Attachment IV

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

New York Independent System Operator, Inc. **Docket No. ER17-___-000**

AFFIDAVIT OF THOMAS A. VIVENZIO AND DR. WILLIAM F. FRAZIER

I. Qualifications

A. Thomas Vivenzio

1. My name is Thomas A. Vivenzio. I am a Senior Principal Consultant at Lummus Consultants International, Inc. (LCI), a technical and economic advisory firm with more than 100 years of experience in the energy and infrastructure sectors, including power generation, transmission and distribution; oil and gas; refinery and petrochemicals production; and liquefied natural gas (LNG). LCI is headquartered in Houston, Texas. My expertise is in design, performance and cost of electric generating plants. My office address is 150 Royall Street, Canton, Massachusetts 02021.

2. I have been with LCI for almost 15 years since 2002. During that period, I advised many clients on selection of new power plants; developed cost and performance data for many clients to utilize in comparing power plant alternative designs and sizes; and developed cost and performance for a range of power plant technologies and capacities.

3. From 1973 to 2000, I worked for Stone & Webster Engineering Corporation (Stone & Webster), a major power plant engineering, design and construction firm. I completed assignments in the Environmental Division, Process Projects Division, Advanced Technologies Division and Mechanical Division. From 2000 to 2002, I worked in the fossil power engineering department of the Shaw Group (Shaw), who had purchased Stone & Webster. My last assignment with Shaw was as lead mechanical engineer responsible for the design of the Ravenswood Unit 40 combined cycle plant in Queens, New York City.

4. I hold a M.S. in Chemical Engineering from the University of Pennsylvania and a B.S. in Chemical Engineering from the University of Rhode Island. My curriculum vitae is attached as Exhibit A.

B. Dr. William Frazier

5. My name is William F. Frazier. I am a Principal Consultant at LCI, also in its Canton, Massachusetts office.

6. I have been with LCI and its predecessor companies since 2003. During that period, I have worked on wide range of environmental projects related to electrical energy production in various areas, including New York State. Prior to working for LCI, I worked for Earth Tech an environmental consulting firm, Stone & Webster, Dominion Energy, and Virginia Power.

7. I hold a Ph.D. in Civil Engineering/Environmental Engineering from the University of Tennessee, an M.S. in Civil Engineering/Environmental Engineering from Northeastern University, and a B.S. in Electrical Engineering from Worcester Polytechnic Institute. My curriculum vitae is attached as Exhibit B.

II. Purpose and Summary of Affidavit

8. Section 5.14.1.2 of the New York Independent System Operator, Inc. (NYISO) Market Administration and Control Area Services Tariff (Services Tariff) requires that locational ICAP Demand Curves be established periodically through an independent review of the ICAP Demand Curve parameters by an independent consultant.[1] In order to develop the recommended ICAP Demand Curve parameters, the independent consultant develops the initial assumptions and analysis, and reviews these with the NYISO and stakeholders through a stakeholder process. This process culminates in the filing with the Federal Energy Regulatory Commission (FERC) of the ICAP Demand Curves approved by the NYISO Board of Directors. This process is commonly referred to as the ICAP Demand Curve reset (DCR) process.

9. Analysis Group Inc. (AGI) was hired as the independent consultant for review of the ICAP Demand Curves to be used starting in the 2017/2018 Capability Year. LCI worked with AGI to complete the tariff-required periodic review process (together, AGI and LCI are referred to in this Affidavit as the Consultants).

10. The purpose of this affidavit is threefold. First, we provide an overview of LCI's role in the DCR process, which is described more fully in the accompanying *Affidavit of Paul J. Hibbard, Dr. Todd Schatzki, and Craig Aubuchon* (AGI Affidavit). Second, we describe the methodology used to screen generating technology options and to estimate costs for technologies meeting the screening criteria. Third, we address certain key issues which impacted our basis for conceptual plant design and the resulting cost estimates, all of which are described more fully in Section II and Appendices A and B of the *Study to Establish New York Electricity Market ICAP*

[1] Capitalized terms that are not specifically defined in this Affidavit shall have the meaning set forth in the filing letter to which this Affidavit is attached or, if not defined therein, the meaning set forth in the Services Tariff.

Demand Curve Parameters dated September 13, 2016 (Final Report). The Final Report is attached as Exhibit D to the AGI Affidavit.

III. Overview of Role and Methodology

11. As more fully described in Section II of the Final Report and the AGI Affidavit, LCI's role was to select peaking unit technology options to be evaluated for each ICAP Demand Curve and to develop the necessary design (including site requirements, zone/location considerations and emission controls), cost and performance information for each option in Load Zones C, F, G, J, and K.

12. To comply with the Service Tariff requirements and applicable FERC precedent regarding peaking unit technology selection matters, LCI utilized the following screening criteria for technology selection:

    - Standard generating facility technology – available to most market participants;
    - Proven technology – operating experience as a commercial power plant;
    - Unit characteristics that can be economically dispatched;
    - Ability to cycle and provide peaking service;
    - Can be practically constructed in a particular location; and
    - Can meet environmental requirements and regulations.

13. LCI determined that the following peaking technologies satisfy the screening criteria:
    - Aeroderivative Combustion Turbines
        - General Electric (GE) LM6000
        - Rolls Royce (Siemens) Trent 60
        - GE LMS100
        - Mitsubishi Hitachi Power Systems (MHPS) Pratt & Whitney (P&W) FT4000 SwiftPac 60/120
    - Frame Combustion Turbines
        - GE 7FA.05[2]
        - Siemens SGT6-5000F5
        - MHPS 501GAC
        - Siemens SGT6-8000H
    - Reciprocating Internal Combustion Engines (RICE)
        - Wartsila 18V50SG (gas only) and 18V50DF (dual fuel)

[2] As more fully discussed in Section II and Appendix A of the Final Report, the GE 7HA.02 frame turbine does not currently have any commercial operating experience in simple cycle mode. Therefore, it was deemed ineligible for consideration as a peaking unit technology for this DCR. However, at the NYISO's request, LCI developed cost estimates and performance data for the GE 7HA.02 frame turbine for informational purposes only.

