APPENDIX D

Air Quality and Greenhouse Gas Emissions

APPENDIX D.1
Jaros Baum & Bolles Memorandum

JAROS BAUM & BOLLES

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15 Penn Cogeneration Study
Vornado Realty Trust
New York, New York
Project No. 14292.B.000

October 14, 2009

MEMORANDUM

To: Mr. Scott Milsom
Vornado Realty Trust

From: Mr. Christopher Colasanti

Re: 15 Penn Cogeneration Study

In accordance with your request, we performed a high-level study for the proposed 15 Penn Building for the feasibility of integrating a Cogeneration Plant. We have estimated electrical and HVAC loads to develop building peak minimum and average load profiles for normal electric power, steam and chilled water. For the purposes of this study, two (2) separate building profiles have been analyzed – a Class "A" general office profile and a Financial Services Tenant (Trading) profile.

In general, our basic assumptions are summarized as follows:

- 2,250,000 gross square feet (gsf) building area.
- Summer Operating Hours: 1,517 peak, 2,123 off-peak (5 months).
- Winter Operating Hours: 1,997 peak, 2,787 off-peak (7 months).
- Class "A" Office Building Electrical Load: 5 watts/gsf peak, 1 watt/gsf off-peak.
- Financial Services Tenant Building Electrical Load: 6.0 watts/gsf peak, 2.3 watts/gsf off-peak. (Blended density of trading at 12 watts/gsf peak; 10 watts/gsf off-peak, and office loads as noted above.)
- Cogeneration Maintenance Downtime: 2 weeks/year.
- Utility Costs Used for This Analysis:
  - Average Summer Electrical Cost: $0.22/$0.15 peak/off-peak.
  - Average Winter Electrical Cost: $0.17/$.10 peak/off-peak.
  - Average Gas Cost: $0.80/therm.
  - Average Steam Cost: $30.00/1,000 lbs.

Based upon our building profile calculations, we have performed a "test fit" of the following cogeneration options for each respective building profile. For each option, we have evaluated the approximate capital costs and approximate energy savings with respect to the estimated base building load profiles, and performed a simple payback analysis.

Option 1: Office Building Profile

Scheme A: Two (2) 2,000 kW natural gas-fired reciprocating engines with heat recovery.

Scheme B: Three (3) 2,000 kW natural gas-fired reciprocating engines with heat recovery.

Scheme C: Four (4) 2,000 kW natural gas-fired reciprocating engines with heat recovery.

In this option, the natural gas-fired reciprocating engines will be utilized to generate electricity to offset the peak electrical load of the building during "normal" business hours, which are assumed for the purposes of this study to coincide with Con Edison's "on-peak" hours (i.e., peak shaving). As such, the system will operate during "on-peak" hours only (Monday through Friday, 8 A.M. to 10 P.M.) and remain off at all other hours during the week and Saturday and Sunday. Thus, the electric usage offset occurs during this timeframe when electric rates from the utility are the highest. The waste heat from the exhaust stream of the generators will be captured through the use of heat recovery silencers and be converted to high-pressure steam. During the cooling season, the steam will be used to fire a high-pressure steam turbine-driven chiller; in the heating season, it will be used to heat the building via steam-to-hot water heat exchangers. The chilled water generated by the steam chiller during the cooling season will offset the amount of chilled water the building's chiller plant will be required to produce, thereby further reducing energy costs. The steam generated during the heating season will offset the steam purchased from Con Edison required for heating, also reducing energy costs.

In summary, this scheme reduces the amount of electricity and steam to be purchased from Con Edison and the amount of chilled water needed from the building during the hours when utility costs are the highest, thereby realizing energy savings. The results of this analysis can be found in Appendices A, B and C for the 4,000 kW, 6,000 kW and 8,000 kW schemes, respectively.

