Appendix E

Capital Power Corporation

FEED for Genesee IGCC Facility with CO_2 Capture

Final Report Executive Summary

1. Executive Summary

1.1 Overview

Between 2006 and 2010, Capital Power Corporation (CPC), on behalf of the Canadian Clean Power Coalition (CCPC) and with funding from Alberta Innovates: Energy and Environment Solutions (AIEES) (formerly the Alberta Energy Research Institute) and Natural Resources Canada (NRCan), performed a Front End Engineering Design (FEED) study for an approximately 240 MW_{net} Integrated Gasification Combined Cycle (IGCC) facility with carbon dioxide capture. This study was aimed at discovering the true cost and viability of such a facility, which would be built at the existing Genesee Generating Station in Alberta, Canada, approximately 50 km west of the city of Edmonton.

The facility was designed to provide baseload electric power to the Alberta electricity grid, with carbon capture of over 85%, and a significant reduction in all other criteria air emissions. A decision was made early in project planning that the facility was to be developed using only commercially available technologies and that these technologies would be demonstrated at the lowest capital cost possible. The driver behind this decision was to manage overall project exposure and risk as CPC had the intention of building the demonstration facility should the economics prove favourable. CPC did not see this FEED work as a study, but rather the front end engineering to build and demonstrate the next base load, near zero emissions coal fired generation facility in Alberta. As the project progressed the logic of CPC's approach was validated when the Province of Alberta announced their Carbon Capture and Storage Fund program with the requirement of reliably placing carbon in the ground by 2015. The resulting design has a very high probability of smooth start-up and high availability; however the configuration is not economically optimal from an overall size and configuration basis. CPC understood the tradeoffs of taking this approach in the development of the Genesee IGCC facility and intended to take steps to optimize the facility in subsequent development steps once the facility was proven. This report discusses the process, methodology, engineering and estimating deliverables completed in the course of producing the FEED work, and outlines the costs and benefits associated with the facility. Possible areas of investigation for future study are also provided.

The two main questions that were to be addressed by the FEED work are as follows:

- Are there technical issues with the utilization of Western Canadian Sub-Bituminous coals in a carbon capture IGCC facility?
- What would be the true costs of the development of a commercial scale IGCC facility in Western Canada?

In response to the first question:

With the selection of commercially available technologies, there are no major technical issues with utilizing Western Canadian sub-bituminous coals in a carbon capture IGCC facility. Based on testing and process design work completed for the Genesee IGCC project, it is anticipated that there is a high probability that the facility would operate at the availability and efficiency levels described in this report.

In response to the second question:

The FEED Study final results produced a capital cost estimate of 2.24 billion dollars (Q42009 CAD) and an annual Operations and Maintenance (O&M) budget of 138.1 million dollars for the 235 MW_{net} facility. Based on these estimates the true cost of electricity for the Genesee IGCC facility is $266 Canadian dollars (CAD)/MWh (cost of electricity at start-up in 2015). The installed cost of the facility is $9,500/kW (including escalation but not including Interest during Construction).

The cost data results provided are based on project execution and initial operation of the facility at the Genesee site during the 2011 to 2015 time frame. There are several large construction projects slated for Northern Alberta during this time frame which will task local skill labour and suppliers. Labour and material costs have been estimated at a premium due to this anticipated period of intense construction activity, contributing to overall high project installed and operating costs. Rescheduling the project execution to a lower intensity time period would have a marked effect on project economics.

The cost of electricity is based on an indicative generic set of assumptions as provided in Section 15 of this report which are not necessarily identical to CPC's internal cost and forecast data. The plant was configured using commercially available and proven technologies. It is anticipated that the utilization of an optimized plant configuration and the next generation of technologies currently in development would have a significant positive effect on project economics. Utilization of these unproven technologies and much larger optimized plant configuration was not considered as part of the scope of this project, as CPC had full intention of moving into execution with the goal of demonstrating the production of high availability near zero emissions base load power by early 2015, at the overall lowest capital cost and risk possible.