14. Based on further evaluation of candidate aeroderivative combustion turbines, frame combustion turbines and RICE machines, as discussed in Section II of the Final Report, LCI recommended that capital cost estimates be prepared for the following peaking plant configurations:

    - Two GE LMS100 PA+ units
    - One Siemens SGT6-5000F5 unit
    - Twelve Wartsila 18V50SG/DG engines

15. Capital investment costs comprised of plant installed cost, owner's costs, financing costs and working capital were developed for each technology in each zone. These cost estimates are more fully described in Section II of the Final Report with additional details set forth Appendix B of the Final Report.

16. The plant installation costs were obtained from the LCI proprietary power plant cost and performance models. Inputs to these models are derived from estimates prepared by CB&I Fossil Power Estimating Group (CB&I Power). CB&I Power and LCI are owned by Chicago Bridge & Iron Company N.V. (CB&I), a large technology, engineering, and construction company. These estimates were updated in the fourth quarter of 2015 and include the latest vendor budgetary pricing. We adjusted the bulk materials costs for each Load Zone using the city cost indices published in the RS Means® Building Construction Cost Data 2013 (Syracuse in Load Zone C, Albany in Load Zone F, Poughkeepsie and Suffern in Load Zone G, Queens in Load Zone J, and Riverhead in Load Zone K). We adjusted the construction labor cost assuming a totally subcontracted construction approach and developing labor cost for each Load Zone using the County General Construction Prevailing Wage Rate Schedules published by the New York State Department of Labor on June 1, 2015. Subcontracted labor rates were developed by adding Federal Insurance Contributions Act (FICA) tax, workmen's compensation, small tools, construction equipment and subcontractor overhead and profit. Work is assumed to be performed on a 50-hour work week by qualified craft labor available in each relevant location. Direct installation labor man-hours were adjusted for location productivity using in-house experience in power plant construction in New York City and New York State.

17. Owner's costs were estimated as 9 percent of direct capital costs, plus the cost of emission reduction credits (ERCs). In addition, social justice costs were estimated to be 0.9 percent of plant installed cost in New York City and 0.2 percent of plant installed cost in all the other Load Zones. These same assumptions were accepted by FERC in the last reset and in LCI's opinion remain valid and appropriate for this DCR.

18. Construction financing costs were developed from project schedules and associated cash flow curves.

19. Finally, working capital was estimated as 1 percent of direct capital costs plus the cost of an inventory of ultra-low sulfur diesel (ULSD) fuel equivalent to six days of full load operation for 16 hours per day priced at $14/MMBtu.

20. Fixed and variable operating and maintenance (O&M) costs were developed using the LCI proprietary power plant cost and performance models. These models include a detailed O&M cost program, which calculates the fixed costs (plant staffing, materials and contract labor, administrative & general costs, taxes, insurance and site leasing costs) and variable costs (water, chemicals, catalyst and major maintenance) dependent on the annual quantity of electricity generated and number of plant starts.

21. In assessing the plant staff average labor rate and benefits, LCI examined the wage rate information for power plant workers from the New York Department of Labor (DOL) website, as well as the operating and maintenance labor rates accepted by FERC in the last reset. The DOL wage rates for various occupations are available for all Load Zones, but are dependent on reported information from employers. As a result of LCI's review, it was determined that the DOL wage rates are inconsistent due to the varying levels of reporting by employers in each location and not necessarily representative of the current wage rates. Therefore, LCI escalated the labor rates accepted by FERC in the last reset for this study using the cumulative change in the Gross Domestic Product (GDP) implicit price deflator. The DOL data reviewed by LCI in assessing plant staff average labor rate and benefits for fixed O&M cost purposes is separate from the DOL data that was relied in developing the construction labor costs in connection with the capital investment cost estimates. The data utilized in developing the capital investment cost estimates represents union construction labor rates by county throughout New York State and does not raise the same concerns LCI noted with respect to employer reported information underlying the DOL data regarding wage rate information for power plant workers.

22. Section II of the Final Report contains an organized and detailed presentation of LCI's work as described above. Appendix B of the Final Report provides additional detail on the total capital investments, fixed and variable O&M costs, and performance data.

IV. Key Issues

23. LCI was involved in some of the key issues raised by stakeholders. These issues and our responses and assessment are summarized below.

A. Application of Selective Catalytic Reduction (SCR) Emission Controls

24. As further described in Section II of the Final Report, the conceptual designs and cost estimates developed by LCI for each peaking unit technology option included the necessary equipment and operating costs in order to meet the federal and New York State environmental requirements and regulations within each of the Load Zones evaluated in this DCR.

25. All of the peaking unit technology options considered in this DCR would require the installation of SCR to reduce NO_X emissions for a dual fuel plant design, primarily due to the higher uncontrolled NOx emission rates when firing liquid fuels.

26. Each of the peaking unit technologies evaluated in this DCR, with the exception of the Siemens SGT6-5000F5, would require the installation of an SCR on a gas-only plant in order to comply with New Source Performance Standards (NSPS) for Stationary Combustion Turbines. For a dual fuel plant design, the Siemens SGT6-5000F5 would require an SCR.

27. Load Zones C, F, and G (Dutchess County) have a non-attainment new source review (NNSR) major source threshold for NO_X of 100 tons/yr. A Siemens SGT6-5000F5 simple cycle gas-only plant constructed in these Load Zones could potentially accept a federally enforceable operating hour restriction of approximately 2,500 hours/year to avoid the installation of an SCR, often referred to as a "synthetic minor" air permitting approach. As noted above, a dual fuel Siemens SGT6-5000F5 simple cycle plant constructed in these Load Zones would require an SCR.

