IPM Model – Revisions to Cost and Performance for APC Technologies

SCR Cost Development Methodology

FINAL

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LEGAL NOTICE

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Establishment of Cost Basis

The formulation of the SCR cost estimating model is based upon two data bases of actual SCR projects. The data bases used were those of the 2004 to 2006 industry cost estimates for SCR units published in the "ANALYSIS OF MOG AND LADCO'S FGD AND SCR CAPACITY AND COST ASSUMPTIONS IN THE EVALUATION OF PROPOSED EGU 1 AND EGU 2 EMISSION CONTROLS" report prepared for Midwest Ozone Group (MOG) and a Sargent & Lundy LLC (S&L) proprietary in-house database. The available data was analyzed in detail regarding project specifics such as coal type, NOx reduction efficiency and air pre-heater requirements, and updated to include the cost of SCR projects available with both data sets.

The data sets were escalated to update the MOG information to 2009 and all of the data was cross referenced with current 2009 projects. The MOG and S&L cost data were updated to reflect the changes in equipment and labor rates. The CEPCI index for power plants was used to escalate the costs. The Handy-Witman index was also used to escalate the project costs to account for regional effects; the results were compared with the CEPCI index and were within 2% for total project costs.

The comparison between the two sets of data was refined by fitting each data set with a least squares curve to obtain an average $/kW project cost as a function of unit size. The data set was then collectively used to generate an average least-squares curve fit. The curve fit indicated that both sets of data produced similar average costs (within 4%) at the 200 MW range, but deviate as the unit size increases to approximately 11% at 600 MW and 13% at 900MW. The costs for retrofitting a plant smaller than 100 MW increase rapidly due to the economy of size. The older units which comprise a large proportion of the plants in this range generally have more compact sites with very short flue gas ducts running from the boiler house to the chimney. Because of the limited space, the SCR reactor and new duct work can be expensive to design and install. Additionally, the plants might not have enough margins in the fans to overcome the pressure drop due to the duct work configuration and SCR reactor and therefore new fans may be required.

The least squares curve fit was based upon an average of the SCR retrofit projects. Retrofit difficulties associated with an SCR may result in capital cost increases of 30 to 50% over the base model. The least squares curve fits were based upon the following assumptions:

- Retrofit Factor =1
- Gross Heat Rate = 9880
- SO_2 Rate = < 3 lb/MMBtu
- Type of Coal = Bituminous
- Project Execution = Multiple lump sum contracts

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Methodology

Inputs

To predict future SCR retrofit costs several input variables are required. The unit size in MW is the major variable for the capital cost estimation followed by the type of fuel (Bituminous, PRB, or Lignite) which will influence the flue gas quantities as a result of the moisture content. The fuel type also affects the air pre-heater costs if ammonium bisulfate or sulfuric acid deposition poses a problem. The unit heat rate factors into the amount of flue gas generated and ultimately the size of the SCR reactor and reagent preparation. A retrofit factor that equates to difficulty in construction of the system must be defined. The NO_x rate and removal efficiency will impact the amount of catalyst required and size of the reagent handling equipment. The elevation of the site must be considered separately and factored into the unit MW size accordingly due to its effects on the flue gas volume.

The inputs that impact the variable O&M costs are based primarily on the plant capacity factor and the removal efficiency. The NOx removal efficiency specifically affects the SCR catalyst, reagent and steam costs. The lower level of NOx removal is recommended as:

- 0.07 NOx lb/mmBtu – Bituminous
- 0.05 NOx lb/mmBtu – PRB
- 0.05 NOx lb/mmBtu – Lignite

Outputs

Total Project Costs (TPC)

First the bare costs are calculated for each required module (BM). The bare module costs include:

- Equipment
- Installation
- Buildings
- Foundations
- Electrical
- Retrofit factor

The bare module costs do not include:

- Engineering and Construction Management
- Owner's cost
- AFUDC

The modules are:

BMR = Base module SCR cost

BMF = Base module reagent preparation cost

BMA = Base module air pre-heater cost

BMB = Base module balance of plan costs including: ID or booster fans, piping, etc…

BM = BMR + BMF + BMA + BMB

The total bare module cost (BM) is then increased by:

- Engineering and construction management costs at 10% of the BM cost.
- Labor adjustment for 6 x 10 hour shift premium, per diem, etc., at 10% of the BM cost.
- Contractor profit and fees at 10% of the BM cost.

