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August 2, 2013

Christian Johanningmeier, PE
Power Production Superintendent
Columbia Water & Light
P.O. Box 6015
Columbia, MO 65205

Dear Mr. Johanningmeier:

Subject: Final Combined Cycle Conversion Feasibility Review Report

This letter report presents a high level feasibility review for converting four existing GE Frame 6B simple cycle combustion turbines to a combined cycle configuration for Columbia Water & Light (CWL) at their Columbia Energy Center (CEC) located in Columbia, Missouri. The scope of work for this project included the following:

- Prepare conceptual combined cycle arrangement drawing showing approximate equipment sizes and locations.
- Prepare simple payback analysis including conceptual capital cost estimate for converting to combined cycle.
- Develop sensitivity analysis that shows the impact that purchased electricity price, capital cost and gas price variations have on the payback period.

Results of the feasibility review indicate that the CEC has adequate space for converting the existing simple cycle equipment to a combined cycle facility with only minor impact to the operational availability of the existing combustion turbines during construction. Off-site utility services to support the combined cycle including natural gas supply, potable water, sewer, process water supply, discharge water return, and electrical transmission lines either exist already or are believed could be made readily available.

The conceptual capital cost for converting the facility to combined cycle was estimated to be $160 million. Results of the simple payback analysis indicate a payback period of 17.6 years assuming the facility operates at a 92 percent capacity factor (approximately 8,060 hours per year at full load equivalent). Other values and assumptions used in the analysis including purchased electricity price, fuel price, labor cost, property tax and insurance costs, and maintenance costs are identified in the write-up that follows.

Finally, the sensitivity analyses that were generated show that purchased electricity price has the most significant impact on payback period; followed by capital cost. The fuel price has very little impact on payback period since gas consumption will be approximately the same for combined cycle operation as simple cycle operation. Results of the sensitivity analysis are summarized in Table 1, below.

This document was sent electronically.

Table 1: Sensitivity Analysis Summary

Variable	Low		High	
	Value	Payback Period	Value	Payback Period
Purchased Electricity Price	$0.042/kW-hr	8.3 yrs	$0.020/kW-hr	41.8 yrs
Capital Cost	$112 million	9.6 yrs	$208 million	32.3 yrs
Gas Price	$2.56/MMBtu	16.4 yrs	$7.68/MMBtu	19.0 yrs

Existing Facility
The existing simple cycle plant is located at 4902 Peabody Road in Columbia, Missouri. Currently, the facility operates in simple cycle operation with four single-fuel GE Frame 6B combustion turbines. Each combustion turbine is rated for 36 MW at 95°F for a nominal total of 144 MW for the facility. The associated existing ancillary equipment is shown on the general arrangement, Drawing X-1, included in the end of this report.

High pressure natural gas is supplied to the facility by a pipeline operated by AmerenUE. Two, 50 percent dew point heaters are located on-site. The GE combustion turbines are equipped with diesel engines for starting and are capable of black-start operation.

Conceptual Combined Cycle Arrangement
Drawing X-1 demonstrates that there is adequate space to convert the existing simple cycle facility to combined cycle. Further arrangement optimization would be performed during preliminary engineering phase.

As shown, the conversion can be completed with minimal existing equipment being relocated. The relocation of this equipment can be staggered throughout the construction schedule so that only one CT would be unavailable at any given time. Further discussion on the conceptual combined cycle arrangement follows.

Off-Site Utility Services
The existing natural gas pipeline to the site has adequate capacity and pressure to support combined cycle operation. Potable water and sewer line connections to the City of Columbia already exist. It was assumed that off-site process water supply and discharge pipelines to and from the facility could be made available through interconnections with the City of Columbia. Process water supply requirements to combined cycle facility are estimated to be approximately 3 MGD at average annual ambient conditions.