28. Including an SCR on a Siemens SGT6-5000F5 simple cycle gas-only plant mitigates certain siting, permitting, and future market risks, which are considered by power plant project developers. For example, the peaking unit technologies will need to obtain a Certificate of Environmental Compatibility and Public Need from the New York State Board on Electric Generation Siting and the Environment. In issuing a certificate, the Siting Board is required to determine the facility will minimize or avoid adverse environmental impacts to the maximum extent practicable.[3] A power plant design without state-of-the-art emission controls may receive significant local and environmental opposition, which could lengthen the project permitting schedule and adversely affect local community relations.

29. As further described in Section II of the Final Report, the NSPS for CO_2 emissions from "non-base load" combustion turbines would require an operating hour restriction of approximately 3,360 hours/year for a Siemens SGT6-5000F5 simple cycle plant. A Siemens SGT6-5000F5 simple cycle gas-only plant with SCR, limited to 3,360 hours/year of operation would have the potential to emit (PTE) approximately 40 tons/year of NO_X. A Siemens SGT6-5000F5 simple cycle gas-only plant without SCR that achieves a synthetic minor status by limiting the PTE NO_X below 100 ton/year of NO_X would have approximately 2.5 times the annual PTE NO_X as a Siemens SGT6-5000F5 simple cycle gas-only plant with SCR. These differences in the PTE NO_X would need to be considered by the Siting Board as it determines whether the facility will minimize or avoid adverse environmental impacts to the maximum extent practicable.

[3] New York Public Service Law, Section 168(3)(c) requires that "the adverse environmental effects of the construction and operation of the facility will be minimized or avoided to the maximum extent practicable…"

30. There would also be permitting risks to the extent the developer may seek to modify a gas only air permit to allow future dual fuel operations. Due to the changes in emission profiles (including start-up emissions) for a dual fuel plant, dual fuel at a gas only permitted site could create unacceptable permit restrictions in demonstrating compliance with National Ambient Air Quality Standards (NAAQS). In short, the decision to construct a facility anywhere in New York State without SCR introduces development risks and the potential for significant additional future SCR retrofitting cost (relative to the cost of an SCR included in the original plant design). LCI estimates that retrofitting a peaking plant that did not contemplate including an SCR at the time of construction could result in the cost of installing the SCR system at a later date of approximately 40 percent higher in cost than if the SCR had been considered in the original plant design. Future retrofits may be warranted or required due to regulatory action.

31. Considering the mix of project development and future risks discussed in the Final Report, it is AGI's and LCI's opinion that the developer of a new unit in any Load Zone in New York would more likely than not seek to include SCR technology at the time of construction.

B. New York City Site Elevation Requirements

32. As indicated in Section II of the Final Report, LCI included the cost to raise the Load Zone J, New York City site 3.5 feet to satisfy floodplain zoning requirements and New York City building codes to prevent damage to a facility from flooding similar to what occurred due to Hurricane Sandy in 2012. LCI considered that new power projects in Load Zone J would most likely be located on brownfield sites along the waterfront. The Federal Emergency Management Agency (FEMA) minimum site elevation requirement is 14 feet North American Vertical Datum of 1988 (NAVD88). LCI reviewed elevation maps and found that site elevations along the waterfront ranged from 10 feet to greater than 16 feet NAVD88. Accordingly, LCI concluded that 3.5 ft. of fill was a reasonable assumption.

C. Natural Gas Interconnection Costs

33. In developing the capital investment cost estimates described in Section II and Appendix B of the Final Report, LCI researched publicly available gas interconnection costs for recent power generation projects. The research included projects in New York State, as well as projects in neighboring regions. Based on this research and LCI's experience with gas laterals, an installed pipeline cost of $200,000 per inch diameter per mile was used. Using recent combined cycle power projects in New York State (with one project next to the pipeline and another project eight miles from the pipeline), LCI developed costs reflecting an average gas lateral length of four miles. Assuming a typical 16-inch diameter pipe interconnection and a length of four miles (except for New York City where LCI expects that the pipe diameter is likely to be smaller and the lateral length significantly shorter) the gas interconnection cost equals $12.8 million. The average cost for a metering and regulation station was

estimated at $2.8 million, which results in a total gas interconnection cost of $15.6 million. This cost was applied to all Load Zones.

34. These natural gas interconnection costs represent a generalized estimate to interconnect with either an interstate natural gas pipeline or a natural gas local distribution company (LDC) distribution system. Interconnection costs to an LDC may be higher or lower than comparable interconnection costs to an interstate pipeline, depending on such things as distance, terrain, and existing right-of-way. In LCI's professional opinion, it is reasonable to expect that the interconnection for Load Zone J would be significantly shorter than estimated above with a smaller pipeline diameter; however, the difficulty of installing a pipeline in New York City would likely offset any savings from a smaller and shorter pipeline. This would result in an installed pipeline cost greater than $200,000 per inch diameter per mile in New York City. LCI believes that a non-site specific cost for Load Zone J of $15.6 million for a one mile interconnect to a lower pressure LDC pipeline plus a metering station is reasonable.

D. Potential Capital Costs for Peaking Plant in Orange County versus Rockland County

35. Certain stakeholders requested that AGI and LCI assess the potential use of Orange County instead of Rockland County for an alternative site location within Load Zone G in addition to the Dutchess County location. LCI examined the difference in capital investment cost between Orange County and Rockland County and found that they were not materially significant. Although certain union construction craft rates for certain trades are lower for Orange County than for Rockland County, this slight difference would result in only about a one percent change in the total capital cost estimate for the Siemens SGT6-5000F frame combustion turbine if the plant were located in Orange County rather than Rockland County. This cost difference is not materially significant and is within the accuracy of the current estimates for a unit located within Rockland County. Therefore, AGI and LCI concluded that continued reliance on Rockland County as an alternative location for evaluation within Load Zone G is reasonable and appropriate.

