Appendix D
Healy w LNB+OFA+SCR

Given/Assumptions

New or Retrofit?	Retrofit						
Extra retrofit cost factor	1.5	**NPS estimate**					
Generation capacity (MW)	25	**company report**					
SCR bypass included?	No						
Fuel High Heating Value (Btu/lb)	6,766	**from Table 2-1**	**company report**				
Maximum Fuel Consumption Rate (lb/hr)	5.0E+04	**from Appendix A**		**340**	**from Appendix A**		**company report**
Average Annual Fuel Consumption (lb)	4.37E+08	**calculated from Appendix A**		**218,482**	**tpy calculated from Appendix A**		**company report**
Number of SCR Operating Days	365	**company report**					
Plant Capacity Factor	100%	**calculated**					
Uncontrolled NOx Concentration (lb/mmBtu)	0.25	**from Appendix A**	**company report**				
Uncontrolled NOx Emissions (tpy)	370	**from Appendix A**	**company report**				
LNB+OFA Total Capital Investment	$ 20,000	**from Appendix A**	**company report**				
LNB + OFA Total Annual Cost	$ 2,337	**from Appendix A**	**company report**				
LNB+OFA outlet = SCR inlet NOx Concentration (lb/mr	0.23	**from Appendix A**	**company report**				
Required Controlled NOx Concentration (lb/mmBtu)	0.05	**NPS estimate**					
Acceptable Ammonia Slip (ppm)	2.0	OAQPS Control Cost Manual					
Fuel Volume Flow Rate (ft3/min/mmBtu/hr)	547	OAQPS Control Cost Manual					
Fuel Sulfur Content	0.17%	**from Table 2-1**	**company report**				
Fuel Ash Content	13.65%	**from Table 2-1**	**company report**				
Number of SCR reactor chambers	1	OAQPS Control Cost Manual					
ASR	1.05	OAQPS Control Cost Manual					
Stored Ammonia Concentration	29%	OAQPS Control Cost Manual					
Reagent Molecular Weight (g/mole)	17.03	OAQPS Control Cost Manual					
Reagent Density (lb/ft3 @ 60F)	56.0	OAQPS Control Cost Manual					
Reagent Specific Volume (gal/ft3)	7.481	OAQPS Control Cost Manual					
NOx Molecular Weight (g/mole)	46.01	OAQPS Control Cost Manual					
Number of Days of Storage for Ammonia	14	OAQPS Control Cost Manual					
Pressure Drop for SCR Ductwork H2O")	3	OAQPS Control Cost Manual					
Pressure Drop for each Catalyst Layer (H2O")	1	OAQPS Control Cost Manual					
Temperature at SCR Inlet (degrees F)	650	**NPS estimate**					
Equipment Life (years)	15	**company report**					
Annual Interest Rate	7%	OAQPS Control Cost Manual					
Inflation Since 1998	1.35	CEPCI 2007/CEPCI 1998					
Catalyst Cost, Initial ($/ft3)	$ 85	**calculated from Appendix A**	$	3,000	/m^3	from company report	**Appendix A**
Catalyst Cost, Replacement ($/ft3)	$ 85	**calculated from Appendix A**	$	3,000	/m^3	from company report	**Appendix A**
Electrical Power Cost ($/kWh)	$ 0.05	**calculated from Appendix A**	$	50.00	/MWh	from company report	**Appendix A**
29% Ammonia Solution Cost ($/lb)	0.058	**calculated from Appendix A**	$	400.00	/ton	from company report	**Appendix A**
Operating Life of Catalyst (hours)	24,000	OAQPS Control Cost Manual					

	LNB Control Efficiency = (Inlet Conc - Outlet Conc)/Inlet conc													
			(	0.25	-	0.23	)/	0.25	=	8%				
	Boiler Calculations													
	2.3	$Q_B = HVm\text{-}dot_{fuel}$												
	QB =	6766	Btu/lb *	49882	lb/hr									
	QB =	338	Btu/hr											
	2.7	CF_{Plant} = actual m_{fuel}/maximum m_{fuel}												
	CFPlant =	4.37E+08	lb/yr /	8760	hr/yr /	49882	lb/hr							
	CFPlant =	100%												
	2.8	$CF_{SCR} = t_{SCR}$/365 days												
	CFSCR =	365	days/	365	days									
	CFSCR =	100%												
		$CF_{Total} = CF_{Plant}$ x CF_{SCR}												
	CFTotal =	100%	*	100%										
	CFTotal =	100%												
	2.12	$q_{fluegas} = q_{fuel}Q_B(460+T)/(460+700^oF)n_{SCR}$												
	qfluegas =	547	ft3/min/(mmBtu/hr)*	338	mmBtu/hr*(	460	+	650	)/(	460	+	700	/*	1
	qfluegas =	176,656	acfm											
	2.9	$\eta_{NOx} = (NOx_{in} – NOx_{out}) / NOx_{in}$												
	ηNOx =	(	0.23	lb/mmBtu -	0.05	lb/mmBtu)/	0.23	lb/mmBtu						
	ηNOx =	78%												
	Uncontrolled NOx emissions (tpy)			**370**										
	Overall Control Efficiency = (Inlet Conc - Outlet Conc)/Inlet conc													
			(	0.25	-	0.05	)/	0.25	=	80%				
	NOx removed =			296	tpy									
	Controlled NOx emissions (tpy) =			74	tpy									