CT and HRSG Configuration
The combined cycle configuration used in this analysis is based on each combustion turbine (CT) being paired with a separate heat recovery steam generator (HRSG) as an individual CT/HRSG train. The four CT/HRSG trains will generate steam at approximately 1,000 psig for two steam turbines (ST) located in a steam turbine building. An alternate configuration had been considered that included a common HRSG for two CTs for a total of two HRSGs and two STs with the four existing CTs. The alternate configuration was eliminated early on for the following reasons:

- Site Space Constraints – There is limited space for adding HRSGs between the existing CTs and the western site boundary. The alternate configuration requires more space because of the larger HRSG and the additional interconnecting ductwork.
- Cost – The four existing CTs are identical with left-hand radial exhausts. The alternate configuration requires a mirrored CT arrangement to minimize interconnecting ductwork. The cost savings that might be realized with the alternate arrangement would be offset by the need to modify two of the existing CTs with right-hand axial exhausts.
- Less Operational Flexibility – A forced outage (e.g., tube leak) on one HRSG would mean a 50 percent loss of steam generating capacity as compared to 25 percent for the four CT/HRSG arrangement.

An SCR and CO catalyst would be included with each HRSG. Duct burners have not been included in our analysis because of the additional costs associated with the burners themselves and the incremental plant size increase on the steam cycle side associated with supplemental firing. It is assumed that an unfired HRSG will provide the most favorable economics for this review. In addition, bypass stacks on each CT would be included to preserve quick startup capability of simple cycle operation.

Outlines of the HRSGs are shown on Drawing X-1. The HRSG outlines include space for SCR and CO catalyst sections. For conservatism, we've shown a longer HRSG that includes a 20-foot section for duct burners. A boiler feed pump skid is located adjacent to each HRSG.

Steam Turbine Building
The steam turbine building will house the two steam turbine generators, condensers and air removal equipment, condensate pumps, control room, lab, water treatment system and chemicals, compressed air equipment, and electrical room. The steam turbine building will be located in close proximity to both the existing generator step-up (GSU) transformer area and the HRSGs. The generator output from the two steam turbines will be bussed together in common switchgear that feed a new GSU transformer. Locating the steam turbine building near the HRSGs reduces steam and condensate pipe lengths. The existing parking lot would be enlarged and relocated to the north side of the steam turbine building, with a new road. Water and wastewater tanks will be located on the west side of the steam turbine building.

Cooling Towers
One cooling tower for each condenser is proposed. The two cooling towers would be located relatively close to the steam turbine building to minimize circulating water piping and pump head, but far enough away to optimize free flow of air to the cooling towers. In addition, the cooling towers would be located away from the GSU transformers and Bolstad Substation. Based on examination of the wind rose plots for the City of Columbia, prevailing winds are generally out of the northwest. The cooling towers would be oriented in-line and longitudinally in the direction of prevailing winds to minimize interference and recirculation effects.

Relocated Existing Equipment
The proposed arrangement shown on Drawing X-1 would require minimum relocation of equipment. The combustion turbine lube oil air coolers and CO_2 skids would need to be moved to allow for the installation of the HRSG. The combustion turbine wash water skid may also need to be relocated depending on the final size and location of the steam turbine building.

Electrical Discussion
The upgrade to the electrical system involves adding an additional GSU transformer to the 69-kV main bus. This transformer would be protected with a 69-kV breaker, and have a 69-kV disconnect switch for isolation. Our review assumes that the bus and line are capable of handling the increased capacity. This could be further verified by a system and transmission interconnect planning study. Items that should be verified include the load and fault current capacity of the existing equipment and relay settings.

Economic Evaluation
A simple payback analysis was performed to determine the number of years required to recover the initial capital investment associated with converting the simple cycle facility to combined cycle. The simple payback analysis does not account for time value of money. Performance data used in the analysis was produced with GT PRO modeling software. Based on the performance modeling for an average annual ambient temperature of 55°F, 60 percent relative humidity, and elevation of 840 feet the output of each simple cycle gas turbine was determined to be approximately 40 MW. This is consistent with our discussion with CWL, where they indicated that the existing combustion turbine generator output ranges from 35 MW to 40 MW.

Table 2, below, summarizes the predicted output and heat rate performance data used in the analysis for simple cycle and combined cycle operation at the average annual conditions identified above.

Table 2: Predicted Plant Performance Data

Plant Performance	Unit	Simple Cycle	Combined Cycle
Net Output	kW	160,250	249,940[1]
Net Heat Rate	BTU/kW-hr (HHV)	11,933	7,779

Notes:
1. The net output from the combustion turbines for combined cycle operation will be approximately 0.4 percent less than for simple cycle operation due to the added backpressure from the HRSG and associated ductwork.

