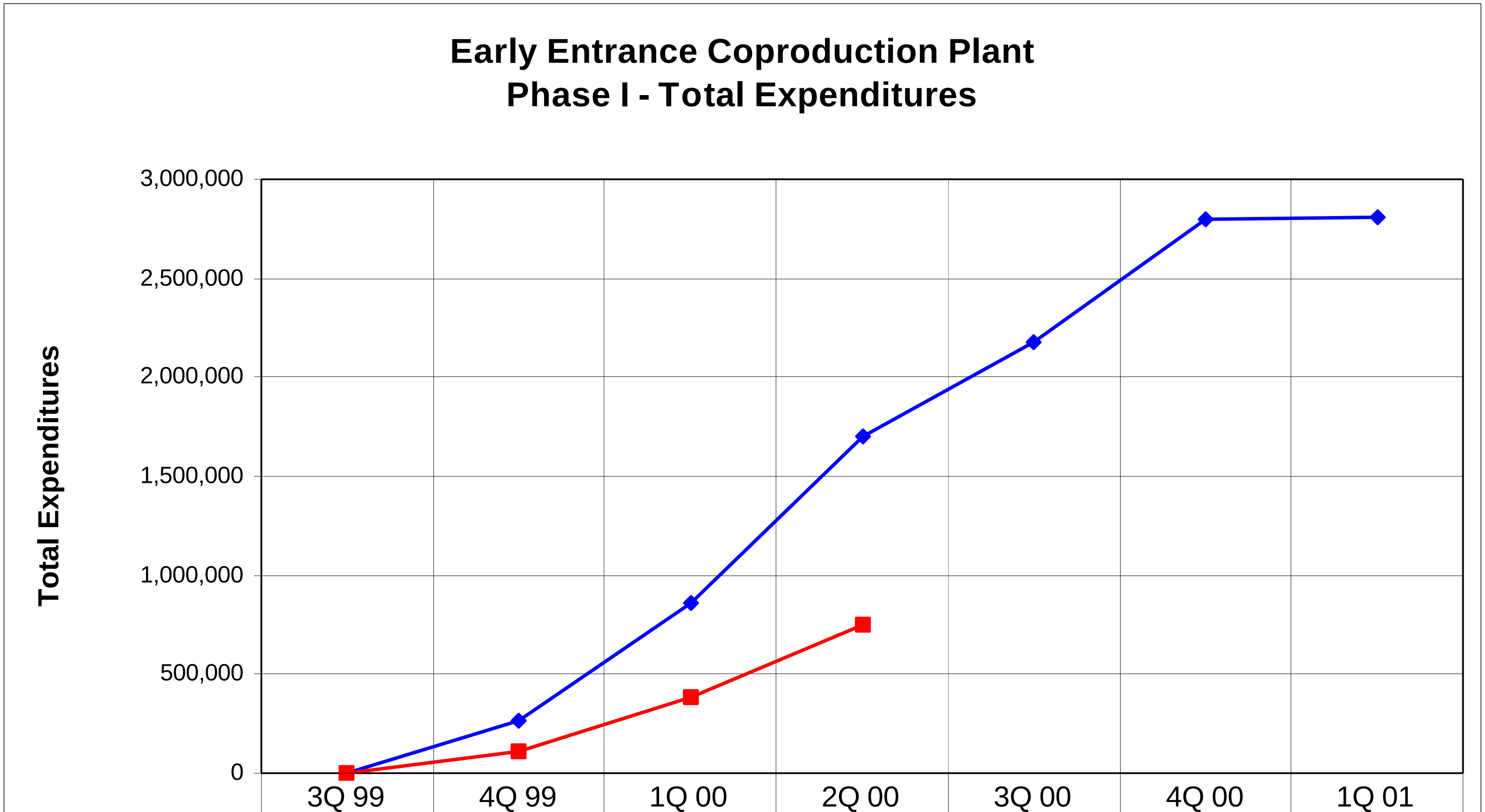
The following list is provided as a brief summary of the work planned for the upcoming quarter:

