



APPENDIX I TECHNOLOGY ASSESSMENT

During the initial planning stages of any electricity generating project, it is necessary to define the project objectives and criteria including, among other things: requisite generating capacity, capital and operating costs, reliability, availability, fuel price, fuel price volatility, fuel availability, site characteristics, safety factors and potential environmental impacts. Consumers performed a technology assessment to review and assess the various technologies currently available through commercial means for baseload power generation. The basis for the assessment defined the new facility as a minimum 600 MW generating facility utilizing Powder River Basin coal or natural gas as the primary fuel with an intended commercial operation date in 2013. The technology assessment evaluated the following technologies:

1. Pulverized Coal
 - a. Subcritical
 - b. Supercritical (including advanced supercritical)
 - c. Ultra-Supercritical
2. Circulating Fluidized Bed
3. Integrated Gasification Combined Cycle
4. Natural Gas Combined Cycle

In addition, the technology assessment also reviewed the following emerging technologies:

1. Pressurized Fluidized Bed Combustion
2. Oxy-Fuel Firing
3. Advanced Ultra-Supercritical Designs (High Temperature Materials)

I.1 Pulverized Coal (PC) Technology

Pulverized coal technology is a well-proven clean coal technology that uses finely ground coal as the fuel input into the boiler. The coal is ground, or “pulverized”, into a fine powder to a size of 50 microns or smaller and is the consistency of talcum powder. It currently represents the most developed and proven technology for large utility boilers and offers the greatest reliability and efficiency of all boiler configurations. The different types of PC technology are differentiated by the thermodynamic steam cycles and consist of subcritical, supercritical, and ultra-supercritical.



I.1.1 Subcritical Pulverized Coal Technology

Subcritical PC boilers operate at lower pressure cycle than Supercritical PC technology and have somewhat lower capital costs associated with construction materials. These boilers commonly operate in pressure ranges of 1,800 to 2,400 psia and steam temperatures of 950°F to 1,050°F. In general, these boilers operate with cycle efficiencies in the low 30% range. This type of unit however, has been the workhorse for utilities with many units built between the 1940s and 1980s, offering the highest degree of operating experience.

I.1.2 Supercritical Pulverized Coal Technology

Supercritical PC (SCPC) boilers operate at a higher pressure cycle than a subcritical PC boiler. First generation SCPC boilers used steam turbine throttle pressures in the range of 3,500 psig and 1,000 to 1,050° F superheat and reheat temperatures. Next generation supercritical boilers or advanced SCPC (ASCPC) boilers have steam turbine throttle pressures over 3,800 psia with superheat and reheat temperatures in the range of 1,075 to 1,100°F. All SCPC boiler designs operate at higher efficiencies and can produce more electricity than an identical sized subcritical PC boiler. Cycle efficiencies for supercritical and advanced supercritical units range from about 36% to 40% on an HHV basis. The experience base with these units is not as broad as with subcritical units; however, a solid experience base has been accumulated in Europe and Japan in the 1980s and 1990s. Currently, there are about 400 operating supercritical units around the world. Of these, approximately 25 fall into the range of “advanced” supercritical.

I.1.3 Ultra-Supercritical Pulverized Coal Technology

Ultra-supercritical boilers (USCPC) operate at very high steam pressures of 4,200 psig and require a significant use of austenitic (non-corrosive) materials for boiler tube construction due to the high pressures. Superheat and reheat temperatures are somewhat higher than an ASCPC boiler, at 1,114°F to 1,130°F. These boilers are capable of higher efficiencies into the low 40% range HHV, but are susceptible to boiler tube failure and overall reliability is of paramount concern. Operating experience with this type of boiler design is limited to less than a dozen units, most of which have limited accumulated operating hours.



I.2 Circulating Fluidized Bed (CFB)

Circulating Fluidized Bed (CFB) technology was developed under the U.S. Department of Energy (DOE) as a clean coal technology (CCT) and gained popularity in the late 1980s. CFB technology represents a mature, clean coal combustion technology in which crushed fuel (coal) and limestone are circulated in a furnace. These boilers typically operate at low combustion temperatures of 1,600°F to 1,700°F and are limited in size. Currently, the largest CFB boiler design is limited to 300 MW. Therefore, for plants designed at 800 MW to 900 MW in size, up to 3 CFB units (3 x 300) would need to be employed causing a dramatic increase in capital costs and site preparation. Cycle efficiencies for CFBs are generally comparable or slightly less than subcritical pulverized coal units.