1.2 FEED Project Basis

Early in the project, it was decided that the facility should be located at CPC's existing mine-mouth, coal-fired Genesee power station, west of Edmonton, Alberta, due to the following factors:

- A feedstock which represents typical western Canadian coals
- Proximity to carbon dioxide sequestration and Enhanced Oil Recovery (EOR) opportunities
- Proximity to supporting infrastructure such as water source, power transmission and highway access and
- A host location where there would be a high probability of eventual plant construction.

It was ultimately decided that due to space considerations required for the IGCC facility, the plant would be sited on the east side of Secondary Highway 770, across the road from the existing Genesee facility.

The facility was originally intended to be sized at approximately 450 MW_{net}; however, initial cost estimates proved that such a facility would likely be cost-prohibitive in nature. All funding members agreed that the facility would be down-sized to approximately 250 MW_{net}, while still utilizing commercially proven technologies. The exact electrical output of the facility would be determined through process modeling of the facility.

The facility would be, first and foremost, a commercial demonstration of the ability to gasify Genesee coal for the generation of baseload power and the capture of carbon dioxide (CO_2), while minimizing other criteria air contaminants including nitrogen oxides (NO_x), sulphur dioxide (SO_2), mercury (Hg) and total particulate matter (PM). The target emissions levels for the plant would be as shown in Table 1.1 below, which are representative of emissions from the combined cycle facility only, and are based on the gas turbine being fired on synthesis gas (syngas) only.

TABLE 1.1 – TARGET EMISSION LEVELS BASED ON SYNGAS ONLY OPERATION

Emission	Target
NO_X (dry, diluted to 15% O_2)	5 ppmv
SO_2	0.019 kg/MWh (Net Output)
PM	0.040 kg/MWh (Net Output)
Mercury	90% capture
CO_2	85% capture from syngas

The focus of the FEED study was to obtain a ±15 to 20% cost estimate for the facility after having gone through rigorous technology selection and Pre-FEED phases.

1.3 Technology Selection

Phase 1 of the overall FEED study was to complete the selection of primary plant technologies. This work was executed with Jacobs Engineering, the Owner's Engineer selected for this phase of the project. During this phase a number of gasification vendors were assessed and examined for suitability for the IGCC facility. A screening study previously completed by the CCPC had narrowed the focus from nine gasification technologies which were commercially available worldwide, down to four gasification vendors which were studied in detail during the Technology Selection phase. These vendors / technologies were: Siemens Fuel Gasification Technology (SFGT) / SFG-500, Shell / SCGP, GE Energy (GE) / GE Gasifier and

ConocoPhillips (CoP) / E-Gas. Requests for Proposal (RFPs) were sent to each of these vendors in Q1 2007, with responses received in Q2 2007. Between Q3 and Q4 2007 process modeling, coal testing, economic modeling and evaluation of each of the four technologies was completed specifically in relation to the Genesee site and its coal characteristics. The technologies were then ranked against each other through a list of 20 weighted criteria.

1.4 FEED Initiation

Based on the results of the evaluation criteria, license negotiations were entered into with top-ranked gasification technologies. Ultimately, SFGT was selected as the gasification technology provider of choice. Three agreements were negotiated and entered into with SFGT, a License Agreement, an Equipment Supply Agreement (ESA) and an Engineering Agreement for the provision of a Basic Engineering Design Package for the gasification island portion of the IGCC facility. This engineering work was completed between Q3 2008 and Q2 2009, and the results of this work were fed directly into the FEED engineering study. In Q3 2008, Jacobs Engineering based in Calgary, Alberta was chosen to complete the engineering and cost estimating portion of the Balance of FEED.

Also during this time, an RFP was issued for an experienced environmental contractor, who would be responsible for completion of the environmental impact assessment (EIA) and supporting the permitting process for the Genesee IGCC facility and the expansion of the mine permit area. Golder Associates Ltd. (Golder) was selected as the environmental contractor for the project.

An approximation of the timeline used for the FEED Initiation Stage can be seen below in Figure 1.1.