- Complete conceptual process design for selected site
- Complete technical assessment of subsystems
- Complete preparation of subsystem design specifications
- Initiate cost estimating activities for EECP at selected site
- Update market assessment for selected site
- Update environmental assessment for selected site
- Update economic assessment for selected site
- Begin RD&T planning
- Issue 2Q2000 quarterly report to DOE

VII. Graphs

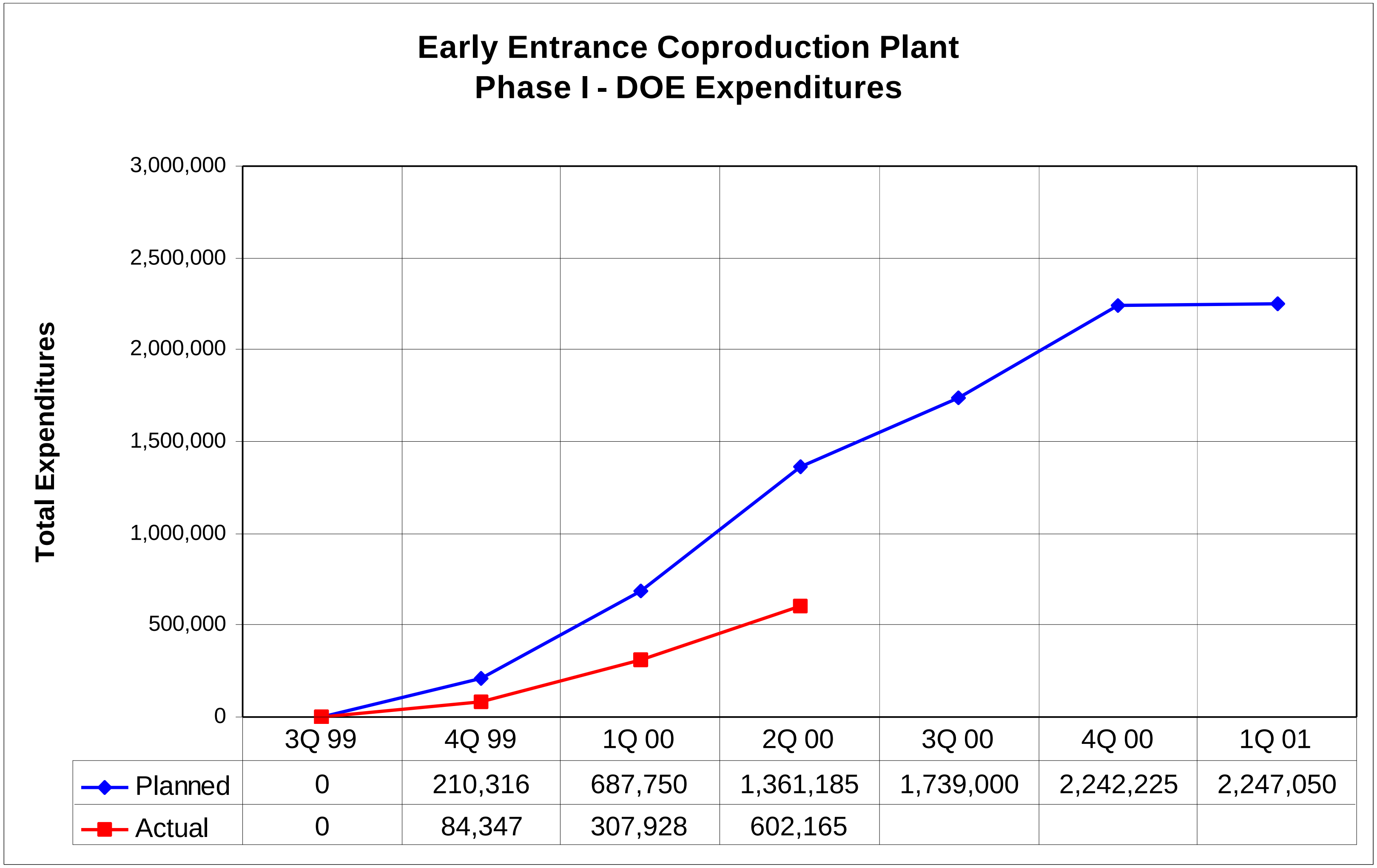
The following three graphs depict the financial status and progress of Phase I activities. The graphs are shown on the following three pages:

Phase I, Planned vs. Actual Total Expenditures



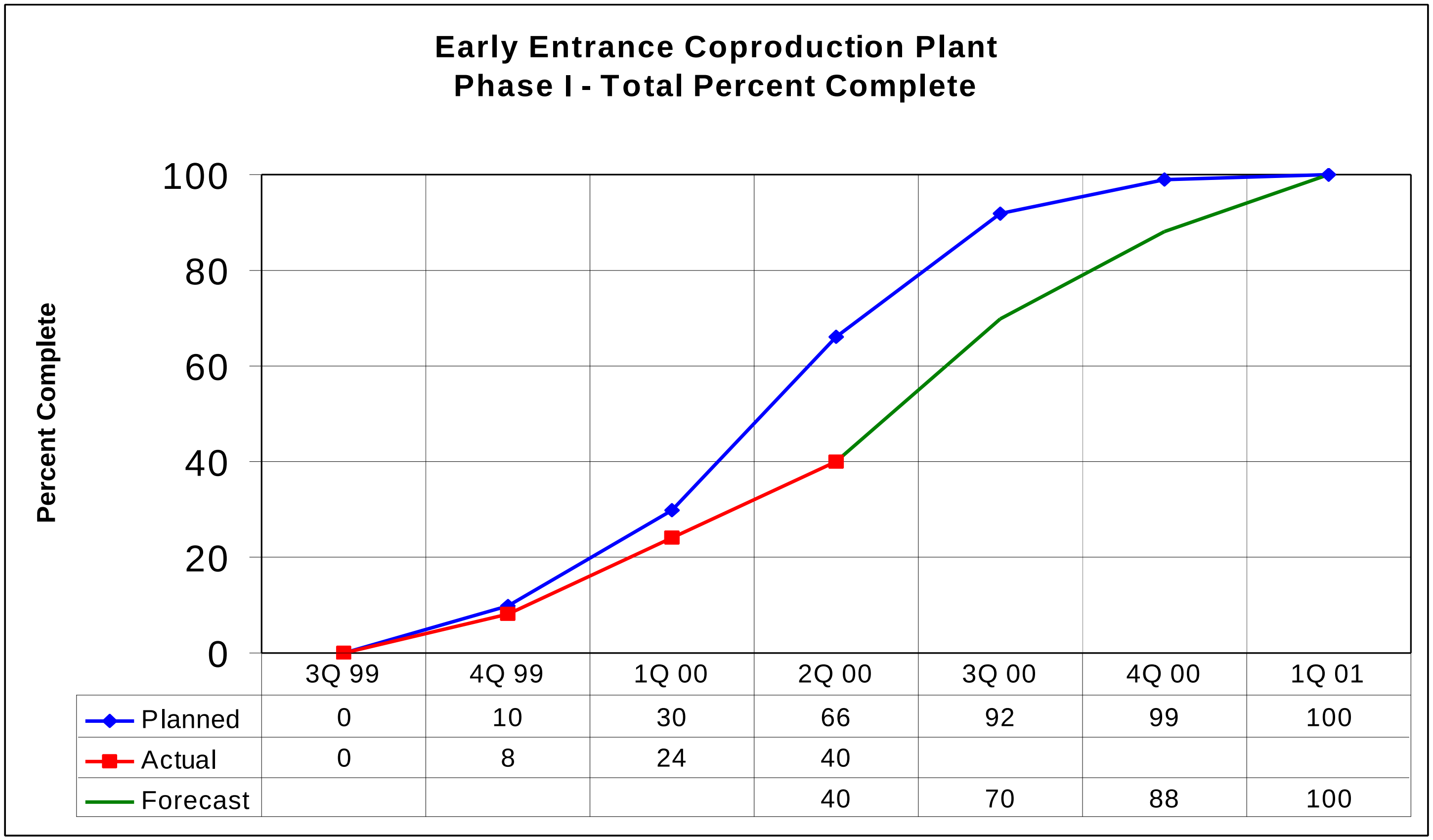
	3Q 99	4Q 99	1Q 00	2Q 00	3Q 00	4Q 00	1Q 01
Planned	0	262,896	859,687	1,701,482	2,173,750	2,802,782	2,808,813
Actual	0	105,434	384,911	752,706			

