

Toxic Releases from Power Plants: The Next Shoe to Drop

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April 7, 1999

HDGC Seminar

The Toxics Release Inventory

- Established by section 313 of Emergency Planning and Community Right-to-Know Act (EPCRA) of 1986
- Strengthened by Pollution Prevention Act of 1990
- Lists approximately 600 chemicals and 28 chemical categories
- Public database for community access to toxic release information
- No consideration of risks or effects

Largest Total Releases by Industry in 1995-96 (millions of pounds per year)

SIC	Industry	1995 Releases		1996 Releases	
		Air	Total	Air	Total
28	Chemicals	407	844	392	785
33	Primary Metals	138	524	145	565
26	Paper	213	238	204	228
30	Plastics	112	127	105	116
37	Transportation Equipment	109	121	103	111
All Industries		1,562	2,531	1,452	2,434

Largest Total Releases by Chemical in 1995-96 (millions of pounds per year)

Chemical	1995 Releases		1996 Releases	
	Air	Total	Air	Total
Methanol	210	255	206	241
Ammonia	157	195	155	193
Zinc compounds	5	189	6	207
Toluene	145	147	125	127
Nitrate compounds	<1	145	<1	164
All Chemicals	1,562	2,531	1,452	2,434

Newly Listed Industries

- Seven new industries added in 1998, including electric power plants
- Covers all coal-fired and oil-fired plants with more than ten employees (approximately 1000 facilities)
- First reports due by July 1, 1999 for releases in calendar year 1998
- Results for 1998 expected by mid-2000

What Gets Reported?

- “Processed” chemicals, if more than 25,000 lbs/yr
- “Coincidentally manufactured” chemicals, if more than 25,000 lbs/yr
- “Otherwise used” chemicals, if more than 10,000 lbs/yr
- *De minimus* exemption for byproducts distributed in commerce

Annual Releases (lbs/year) Reportable on TRI Form R

- Stack Air Emissions
- Fugitive Air Emissions
- Water Discharges
 - By water body name
 - % from stormwater
- Land Releases to:
 - Landfill
 - Land treatment
 - Surface impoundment
 - Other disposal
- Transfers Off-Site to:
 - Publicly Owned Treatment Works
 - Other Sites (divided by site) for:
 - Treatment
 - Disposal
 - Recycling
 - Energy recovery
- Underground Injections

Continued...

Annual Releases (lbs/year) Reportable on TRI Form R

- On-Site Waste Treatment Methods and Efficiency
 - List of methods, concentration and efficiency
 - Divided by waste stream
- Source Reduction and Recycling Activities
 - Quantity released
 - Quantity used for on-site energy recovery
 - Quantity used for off-site energy recovery
 - Quantity recycled on-site
 - Quantity recycled off-site
 - Quantity treated on-site
 - Quantity treated off-site
 - Quantity released to environment not associated with production process
 - Production ratio or activity index

TRI Chemicals Potentially Relevant to the Electric Utility Industry

Compounds of	Organics	Other
Antimony	Benzene	Ammonia
Arsenic	Dichloromethane	Asbestos (friable)
Barium	Ethylbenzene	Bromine
Beryllium	Ethylene Glycol	Chlorine
Cadmium	Formaldehyde	Chlorine Dioxide
Chromium	Formic Acid	Hydrazine
Cobalt	Methanol	Hydrogen Fluoride
Copper	Naphthalene	Hydrochloric Acid
Lead	PCBs	Nitric Acid
Manganese	Polycyclic aromatics	Ozone
Mercury	Propylene	Sulfuric Acid
Molybdenum	Toluene	Thiourea
Nickel	Xylene	
Selenium		
Silver		
Thallium		
Zinc		

Coincidentally Manufactured Chemicals

- Assume metals convert to lowest weight oxide per unit of metal:



