The Market Opportunities for Dry Scrubbing System, Components and Consumables

Presentation at Dry Scrubber Users Association Annual Meeting in Kansas City, Sept 9-12, 2019
By Bob McIlvaine, president of the McIlvaine Company

Overview

Dry scrubbers are taking market share away from the wet scrubbing alternative in coal fired power, biomass combustion, cement, steel, waste to energy and other applications involving hot acid gases and particulate.

The advantages of dry scrubbers are the reduced need for water, the elimination of wastewater, and the capture of mercury, dioxins, and sulfuric acid mist. The negative aspect is the elimination of valuable byproducts. If the acid gas ratio in the fuel is low dry scrubbing has the lowest total cost of ownership. The higher the acid content the less competitive dry scrubbing is to wet.

Dry scrubbing is the preferred choice in glass plants, waste to energy, and cement plants. In some other applications it has half the market share. In coal fired power generation it has less than a 6 percent share. A major change is taking place in India where coal fired power plants are expected to use dry scrubbing for one third of the requirements. As a result India will be a leading purchaser of dry scrubber hardware, lime and services in the future. It will spend just under $3 billion for dry scrubber hardware and construction over the seven year period ending in 2025. It will be spending $650 million/yr for lime for dry scrubbing by 2025 and $325 million for service, repair and remote operation and maintenance.

	2025 CFM (millions)	2025 MW Equivalent	2018-2015 CFM Additions (millions)	2018-2025 MW Equivalent Additions	Lime Market $ millions (2025)	Hardware Market 2018-25 $ millions	Service, Repair Remotely Operate $ millions 2025
U.S	135	45,000	15	5,000	675	400	225
China	180	60,000	45	15,000	600	675	300
India	195	65,000	134	64,000	650	2,880	325
ROW	270	90,000	120	40,000	900	3,200	450
Total	**780**	**260,000**	**314**	**124,000**	**2825**	**7155**	**1300**

Cement, waste to energy and furnace applications are sized based on CFM. Equivalent MW is provided as a convenience.

MW - CFM equivalent is 3000 CFM at 240F

U.S lime at $150/ton and 100 tons per equivalent MW

Lime in China, India, and ROW at $100/ton and 100 tons per equivalent MW

Hardware for new plants is $45,000/equivalent MW in India and China and $80,000/equivalent MW in U.S. and ROW.

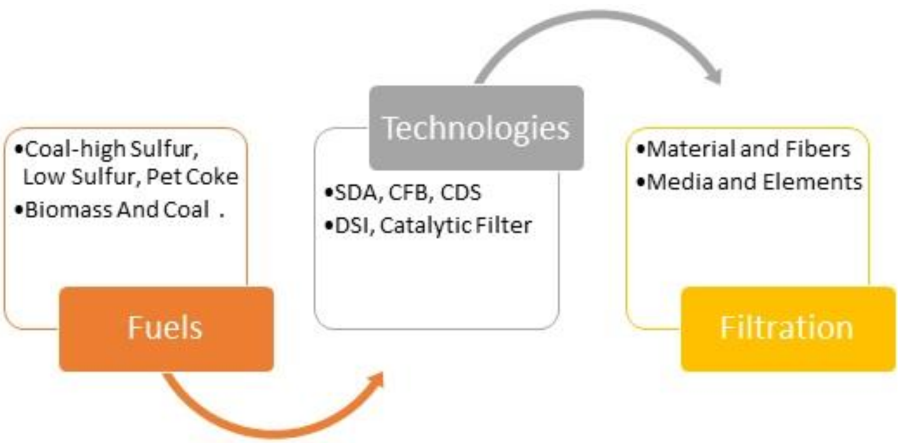
Service, repair and remotely operate is $5000/ MW/yr

The world market for dry scrubbing hardware will average $710 million/yr over the period to 2025. Lime purchases will be just under $3 billion by 2025 while service, repair and remote O&M will rise to over $1.3 billion/yr.

Technology

Dry scrubbing is one of the options used by plant operators to capture SO_2, sulfuric acid mist and other acid gases. End users and suppliers are tasked to determine which pollution control options are best for a specific plant. Because of lack of water, low SO_2 and other acid gas concentrations, weak gypsum market demand, and other factors a dry rather than wet scrubbing solution may be the best choice.

The choice of scrubber technologies is made complex by the need to address multiple pollutants. Dry scrubbing is effective in removing SO_3 whereas this is not true of wet scrubbers. With the addition of activated carbon, dry scrubbers can also remove mercury. There are multiple dry scrubber designs. Some are better with higher sulfur levels. So the fuel becomes one variable in the pursuit of the lowest total cost of ownership solution.