SCR Reactor Calculations

2.19	$Vol_{catalyst} = 2.81 \times Q_B \times \eta_{adj} \times Slip_{adj} \times NOx_{adj} \times S_{adj} \times T_{adj}/N_{SCR}$									
Volcatalyst =	2.81	*	338	=	948					
	2.2	$\eta_{adj} = 0.2869 + (1.058 \times \eta)$								
	ηadj =	0.2869	+(	1.058	*	0.78	)			
	ηadj =	1.115								
	2.22	$Slip_{adj} = 1.2835 - (0.0567 \times Slip)$								
	Slipadj =	1.2835	- (	0.057	*	2	)			
	Slipadj =	1.170								
	2.21	$NOx_{adj} = 0.8524 + (0.3208 \times NOx_{in})$								
	NOxadj =	0.8524	+ (	0.321	*	**0.23**	)			
	NOxadj =	0.926								
	2.23	$S_{adj} = 0.9636 + (0.0455 \times S)$								
	Sadj =	0.9636	+ (	0.046	*	0.17	)			
	Sadj =	0.971								
	2.24	$T_{adj} = 15.16 - (0.03937 \times T) + (2.74 \times 10^{-5} \times T^2)$								
	Tadj =	15.16	- (	0.039	*	650	) +	2.74E-05	*	422500
	Tadj =	1.146								
Volcatalyst =	1,276	ft3								
2.25	$A_{catalyst} = q_{fluegas}/(16 \text{ ft/sec} \times 60 \text{ sec/min})$									
	Acatalyst =	176656	/(	16	*	60	)			
	Acatalyst =	184	ft2							
2.26	$A_{SCR} = 1.15 \times A_{catalyst}$									
	ASCR =	1.15	*	184						
	ASCR =	212	ft2							
2.27	$l = w = A_{SCR}^{1/2}$									
	l = w =	14.5	ft							
2.28	$n_{layer} = Vol_{catalyst}/(h'_{layer} \times A_{catalyst})$									
	nlayer =	1276	/(	3.1	*	184	)			
	nlayer =	2.0								
2.29	$h_{layer} = [Vol_{catalyst}/(n_{layer} \times A_{catalyst})] + 1$									
	hlayer =	1276	/(	3	*	184	) +	1		
	hlayer =	3.3								
2.3	$n_{total} = n_{layer} + n_{empty}$									
	ntotal =	2	+	1						
	ntotal =	3								
2.31	$h_{SCR} = n_{total}(c_1 + h_{layer}) + c_2$									
	hSCR =	3	* (	7	+	3.3	) +	9		
	hSCR =	40	ft							

	Reagent Calculations												
	2.32	$m\text{-}dot_{reagent} = NOx_{in}Q_BASR\eta_{NOx}M_{reagent}/M_{NOx}$											
		m-dotreagent =	**0.23**	*	338	*	1.05	*	78%	*	17.03	/	46.01
		m-dotreagent =	24	lb/hr									
	2.33	$m\text{-}dot_{sol} = m\text{-}dot_{reagent}/C_{sol}$											
		m-dotsol =	24	/	0.29								
		m-dotsol =	81	lb/hr									
	2.34	$q_{sol} = (m\text{-}dot_{vol}/\rho_{sol})V_{sol}$											
		qsol =	81	*	7.481	/	56						
		qsol =	11	gph									
	2.35	Tank Volume = $q_{sol}t$											
		Tank Volume =	11	*	14	*	24						
		Tank Volume =	3,654	gal									