Option 2: Financial Services Tenant (Trading) Building Profile

One (1) 4.5MW natural gas-fired turbine with heat recovery

In this option, the above gas turbine will operate 24 hours per day, 7 days per week. The building minimum load coincides with the turbine size such that the plant is 100% loaded all the time for peak efficiency. As such, the electricity produced by the turbine will offset the building's electricity usage during both peak and off-peak times. As with Option 1, the waste heat generated by the turbine will be utilized to offset both steam and chilled water usage in the Winter and Summer seasons, respectively. The results of this analysis can be found in Appendix D.

The following chart summarizes the results of our analysis. Further detail can be found in Appendices A, B, C and D.

	Description	Capital Cost	Utility and Plant Operations Cost (per year)	Total Energy Savings (per year)	Simple Payback (years)
Option 1 *Peak Load Shaving Cogeneration Class 'A' Office Tenant)*	Two (2) – 2,000 kW Reciprocating Engines	$15,200,000	$10,792,369	$1,000,293	15.2
	Three (3) – 2,000 kW Reciprocating Engines	$21,450,000	$9,679,927	$2,112,735	10.2
	Four (4) – 2,000 kW Reciprocating Engines	$26,900,000	$8,657,494	$3,135,168	8.6
Option 2 *Continuous Cogeneration (Financial Service Tenant)*	One (1) – 4,500 kW Gas Turbine	$22,050,000	$11,672,727	$3,504,920	6.3

In summary, for both the Office and Financial Services Tenant building profiles, viable cogeneration schemes exist that can provide favorable financial savings. Should one of these schemes be pursued, a more in-depth energy model should be constructed, schematic plans developed for pricing, and current utility rates be applied to fine-tune this analysis.

In addition to the above, we have provided engine emissions data for use by AKRF, the Environmental Consultant, to perform an air dispersion analysis.

Should you have any questions or comments regarding the above, please do not hesitate to contact this office.

Christopher Colasanti

CC:jb
cc: (1) Mr. H. Kearney
(1) Mr. C. J. Prochner
(1) Mr. C. Colasanti
(1) Ms. G. Crifasi
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OPTION 1 - SCHEME A

PEAK LOAD SHAVING COGENERATION (OFFICE PROFILE)

(2) 2000 KW RECIPROCATING ENGINES

	Season	Building Load Profile			Utility Usage						Utility Costs								
		Electric Load - Peak (MW) (1)	Electric Load - Off Peak (MW) (2)	Plant Size (MW) (3)	Amount of electricity purchased from ConEd -Peak (MW)	Amount of electricity purchased from ConEd - Off Peak (MW)	Average Building Steam Load (lbs/hr) (4)	Amount of Steam Purchased from Con-Ed - Peak (lbs/hr)	Gas Consumed by Turbine (MMBtu/hr)	Total Gas Consumed (therm/year)	Annual Total Net Steam Cost	Annual Total Net Electric Cost (5)	Annual Total Net Gas Cost	Total Annual Net Utility Cost	Annual Cogen Service/ Maintenance Cost (6)	Total Operating Cost (per year) (7)	Total Energy Savings (per year)	Total Capital Cost (8)	Simple Payback (Years)
Building Load Profile	Summer	11.30	2.26	0	11.30	2.26	0	0	0	0	$0	$4,887,043	$0	$11,792,662	$0	$11,792,662	n/a	$0	n/a
	Winter	11.30	2.26	0	11.30	2.26	15,871	15,871	0	0	$2,437,768	$4,467,852	$0						
Building Load Profile (w/ Cogen)	Summer	10.73	2.26	4	6.73	2.26	8,642	0	38.28	580,580	$0	$3,264,583	$464,464	$10,105,569	$686,800	$10,792,369	$1,000,293	$15,200,000	15.2
	Winter	11.30	2.26	4	7.30	2.26	15,871	7,229	38.28	764,579	$1,883,643	$3,881,216	$611,663						

Utility Cost Assumptions:

Gas:	$0.80	/therm
ConEd Steam:	$30.00	/1000lbs

Equipment Performance:

Steam Produced:	8642	lbs/hr
Electricity Produced:	4	MW
Fuel Used:	38.28	MMBtu/hr
Steam Chiller Size:	960	tons
Chiller Electric	576	kw saved

Electric Rates	Peak	Off-Peak	
Summer	$0.22	$0.15	/kwh
Winter	$0.17	$0.10	/kwh
Premium for standby electric	$0.02	/kwh for all hours	

Electric Use	Peak	Off-Peak	
Summer	11.30	2.26	MW
Winter	11.30	2.26	MW

Avg Hourly Steam Use: (4)	15,871	lbs/hr

Season Breakdown

Summer Months	5	months
Winter Months	7	months
Downtime	2	weeks (in winter)

	Summer	Winter	
Peak Time	1517	1997	hours
Off-Peak Time	2123	2787	hours
	Peak	Off-Peak	
Downtime	140	196	hours

Construction & Service

Construction Cost Estimates (8)	$15,200,000
Service & Maint. Estimate (6)	$686,800

Peak	*Area*	*Watt/sqft*	*kw*
Offices:	2,260,601	5	11303
Trading:	0	0	0

Off-Peak	*Area*	*Watt/sqft*	*kw*
Offices:	2,260,601	1	2261
Trading:	0	0	0

Notes:

1. Average electric load during peak hours (8am-10pm, mon-fri)
2. Average electric load furing off-peak hours (10pm-8am, Mon-Fri; 10pm Fri - 8am Mon)
3. Cogeneration plant will consist of (2) 2000kw caterpillar gas fired reciprocating engines with heat recovery silencers.
4. This is the average hourly steam use over the 7th month winter period and the steam used for the steam chiller during the summer in the cogen scheme.
5. Includes purchasing all electricity for the downtime.
6. This number consists of $436,800 ($0.03/kwh) for the long term service agreement and $250,000 for the operators.
7. This is the net utility cost and the cost of service and maintenance.
8. This is the construction cost estimates. (Assumes $3500/ kw + 4000 sqft@$300/sqft)

OPTION 1 - SCHEME B

PEAK LOAD SHAVING COGENERATION (OFFICE PROFILE)

(3) 2000 KW RECIPROCATING ENGINES

		Building Load Profile			Utility Usage						Utility Costs								
	Season	Electric Load - Peak (MW) (1)	Electric Load - Off Peak (MW) (2)	Plant Size (MW) (3)	Amount of electricity purchased from ConEd -Peak (MW)	Amount of electricity purchased from ConEd - Off Peak (MW)	Average Building Steam Load (lbs/hr) (4)	Amount of Steam Purchased from Con-Ed - Peak (lbs/hr)	Gas Consumed by Turbine (MMBtu/hr)	Total Gas Consumed (therm/year)	Annual Total Net Steam Cost	Annual Total Net Electric Cost (5)	Annual Total Net Gas Cost	Total Annual Net Utility Cost	Annual Cogen Service/ Maintenance Cost (6)	Total Operating Cost (per year) (7)	Total Energy Savings (per year)	Total Capital Cost (8)	Simple Payback (Years)
Building Load Profile	Summer	11.30	2.26	0	11.30	2.26	0	0	0	0	$0	$4,887,043	$0	$11,792,662	$0	$11,792,662	n/a	$0	n/a
	Winter	11.30	2.26	0	11.30	2.26	15,871	15,871	0	0	$2,437,768	$4,467,852	$0						
Building Load Profile (w/ Cogen)	Summer	10.44	2.26	6	4.44	2.26	12,963	0	57.42	870,870	$0	$2,431,727	$696,696	$8,774,727	$905,200	$9,679,927	$2,112,735	$21,450,000	10.2
	Winter	11.30	2.26	6	5.30	2.26	15,871	2,908	57.42	1,146,869	$1,606,580	$3,122,229	$917,495						