Phase I - Planned vs. Actual DOE Expenditures



	3Q 99	4Q 99	1Q 00	2Q 00	3Q 00	4Q 00	1Q 01
Planned	0	210,316	687,750	1,361,185	1,739,000	2,242,225	2,247,050
Actual	0	84,347	307,928	602,165			

Phase I - Total Project Percent Complete

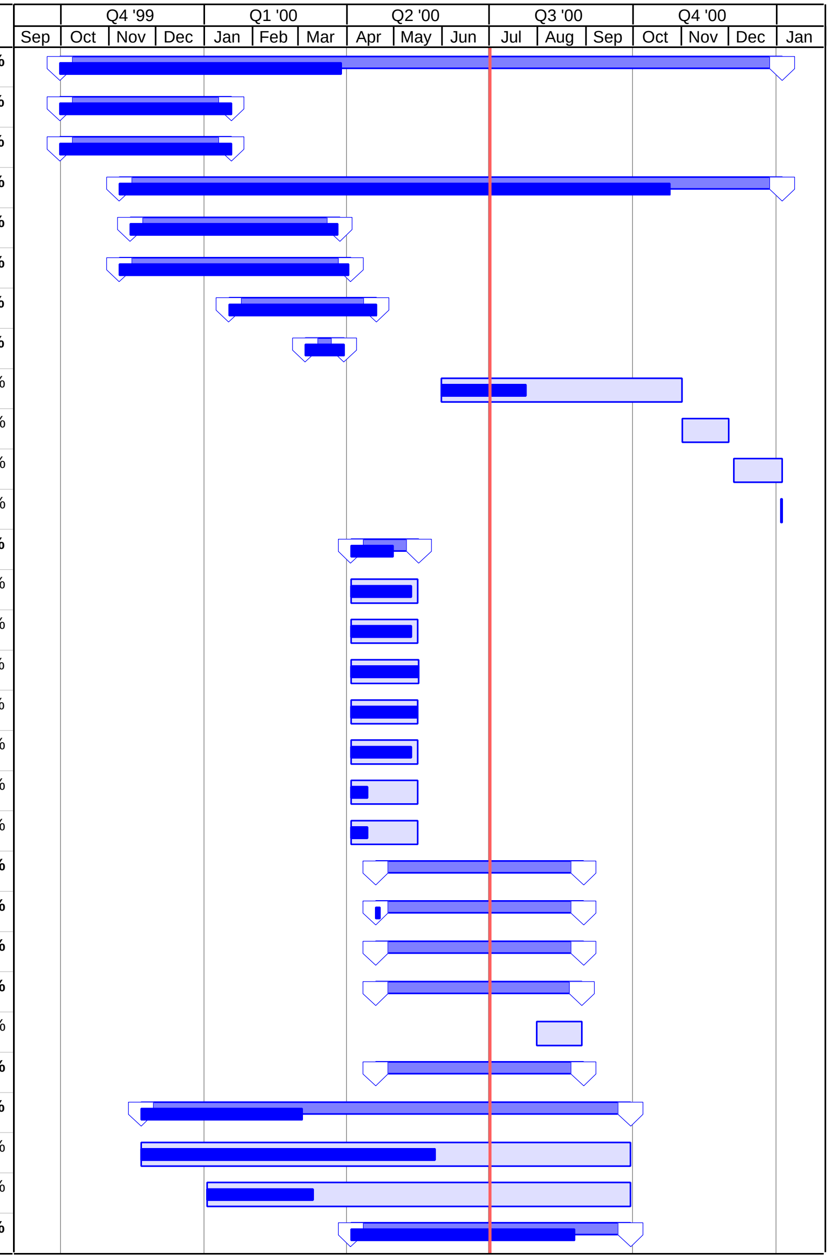


VIII. Schedule

The following two pages depict the Phase I project schedule and show percent complete by task as of the end of 2Q2000. For a description of the work involved in each task, refer to the Cooperative Agreement. This schedule was prepared using MS Project 98 software.

DOE – Early Entrance Coproduction Plant

ID	Task Name	% W/C
1	**Phase 1:Concept Definition**	**39%**
2	**Task 1 - Project Plan**	**100%**
3	**1.1 Project Management Plan**	**100%**
7	**Task 2 - Concept Definition, Development & Technical Assessment**	**83%**
8	**2.1 Overall concept definition & development**	**99%**
54	**2.2 Alternatives and options assessment and selection**	**99%**
64	**2.3 Preliminary Block Flow Diagrams with mass and energy balance**	**100%**
69	**2.4 Design considerations for advanced subsystems**	**100%**
73	2.5 Preliminary report	35%
74	2.6 DOE review	0%
75	2.7 Final report	0%
76	2.8 Milestone - Issue final report	0%
77	**Task 3 - Subsystem Technical Assessment**	**62%**
78	3.1 ASU	90%
79	3.2 Gasification	90%
80	3.3 H2:CO ratio adjustment	100%
81	3.4 Fischer-Tropsch Synthesis	100%
82	3.5 Gas Turbine	90%
83	3.6 Steam system	25%
84	3.7 Fischer-Tropsch product upgrading to market identifiable products	25%
85	**Task 4 - Subsystem Design Specifications**	**0%**
86	**4.1 Fischer-Tropsch synthesis**	**2%**