Utility Prices
The purchase electricity price used in the analysis was based on MISO day ahead monthly average locational marginal prices (LMP) for the CWLD location. Data from the past four years were averaged to establish the purchase electricity price. The fuel price used in the analysis is the average of the NYMEX Henry Hub forward curves from June 2013 to June 2014 plus $0.55. The prices are shown in Table 3, below.

Table 3: Utility Prices Used in the Economic Analysis

Utility	Unit	Price
Natural Gas (HHV)	$/MMBtu	5.12
Purchased Electricity	$/kW-hr	0.0277

Conceptual Capital Cost Estimate for Combined Cycle Conversion
The conceptual capital cost associated with converting to combined cycle was estimated based on the cost estimating package (PEACE) included with the performance modeling software, equipment pricing from past similar projects, and cost estimating database references. A budgetary quote for the HRSG was obtained from Vogt. Other factors not considered that can impact cost include tax credits and incentives and depreciation. The estimated conceptual capital cost for the conversion project is shown in Table 4, below.

Savings Associated with Combined Cycle Case
The analysis assumes that all units operate with a 92 percent capacity factor (approximately 8,060 hours per year at full load equivalent) and that all electricity generated will be sold to municipal customers. The simple cycle case will not produce as much electricity as the combined cycle case. For the analysis, it was assumed that this difference in quantity will be purchased by CWL from MISO at wholesale prices (purchased electricity price) and sold to their municipal customers. The cost to purchase the additional electricity from MISO for the simple cycle case is considered the savings associated with the combined cycle case. This savings is shown in Table 4, below.

Annual Operating and Maintenance Costs
Fuel costs are only slightly higher for combined cycle operation as most of the additional electric generation is attributable to heat recovered from the CT flue gas. For labor costs, two additional operators per shift; for a total of eight operators at $100,000 each was assumed for the analysis. Annual property tax and insurance was assumed to be 3 percent of the capital investment. Annual maintenance costs were assumed to be 2.5 percent of the capital investment. A summary of the annual operating and maintenance costs are included in Table 4, below.

The following items were not considered in the analysis that may add costs and, if so, would result in a longer payback period:

- System Planning Studies
- Transmission and Planning Analysis and Interconnection
- Air and Environmental Permitting
- Conceptual capital costs to cover the following off-site utilities were not considered:
  - Process Water Supply
  - Discharge Water Pipeline
  - Potable Water Supply
  - Sanitary Sewer
  - Transmission Line to Existing Switchyard
- Other operating costs including, but not limited to:
  - Process Water Supply Costs
  - Discharge Water Costs
  - Chemical Costs

Table 4: Economic Analysis Summary for Combined Cycle Conversion

Estimated Capital Cost for Conversion Project	$160,000,000
Savings Associated with Combined Cycle	$20,008,635
Annual Operating and Maintenance Costs	
Incremental Fuel Cost	$1,322,935
Labor Cost	$800,000
Property Tax and Insurance	$4,800,000
Maintenance Cost	$4,000,000
Net Annual Savings for Combined Cycle	$9,085,700
Payback Period (years)	17.6

Estimated Annual Cost per Megawatt-Hour
Table 5 shows the estimated annual cost per megawatt-hour for the facility.

Table 5: Estimated Annual Cost per MW-hour

Annual Costs	Simple Cycle[1]	Incremental Combined Cycle	Total
Principal and Interest Payment	$2,564,532	$12,838,814[2]	$15,403,346
Pollution Monitoring Support Fee	$21,108	------	$21,108
Property Tax Equivalent	$1,145,901	------	$1,145,901
Pro Energy Services Fee (O&M)	$367,055	------	$367,055
Monthly Service Fee (Trading)	$88,900	------	$88,900
Fuel Cost	------	$80,203,024	$80,203,024
Labor Cost	------	$800,000	$800,000
Property Tax and Insurance	------	$4,800,000	$4,800,000
Maintenance Cost	------	$4,000,000	$4,000,000
		Total	**$106,829,334**
Capacity Factor			92 percent
Generation, MW-Hours			2,014,316
Annual Cost per MW-Hour, $/MW-hr			**$53.04**