CFB technology has an advantage over other boiler designs regarding fuel flexibility. Typically, minimal design changes are necessary to allow these boilers to operate on several types of solid fuel. Typically, CFB boilers are designed for optimal fuel flexibility and accommodate coal, petcoke, wood, sludge, and tire-derived fuels. Therefore, this technology is optimal for those circumstances where varying types of fuel will be supplied, smaller unit sizes are not an issue and cycle efficiency is not as critical.

I.3 Integrated Gasification Combined Cycle (IGCC)

Integrated Gasification Combined Cycle (IGCC) is a developing technology that uses solid fuels to produce synthesis gas, “syngas” that can be fed to a combustion turbine to generate electricity. Gasification is not a new concept or process. In fact, gasification technologies and processes have been used in the chemical and petroleum industries for nearly three decades. Primarily, the syngas was used to produce chemicals such as ammonia and fertilizers. However, it wasn’t until the 1990’s under direction of the DOE, and with substantial financial grants, that coal gasification was used to produce electricity.

IGCC technology combines these two proven technologies (solid fuel synthesis and combustion turbines) by producing a medium-Btu value syngas from coal or other solid fuel (petcoke) and firing it in a modified conventional gas turbine as part of a combined cycle application. When combining these two technologies, high levels of integration between the two processes are often required to increase plant efficiency. The integration is accomplished by using heat exchangers to



capture heat produced in the gasification process and utilizing it to increase the output and efficiency of the steam cycle, yet at the same time increasing the complexity of the plant. Even with this degree of integration, the high level of auxiliary load to operate the gasifier results in cycle efficiencies that are close to, but slightly less efficient than an advanced supercritical pulverized coal unit using the same fuel (feedstock).

This complexity has led to low total system reliability in the first generation plants, and continues to be a significant enough of an issue on the newly permitted second generation plants to require the potential use of significant quantities of natural gas as a fuel to offset the unavailability of syngas. Reduced availability as compared to pulverized coal units is a serious issue when a unit is required to meet base load generation requirements. Demonstrated availability of the two IGCC units currently in service in the USA have averaged in the mid 70% range, versus availabilities for supercritical units which are around 90%. To compound this issue, operating experience on IGCC units is very limited. The two units in the USA are part of a fleet of six operating units worldwide compared to 400 supercritical pulverized coal units.

During the process of gasification, coal is reacted in a gasifier to produce raw syngas that must be cleaned of contaminants prior to combustion in a gas turbine. Coal gasification involves the partial oxidation of the coal at elevated pressures and temperatures to produce a syngas that is composed mainly of hydrogen, carbon monoxide and methane. Typical syngas also has a relatively low heating value, ranging from 100 to 150 Btu/scf, requiring a large and reliable amount of syngas to meet the heat input requirements of a utility boiler or combustion turbine.

I.4 Natural Gas Combined Cycle (NGCC)

Natural Gas Combined Cycle (NGCC) is a well-proven technology where natural gas is fired in a combustion turbine to produce electricity. Combined cycle refers to the fact that the waste heat exhaust through the combustion turbine and is captured in a heat recovery steam generator (HRSG) to produce steam to send to a steam turbine for additional electrical generation. The viability of NGCC generally depends on fuel prices, and with current natural gas prices, tend to be used as cycling plants that are operated intermittently (approximately 20 to 30% capacity factor) when load demand is high and not for baseload generation.



I.5 Emerging Technologies

As mentioned previously, three emerging technologies were investigated to determine their potential for baseload power generation. These technologies pressurized fluidized bed combustion, oxy-fuel firing, and advanced ultra-supercritical designs.

I.5.1 Pressurized Fluidized Bed Combustion (PFBC) Combined Cycle

Pressurized fluidized bed combustion (PFBC) combined cycle is similar to a NGCC facility with the exception that the gas turbine and steam turbine are not operated in tandem. In PFBC technology, coal and sorbent are mixed as a slurry in a pressurized vessel (combustor) where the hot pressurized flue gas is used to produce steam and supplied to a gas turbine for expansion and additional electricity production. In such systems, the steam turbine accounts for approximately 80% of the plant power output and the gas turbine accounts for the other 20%. A key challenge with PFBC systems is having a gas turbine that is capable of accepting flue gas that has some particulate.

To date, PFBC systems have been very limited in size and ranging from 8 MW to 85 MW with one unit operating at 250 MW.

I.5.2 Oxy-Fuel Firing (OFF)

Oxy-Fuel Firing (OFF) is similar in design to conventional CFB or PC units but differ from normal combustion technologies in that a pure oxygen stream is used as the combustion medium rather than air, which results in a exhaust flue gas stream largely devoid of atmospheric nitrogen. Consequently, much smaller volumes of air contaminants (e.g., thermal NO_x) are present in the flue gas. Because of the need for a pure oxygen stream, these systems require that a cryogenic air separation unit be employed to supply the oxygen.