	Direct Capital Cost																					
	2.36		$DC = Q_B[(\$3380/MMBtu/hr) + f(h_{SCR}) + f(NH_3 rate) + f(new) + f(bypass)](3500/Q_B)^{0.35} + f(Vol_{catalyst})$																			
		DC =	338	((	$ 3,380	+																
			2.37	$f(h_{SCR}) = \{[\$612/(ft\text{-}mmBtu/hr)]h_{SCR}\} - \$187.9/(mmBtu/hr)$																		
			f(hSCR) =	6.12	*	40	-	187.9														
			f(hSCR) =	$ 56	/mmBtu/hr																	
			2.38	$f(NH_3 rate) = [(\$411/lb/hr)(m\text{-}dot_{reagent}/Q_B)] - \$473/(mmBtu/hr)$																		
			f(NH3rate) =	411	*	24	/	338	-	47.3												
			f(NH3rate) =	$ (19)	/mmBtu/hr																	
			2.39	f(new) = $0/(mmBtu/hr) for retrofit																		
			f(new) =	$ -																		
			2.41	f(bypass) = $0/(mmBtu/hr) for no bypass																		
			f(bypass) =	$ -	/mmBtu/hr																	
			2.43	$f(Vol_{catalyst}) = Vol_{catalyst} CCinitial$																		
			f(Volcatalyst) =	1276	*	85																
			f(Volcatalyst) =	$ 108,441																		
		DC =	337.501612	* (	$ 3,380	+	$ 56	+	$ (19)	+	$ -	+	$ -	)*(	3500	/	338	)^	0.35	+	$ 108,441	
		DC =	$ 2,724,013																			
	Inflation Adjustment =			1.35																		
		DC =	$ 3,677,417																			

	Indirect Capital Costs										
	Total Direct Capital Costs, A										$ 3,677,417
	Indirect Installation Costs										
		General Facilities					0.05	A			$183,871
		Engineering and Home Office Fees					0.10	A			$367,742
		Process Contingencies					0.05	A			$183,871
	Total Indirect Installation Costs, B		Retrofit factor =		1.5	*	0.20	A =	0.30	A =	$1,103,225
		Project Contingency, C =	Retrofit factor =		1.5	*	0.15	(A+B) =	0.225	(A+B) =	$1,075,645
	Total Plant Cost D =								A+B+C		$5,856,287
		Allowance for Funds During Construction, E =						0			$0
		Royalty Allowance, F =						0			$0
		Preproduction Cost, G =						0.02	(D+E)		$117,126
		Inventory Capital, H =									
		Initial Catalyst and Chemicals, I =	0.058	/lb *	81	lb/r *	24	hr/day *	14	days =	$1,587
	Total Capital Investment TCI = D+G+H								+D+E+F+G+H+I		$5,974,999
									Cost/kW =		$ 239
	Total Capital Investment TCI including LNB + OFA =										$5,994,999
									Cost/kW =		$ 240

	Annual Costs																			
	2.45	DAC = Annual Maintenance Cost + Annual Reagent Cost + Annual Electricity Cost + Annual Water Cost + Annual Catalyst Cost																		
		2.46	Annual Maintenance Cost = 0.015 TCI																	
		Annual Maintenance Cost =	0.015	*	**$ 5,974,999**															
		Annual Maintenance Cost =	$ 89,625																	
		2.47	Annual Reagent Cost = $q_{reagent}Cost_{reagent}t_{op}$																	
		2.47a	$t_{op} = CF_{total}8760hr/yr$																	
		top =	100%	*	8760															
		top =	8760																	
		Annual Reagent Cost =	81	*	8760	*	0.058													
		Annual Reagent Cost =	$ 41,365																	
		2.49	Annual Electricity Cost = Power $(Cost_{elect})t_{op}$																	
		2.48	Power = $0.105Q_B[NOx_{in}\eta NOx + 0.5(\Delta P_{duct} + n_{total}\Delta P_{catalyst})]$																	
		Power =	0.105	*	338	*(	**0.23**	*	78%	+	0.5	* (	3	+	3	*	1	))		
		Power =	113	kW																
		Annual Electricity Cost =	113	*	8760	*	0.05													
		Annual Electricity Cost =	$ 49,359																	
		2.51	Annual Catalyst Replacement Cost = (Catalyst Replacement Cost)FWF																	
		2.5	Catalyst Replacement Cost = $n_{SCR}Vol_{catalyst}CC_{replace}/R_{layer}$																	
		Catalyst Replacement Cost =	1	*	1276	*	85.0158152	/	2											
		Catalyst Replacement Cost =	$ 54,220																	
		2.52	$FWF = i\{1/[(1+i)^Y-1]\}$																	
		2.53	$Y = h_{catalyst}/h_{year}$																	
		Y =	24000	/(	42%	*	8760	)												
		Y =	6																	
		FWF =	0.07	*(	1	/(	1	+	0.07	)^	6	-	1	)						
		FWF =	0.14																	
		Annual Catalyst Cost =	$ 7,580																	
		DAC =	**$ 187,928**																	
		2.55	$CRF = i(1+i)^n/[(1+i)^n-1]$																	
		CRF =	0.07	*(	1	+	0.07	)^	15	/((	1	+	0.07	)^	15	-	1	)		
		CRF =	0.1098																	
		Indirect Annual Cost =	CFR	*	TCI															
		Indirect Annual Cost =	0.1098	*	**$ 5,974,999**															
		Indirect Annual Cost =	$ 656,023																	