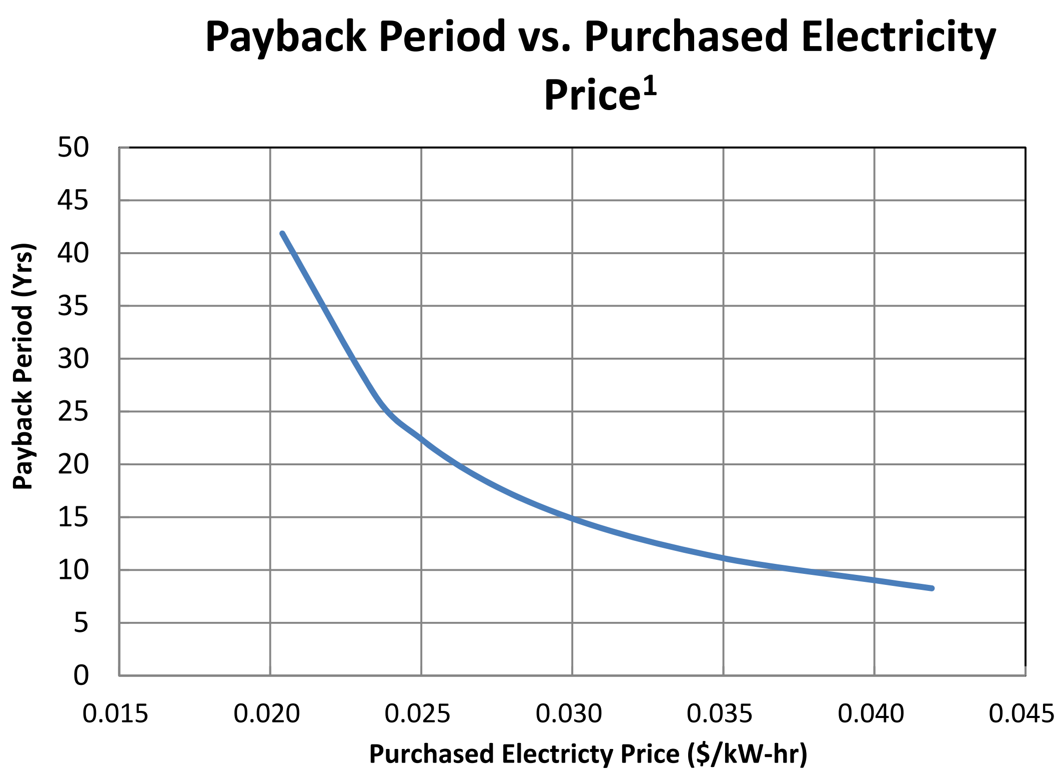
Notes:
1. Based on 2012 data furnished by CWL in Excel spreadsheet titled, “CEC Cost Data.xls” included in e-mail from C. Johanningmeier (CWL) to D. Einck (SCI) dated 7/26/13. Excludes variable costs.
2. Based on 5 percent annual interest rate over 20-year period on $160 million.

Sensitivity Analysis

Sensitivity analyses were performed that shows how variations in purchased electricity price, capital cost and fuel price impact the payback period.