Elemental Threshold Releases for Combustion-Generated Manufactured Compounds

Substance	Lowest Wgt Oxide	Molecular Weight	Ratio	Threshold (lbs/yr)
Antimony	Sb ₂ O ₃	291.50	0.833	20,833
Arsenic	As ₂ O ₃	197.84	0.758	18,939
Barium	BaO	153.33	0.895	22,391
Beryllium	BeO	25.01	0.360	9,009
Cadmium	CdO	128.41	0.876	21,891
Chromium	CrO	68.00	0.765	19,113
Cobalt	CoO	74.93	0.787	19,670
Copper	Cu ₂ O	143.09	0.888	22,202
Lead	PbO	223.20	0.929	23,213
Manganese	MnO	70.94	0.775	19,365
Mercury	Hg ₂ O	417.18	0.962	25,000
Molybdenum	MoO ₃	143.94	0.667	16,663
Nickel	NiO	74.70	0.786	19,645
Selenium	SeO ₂	110.96	0.712	17,790
Silver	Ag ₂ O	231.74	0.931	23,273
Thallium	Tl ₂ O	424.74	0.962	24,058
Zinc	ZnO	81.38	0.803	20,080

Formation of HCl and HF



Formation of Sulfuric Acid



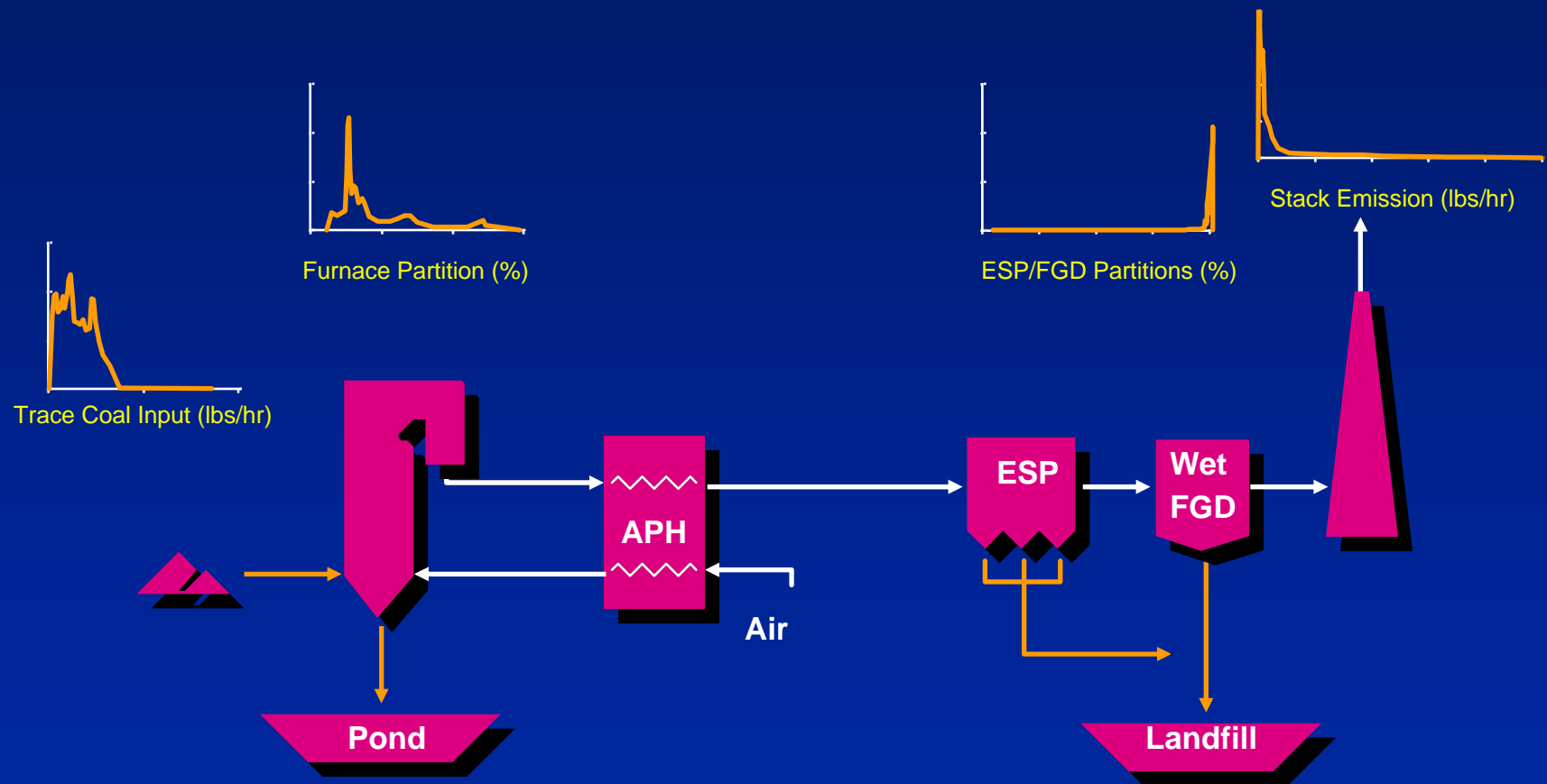
Estimating TRI Releases

- Utilities must determine:
 - Which species are reportable
 - Quantities to report
- No new monitoring programs required (use reasonable estimating methods)
- EPA draft guidance document (January 1999) endorses mass balance approach