		2008				2009				2010		
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3
Gasification	Selection	■										
	Negotiation	■	■									
	Agreement			■								
FEED Contractor	RFP Issued		■									
	Evaluation		■	■								
	Agreement			■								
EIA Contractor	RFP Issued		■									
	Evaluation		■	■								
	Agreement			■								

FIGURE 1.1 – GENERAL TIMELINE FOR FEED INITIATION

1.5 FEED Execution

During FEED Execution, it was the recommendation of Jacobs Engineering that a power block Original Equipment Manufacturer (OEM) be brought into the project. This direct OEM assistance would facilitate the optimization and integration of the power block with the remainder of the facility. These optimizations included integration between the power block and the Air Separation Unit (ASU) and with various other areas in the plant which require or produce steam at a variety of pressures and temperatures. Based on this recommendation, in Q4 2008, Capital Power issued an RFP to Siemens Energy Inc. (SEI) and GE to provide optimization studies, design engineering, and cost / quantity estimating for the power block. After review of these proposals, in Q1 2009, SEI was chosen to provide these services and optimization was initiated and completed within Q2 2009. The remainder of the engineering and estimating work was completed by Q4 2009.

An approximation of the timeline used for the FEED Execution Stage can be seen below in Figure 1.2.

		2008				2009				2010		
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**
Jacobs FEED Engineering	Kickoff			■								
	Engineering			■	■	■	■	■				
	Estimating							■	■			
	Final Report								■	■		
Golder EIA	Kickoff Meeting			■								
	Regulatory / EIA Work Plan			■	■	■						
	Baseline Field Work					■	■	■	■			
	Work On Hold								■			
SFGT Gasification BEDP	Kickoff			■								
	Engineering			■	■	■	■					
	BEDP Submission						■					

FIGURE 1.2 – GENERAL TIMELINE FOR FEED EXECUTION

Primary tasks performed by the FEED Contractor included the following:

- Optimization of process streams within facility
- Preparation of Process Flow Diagrams (PFDs) for facility
- Preparation of Material Selection Diagrams (MSDs) for facility

- Completion of a Process Hazards Analysis (PHA)
- Preparation of material requisitions and budgetary pricing requests and evaluation of responses from equipment vendors
- Preparation of the engineering documentation necessary to support the Cost Estimate
- Preparation of a detailed Level 3 schedule for Engineering, Procurement and Construction of the facility
- Preparation of the Capital Cost Estimate to a level of +20/-15%, and preparation of an O&M Cost Estimate using industry standards as well as CPC-specific requirements
- Completion of a Reliability, Availability, Maintainability (RAM) study
- Preparation of the final FEED report

1.6 Facility Description

The Genesee IGCC Facility is intended to produce power from coal while incorporating carbon dioxide capture for storage. This is achieved by converting coal to a mixture of hydrogen and carbon monoxide, syngas, through gasification with oxygen and steam. The aggressive schedule pursued through most of FEED Study would have resulted in the facility being the first of its kind in Canada and potentially North America and the world.

At a high level, the processes included in the IGCC are as follows. Approximately 100 t/h of run of mine coal is received from the Genesee mine, crushed and sorted into stockpiles such that, when blended, the ash variation is held within ±2% of the design value. The blended coal is then conveyed to the coal milling and drying units, where it is milled to a fine, fluidizable powder. A fluxant, limestone, is mixed with the coal prior to milling, which reduces the gasification temperature required, improving efficiency and operability.

The milled coal is conveyed to the gasification island using nitrogen gas provided by the ASU. The gasification unit contains an SFGT 500 MW_{th} gasifier which utilizes a partial water quench. The conveyed coal reacts with oxygen and steam in the gasifier to form a raw syngas consisting mostly of carbon monoxide and hydrogen. The ash in the coal is converted to a molten slag that runs down the walls of a cooling screen inside the gasifier. The hot syngas is quenched with hot water in the lower section of the gasifier, and the slag solidifies in a water bath and is subsequently crushed and dewatered for disposal in the Genesee mine.