There are multiple dry scrubbing technologies. One is the spray dryer absorber (SDA). This utilizes the same principle used in manufacturing instant coffee or powdered soft drinks. A slurry is sprayed into a vessel through which the hot gas flows. The liquid evaporates. The acid gas reacts with the absorbing particles. The particles are then captured in a fabric filter.

The circulating fluid bed (CFB) scrubber functions by passing the acid gas through a fluidized bed of lime particles. Circulating Dry Scrubbers (CDS) entrain and then separate the particles. Lime or sodium particles are injected into the flue gas duct with Dry Sorbent Injection (DSI) systems. The catalytic filter uses the DSI principle ahead of a ceramic filter medium with embedded catalyst for both particulate control and NOx reduction.

There are a number of materials, fibers, media configurations and element designs which are utilized. The collection media in the fabric filter has a major impact on cost. The optimum gas velocity can vary depending on the media selected. If the velocity can be doubled then the size of the unit can be halved. Instead of 4000 bags for a big installation maybe only 2000 would be needed.

On the other hand, the cost of ownership is significantly affected by the bag life. If bags last one year rather than four or five years, then bag costs become a significant part of the total expense. The energy cost is also a factor. Energy consumption increases in direct proportion to velocity. It also increases in direct proportion to the thickness of the dust cake on the filter media.

In the case where only particulate is to be captured it is best to establish a semi-permanent cake on the bags and then pulse off the new cake. In accounting terms this is LIFO (last in first out). However, for dry scrubbing it is best to remove the reacted gypsum and retain the fresh lime (FIFO). The industry has not formally addressed FIFO vs LIFO and needs to do so.

The need to maximize acid gas capture and the resultant substantial increase in particulate loading affects the choice of fibers and filter media. The type of cleaning (reverse air or pulsing with compressed air) also determines the selection of the lowest true cost medium.

The fuel or product being calcined or treated also impacts the medium. If a high sulfur fuel is burned, the costs of dry scrubbing are comparatively higher than if a low sulfur fuel is burned. Various fibers react differently to various combinations of acid gases, temperature and humidity. One fiber may handle SO_2 and HF in relatively humid conditions at 300 F whereas another cannot.

Temperature resistance is important for several reasons. One is that a fiber which can withstand the temperature excursions will have a longer life than one which is dependent on more perfect operation of the system. Another consideration is the potential to recover heat.

An alternative to glass and polymeric resins is a ceramic fiber matrix. Elements can contain embedded catalysts. Dry sorbent injection ahead of the ceramic media can be utilized to provide removal of dust and acid gases while reducing NO_x. The resultant clean hot gas at 600 F or higher can then be directed to an efficient heat exchanger and most of the potential energy recovered.

The material, fiber design, media construction and filter element shape all have to be designed to address the unique requirements of the application and the technology being employed.

The two major fiber types are glass and polymers.

Type of Fiber	Glass	Polymers
Construction	Woven generally but also some non-woven	Non-woven Laminates Laminate with Membrane

Performance varies both in terms of temperature, abrasion and chemical resistance.

Fiber	Type	Max Continuous Temperature	Chemical Resistance	Abrasion Resistance
PPS	Felted	375	Excellent	Excellent
PTFE	Woven	450	Excellent	Fair
Fiberglass	Woven	450	Good	Fair
P84	Felted	500	Very Good	Excellent

There are differences in laminates with multiple non-woven layers being employed with varying support materials and designs. Fiber shape is also a variable.

How complex are the decisions: There are at least 1500 combinations to assess.

But there are also site specific considerations such as cost of electricity, reagents, pollution limits, plant life, existing equipment. So these can present another 100 variables resulting in 150,000 factors.

Coal fired Boilers

Ninety-nine percent of all the coal fired power generation combust, flow, and treat products and services are purchased by just 500 companies. Fifty percent are purchased by just 50 companies. With data analytics and centralized monitoring an increasing percentage of the purchases are made based on lowest total cost ownership. The decision making involves multiple individuals. Success requires major sales efforts long before a request for quotation is issued.

The Shenhua/Guodian merger resulted in an owner with 200,000 MW of coal fired capacity. However, there remain several entities from a decision making perspective. Seventy percent of the purchasing decisions for existing plants are made by 27 companies with more than 10,000 MW of capacity. However, 150 owners are making the decisions for 70 percent of the new plants.

Coal Fired Capacity for Individual Owners		
Above MW	Planned Cumulative #	Operating Cumulative #
80,000		1
60,000		2
50,000		3
40,000		3
30,000		8
20,000	2	10
10,000	8	27
5000	25	63
3000	50	110
2000	70	164
1500	90	196
1000	150	255
700	200	307
500	250	379
300	300	491
200	350	570
100	400	710
< 100		900

There is a logical disparity between the ratio of new plants to existing plants by owner. For comparison we picked owners with 6000 – 9000 MW range of existing and planned capacity. J-Power is the only company appearing on both lists.