V. Conclusion

37. LCI's role in this DCR process was to select peaking unit technology options to be evaluated for each ICAP Demand Curve and to develop the necessary design (including site requirements, zone/location considerations and emission controls), cost and performance information for each option in Load Zones C, F, G, J, and K.

38. In this role, we identified and evaluated technologies, selected the options and provided information on each option with the goal of fulfilling the Services Tariff's requirement that the peaking plant be the technology with the lowest fixed and highest variable costs among technologies that are economically viable. For each selected option, we developed capital costs, operating costs, operating parameters,

and considered applicable siting and environmental permitting requirements. We also considered how the peaking plant could be practically constructed within each location, and how a potential developer would evaluate various design capabilities and environmental control technologies when making investment decisions in consideration of project development and operational risk, and opportunities for revenues over the economic life of the project.

39. LCI's work products are presented in Section II and Appendices A and B of the Final Report.

40. This concludes our affidavit.

ATTESTATION

I am a witness identified in the foregoing Affidavit of Thomas A. Vivenzio, Dr. William F. Frazier dated November 17, 2016 (the "Affidavit"). I have read the Affidavit and am familiar with its contents. The facts set forth therein are true to the best of my knowledge, information, and belief.

Thomas A. Vivenzio
November 17, 2016

Subscribed and sworn to before me
This 17th day of November 2016.

Notary Public

My commission expires: June 24, 2022

ATTESTATION

I am a witness identified in the foregoing Affidavit of Thomas A. Vivenzio, Dr. William F. Frazier dated November 17, 2016 (the "Affidavit"). I have read the Affidavit and am familiar with its contents. The facts set forth therein are true to the best of my knowledge, information, and belief.

W.F. Frazier

Dr. William F. Frazier
November 17, 2016

Subscribed and sworn to before me
This 17th day of November 2016.

Notary Public

My commission expires: June 24, 2022

Exhibit A

THOMAS A VIVENZIO **Senior Principal Consultant**

Mr. Vivenzio is a Senior Principal Consultant with over 40 years of experience in power, process, and environmental engineering. He is the author of many technical papers and several EPRI Reports. He has extensive experience in the design, cost and performance of pulverized coal, fluidized bed, combustion turbine and combined cycle power plants. He is also a specialist in gasification technologies and in the design of gasification combined cycle power plants. He has developed a library of power plant cost and performance Excel spreadsheet models that Xcel Energy, Exelon Generation and the Long Island Power Authority have utilized for resource planning and project evaluations.

He has performed numerous assessments of gasification and pyrolysis technologies and has participated in studies of the design and cost of carbon dioxide removal from power plant flue gas.

Mr. Vivenzio has performed due diligence reviews, asset evaluations and condition assessments in support of financing of new projects, refinancing of existing assets and purchases/sales of assets for many clients including Arclight, Energy Capital Partners, Topaz Power Group, HighStar Capital, Direct Energy, Blackstone Group, Exelon Generation, National Grid, LS Power, Indiantown Cogeneration L.P., Birchwood Power Partners L.P., Alterna Springerville LLC., Longview Power LLC., Capital Power, GE Capital, Leucadia National, MC Credit Partners and I Squared Capital.

Prior to joining the consulting group in 2002, Mr. Vivenzio was Shaw's Lead Mechanical Engineer for the Keyspan Ravenswood Combined Cycle Project in New York City.

PROFESSIONAL EXPERIENCE

- 2002 - Present**:** Lummus Consultants International, Inc., Senior Principal Consultant
- 2000 -2002 Shaw Group, Senior Lead Engineer
- 1973 – 2000: Stone & Webster Engineering Corporation, Senior Lead Engineer

SELECTED CONSULTING ASSIGNMENTS

Longview Power, LLC and GenPower Services, LLC, Longview Supercritical Pulverized Coal Power Plant, West Virginia

In support of financing, Mr. Vivenzio was part of a Lummus Consultants team reviewing this supercritical 700 MW Coal Plant to validate the scope and cost of the rehabilitation plan necessary to resolve problems that have plagued the plant since commissioning.

General Electric Financial Services (GE Capital), Linden Cogeneration Facility, New Jersey

In support of the sale of GE Capital's ownership position in this large multi-unit cogeneration plant located inside a refinery, Mr. Vivenzio coordinated the preparation of an independent engineers report for potential buyers. He was also responsible for developing an indicative cost estimate for the planned new unit at the site.

MC Credit Partners LP, Argex Titanium Dioxide Plant, Valleyfield, Canada

In support of financing, Mr. Vivenzio was part of a team reviewing the proposed project utilizing new technology to convert ilmenite ore to high quality titanium dioxide pigment. Mr. Vivenzio identified the design, capital cost overrun, performance and O&M cost risks and worked on a risk management plan.

HighStar Capital IV LP, New Salem Harbor Combined Cycle Power Station

Mr. Vivenzio was part of a Lummus Consultants team that performed an independent technical review of the project which led to HighStar making an equity investment. In finalizing the EPC contract, he

recommended changes in the technical specification and approved vendor list. Mr. Vivenzio also reviewed Spectra Energy's design basis and execution plan for the gas pipeline to the site and the onsite metering/regulation station.

RJS Power Holdings LLC, Back-up Fuel Study for York Power Plant, Pennsylvania

Mr. Vivenzio was responsible for investigating the technical and economic feasibility of providing a back-up fuel for the York combined cycle plant with interruptible pipeline gas supply. The options studied included adding distillate fuel capability; providing onsite LNG; and providing onsite liquid propane storage and air mixing system to produce a "substitute natural gas".