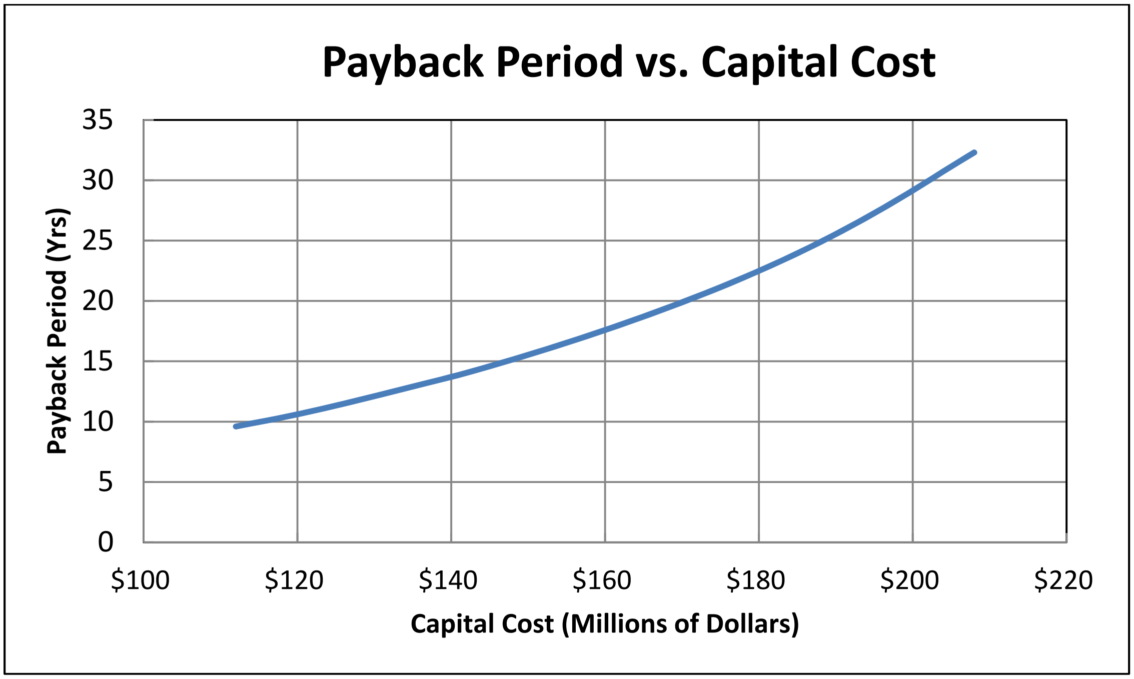
Purchased Electricity Price Sensitivity

The day ahead monthly average locational marginal price for the past four years ranged from approximately $0.020 per kW-hr to $0.042 per kW-hr. The sensitivity analysis shown on the graph below illustrates how this range in price affects payback period. All other variables remain fixed.

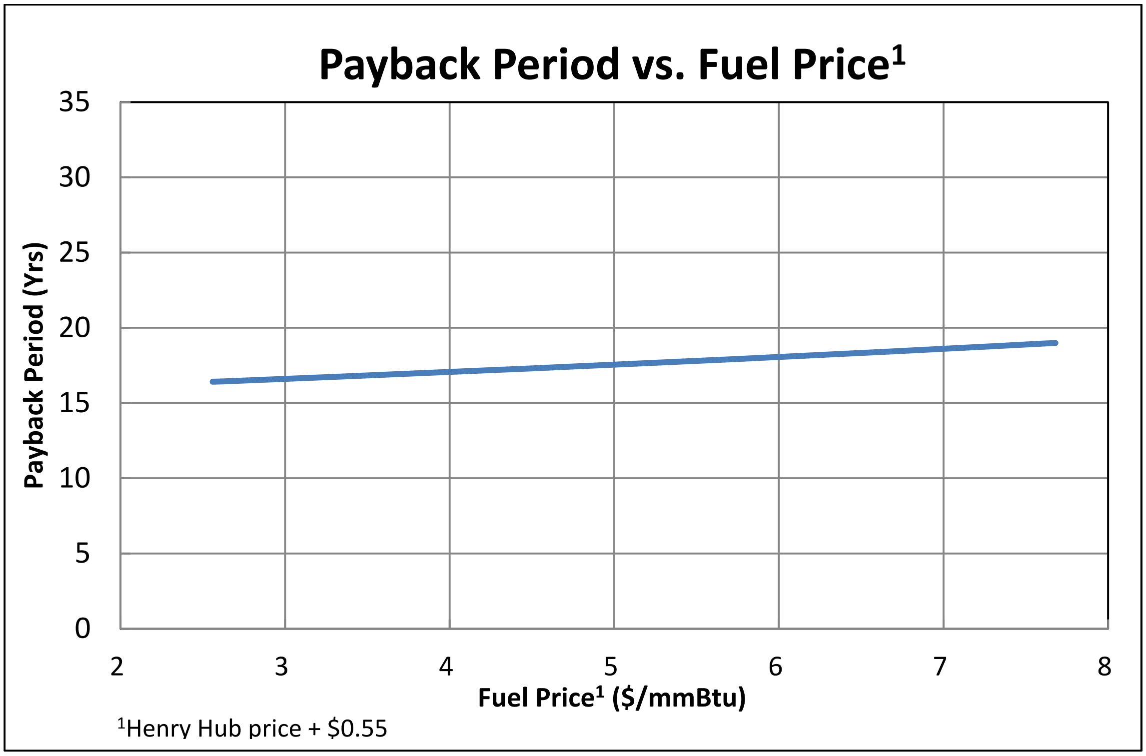


[1]MISO day ahead monthly average locational marginal prices for the CWLD

Capital Cost Sensitivity
The sensitivity analysis shown on the graph below illustrates how a +/-30 percent margin of error in the capital cost affects payback period. All other variables remain fixed.