A capital, engineering, and construction cost subtotal (CECC) is established as the sum of the BM and the additional engineering and construction fees.

Additional costs and financing expenditures for the project are computed based on the CECC. Financing and additional project costs include:

- Owner's home office costs (owner's engineering, management, and procurement) at 5% of the CECC; and
- Allowance for Funds Used During Construction (AFUDC) at 6% of the CECC and owner's costs. The AFUDC is based on a two-year engineering and construction cycle.

The total project cost is based on a multiple lump sum contract approach. Should a turnkey engineering procurement construction (EPC) contract be executed, the total project cost could be 10 to 15% higher than what is currently estimated.

Escalation is not included in the estimate. The total project cost (TPC) is the sum of the CECC and the additional costs and financing expenditures. Table 1 contains an example of the capital cost estimation.

Fixed O&M (FOM)

The fixed operating and maintenance cost is a function of the additional operations staff (FOMO) and maintenance labor and materials (FOMM) associated with the SCR installation. The FOM is the sum of the FOMO and the FOMM.

In general, 1 additional operator is required for all installations. The FOMO is based on the number of additional operations staff required.

The fixed maintenance materials and labor is a direct function of the bare module cost (BM) at a retrofit factor of 1.0.

Variable O&M (VOM)

Variable O&M is a function of catalyst required and disposal costs, reagent consumption, and steam consumption. All of the VOM costs must be adjusted for plant capacity factor.

The reagent consumption rate is a function of unit size, NO_x feed rate and removal efficiency. The steam usage is based upon reagent consumption rate.

The power required for the SCR system was not included in the variable O&M costs. The power requirements include increased fan power to overcome the added pressure drop across the catalyst and ductwork and the reagent supply system.

The variables that contribute to the overall VOM are:

VOMR = Variable O&M costs for urea reagent

VOMW = Variable O&M costs for catalyst replacement & disposal

VOMM = Variable O&M costs for steam

VOM = VOMR + VOMW + VOMM.

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Table 1. Example of the Capital Cost Estimate Work Sheet.

Variable	Designation	Units	Value	Calculation
Unit Size	A	(MW)	600	<--- User Input
Retrofit Factor	B		1	<--- User Input (An "average" retrofit has a factor = 1.0)
Heat Rate	C	(Btu/kWh)	9880	<--- User Input
NOx Rate	D	(lb/MMBtu)	0.21	<--- User Input
SO2 Rate	E	(lb/MMBtu)	1.71	
Type of Coal	F		PRB	<--- User Input
Coal Factor	G		1.05	Bit=1.0, PRB=1.05, Lig=1.07
Heat Rate Factor	H		0.988	C/10000
Heat Input	I	(Btu/hr)	5.93E+09	A*C*1000
Capacity Factor	J	(%)	85	<--- User Input
Nox Removal Efficiency	K	%	70	
Nox Removal Factor	L		0.875	I/J
Nox Removed	M	lb/h	8.71E+02	D*I/10^6*K/100
Urea Rate (100%)	N	(lb/hr)	609	M*0.525*60/46*1.01/0.99
Steam Required	O	(lb/hr)	689	N*1.13
Aux Power	P	(%)	0.57	0.56*(G*H)^0.43; Auxiliary Power is not used in the Variable O&M Costs.
Urea Cost 50% wt solution	R	($/ton)	310	
Catalyst Cost	S	($/m3)	8000	
Aux Power Cost	T	($/kWh)	0.06	
Steam Cost	U	($/klb)	4	
Operating Labor Rate	V	($/hr)	60	Labor cost including all benefits