Xcel Energy, Development of a Power Plant Cost & Performance Database

Mr. Vivenzio has been developing, expanding and updating a power plant database for Xcel to use for planning since 2004. The database is comprised of Excel spreadsheet models of all types of power plants with fuel and cooling system design options. The models include spreadsheets showing the capital cost breakdown and typical project schedule; start up times, start up fuel consumption and full and part load performance; planned and forced outage rate; plant fixed and variable operating and maintenance cost breakdowns; and water consumption and environmental emissions.

Leucadia National Corporation, Review of Lake Charles Gasification Project, Louisiana

Mr. Vivenzio performed a review of the Lake Charles Gasification Project for the Leucadia Board of Directors. Mr. Vivenzio reviewed he project documents and identified the technical risks and pointed out that compared to similar projects the project capital cost estimate was significantly low. Leucadia could not come to terms with the EPC contractor and decided not to continue with the project.

I Squared Capital, Review of MacQuarie District Energy Facilities, Chicago

Mr. Vivenzio was responsible for evaluating the condition, operating and maintenance costs and future capital expenses for MDE's Chicago Thermal district chilling facilities.

NStar Electric, Non-Transmission Alternatives Analysis, Massachusetts

Mr. Vivenzio was responsible for developing design, reliability and performance and cost information for distributed generation and energy storage alternatives to a proposed transmission line upgrade project.

Energy Capital Partners, Brayton Point Repowering Study, Massachusetts

Mr. Vivenzio was responsible for developing capital cost estimates, performance information and O&M cost estimates for various combined cycle steam turbine repowering configurations.

Exelon Generation, Gas fired power Plant Technology Book

Mr. Vivenzio was the project engineer developing cost and performance models for combustion turbine combined cycle power plants and simple cycle combustion turbine power plants representing the range of current combustion turbine models and plant configurations/sizes. More recently he has developed a cost and performance model for reciprocating engine plants based on the largest Wartsila and Jenbacher engines. Mr. Vivenzio has worked continuously with Exelon Generation to develop power plant cost and performance information for project planning and to perform numerous site specific repowering studies since 2005.

ISO New England, Benchmark Pricing Model

Mr. Vivenzio was responsible for providing cost and performance information for a range of new power plant sizes and designs for the internal market monitor's Benchmark Pricing Model for evaluating the reasonableness of new plant bids for the forward capacity market auction.

Lignite Energy Council, Study of Carbon Dioxide Capture Technologies and Costs Associated with Lignite-Based Electrical Generating Stations, North Dakota

For five existing lignite coal fired power stations in North Dakota, Mr. Vivenzio developed post combustion CO_2 capture and compression systems designed for 90% CO_2 capture and 50% CO_2 capture. He identified the modifications to the existing equipment; developed detailed heat and material balances with stream tables, equipment lists, chemicals and utilities breakdowns and capital and operating cost estimates; and calculated the resulting reduction in the station's net output and increase in net heat rate.

EDUCATION

- Master of Science (MS), Chemical Engineering, University of Pennsylvania
- Bachelor of Science (BS), Chemical Engineering, University of Rhode Island

PROFESSIONAL REGISTRATION

- Registered Professional Engineer (PE), State of Wisconsin (for 35 years, did not renew in 2015)

PUBLICATIONS

- "Integration of Advanced Gas Fired Power Plants with the Expansion of Enhanced Oil Recovery", Electric Power Conference, April, 2014
- "Preparing Nuclear New Build with the Economics of Existing and New Coal Fired Power Generation", Kuhr, R., Vivenzio, T. and Hannink, R., May 12, 2012
- "Repowering or Relacement? Is Repowering the Solution for your Brownfield site?", Youmans, J Frazier, W., Grieve, R, and Vivenzio, T., Coal Power, 2006
- "Investing in MegaProjects – A Comparison of Costs and Risks", Kuhr, R.W. and Vivenzio, T.A., Power-Gen 2005
- "Coal to Synfuels Economics", Sheridan, M.E. and Vivenzio, T.A., Coal-Gen 2005
- Brushwood, J.S.; Campbell, K.; Hanson, C.V.; Horvath, A.; and Vivenzio, T. "A Combined Cycle Power Generation/Alfalfa Processing System: Part 1: Development and Testing." Stockholm, Sweden, June 1998.
- "New Bern Biomass to Energy Feasibility Study." EPRI Project 3407-3, EPRI Report TR-106062, February 1996.
- Hulkkonen, S, Vivenzio, T.A.; Wells, P. "Performance and Cost of an IVOSDIG Biomass GCC System." San Francisco, California, October, 1995.
- Kuhr, R.W.; Vivenzio, T.A.; Wong, P.K.; Boudreaux, J.P.; Rorstrom, E.G.; and Bradley, C.F. "Developing Regional Cost and Performance Data for Generation Planning." Chicago, Illinois, April 1992.
- Vivenzio, T.A.; Zabolotny, E.R.; and Virr, M.J. "Application of Coal Gasification in the Power Generating Industry" Orlando, Florida, December 1990.
- Vivenzio, T.A. "Using the Slagging Combustor for Power Plant Retrofits" Cleveland, Ohio, May, 1990.
- Zabolotny, E.R.; Vivenzio, T.A.; and LaHaye, P.G. "Externally Fired Combined Cycle." Chicago, Illinois, April, 1990.
- Vivenzio, T.A. and Rossi, J.V. "Combined Cycle Coal Gasification: Options for Utilities." Power Engineering, 1984.
- Rosenberg, R.A.; Vivenzio, T.A.; and Zabolotny, E.R. "Piping Design Considerations for Coal Gasification Combined Cycle Power Plants." Orlando, Florida, June 1982.
- "Impact of Cleaned Coal on Power Plant Performance and Reliability." Electric Power Research Institute Project 1030-6, CS1400, Final Report, April 1980.