These systems are very early in the emerging technology stage and are still considered demonstration projects since commercial availability is absent.

I.5.3 Advanced Ultra-Supercritical Designs (High Temperature Materials)

Boiler and turbine suppliers have optimized steam conditions to achieve the highest available efficiencies. However, the materials necessary for these optimized boiler conditions are still



developing but primarily include alloy or austenitic materials. Steam temperatures in the range of 1,114°F and above require use of these materials to prevent damage and failure of the furnace box and boiler tubes. Consequently, due to supply restrictions, boilers designed to operate in ultra-supercritical mode are limited in use and availability.

I.6 Technology Chosen

As a result of the comprehensive technology assessment evaluating each of the combustion technology options commercially available for baseload power generation on-line by 2015, Consumers has determined that the advanced supercritical pulverized coal technology offers the best combination of efficiency, reliability, low emissions, installed cost and operating cost. It provides a more economic and reliable source of energy to the ratepayers of Michigan. Furthermore, the ASCPC boiler is designed to burn PRB coals but will maintain a capability to fuel with a mix of bituminous coals into the boiler in order to minimize risks in coal price volatility.

In summary, it was determined that pulverized coal firing would be selected as the combustion technology for the new plant considering availability, economics, environmental, and fuel stability. The pulverized coal technology that will be employed by Consumers is a single 930 MW_{gross} advanced supercritical pulverized coal boiler with steam turbine throttle pressure of 3,805 psia and with 1,100°F and 1,100°F superheat and reheat temperatures, respectively, with a single steam reheat system. This design provides the highest rated efficiency of any commercially available PC boiler today. Furthermore, the primary coal to be fired will be low sulfur, low mercury PRB with a state-of-the-art air quality control system. Specifically, the new plant will include SCR to minimize NO_x emissions, fabric filter for particulate control, wet FGD for SO₂ and H₂SO₄ control, hydrated lime injection to reduce SO₃ and acid gas formation, and ACI to minimize mercury. Ultimately, it was determined that maintaining an ability to blend up to 50% bituminous coal with the sub-bituminous PRB coal provides the most stability in fuel pricing and supply.

I.7 Alternate Technology Review

The technology assessment performed by Consumers and their engineering consultant is an objective review of the available technologies and fuels. Consumers, however, recognizes that



there is a public interest in alternative means of producing electricity. There is growing interest in the IGCC technology, and continuing interest in NGCC. Both were subject of extensive review and merit some additional discussion here.

I.7.1 IGCC

IGCC power systems use a gasifier to convert coal (or other carbon-based solids) into a synthesis gas (syngas) consisting of a mixture of carbon monoxide (CO), hydrogen (H₂), carbon dioxide (CO₂) and traces of other gases. Syngas from the gasifier is filtered and scrubbed to reduce particulates, sulfur and other contaminants prior to being combusted in a gas-fired combustion turbine. Heat from the turbine exhaust gas is extracted in a heat recovery steam generator (HRSG) to produce steam to drive a steam turbine generator.

Gasification processes require an oxidant to react with the coal and maintain the temperature required for gasification. The oxidant reacts with coal to produce syngas. The typical air separation unit (ASU) cryogenically separates ambient air into its major constituents: oxygen (O₂) and nitrogen (N₂). Most of the O₂ is needed in the gasification plant for the production of syngas. A small percentage of the O₂ is used separately in a sulfuric acid plant. Most of the N₂ goes to the power plant's combustion turbine to dilute the fuel gas for NO_x abatement. This diluent N₂ also increases the combustion turbine's power production as it expands through the turbine.

There are currently three IGCC power generation plants operating in the United States designed specifically to generate electricity from gasified bituminous coal and/or petroleum coke: Polk Power Station, Wabash River Generation Station and Delaware Star Refinery Station. The DOE's CCT Demonstration Project co-funded the construction and initial operation of Tampa Electric's Polk Power Station and PSI Energy's Wabash River Generation Station. The rated outputs for the three commercial IGCC facilities are 250 MW, 262 MW and 180 MW for the Polk Power Station, Wabash River Generation Station and the Delaware Star Refinery Station, respectively. Based on available information, other IGCC plants have not been able to demonstrate syngas availability greater than 80 percent, and none of the plants identified herein has ever operated at an annual capacity factor higher than 77 percent, including periods when they operated on oil or natural gas as backup with no attempt to use coal.