Utility Cost Assumptions:

Gas:	$0.80	/therm
ConEd Steam:	$30.00	/1000lbs

Equipment Performance:

Steam Produced:	12963	lbs/hr
Electricity Produced:	6	MW
Fuel Used:	57.42	MMBtu/hr
Steam Chiller Size:	1440	tons
Chiller Electric	864	kw saved

Electric Rates	Peak	Off-Peak	
Summer	$0.22	$0.15	/kwh
Winter	$0.17	$0.10	/kwh
Premium for standby electric	$0.02	/kwh for all hours	

Electric Use	Peak	Off-Peak	
Summer	11.30	2.26	MW
Winter	11.30	2.26	MW

Avg Hourly Steam Use: (4)	15,871	lbs/hr

Season Breakdown

Summer Months	5	months
Winter Months	7	months
Downtime	2	weeks (in winter)

	Summer	Winter	
Peak Time	1517	1997	hours
Off-Peak Time	2123	2787	hours
	Peak	Off-Peak	
Downtime	140	196	hours

Construction & Service

Construction Cost Estimates (8)	$21,450,000
Service & Maint. Estimate (6)	$905,200

Peak	*Area*	*Watt/sqft*	*kw*
Offices:	2,260,601	5	11303
Trading:	0	0	0

Off-Peak	*Area*	*Watt/sqft*	*kw*
Offices:	2,260,601	1	2261
Trading:	0	0	0

Notes:

1. Average electric load during peak hours (8am-10pm, mon-fri)
2. Average electric load furing off-peak hours (10pm-8am, Mon-Fri; 10pm Fri - 8am Mon)
3. Cogeneration plant will consist of (2) 2000kw caterpillar gas fired reciprocating engines with heat recovery silencers.
4. This is the average hourly steam use over the 7th month winter period and the steam used for the steam chiller during the summer in the cogen scheme.
5. Includes purchasing all electricity for the downtime.
6. This number consists of $655,200 ($0.03/kwh) for the long term service agreement and $250,000 for the operators.
7. This is the net utility cost and the cost of service and maintenance.
8. This is the construction cost estimates. (Assumes $3300/kw + 5500 sqft@$300/sqft)

OPTION 1 - SCHEME C

PEAK LOAD SHAVING COGENERATION (OFFICE PROFILE)

(4) 2000 KW RECIPROCATING ENGINES

		Building Load Profile			Utility Usage						Utility Costs								
	Season	Electric Load - Peak (MW) (1)	Electric Load - Off Peak (MW) (2)	Plant Size (MW) (3)	Amount of electricity purchased from ConEd -Peak (MW)	Amount of electricity purchased from ConEd - Off Peak (MW)	Average Building Steam Load (lbs/hr) (4)	Amount of Steam Purchased from Con-Ed - Peak (lbs/hr)	Gas Consumed by Turbine (MMBtu/hr)	Total Gas Consumed (therm/year)	Annual Total Net Steam Cost	Annual Total Net Electric Cost (5)	Annual Total Net Gas Cost	Total Annual Net Utility Cost	Annual Cogen Service/ Maintenance Cost (6)	Total Operating Cost (per year) (7)	Total Energy Savings (per year)	Total Capital Cost (8)	Simple Payback (Years)
Building Load Profile	Summer	11.30	2.26	0	11.30	2.26	0	0	0	0	$0	$4,887,043	$0	$11,792,662	$0	$11,792,662	n/a	$0	n/a
	Winter	11.30	2.26	0	11.30	2.26	15,871	15,871	0	0	$2,437,768	$4,467,852	$0						
Building Load Profile (w/ Cogen)	Summer	10.15	2.26	8	2.15	2.26	17,284	0	76.56	1,161,160	$0	$1,598,870	$928,928	$7,534,494	$1,123,000	$8,657,494	$3,135,168	$26,900,000	8.6
	Winter	11.30	2.26	8	3.30	2.26	15,871	0	76.56	1,529,158	$1,420,127	$2,363,243	$1,223,327						