		2.56	Total Annual Cost = Direct Annual Cost + Indirect Annual Cost																		
		Total Annual Cost =	$ 187,928	+	$ 656,023																
		Total Annual Cost =	**$ 843,951**	+	$ 2,337	=	$ 846,288														
		2.57	NOx Removed = $NOx_{in}\eta_{NOx}Q_Bt_{op}$																		
		NOx Removed by SCR =	0.23	*	78%	*	338	*	8760	/	2000										
		NOx Removed by SCR =	266																		
		Total NOx Removed =	296																		
		2.58	Cost effectiveness = TAC/NOx removed																		
		SCR Cost effectiveness =	$ 3,172																		
		Total Cost effectiveness =	$ 2,862																		

Operating company	**Golden Valley Electric Association (GVEA)**					
Facility	**Healy**					
State	**AK**	**Alaska Department of Environmental Conservation**				
Contact	**Rebecca Smith, Environmental Program Specialist, Air Permit Program,**				**rebecca.smith@alaska.gov**	
Proposed Controls	SCR	rejected by GVEA	**SCR proposed by AK**	added to Low NOx burners (LNB) and over-fired air (OFA) ports installed in 1996		
Unit	#1		#1	Healy 1 began operation in 1967		
Boiler Type	wall-fired, wet bottom		wall-fired, wet bottom	manufactured by Foster Wheeler		Emviroplan report
Fuel	sub-bituminous		sub-bituminous	Company report		
Rating (MW Gross)	25		25	Emviroplan report		
Presumptive BART limit (lb/mmBtu)	0.23		0.23	wall-fired boiler > 200 MW burning sub-bituminous coal		
Rating (mmBtu/hr)	340	Company report	340	Company report	340	Company report
Current Emissions (tpy)	369	calculated	370	Emviroplan report	370	Emviroplan report
Current Emisison Rate (lb/mmBtu)	0.25	Company report	0.25	Emviroplan report	0.25	Emviroplan report
Cost-benefit Analyses						
Control Efficiency	72%	Company report	72.0%	Emviroplan report	80%	calculated
New Emisison Rate (lb/mmBtu)	0.07	Company report	0.07	Emviroplan report	0.05	NPS estimate
New Emissions (tpy)	103	calculated	104	calculated	74	calculated
Emissions Reduction (tpy)	266	Company report	266	Emviroplan report	296	NPS/OAQPS Control Cost Ma
Capital Cost	$ 8,775,000	Company report	$ 6,023,332	Emviroplan report	$ 5,994,999	NPS/OAQPS Control Cost Ma
Capital Cost ($/kW)	$ 351	calculated	$ 241	Emviroplan report	$ 240	calculated
O&M Cost	$ 238,072	Company report	$236,229	Emviroplan report	$ 187,928	NPS/OAQPS Control Cost Ma
Total Annual Cost	$ 1,263,251	Company report	$897,559	Emviroplan report	$ 846,288	NPS/OAQPS Control Cost Ma
Cost-Effectiveness ($/ton)	$ 4,749	Company report	$ 3,374	Emviroplan report	$ 2,862	NPS/OAQPS Control Cost Ma
Proposed BART Limits						
Proposed BART limit (company)	0.25	Company report				
Proposed BART limit (state)			**0.07**	**lb/mmBtu 30-day rolling average**		
Effective Reduction from Current	0%	calculated	72%	calculated		
Effective BART Limit (tpy)	372	calculated	104	calculated		
Effective Reduction from Current (tpy)	(3)	calculated	266	calculated		
Visibility analyses						
Visibility Improvement (dv at Max Class I)	0.786	calculated from Company	0.786	Emviroplan report	0.786	Emviroplan report
Cost-Effectiveness ($/98th % dv at Max Class I)	$1,607,190	Company report	$1,141,933	Emviroplan report	$ 1,076,703	calculated
Pollutant Control Effectiveness (dv/ton)	0.0030	calculated	0.0030	calculated		
Visibility Improvement (dv at Summed Class I)						
Cost-Effectiveness ($/98th % dv at Summed Class I)						
Pollutant Control Effectiveness (dv/ton)						
	CH2M HILL was requested to perform a BART analysis for			Enviroplan Consulting (Enviroplan) was retained by the Alaska Department of Env		
	Golden Valley Electric Association, Inc. (GVEA) Healy Power Plant. Unit 1			Conservation (Department) to review a Best Available Retrofit Technology (BART		
				analysis submitted on July 28, 2008 by Golden Valley Electric Association (GVEA		
				supplemental information submitted on October 3, 2008, November 11, 2008 and		
				2008; with a revised final BART analysis report submitted on January 2, 2009.		
				Enviroplan calculated the cost of SCR on a dollar per ton ($/ton) of NOx removed		
				the OAQPS Control Cost Manual		

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