The hot raw syngas is scrubbed and slightly cooled in venturi scrubbers to remove aerosol contaminants and any particulate matter in the gas stream. The small volume of solids is processed and collected for disposal. Raw gas from the gasifier is treated in two shift reactors, which convert the carbon monoxide into carbon dioxide and more hydrogen gas through a reaction with the water in the saturated gas stream over a catalyst. Excess moisture is condensed and returned to the process after any additional ammonia created in the gasifier has been removed from this water stream.

The remaining components in the syngas stream are carbon dioxide, hydrogen gas and a small amount of sulphur compounds. The sulphur compounds, present in gaseous form, and the carbon dioxide are selectively absorbed in a solvent which separates the two components into separate streams, allowing the hydrogen gas product to remain as one of three high purity products. The sulphur compounds are converted to molten sulphur via a two stage Claus process, which recovers over 99% of the sulphur in the stream. This sulphur is stored on site and sold to a sulphur marketer within the Alberta sulphur market. Carbon dioxide is compressed to 165.47 bar(g) (2400 psig) and dried to remove water and any final impurities before being sent to a carbon dioxide pipeline.

The final product, hydrogen, is sent to the power island, where it is diluted with nitrogen and supplemented with a natural gas / steam mixture. These gases are burned in a gas turbine specifically chosen to be able to combust high-hydrogen fuels. The gas turbine is connected to a generator to create power, and the hot exhaust gases from the gas turbine generate steam through a heat recovery steam generator (HRSG). This generated steam subsequently powers a steam turbine for the production of additional power.

1.7 Facility Performance

The facility's environmental targets were established, as outlined above in Section 1.2, to meet or exceed existing requirements while proving carbon capture. The performance values shown in Table 1.3 below are based on expected figures obtained during the FEED study.

TABLE 1.3 – EXPECTED ENVIRONMENTAL PERFORMANCE FOR IGCC FACILITY

Emission	Target	Estimated
NO_x (dry, diluted to 15% O_2)	5 ppmv	5 ppmv
SO_2	0.019 kg/MWh (Net Output)	0.011 kg/MWh (Net Output) [1]
PM	0.040 kg/MWh (Net Output)	0.037 kg/MWh (Net Output)[4]
Mercury	90% capture	> 99% capture [2]
CO_2	85% capture from syngas	87.9% capture from syngas [3]

Notes: [1] Excludes odorant added to natural gas used for building heating.
[2] Maximum emission to atmosphere 0.003 g/h, syngas firing only.
[3] High Ammonia Winter End of Life (EOL) case.
[4] Does not include coal receipt, handling and storage.

Figure 1.3 illustrates the significant improvement in environmental performance of IGCC compared to Alberta's conventional coal fired generation. The >99% capture of mercury exceeds the 75% capture required for new sub-bituminous units.