Exhibit B

WILLIAM F. FRAZIER, PHD **Principal Consultant**

Dr. Frazier has over 35 years of environmental and power engineering experience. He has been responsible for developing and evaluating compliance strategies for electric utilities as well as bidders for electric utility generating assets. He has provided project management on matters pertaining to air pollution control, compliance strategies, fossil power plant permitting and environmental due diligence for energy facilities. Dr. Frazier has also been responsible for the environmental assessment of various utility assets as part of multiple Independent Engineer reports.

Dr. Frazier has directed the development and/or evaluation of numerous environmental compliance plans. This includes evaluations of the potential cost impacts of compliance options for Title I and Title IV of the Clean Air Act Amendments of 1990, the Regional NO_X SIP Call, the Clean Air Interstate Rule (CAIR), the Cross State Air Pollution Rule (CSAPR), the Clean Air Mercury Rule (CAMR), the Mercury and Air Toxics Standard (MATS), Coal Combustion Residuals (CCR) rule, proposed revisions to the Effluent Limitations Guidelines (ELGs) for the Steam Electric Power Generating Category, and various state multi-pollutant regulations. The projects have involved coal, oil, and gas-fired generating units.

PROFESSIONAL EXPERIENCE

2003 – Present	Lummus Consultants International, Inc.
2000 - 2003	Earth Tech
1990 - 2000	Stone & Webster Engineering
1981 - 1990	Virginia Power/Dominion Energy
1978 - 1981	University of Tennessee

EXAMPLE CONSULTING ASSIGNMENTS

Topaz Power Group, Combined Cycle Power Plant Development and Permitting, Corpus Christi, Texas. Dr. Frazier was the responsible Environmental Engineer for the repowering of the Barney M. Davis and Nueces Bay Stations in Corpus Christi, Texas. These repowering projects originally involved the removal and replacement of the gas-fired steam generators with pet coke fueled, fluidized boilers. Topaz Power later decided to repower the plants with General Electric 7FA combustion turbines and heat recovery steam generators. Dr. Frazier served as an interface between Shaw Consultants (Lummus Consultants' predecessor company) and an environmental consulting company responsible for preparing air permit applications for each of the repowering projects. This involved timely delivery of various plant design and environmental performance data required for the air permit applications, review of air permit application documents and development of emissions data required for each of the applications.

Entergy, Natural Gas Combined Cycle Repowering Project, Louisiana. Dr. Frazier was the technical lead for the preparation of a combined cycle BACT analysis for a proposed 2 x 1 combined cycle facility in Louisiana. He also was responsible for developing emission estimates for the combustion turbine/duct burner for all operating scenarios.

National Grid and Long Island Lighting Company (LIPA), Repowering Studies, Long Island, NY, Dr. Frazier was the Environmental Lead for the Northport and Port Jefferson repowering studies, which evaluated the options available for re-powering both facilities with combined-cycle technology. The Study considered both traditional "hybrid" re-powering scenarios utilizing the existing steam turbines and "backyard" or site repowering scenarios utilizing stand-alone new combined cycle units. Some of the key environmental issues that were addressed by the Study included water use, air emissions, cooling system,

stormwater and wastewater, noise, and air dispersion modeling. The study produced estimates of capital cost, schedule, performance, operating costs, availability, site layouts and renderings for each of the options considered.

Confidential Client, Critical Issues Assessment for Power Plant Development in Georgia
Project Manager for a critical issues assessment for the development of a 276-megawatt (MW) combined-cycle facility at a site in Georgia. The proposed project included a GE 7FA combustion turbine, heat recovery steam generator (HRSG), and steam turbine. Inlet air cooling, duct firing and wet cooling towers are included in the initial project design. The assessment identified critical permitting issues that could affect the ultimate successful licensing of the project. The project also identified and assessed alternatives and opportunities to address these issues. The key environmental issues that were addressed included:

- Air Quality.
- Endangered Species and Ecological Resources
- Water Supply
- Wastewater Disposal
- Wetlands and Coastal Resources
- Land Use and Zoning
- Potential Site Contamination
- Environmental Justice

A permitting plan, including a list of required permits and an environmental permitting schedule, was also prepared.

James City Energy Park LLC, Combined Cycle Power Plant Permitting, James City County, Virginia. Dr. Frazier was the Project Manager for a proposed combined cycle project consisting of two GE 7FA in combined cycle. The Project included a PSD Permit to Install application, which was submitted to Virginia Department of Environmental Quality (VDEQ). The Project included a Phase I Archaeological Study and a Sound Level Evaluation in support of a Special Use Permit from James City County as well as an Army Corps of Engineers Jurisdictional Wetlands Determination and Delineation. In addition, an Environmental Assessment was prepared to support the Virginia State Corporation Commission filing for authority to construct and operate an electric generating facility.

Mirant, Danville Power Project, Combined Cycle and Peaking Units, Danville, Virginia. Project Manager for environmental permitting support for a proposed power project consisting of both combined cycle and peaking power facilities. Two GE 7FA turbines in combined cycle and four GE 7EA turbines in simple cycle mode were proposed. The Project included the preparation of an air quality modeling protocol and a PSD Permit to Install application to the Virginia Department of Environmental Quality and an assessment of the impacts of the proposed facility at the Shenandoah National Park and the James River Face Wilderness Area. This Class I area analysis was submitted to the VDEQ and Federal Land Managers (FLMs). Prepared technical memoranda concerning air emissions for local meetings, evaluation of potential surface water supplies, and use of POTW effluent as cooling tower make-up. Managed input to an Environmental Assessment that was prepared to support the Virginia State Corporation Commission filing for authority to construct and operate an electric generating facility.

California Energy Commission (CEC), Study of Carbon Capture and Storage (CCS) Systems for Natural Gas Combined Cycle (NGCC) Power Plants, Dr. Frazier provided technical input and peer review of a study of CCS systems for NGCC power plants in California. His input and peer review has

focused on environmental permitting issues for retrofitting CO_2 capture technologies to existing facilities, potential dispatch of an existing and a new NGCC facility equipped with CCS, and options to minimize water consumption within the design constraints of CO_2 post-combustion capture systems.