Utility Cost Assumptions:

Gas:	$0.80	/therm
ConEd Steam:	$30.00	/1000lbs

Electric Rates

	Peak	Off-Peak	
Summer	$0.22	$0.15	/kwh
Winter	$0.17	$0.10	/kwh
Premium for standby electric	$0.02	/kwh for all hours	

Season Breakdown

Summer Months	5	months
Winter Months	7	months
Downtime	2	weeks (in winter)

Construction & Service

Construction Cost Estimates (8)	$26,900,000
Service & Maint. Estimate (6)	$1,123,000

Peak	*Area*	*Watt/sqft*	*kw*
Offices:	2,260,601	5	11303
Trading:	0	0	0

Equipment Performance:

Steam Produced:	17284	lbs/hr
Electricity Produced:	8	MW
Fuel Used:	76.56	MMBtu/hr
Steam Chiller Size:	1920	tons
Chiller Electric	1152	kw saved

Electric Use

	Peak	Off-Peak	
Summer	11.30	2.26	MW
Winter	11.30	2.26	MW

Avg Hourly Steam Use: (4) 15,871 lbs/hr

	Summer	Winter	
Peak Time	1517	1997	hours
Off-Peak Time	2123	2787	hours
	Peak	Off-Peak	
Downtime	140	196	hours

Off-Peak	*Area*	*Watt/sqft*	*kw*
Offices:	2,260,601	1	2261
Trading:	0	0	0

Notes:

1. Average electric load during peak hours (8am-10pm, mon-fri)
2. Average electric load furing off-peak hours (10pm-8am, Mon-Fri; 10pm Fri - 8am Mon)
3. Cogeneration plant will consist of (2) 2000kw caterpillar gas fired reciprocating engines with heat recovery silencers.
4. This is the average hourly steam use over the 7th month winter period and the steam used for the steam chiller during the summer in the cogen scheme.
5. Includes purchasing all electricity for the downtime.
6. This number consists of $873,000 ($0.03/kwh) for the long term service agreement and $250,000 for the operators.
7. This is the net utility cost and the cost of service and maintenance.
8. This is the construction cost estimates. (Assumes $3100/kw + 7000 sqft@$300/sqft)

OPTION 2

CONTINUOUS COGENERATION (OFFICE & TRADING PROFILE)

(1) 4500 KW GAS TURBINE

	Season	Building Load Profile: Electric Load - Peak (MW) (1)	Electric Load - Off Peak (MW) (2)	Plant Size (MW) (3)	Utility Usage: Amount of electricity purchased from ConEd -Peak (MW)	Amount of electricity purchased from ConEd Off Peak (MW)	Average Building Steam Load (lbs/hr) (4)	Gas Consumed by Turbine (MMBtu/hr)	Gas Required for Duct Firing (MMBtu/hr)	Total Gas Consumed (therm/year)	Utility Costs: ConEd Steam Standby Annual Charge	Annual Total Net Steam Cost	Annual Total Net Electric Cost (5)	Annual Total Net Gas Cost	Total Annual Net Utility Cost	Annual Cogen Service/ Maintenance Cost (6)	Total Operating Cost (per year) (7)	Total Energy Savings (per year)	Total Capital Cost (8)	Simple Payback (Years)
Building Load Profile	Summer	13.67	5.30	0	13.67	5.30	0	0	0	0	$0	$0	$6,781,491	$0	$15,177,646	$0	$15,177,646	n/a	$0	n/a
	Winter	13.67	5.30	0	13.67	5.30	15,871	0	0	0		$2,277,789	$6,118,366	$0						
Building Load Profile (w/ Cogen)	Summer	12.73	4.36	4.3	8.43	0.06	14,135	40.3	0	1,466,920	$136,554	$0	$3,088,402	$1,173,536	$10,402,727	$1,270,000	$11,672,727	$3,504,920	$22,050,000	6.3
	Winter	13.67	5.30	4.3	9.37	1.00	15,871	40.3	2.2	2,032,335		$0	$4,378,366	$1,625,868						