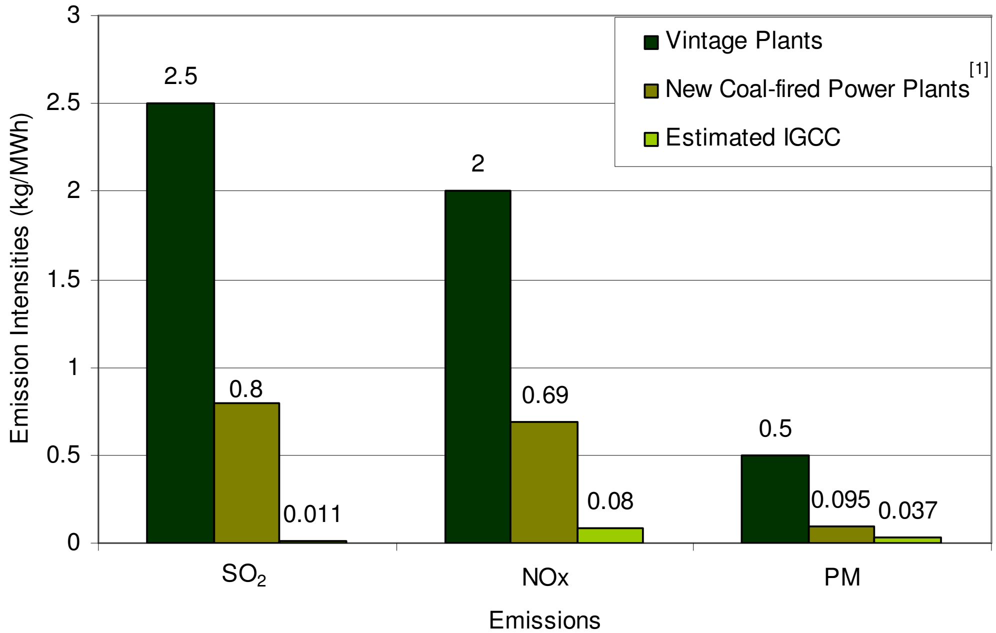

FIGURE 1.3 – ESTIMATED SO_2, NO_X AND PM EMISSION INTENSITIES COMPARISON

Notes: [1] Alberta Air Emission Standards for Electricity Generation December 2005

The primary performance indicators for the facility are plant net power output, carbon dioxide capture and emissions rate, plant availability and coal / natural gas consumption. These values are shown in Table 1.4.

TABLE 1.4 – EXPECTED PERFORMANCE VALUES FOR IGCC FACILITY

Parameter	Value	Units
Availability in Syngas / Natural Gas Co-firing	83.7	%
Availability including Natural Gas only firing	91.8	%
Long Term Compressed CO_2 Availability	82.3	%
Long Term Carbon Dioxide Capture Rate	1.08	Mt/y
Plant Net Output (Co-firing – Summer / Design / Winter)	212 / 235 / 232	MW_{net}
Plant Net Output (Syngas Only – Summer / Design / Winter)	107 / 103 / 96	MW_{net}
Long Term Coal Consumption	733,140	t/y
Plant-wide Natural Gas Usage (Syngas Only / Co-firing) (Design)	123 / 993	GJ/h

The performance values that have the greatest impact on project economics are the facility availability and net output.

The availability was determined based on the FEED study process design, with the power and gasification islands having the greatest overall impact. A reliability, availability, maintainability study was carried out to identify opportunities to optimize project capital cost and availability. There was a net improvement to the availability of syngas production of 1.6% at no net capital cost to the project. There was no impact on the availability of natural gas only and so did not have a significant impact on the overall project economics. The high hydrogen gas turbine technology in the power island is an area that requires further work to improve its availability through the reduction of forced outages. Additionally, the gasification island has three systems that contribute significantly to forced unavailability: the burner and quench systems, the cooling screen system and the slag handling systems. The configuration of these focus areas would be near first-of-kind, therefore availability improvements would primarily be achieved through the experience gained from actual construction and operation.

Net output is improved through the reduction of the onsite power consumption; however, small gains result in a significant change to the installed cost. Most of the potential gains in this area would be the result of technological advances in the areas of large power consumption such as the air separation unit and carbon dioxide compression. Some gains may also be achieved through the process optimization that would occur in the next phase of the development of the facility. Optimization would focus on items such as ammonia removal where a lower concentration of ammonia in the syngas would require less steam consumption freeing it for power generation. Improvements in this area alone could result in a drop of 5 MW of internal power demand.

1.8 Construction and Schedule

As part of the completion of the FEED study, a Level 3 schedule was created based on certain construction and contracting assumptions. A poorly developed execution schedule can lead to significant labour and equipment inefficiencies, increasing project cost and risk – for these reasons, among others, the project formulated a detailed project execution strategy. Some of the key assumptions with the preparation of this execution strategy include:

- An Engineering, Procurement and Construction (EPC) cost reimbursable strategy was chosen which was based on the utilization of direct hire construction labour, whereby a single contract exists between EPC contractor and owner, with all costs flowing through to the owner.
- Long lead delivery items were identified and timed for construction and delivery to minimize early procurement costs while ensuring that installation and commissioning would occur within warranty expiration periods
- Permitting approval was assumed to be received on August 1, 2011, with construction and “groundbreaking” occurring immediately thereafter.

Primary activities are as per the schedule provided in Table 1.5.