The EPRI PISCES Model

- A mass and energy balance model for tracking all flows to and from fossil fuel power plants
- Linked to EPRI PISCES database
- Includes trace species and criteria pollutants
- Multi-media coverage (air, water, land)
- Probabilistic capability

Probabilistic Emissions Path



PISCES Model Package

Fuel Properties

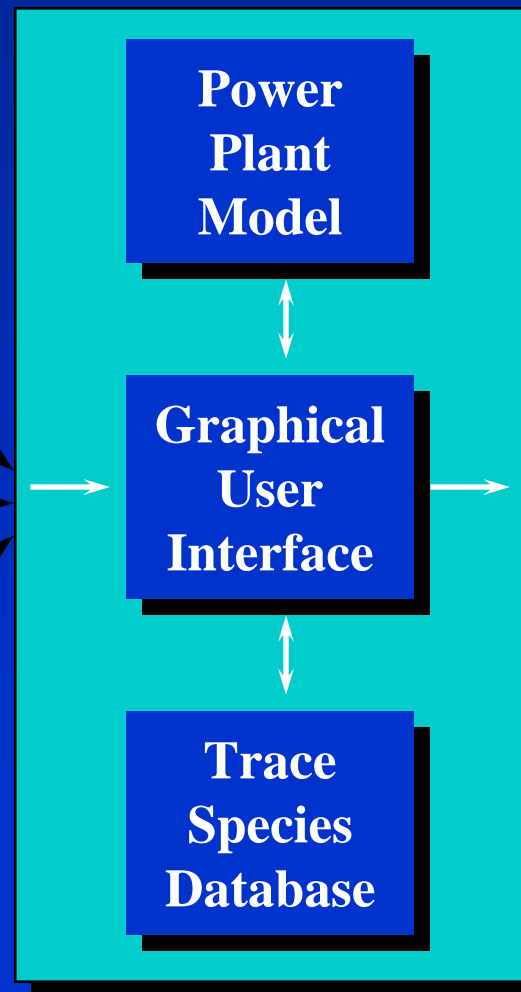
Coal
Oil
Natural Gas

Plant Design

Furnace Type
Air Pollution Controls
Solid Waste Systems
Water Treatment

Chemicals

Reagents
Additives
Makeup Water



Atmospheric
Emissions

Solid
Discharges

Liquid
Effluents

Welcome to the EPRI PISCES Model



Start Session

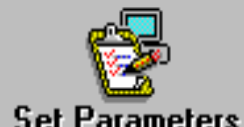


About



Exit





Configure Plant / Get Results

 **1. Fuel Type**

 **2. Combustion**

 **3. Flue Gas Cleanup**

 **4. Water System**

 **5. Waste Management**

Plant Diagram 

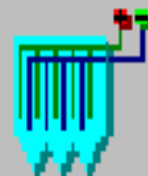
Water Diagram

SO2 Removal

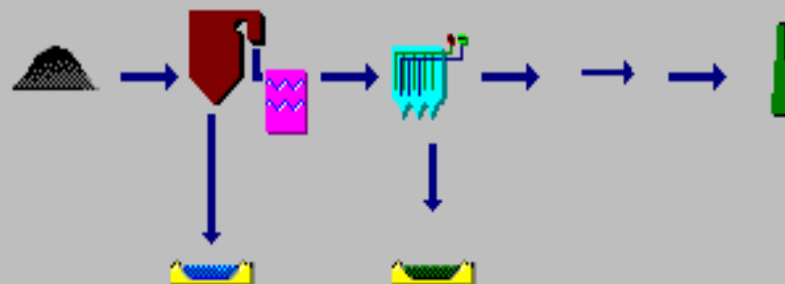
- Wet Lime/Limestone
- Lime Spray Dryer
- None