Confidential Client, Evaluation of Potential GHG Impacts on Future Operations and Net Revenues of Various Generating Assets, Dr. Frazier was responsible for performing an evaluation of potential impacts of GHG legislative/regulatory programs on future operations of coal-fired and natural gas combined cycle power plants. This effort explored the potential impacts on future capacity factors and net revenues on a portfolio of generating assets in support of a bid preparation for asset acquisition. The effort utilized the PROSYM model and evaluated impacts over a range of assumed CO_2 allowance prices. The analysis captured the potential impacts of CO_2 allowance prices on marginal clearing prices as well as allowance costs for each of the assets.

Lignite Energy Council, Study of CO_2 Capture Technologies and Costs for Lignite-Based Electrical Generating Units, Dr. Frazier was a Peer Reviewer for a study sponsored by the Lignite Energy Council (LEC). This study assessed CO_2 capture technologies and determined the most promising approaches for implementing CO_2 control at lignite-fired power stations within five years of the study period. Current technology suppliers were solicited for information on mature CO_2 control technologies and this information, coupled with public domain data and recent cost data, was applied to the individual lignite-based power stations.

Confidential Client, Natural Gas Simple Cycle and Combined Cycle Environmental Due Diligence, California, Dr. Frazier provided environmental due diligence support for nine generating stations in California, including both simple cycle and combined cycle configurations.

Emissions Control Technology Summary Report, Lead technical consultant for an assessment of alternative emissions control technologies for nitrogen oxides (NO_X), sulfur dioxide (SO_2), sulfur trioxide (SO_3), particulate matter (PM), mercury (Hg), carbon monoxide (CO), and carbon dioxide (CO_2) for pulverized coal (PC) boiler, circulating fluidized bed (CFB) boiler, integrated gasification combined cycle (IGCC), combined cycle gas turbines (CCGT), and simple cycle gas turbines (SCGT) generating technologies. The report provided a brief description of the emission control technologies commonly applied to each of the generating technologies assuming a new unit installation. A discussion of impacts of retrofitting emission control technologies to existing power plants was also presented. The report provided a range of capital and O&M costs associated with the installation of each emission control technology as well as expected emission rates for each technology for typical fuel options.

Edison Mission Energy, Multi-State Environmental Permitting Assessment, Nine States. Project Manager for the evaluation of permitting requirements for generic simple cycle and combined cycle power plants in nine states. Managed review of permitting requirements in each state and the development of permitting schedules for each type of facility. Unique aspects of permitting energy facilities were identified for each of the states.

NRG, Limestone Unit 3 New Coal-Fired Generating Unit, Texas. Lead technical consultant related to best available control technology (BACT) analysis for a nominal 800 MW pulverized coal-fired boiler firing low sulfur subbituminous coal, blends of subbituminous coal with pet coke, and blends of subbituminous coal with bituminous coal. Dr. Frazier served as an expert witness concerning Best Available Control Technology for NRG Texas Power LLC before the Texas State Office of Administrative Hearings.

Exelon, Clean Coal Technology Assessment, Lead technical consultant related to K-Fuel and Carbon Sequestration for an assessment of several developing Clean Coal Technologies, including K-Fuel, IGCC (with and without CO_2 capture), PFBC (including supercritical PFBC), Ultra Supercritical PC, Oxyfuel Combustion, Chilled Ammonia CO_2 Scrubbing, Amine CO_2 Scrubbing, and Carbon Sequestration. For each of the technologies Shaw provided a description of the technology, status of technology development, projected performance, projected capital costs and projected CO_2 removal costs ($/ton of CO_2).

EDUCATION

- PhD, Civil Engineering/Environmental Engineering, University of Tennessee, 1984
- MS, Civil Eng./Environmental Eng., Northeastern University, Boston, Massachusetts, 1976
- BS, Electrical Engineering, Worcester Polytechnic Institute, Worcester, Massachusetts, 1974

PROFESSIONAL REGISTRATION and MEMBERSHIP

- Professional Engineer, Virginia (expired license)
- EPRI, Previous Utility Representative of Environmental Control Task Force
- EPRI, Previous Utility Representative of Flue Gas Desulfurization Process Committee
- ASME, Previous Chair of the Executive Committee of the Environmental Engineering Division

PUBLICATIONS AND PRESENTATIONS

- C. Wedig, M. Spruth, W. F. Frazier, "MATS, CCR, & ELG Perspectives for the Fate of Trace Heavy Metals in Coal Plant Gas, Liquid and Solids Streams" presented at Reinhold Environmental LTD. 2016 APC-Wastewater/PCUG Conference, Dearborn, Michigan, July 19, 2016.
- C. Wedig, W. Frazier, D. Ahern, "Clean Power Plan and Ozone – How does it fit in?" presented at Reinhold Environmental LTD. 2016 NOX-Combustion-CCR Round Table, Orlando, Florida, February 1, 2016.
- W. F. Frazier, and M. Green, "Market Price Forecasting and DCF Analysis", presented at 45th Annual Taxation Conference, Appraisal for Ad Valorem Taxation, Wichita State University, Wichita, Kansas, July 28, 2015.
- W. F. Frazier, and M. Green, "Property Tax Implications of EPA Regulations and Natural Gas Prices on Coal-Fired Generation", presented at 42th Annual Taxation Conference, Appraisal for Ad Valorem Taxation, Wichita State University, Wichita, Kansas, July 31, 2012.
- C. Wedig, D. Ahern, E. Begg, W. F. Frazier, "Air Quality Control Systems (AQCS) for Carbon Capture Ready (CCR) Coal-Fired Power Plants" presented at POWER-GEN International -2009, Las Vegas, Nevada December 8-10, 2009.
- C. Wedig, W. F. Frazier, "Review of Full-Scale Mercury Control Projects" presented at POWER-GEN International 2007, New Orleans, December 11-13, 2007.
- Youmans, J., W. Frazier. R. Grieve, and T. Vivenzio, "Repowering or Replacement? Is Repowering the Solution for your Brownfield Site?" presented at Electric Power 2006, Atlanta GA, May 3, 2006.
- B. K. Maillet, W. F. Frazier, D. Mannion, F. Austin, "The Impact on the Power Generation Community of the Regional Greenhouse Gas Initiatives in the United States: a Late 2004 Perspective," presented at the 2004 PowerGen Conference, December 2004.