Planned Coal Fired	
Company	**MW**
Power Finance Corporation	8,000
Egyptian Electricity Holding Company	7,920
KEPCO	7,698
China Resources	7,035
NLC India	6,700
TANGEDCO	6,640
J-POWER	6,356
Eskom	6,352
UPRVUNL	6,270

Operating Coal Fired	
Company	**MW**
E.ON	8,772

J-POWER	8,482
Inter RAO	8,372
Vedanta Resources	8,327
Xcel Energy	7,915
Henan Investment Group	7,840
Beijing Energy Group	7,772
Engie	7,387
Damodar Valley Corporation	7,240
AES	7,025

The big growth in coal is in South East Asia and Africa where existing capacity is small. The existing capacity is mostly in countries where new coal fired plants are being discouraged.

Seventy percent of the purchasing decisions for existing plants are made by 27 companies with more than 10,000 MW of capacity. However, 150 owners are making the decisions for 70 percent of the new plants. Five hundred owners will purchase 99 percent of CFT products for new and existing plants. Only two companies plan to purchase more than 20,000 MW of new capacity. Only 8 companies plan more than 10,000 MW. On the other hand 150 companies are planning to build at least 1000 MW of new coal fired boilers.

Coal Fired Capacity for Individual Owners		
Above MW	**Planned Cumulative #**	**Operating Cumulative #**
80,000		1
60,000		2
50,000		3
40,000		3
30,000		8
20,000	2	10
10,000	8	27
5000	25	63
3000	50	110
2000	70	164
1500	90	196
1000	150	255
700	200	307
500	250	379
300	300	491
200	350	570
100	400	710
< 100		900

Country forecasts are based on aggregating forecasts for individual owners. Here are some alphabetical examples with additional detail on Brazil.

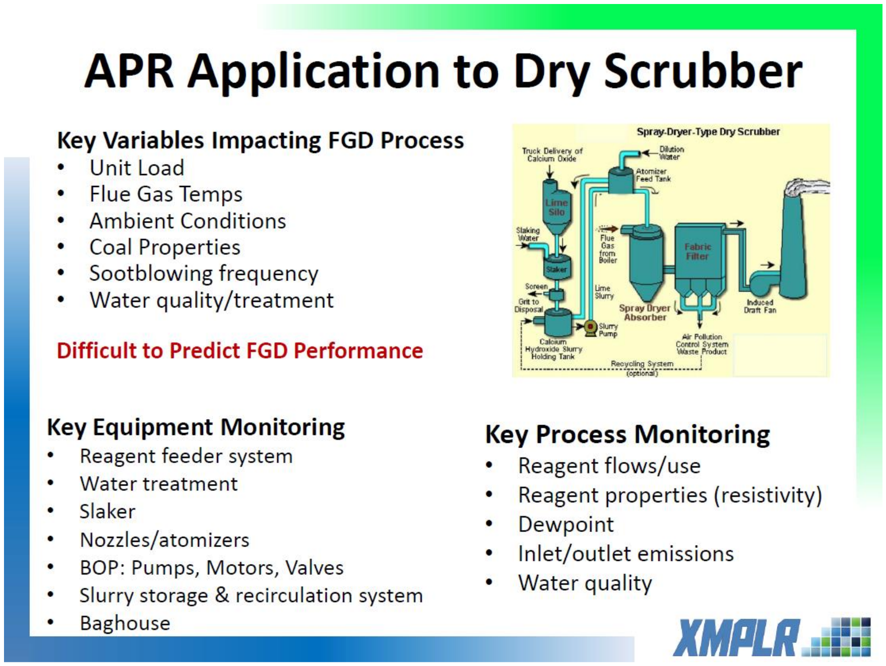
Coal Plants by Country (MW) Installed Base							
Country	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
Albania	0	0	0	0	0	0	0
Argentina	350	350	350	350	350	350	350
Australia	24,442	24,442	24,442	24,442	24,442	24,442	24,442
Austria	635	635	635	635	635	635	635
Bangladesh	525	1,200	2,500	5,500	8,000	10,000	12,000
Belarus	0	0	0	0	0	0	0
Belgium	0	0	0	0	0	0	0
Bosnia & Herzegovina	2,073	2,073	2,073	2,073	2,073	3,000	4,000
Botswana	600	600	732	732	732	1,200	1,200
Brazil	3346	3346	3346	3346	3346	3646	3646
EON	1090	1090	1090	1090	1090	1090	1090
EDP	1460	1460	1460	1460	1460	1460	1460
Electrobas	796	796	796	796	796	796	796
Ouro Negro						300	300