Fuel Price Sensitivity
The sensitivity analysis shown on the graph below illustrates how a +/-50 percent change in the price of natural gas affects payback period. All other variables remain fixed.



Conclusions
The conclusions from this feasibility review are summarized in the list that follows.

- Space is adequate at CEC site for converting the existing simple cycle units to a combined cycle facility. Off-site utility services to support combined cycle operation either exist already or could be made readily available.
- The conversion project would increase generating capacity of the facility by approximately 90 MW. The conceptual capital cost for the project is estimated to be $160 million or $1,777 per kW.
- The simple payback analysis, which does not account for the time value of money, resulted in a payback period of 17.6 years. Assumptions used in the analysis include:
  - Plant operates annually at a 92 percent capacity factor. A lower plant capacity factor would increase the payback period.
  - Purchased electricity price (CWL's price to purchase electricity from the MISO power pool): $0.0277 per kW-hr.

- – Fuel price: \$5.12 per MMBtu (HHV).
- – Two additional operators per shift; for a total of eight operators at \$100,000 each are required for combined cycle operation.
- – Annual property tax and insurance costs: 3 percent of the capital investment.
- – Annual maintenance cost: 2.5 percent of the capital investment.
- – For a list of items not included in the analysis, refer to the "*Annual Operating and Maintenance Costs*" section of this report. It should be noted that including the associated costs would increase the payback period.

- The all-in annual operating cost for the facility is estimated to be \$53.04 per megawatt-hour at 92% capacity factor.
- The sensitivity analysis suggests that payback period has a high dependency on purchased electricity prices. Consequently, the project may become viable if purchased electricity prices were to increase significantly.
- Variances in capital cost have significant impact to the payback period. However, even with a capital cost of \$112 million (a 30 percent reduction to the estimated cost), the payback period is still 9.6 years.
- Variances in fuel price have very little impact on payback period since gas consumption will be approximately the same for combined cycle operation as simple cycle operation.

Should you have any questions regarding this letter report, please contact me at 563.264.6554.

Sincerely,
Stanley Consultants, Inc.

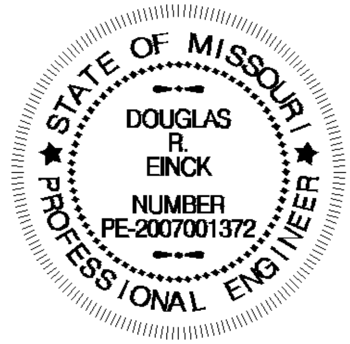
Prepared by Andy Ungerman
Andrew J. Ungerman, P.E., Mechanical Engineer