Costs are all based on 2009 dollars

Capital Cost Calculation		Example		Comments
Includes - Equipment, installation, buildings, foundations, electrical, and retrofit difficulty.				
BMR ($) =	180000*(B)*(L)^0.2*(A*G*H)^0.92	$	65,199,000	SCR (Inlet Ductwork, Reactor, Bypass) Island Cost
BMF ($) =	410000*(M)^0.25	$	2,228,000	Base Reagent Preparation Cost
BMA ($) =	IF E ≥ 3 THEN 65000*(B)*(A*G*H)^0.78; ELSE 0	$	-	Air Heater Modification / SO3 Control (Bituminous only & > 3lb/mmBtu)
BMB ($) =	380000*(B)*(A*G*H)^0.42	$	5,666,000	ID or booster fans & Auxiliary Power Modification Costs
BM ($) =	BMR + BMF + BMA + BMB	$	73,093,000	Total bare module cost including retrofit factor
BM ($/KW) =			122	Base cost per kW
Total Project Cost				
A1 = 10% of BM		$	7,309,000	Engineering and Construction Management costs
A2 = 10% of BM		$	7,309,000	Labor adjustment for 6 x 10 hour shift premium, per diem, etc…
A3 = 10% of BM		$	7,309,000	Contractor profit and fees
CECC ($) = BM+A1+A2+A3		**$**	**95,020,000**	Capital, engineering and construciton cost subtotal
CECC ($/kW) =			**158**	Capital, engineering and construciton cost subtotal per kW
B1 = 5% of CECC		$	4,751,000	Owners costs including all "home office" costs (owners engineering, management, and procurement activities)
B2 = 6% of CECC + B1		$	5,986,000	AFUDC (Based on approximately 3% per year for a 2 year engineering and construction cycle)
TPC ($) = CECC + B1 + B2		**$**	**105,757,000**	Total project cost
TPC ($/kW) =			**176**	Total project cost per kW

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Table 2. Example of the Fixed and Variable O&M Estimate Work Sheet.

Variable	Designation	Units	Value	Calculation
Unit Size	A	(MW)	600	<--- User Input
Retrofit Factor	B		1	<--- User Input (An "average" retrofit has a factor = 1.0)
Heat Rate	C	(Btu/kWh)	9880	<--- User Input
NOx Rate	D	(lb/MMBtu)	0.21	<--- User Input
SO2 Rate	E	(lb/MMBtu)	1.71	
Type of Coal	F		PRB	<--- User Input
Coal Factor	G		1.05	Bit=1.0, PRB=1.05, Lig=1.07
Heat Rate Factor	H		0.988	C/10000
Heat Input	I	(Btu/hr)	5.93E+09	A*C*1000
Capacity Factor	J	(%)	85	<--- User Input
Nox Removal Efficiency	K	%	70	
Nox Removal Factor	L		0.875	I/J
Nox Removed	M	lb/h	8.71E+02	D*I/10^6*K/100
Urea Rate (100%)	N	(lb/hr)	609	M*0.525*60/46*1.01/0.99
Steam Required	O	(lb/hr)	689	N*1.13
Aux Power	P	(%)	0.57	0.56*(G*H)^0.43; Auxiliary Power is not used in the Variable O&M Costs.
Urea Cost 50% wt solution	R	($/ton)	310	
Catalyst Cost	S	($/m3)	8000	
Aux Power Cost	T	($/kWh)	0.06	
Steam Cost	U	($/klb)	4	
Operating Labor Rate	V	($/hr)	60	Labor cost including all benefits

Costs are all based on 2009 dollars			
Fixed O&M Cost			
FOMO ($/kW yr) = (1/2 operator time assumed)*2080**V/(A*1000)	$	0.10	Fixed O&M additional operating labor costs
FOMM ($/kW yr) = IF A < 500 then $200,00 ELSE $300,000	$	0.50	Fixed O&M additional maintenance material and labor costs
FOM ($/kW yr) = FOMO + FOMM	**$**	**0.60**	Total Fixed O&M costs
Variable O&M Cost			
VOMR ($/MWh) = N*R/A/1000	$	0.31	Variable O&M costs for Urea
VOMW ($/MWh) = discrete function of A, G, J, K, S	$	0.35	Variable O&M costs for catalyst: replacement & disposal
VOMM ($/MWh) = O*U/A/1000	$	0.01	Variable O&M costs for steam
VOM ($/MWh) = VOMR + VOMW + VOMM	**$**	**0.66**	