Brazil Plant Details						
Unit	**Sponsor**	**Parent**	**Capacity (MW)**	**Year**	**City**	**State**
MPX Itaqui power project	Eneva	E.ON, EBX Group	360	2013	Itaqui	Maranhão
Porto do Pecém I Unit 1	Eneva, EDP Energias do Brasil	Eneva, EDP	365	2012	São Gonçalo do Amarante	Ceará
Porto do Pecém I Unit 2	Eneva, EDP Energias do Brasil	Eneva, EDP	365	2013	São Gonçalo do Amarante	Ceará
Porto do Pecém II Unit 1	Eneva	E.ON, Eneva	365	2013	São Gonçalo do Amarante	Ceará
Porto do Pecém-1Unit 1	EDP Energias do Brasil	EDP	365	2012	São Goncalo do Amarante	Ceará
Porto do Pecém-1 Unit 2	EDP Energias do Brasil	EDP	365	2013	São Goncalo do Amarante	Ceará
Porto do Pecém-2 Unit 1	Eneva	E.ON, EBX Group	365	2013	São Goncalo do Amarante	Ceará

Brazil Plant Details						
Unit	Sponsor	Parent	Capacity (MW)	Year	City	State
Presidente Médici-A Unit 1	Companhia de Geração Térmica de Energia Elétrica	Eletrobras	63	1974	Candiota	Rio Grande do Sul
Presidente Médici-A Unit 2	Companhia de Geração Térmica de Energia Elétrica	Eletrobras	63	1974	Candiota	Rio Grande do Sul
Presidente Médici-B Unit 1	Companhia de Geração Térmica de Energia Elétrica	Eletrobras	160	1986	Candiota	Rio Grande do Sul
Presidente Médici-B Unit 2	Companhia de Geração Térmica de Energia Elétrica	Eletrobras	160	1987	Candiota	Rio Grande do Sul
Presidente Médici-C Unit 1	Companhia de Geração Térmica de Energia Elétrica	Electrobras	350	2010	Candiota	Rio Grande do Sul

IIoT and Remote O&M

There is a big potential for DSUA supplier and consultant members to provide remote support to dry scrubber operators around the world. With the information being gained from DSUA activities and with additional information supplied by McIlvaine, DSUA subject matter experts (SMEs) will become subject matter ultra-experts Data analytics software programs can be continually improved with the input of the SMUEs. When additional customized assistance is required the SMUE with access to the cloud system will be able to provide the remote guidance. XMPLR is working on the data analytics programs for SDA and addressing all the variables.



Continuing Analysis of the Most Comprehensive, Accurate and Useful Data

McIlvaine is making data available to DSUA members which can be the foundation of future analysis. An example is the recent paper by Sumitomo SHI-FW showing that in India the CFB dry scrubber is more economical than a wet limestone scrubber under parameters specifically outlined in the paper

FGD System Operating Cost	CFB Scrubber	Wet Scrubber	Cost Difference
Reagent cost (Hydrated lime for the CFB scrubber, Limestone for the Wet Scrubber), Rs Crore/yr	25	7	18
Water, Rs Crore/yr	1	2	-1
Scrubber product sales, Rs Crore/yr	0	0	0
Power sales loss to FGD absorber power, Rs Crore/yr	6	9	-3
Power sales loss to Fabric filter/ESP power, Rs Crore/yr	3	0	3
Fixed + Variable O&M, Rs Crore/yr	5	11	-6
Plant income loss due to extended maintenance outage required, Rs Crore/yr	0	1	-1
Total FDG operating cost, Rs Crore/yr	40	29	11
Subtotal NPV FGD operating cost, Rs Crore	**306**	**220**	**86**
FGD system installed cost, Rs Crore	175	350	-175
ESP Upgrade cost (200 to 50 mg/Nm^3), Rs Crore	0	75	-75
Stack modification (borosilicate lining), Rs Crore	0	15	-15
Subtotal FGD Construction cost, Rs Crore	**175**	**440**	**-265**
TOTAL FGD NPV, Rs Crore	**481**	**660**	**-179**

Since the cost of limestone and lime are provided along with utilization factors, fuel parameters, electricity and water costs etc. this document can be discussed in a meaningful way. The impact of larger boiler sizes, different fuels, and other site-specific parameters can be introduced.

To the extent that the global experience is shared the individual operators will benefit. The largest present market is in India where there is little experience to date. The knowledge retained by DSUA and its members will be of considerable value to their Indian counterparts.