92	**4.2 Gas Turbine**	**0%**
99	**4.3 Fischer-Tropsch product upgrading to market identifiable products**	**0%**
106	**4.4 Risk assessment of integrated advanced subsystems**	0%
107	**4.5 Design specifications for proven technologies**	**0%**
115	**Task 5 - Market Assessment**	**33%**
116	5.1 Market analysis of products	60%
117	5.2 Market analysis of technology	25%
118	**5.3 Product slate and quantities**	**80%**



ID	Task Name	% W/C
120	5.4 Full scale commercial plant	0%
121	**Task 6 - Preliminary Site Analysis**	**93%**
122	6.1 Site criteria	100%
123	6.2 Identify specific sites	100%
124	6.3 Identify additional commitments/parties of EECP participation	10%
125	**Task 7 - Environmental Assessment**	**9%**
126	7.1 Emission levels	0%
127	7.2 Adaptability for CO2 sequestration	25%
128	7.3 Water use and remediation	10%
129	7.4 Waste by-products	0%
130	7.5 NEPA requirements	0%
131	**Task 8 - Economic Assessment**	**0%**
132	8.1 Feed, fuel and product cost/price evaluation	0%
133	8.2 Cost estimates	0%
134	8.3 Role of government incentives for commercial viability of EECP	0%
135	**Task 9 - Research, Development & Test Plans**	**2%**
136	9.1 Design deficiency analysis	0%
137	9.2 Proposed test plan	5%
138	9.3 Preliminary report	0%
139	9.4 DOE review	0%
140	9.5 Final report	0%
141	9.6 Milestone - Issue final report	0%
142	**Task 10 - Preliminary Project Financing Plan**	**0%**
143	10.1 Preliminary Financing Report	0%
144	10.2 DOE review	0%
145	10.3 Final report	0%
146	10.4 Milestone - Issue final report	0%
147	**Administration**	**60%**
148	Administration	60%