TABLE 1.5 – KEY TASK DURATIONS FOR IGCC FACILITY DESIGN, CONSTRUCTION AND COMMISSIONING

Task	Start	Finish	Duration (months)
Completion of FEED	Feb 1, 2010	January 31, 2011	12
Early Procurement Activities	February 2, 2010	January 31, 2011	12
Detailed Engineering	October 4, 2010	January 17, 2013	27.5
Procurement / Supply Chain Management Activities	August 18, 2010	September 30, 2013	37.5
Site Mobilization	August 1, 2011	May 31, 2012	10
Construction	August 30, 2011	May 30, 2014	33
Commissioning	June 28, 2013	November 28, 2014	17

1.9 Project Economics

Based on a number of assumptions as outlined in detail later in this report, an economic analysis was completed regarding the economic viability of the IGCC facility. Based on these assumptions, the First Year Cost of Electricity (COE) from this facility was determined to be $266/MWh in 2015. A number of sensitivities were performed in order to investigate the effect of the following factors:

- Carbon Dioxide Offset Credit Price
- Carbon Dioxide Commodity Price (for EOR)
- Changes in Capital Cost within the accuracy range of the Cost Estimate and
- Changes in the O&M expenses.

This showed overwhelmingly that reductions in the overall capital cost of the facility had the most significant impact on lowering COE values.

Table 1.6 shows a high-level summary of the costs of each area of the facility.

TABLE 1.6 – COSTS FOR GENESEE IGCC FACILITY

Direct Costs by Area	Cost (MM CAD Q4-2009)	Contribution to Installed Cost ($/kW)	% of Installed Cost
Gasification and Syngas Treatment	282.6	1,203	12.61
Acid Gas Removal	99.9	425	4.45
Sulphur Recovery	17.2	73	0.77
Gas Conditioning	17.2	73	0.77
Power Island	267.4	1,138	11.93
Coal Milling and Drying	81.6	347	3.64
Coal Handling and Preparation	35.9	153	1.60
Air Separation Unit and Carbon Dioxide Compression and Drying[1]	174.9	744	7.80
Piperacks	62.5	266	2.79
Distributed Control System	12.7	54	0.57
Utility Systems (Raw Water, Service Water, Natural gas, etc.)	82.6	352	3.69
Infrastructure	41.0	174	1.82
Power Distribution / Switchyard	52.8	225	2.36
Cooling Water/Firewater	57.0	243	2.55
Total Direct Costs	**1,285.3**	**5,469**	**57.3**
Total Construction Indirects	**301.2**	**1,282**	**13.4**
Owner's Costs	**84.7**	**360**	**3.8**
Other Items	**279.3**	**1,189**	**12.5**
Escalation	**118.9**	**506**	**5.3**
Contingency	**172.9**	**736**	**7.7**
Total Plant Cost	**2,242.3**	**9542**	**100**

Notes: [1] TIC value supplied by vendor

The O&M costs for the facility were also estimated, and are provided as follows in Table 1.7 and Table 1.8.

TABLE 1.7 – OVERALL PLANT MAINTENANCE COSTS FOR GENESEE IGCC FACILITY

Maintenance Costs	Cost (MM CAD Q4-2009/ year)
Routine Maintenance	8.6
Preventive Maintenance	5.8
Shutdown Maintenance	14.4
Sustaining Capital	14.4
Total Annual Maintenance Costs	**43.2**

TABLE 1.8 – OVERALL PLANT OPERATIONS COSTS FOR GENESEE IGCC FACILITY

Operations Costs	Cost (MM CAD 2010/ year)
Plant Staffing Costs	20.19
General and Admin Cost	0.82
Total Feedstock Cost (Coal, natural gas, fluxant)	88.49
Total Utility Cost	7.46
Annual Catalysts and Chemicals Cost	5.80
Annual Waste Disposal Costs	2.77
Annual Property Taxes (2018)	10.8
Annual Insurance Costs	1.70
Total Annual Operations Costs	**138.03**

These estimates were used to determine the first year cost of electricity of $266/MWh for 2015. Table 1.9 provides an indication of the makeup of that cost. Further details of the economic analysis carried out can be found in Section 15.