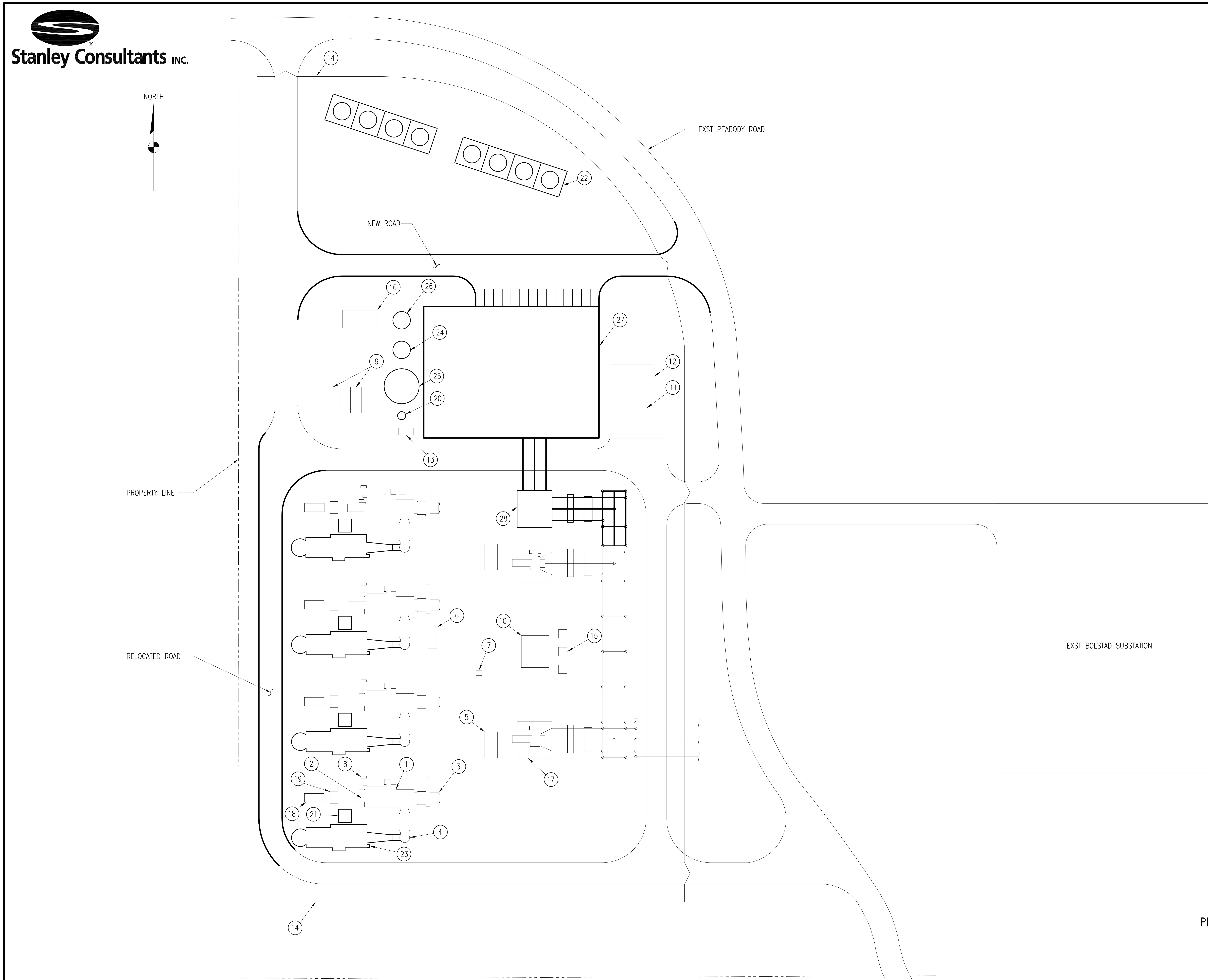
Approved by Douglas R. Einck
Douglas R. Einck, P.E., Project Manager

Attachment(s): General Arrangement – Combined Cycle Drawing X-1, Revision 0

I hereby certify that this letter report was prepared by me or under my direct personal supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Missouri.

Douglas R. Einck, P.E.	Douglas R. Einck	
Name	signature	
August 2, 2013	2007001372	December 31, 2013
Date	reg. no.	exp. date





KEYNOTES:

EXISTING EQUIPMENT

1. COMBUSTION TURBINE
2. AIR INLET
3. C.T. GENERATOR
4. BYPASS STACK
5. 15KV SWITCHGEAR BUILDING
6. CEMS
7. SANITARY LIFT STATION
8. FUEL GAS FILTER/SEPARATOR
9. GAS REGULATOR/HEATER STATION
10. ELECTRICAL SUPPORT BUILDING
11. SERVICE BUILDING
12. STORAGE BUILDING
13. WASH WATER SKID
14. PLANT SECURITY FENCE
15. AUXILIARY TRANSFORMER
16. GAS METERING STATION
17. GSU TRANSFORMER

RELOCATED EQUIPMENT

18. LUBE OIL AIR COOLER
19. CO2 SKID
20. WASH WATER STORAGE TANK

COMBINED CYCLE EQUIPMENT

21. BOILER FEED PUMP
22. COOLING TOWER
23. HEAT RECOVERY STEAM GENERATOR/STACK
24. DEMINERALIZED WATER STORAGE TANK
25. SERVICE/FIRE WATER STORAGE TANK
26. NEUTRALIZED WATER TANK
27. STEAM TURBINE BUILDING
28. STEAM GSU TRANSFORMER

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