As stated previously, the plant proposed by Consumers is to be a baseload capacity power generation facility with a minimum availability factor of 90%. With the demonstrated limited availability and reliability of these existing IGCC plants, IGCC technology would not be technically and commercially feasible to satisfy the requirements of Consumers' generation profile necessary to sustain economic viability for its ratepayers. IGCC is not structurally similar in design or capacity to traditional utility boilers or electrical generation of the size required to serve the needs of the Consumers' ratepayers requiring significant costs and learning to operate such a plant.

Additionally, IGCC technology has been developed around the use of 300 MW power generation blocks, which is far less than the 930 MW capacity proposed for the project. The high capital cost of IGCC, which is a factor that the technology struggles with even at the 300 or 600 MW power increment, would be exorbitant considering that reliability issues and concern dictate that 4 trains would be necessary when scaling up to the 930 MW generation capacity needed by Consumers and potential partners, including Michigan Municipal Electric Generators.

To further test a direct comparison of SCPC technology and IGCC technology, Consumers assessed the cost of generation to the ratepayers of Michigan and the comparisons and contrasts of emissions from both technologies using PRB as the base fuel (feedstock). Based upon the best available information at this time for both technologies and as addressed in Consumers filings for our Balanced Energy Initiative, Consumers calculates that the cost of generation from an IGCC unit will be approximately 60% higher for the IGCC unit than for the ASCPC unit proposed in this permit application. Calculations performed by Consumers show a projected \$60/MWHR cost of generation for the SCPC unit, while the cost of generation for the IGCC unit is estimated at \$95/MWHR. Consumers deems cost of generation at this level to be excessive for intended base load generation and believes that the MPSC will concur with that judgment.

Consumers has also compared the emissions from the proposed ASCPC unit with the emissions from an IGCC unit using PRB as a feedstock. Our comparison shows that, while emissions of CO and particulate are moderately better for an IGCC unit, the emission of NO_x is slightly lower for the ASCPC unit and the net emission of SO₂ is very close for both technologies i.e. 99% removal for the IGCC unit versus 97% for the ASCPC unit. Also very important to the equation,



although not currently regulated, is the emission of CO₂ from both technologies, which is virtually identical. It should be pointed out that this comparison was made between demonstrated emissions results in the case of the ASCPC unit and “projected”, but not yet demonstrated results for the IGCC unit. When compared against actual emissions results for the Polk and Wabash units, the demonstrated emissions from the ASCPC technology are generally lower for SO₂ and NO_x.

The combination of a significantly lower cost of generation for the ratepayer and significantly better experience base and demonstrated reliability for the technology far exceeds any demonstrated or projected benefit from lower emissions from the IGCC technology choice.

Consumers has made the commitment to continue to assess and evaluate the development of IGCC for future units, however it is not the right choice for the Company, the ratepayers or the citizens of Michigan at this time. This position is further confirmed by recent announcements from American Electric Power and Tampa Electric, both strong proponents of IGCC technology development, to suspend further project development of their announced IGCC projects in the near term.

Consumers submitted extensive comments on the use of IGCC technology at this time for a baseload plant in its letter to the MDEQ dated September 27, 2007. This letter was in response to a proposal by the MDEQ to include IGCC in the BACT analysis for a new coal fired power plant and provides further discussion of the points outlined above.

I.7.2 NGCC

As mentioned previously, NGCC has most recently been used to build cycling or peaking plants that are used intermittently when demand for energy is high, supply is low, and spot market prices are at levels that deem operating these facilities profitable. Use of NGCC technology, at current and foreseeable natural gas prices, as a baseload facility would cause electricity prices to climb to levels never seen before. Furthermore, construction of a baseload natural gas facility would require a constant and adequate supply of natural gas and Consumers would likely be required to construct new pipelines and compression stations in order to ensure such a supply to the plant.



For these reasons, use of natural gas as the primary fuel for the proposed baseload plant is economically infeasible. Not only is there a direct consequence on Consumers electric service customers in the form of higher electric rates, the much higher use of natural gas as a power generation fuel will have a collateral impact on Consumers gas customers and will result in significantly higher home heating costs for Michigan's ratepayers. Consequently, natural gas was eliminated from consideration in lieu of solid fuel. Finally, EAB has stated in recent opinions that requiring a project defined as a coal-fueled facility to consider NGCC constitutes redefining the source and outside of the purview of the CAA.

Based on a review of technical, financial and practical considerations, Consumers determined that the appropriate design for the proposed power plant is an advanced supercritical pulverized coal-fired 930 MW baseload designed primarily to burn low sulfur PRB coal that includes a comprehensive air quality control system. Based on a technical review of the potentially available solid fuel electricity-generating configurations (e.g., IGCC, CFB, PC), Consumers concluded that the most appropriate fuel conversion technology for a project of this size was an ASCPC boiler.