TABLE 1.9 – FIRST YEAR COST OF ELECTRICITY FOR GENESEE IGCC FACILITY

Component	Contribution to COE %
Fuel (coal and natural gas, includes transport)	17.5
AESO Tariffs	4.5
Operating and Maintenance Costs	18.0
Investment/Debt/etc.	53.0
Taxes	7.0
CO_2 (net of sales and offsets)	-5.5

1.10 Carbon Capture and Sequestration

During the FEED study CPC investigated its options and the costs associated with carbon capture and sequestration. Transportation costs were developed through the use of a confidential Request for Information (RFI) while the specification for the product carbon dioxide was developed in cooperation with the transportation supplier and potential end users. The purity of carbon dioxide required by the end users can be readily achieved but control of specific contaminants is required.

Efforts were focused on the supply of carbon dioxide for enhanced oil recovery due to the potential positive economic impact on the Project. Piloting of deep saline aquifers for sequestration was also supported as they may needed in the event that enhanced oil recovery options are unavailable. Long term operation of a carbon capture facility may require use of both options if it is necessary to avoid venting of the captured carbon dioxide. Details of these investigations can be found in Section 16.

1.11 Project Status and Next Steps

The Genesee IGCC FEED study was a significant undertaking, and a substantial amount of knowledge was gained regarding the development of gasification for power generation in Alberta. An overview of the achievements of each step in the FEED study is as follows.

Technology Selection – A variety of studies were completed on potential feedstocks, by- and co-products, plant configurations and polygeneration opportunities. These studies were utilized to better understand the most economical and practical basis for the use of gasification technologies for power in Alberta.

FEED Package – Although the package was focused on the development of a cost estimate rather than the creation of fully developed engineering work packages, a solid process design, plant layout, technology selection logic, gasification vendor Basic Engineering Design Package (BEDP), reliability / availability / maintainability analysis, work breakdown structure and a detailed construction schedule were produced as part of the set of deliverables. An understanding was gained regarding the potential contracting strategies available for the construction of such a facility, including the establishment of solid relationships with technology suppliers and vendors in the gasification industry. This understanding will be of critical importance when the project proceeds to the next phase.

EIA Work – Although the EIA work was put on hold after further provincial and federal funding opportunities did not materialize, a significant amount of work was completed regarding the environmental and regulatory permitting requirements for the IGCC facility. This work included the development of emissions schedules and source maps, field work, emissions modeling, noise surveys, development of key regulatory and environmental permitting documents including the Project Disclosure Document and the EIA Terms of References, as well as support to public and First Nations consultation programs. Through this work, a significantly better understanding of the environmental effects of the project was obtained, as well as an understanding of the possible regulations that would be applied to the facility.

The next steps in the development of an IGCC facility include gaining a greater understanding of what value society places on clean power as well as insight into any potential regulatory issues. Opportunities to integrate IGCC into polygeneration facilities and breakthrough commercial technologies with the potential to reduce capital and operating costs are also areas for further study.

1.12 Learnings and Future Considerations

A number of valuable learnings were obtained from the completion of the IGCC FEED study, both in the areas of IGCC technologies and project execution of such a FEED study. These learnings are summarized in Table 1.10.