Utility Cost Assumptions:

Gas:	$0.80	/therm
ConEd Steam:	$30.00	/1000lbs

Electric Rates

	Peak	Off-Peak	
Summer	$0.22	$0.15	/kwh
Winter	$0.17	$0.10	/kwh
Premium for standby electric	$0.02	/kwh for all hours	

Season Breakdov months

Summer Months	5	months
Winter Months	7	months
Downtime	2	weeks (in winter)

Construction & Service

Construction Cost Estimates (8)	$22,050,000
Service & Maint. Estimate (6)	$1,270,000

Peak	*Area*	*Watt/sqft*	*kw*
Offices:	1,922,715	5	9,614
Trading:	337,886	12	4,055

Equipment Performance:

Steam Produced:	14135	lbs/hr
Electricity Produced:	4.3	MW
Fuel Used:	40.3	MMBtu/hr
Steam Chiller Size:	1571	tons
Chiller Electric	942	kw saved

Electric Use

	Peak	Off-Peak	
Summer	13.67	5.30	MW
Winter	13.67	5.30	MW

Avg Hourly Steam Use: (4) 15,871 lbs/hr

	Summer	Winter	
Peak Time	1517	1997	hours
Off-Peak Time	2123	2787	hours
	Peak	Off-Peak	
Downtime	140	196	hours

Con-Ed Steam Stand-by Charges

Max Steam Load:	41,322	lbs/hr
Contract Demand Charge:	$42,918	
Downtime Usage:	$75,936	
Monthly Fee:	$17,700	
Total:	$136,554	

Off-Peak	*Area*	*Watt/sqft*	*kw*
Offices:	1,922,715	1	1,923
Trading:	337,886	10	3,379

Notes:

1. Average electric load during peak hours (8am-10pm, mon-fri)
2. Average electric load furing off-peak hours (10pm-8am, Mon-Fri; 10pm Fri - 8am Mon)
3. Cogeneration plant will consist of (1) 4500kw caterpillar gas fired rturbine with heat recovery silencers.
4. This is the average hourly steam use over the 7th month winter period and the steam used for the steam chiller during the summer in the cogen scheme.
5. Includes purchasing all electricity for the downtime.
6. This number consists of $470,000 for the long term service agreement and $800,000 for the operators.
7. This is the net utility cost and the cost of service and maintenance.
8. This is the construction cost estimates. (Assumes $4500/kw + 9000 sqft@$300/sqft)

APPENDIX D.2
Baseline Electricity and Steam Demand

Appendix D.2: Baseline Electricity and Steam Demand

The following baseline electricity and steam demand was projected by Jaros Baum & Bolles for the Single-Tenant Office Scenario and the Multi-Tenant Office Scenario, assuming no cogeneration, and no energy efficiency measures beyond those required by code.

Projected Baseline Electricity and Steam Demand

	Single-Tenant Office Scenario	Multi-Tenant Office Scenario
Electricity (MWh/year)	77,013	52,844
Steam (thousand lbs/year)	81,259	81,259

Source: Data supplied by Jaros Baum & Bolles.

The electricity consumption projections presented above are based on estimated electric loads during peak and off-peak electricity demand periods, as defined by the utility. The electricity load for the Single-Tenant Office Scenario was estimated at 13.67 MW during peak hours (8 AM to 10 PM, on weekdays), and 5.30 MW for the remaining (off-peak) hours. For the Multi-Tenant Office Scenario, the peak load was estimated at 11.30 MW during peak hours and 2.26 MW during off-peak hours. The steam demand was calculated assuming 7 months of heat usage, and an average steam load of 15,871 lbs per hour. The loads were estimated based on the building size and generic load assumptions for the proposed uses. ✷