- W. F. Frazier and A. Jablonowski, “Estimating Future Costs to Comply with Air Quality Regulations at Coal-Fired Power Plants” presented at the Coal-Gen Conference, Columbus Ohio, August 6, 2003.
- W. F. Frazier, R. M. Dunn, and D. C. Baublis, “Coordinated NOx Control Strategies: Phase II Title IV, Ozone Transport Region and Ozone Transport Assessment Group,” presented at the 1998 American Power Conference, April 1998.
- W. F. Frazier, D. C. Baublis, and R. M. Dunn, “Regulatory and Technical Options for Cost-Effective NOx Control for Power Producers,” presented at the International Joint Power Generation Conference, Denver, Colorado, November 3-5, 1997.
- W. F. Frazier, D. C. Baublis, and R. M. Dunn, “Cost Effective NOx Reduction Strategies for Power Producers and Industrial Sources,” presented at Latin American Power ’97, Caracas, Venezuela, May 1, 1997.
- D. C. Baublis, W. F. Frazier, D. Killen, T. Copolo, D. Flynn, and J. Nelson, “Strategic Compliance Planning Using the NOxCOMP Computer Model,” presented at the American Power Conference, Chicago, Illinois, April 1-3, 1997.
- R. Dunn, W. F. Frazier, and S. Vigeant, "NOx Compliance Planning for Titles I and IV," Expert Opinion Supplement to Compliance Strategies Review, Vol. 4, No. 5, March 1, 1993.
- W. F. Frazier, H. Gastwirth, R. J. Mongillio, D. M. Shattuck, and C. Wedig, "Air Toxics Impact on Environmental Compliance Planning and on Design and Operation of Air Quality Systems," presented at Joint Power Generation Conference, Atlanta, Georgia, October 18-22, 1992.
- F. E. Depenbrock and W. F. Frazier, "Compliance Planning for Title IV, Phase II of the Clean Air Act Amendments of 1990," presented at the American Institute of Chemical Engineers Summer National Meeting, Minneapolis, Minnesota, August 12, 1992.
- Calafiore and W. F. Frazier, "Acid Rain Compliance: An Evaluation of Short-Term and Long-Term Strategies," presented at the Association of Energy Engineers Air Quality Congress '91, Boston, Massachusetts, June 13, 1991.
- W. F. Frazier, H. Gastwirth, R. J. Mongillo, D. M. Shattuck, and C. Wedig, "Wet Flue Gas Desulfurization Systems Designed and Operated to Meet the Clean Air Act Amendments of 1990," presented at the American Power Conference, 53rd Annual Meeting, Chicago, Illinois, April 29-May 1, 1991.
- P. A. Ireland, G. D. Brown, W. F. Frazier and P. T. Radcliffe, "Site Specific Evaluation of Six Sorbent Injection Processes," presented at the FGD and Dry SO_2 Control Symposium, St. Louis, Missouri, October 25-28, 1988.
- W. F. Frazier, and P. A. Ireland, G. D. Brown and M. W. McElroy, "A Site-Specific Evaluation of Dry SO_2 Emission Controls," presented at the 1987 Joint Power Generation Conference, Miami, Florida, October 8, 1987.
- W. F. Frazier, "An Evaluation of Retrofit Options for SO_2 and NOx Control for an Eastern Electric Utility," Proceedings of the American Power Conference, Volume 48, 1986.
- W. Borowy, M. McLauchlin, and W. F. Frazier, "ESP Energy Management and Optimization of Collection Efficiency," presented at the EPRI/EPA Joint Particulate Control Conference, New Orleans, LA, February 26, 1986.
- W. F. Frazier and J. R. Letarte, "Air Pollution Control Equipment Considerations for Coal Water Mixture Combustion Products," presented at the Tenth International Technical Conference on Slurry Technology, Lake Tahoe, Nevada, March 25-28, 1985.

- W. F. Frazier and W. Borowy, "Evaluation of Utility Cold-Side Electrostatic Precipitators," presented at the Joint ASME/IEEE Power Generation Conference, Milwaukee, Wisconsin, October 20-24, 1985, paper 85-JPGC-APC-3.
- W. F. Frazier and W. T. Davis, "Fly Ash Penetration in Periodically-Cleaned Woven Fabric Filters," presented at the Third Conference on Fabric Filtration Technology for Coal-Fired Power Plants, Scottsdale, Arizona, November 19-21, 1985.
- W. F. Frazier, "Penetration Mechanisms in Periodically-Cleaned Woven Fabric Filters," Doctoral Dissertation, University of Tennessee, Knoxville, Tennessee, December 1984.
- R. E. Kohl, R. T. Combs and W. F. Frazier, "Assessment of the Design, Operation and Performance of the Rigid Electrode Precipitators Serving Virginia Electric and Power Company's Chesterfield #5 Boiler After Three Years of Service," presented at the Joint ASME/IEEE Power Generation Conference, paper 83-JPGC-APC-3.
- W. F. Frazier and W. T. Davis, "Effects of Flyash Size Distribution on the Performance of a Fiberglass Filter," presented at the Third Symposium on the Transfer and Utilization of Particulate Control Technology, Orlando, Florida, March 10, 1981.