TABLE 1.10 – SUMMARY OF LEARNINGS AND FUTURE CONSIDERATIONS

Learning Category	Summary
Project Execution Learnings	
Process Design Focus	A strong process engineering team is vital as their work forms the, basis for all of the engineering and cost estimating efforts that follow.
Contractor Selection	Selection based on local experience, gasification expertise and the physical location of contractor offices is highly important.
Execution Strategy	The staged approach for the completion of the Project, through Technology Selection, FEED Initiation and FEED Execution stages worked well. An alternative strategy considered, was the utilization of an EPC contractor engaged at the beginning of FEED right through to commissioning. The EPC approach was ultimately rejected due to the specific nature of this project.
Licenses and Intellectual Property	Technology licenses must be adequately budgeted and planned for, and legal expertise in the area of intellectual property is necessary during license negotiations.
Future Development of IGCC in Alberta Market	The high capital and operating costs for such a plant requires a solid understanding of the accuracy of power price and demand forecasting.
Timing of Vendor Engineering Input	Not all vendor engineering packages are required early in a FEED study. The risk of engaging certain vendors late in development must be weighed against the required accuracy of the estimate and schedule.
Scope Management	Ensure the scope of work is clearly defined initially, and have processes in place to manage scope changes. Changes will inevitably occur if project economics require analysis of polygeneration options, optimization studies, or adjusted engineering deliverables.
Cost / Scope of FEED	A "FEED" study is loosely defined in many instances, and the FEED contractor and developer may initially have different perspectives on the content and requirements of a FEED. The specific deliverables required must be clearly defined prior to start of FEED.
Areas for Estimate Refinement	Although the accuracy for the cost estimate is +20/-15%, there are components of the facility that should be further explored to improve the estimate accuracy. These areas include the coal plant, civil engineering assumptions, site dewatering assumptions, syngas ammonia and mercury investigations, ASU and carbon dioxide compression combinations, air integration possibilities, noise control and deeper analysis of the indirect construction costs.

Learning Category	Summary
Accuracy of Cost Estimate	There were significant differences in the total installed cost estimates at different phases of FEED development. Between Pre-FEED and FEED there was a significant increase in Total Installed Cost (TIC). Great caution should be taken in relying on the accuracy of cost estimates prior to completion of sufficient engineering. This is especially important when considering location specific costs and location effects on costs.
Technical Learnings	
Feedstock Characterization and Testing	Knowing the detailed properties of the proposed feedstock is of paramount importance in a gasification facility, as this will have a significant impact on the performance characteristics of the entire downstream facility. Money spent on characterization and testing is minimal in comparison to money spent changing design parameters later in the process.
Selection of Gasification Technologies	Selection of gasification technology is highly dependent upon chosen feedstock, which has a significant impact on the decision to use dry - or slurry-feed systems.
Natural Gas Fuel Backup	The ability to operate the power island at full load on natural gas when syngas is unavailable carries a significant expense, both in natural gas delivery costs and water treatment capacity required for nitrogen oxide control.
Integration	Integration with existing facilities (e.g. at a brownfield site) can provide significant cost savings, where available. Integration within the plant itself, for example between process island and power island, can also provide significant benefits both for capital cost reduction and increased power output.
Consideration of Plant Configuration and By-Products	If a project is not solely focused on the production of power, a number of polygeneration or cogeneration options are available, including the production of substitute natural gas, hydrogen, or liquid fuels. These alternatives can in some cases provide significant cost benefits to plant economics, and should be seriously considered where possible.
Technology Risks	The technologies utilized for the Genesee IGCC facility are well proven in other sectors of the process industry. IGCC units are quite complex in comparison to conventional power generation, and overall integration, final commissioning and troubleshooting of plant systems will take more time with IGCC than for a similar sized conventional pulverized coal facility. On a relative basis, there are two main areas wherein additional experience in the marketplace is desirable: gas turbine operation on high hydrogen fuels, and the role of flux addition to the gasifier when optimizing slag characteristics.
Opportunities to Optimize Plant Economics	The next generation of gasification and air separation technologies have a significant potential to provide cost reductions to IGCC facilities. The potential cost savings of these and other next generation technologies also carry a significant technology risk that could not be tolerated in the timing and performance of this project. The choice of a single train for syngas production with little or no redundancy impacts the reliability and availability of the facility that is compounded by its first of kind nature. Experience with the operation of the integrated technologies is likely to improve the projected availabilities and with it the economics.

1.13 Success Indicators

The three phases of the Genesee IGCC project discussed in this report were funded jointly by AIEES, NRCan and CPC. All three phases of the Genesee IGCC Project; Technology Selection, FEED Initiation and FEED Execution were successfully executed, on time and within budget. Key learnings, deliverables and financial reconciliation as agreed upon have been outlined within this report as requested by CPC's funding partners, and a full explanation of the use of the associated funds has been included as Section 20 of this report.