Particulate Removal

- Cold-Side ESP
- Fabric Filter
- None










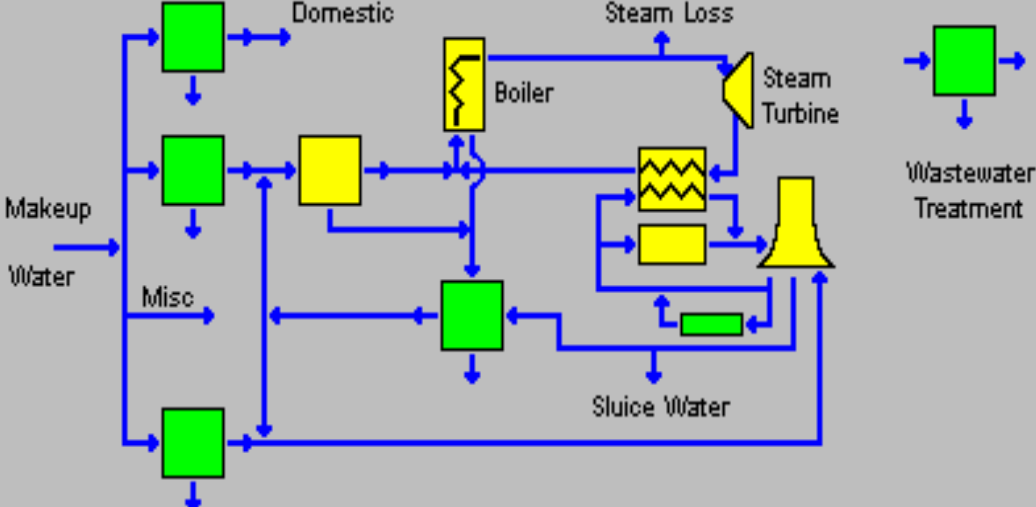

Plant Diagram



Click on buttons 1 through 5 to describe your plant.

 <p>Configure Plant</p>	 <p>Trace Species</p>	 <p>Set Parameters</p>	 <p>Get Results</p>	 <p>Close Session</p>
---	--	---	--	--


Configure Plant / Get Results



 <p>1. Fuel Type</p>	
 <p>2. Combustion</p>	<p>Treatment System</p> <p><input checked="" type="checkbox"/> Boiler Makeup Water</p> <p><input checked="" type="checkbox"/> Domestic Water</p> <p><input checked="" type="checkbox"/> Cooling Water</p> <p><input checked="" type="checkbox"/> Tower Slip Stream</p> <p><input checked="" type="checkbox"/> Wastewater</p>
 <p>3. Flue Gas Cleanup</p>	<p>Cooling System</p> <p><input checked="" type="radio"/> Cooling Tower</p> <p><input type="radio"/> Fresh Once-Through</p> <p><input type="radio"/> Saline Once-Through</p>
 <p>4. Water System</p>	<p>Discharges</p> <p><input type="radio"/> NPDES</p> <p><input checked="" type="radio"/> Recovered</p> 
 <p>5. Waste Management</p>	<p>Water Diagram : Cooling Tower</p> 
<p><input type="radio"/> Plant Diagram</p> <p><input checked="" type="radio"/> Water Diagram</p> 	<p>Click on buttons 1 through 5 to describe your plant.</p>

Configure Plant | Trace Species | Set Parameters | Get Results | Close Session

Configure Plant / Get Results

1. Fuel Type ✓
2. Combustion ✓
3. Flue Gas Cleanup ✓
4. Water System ✓
5. Waste Management ✓

Plant Diagram 
 Water Diagram

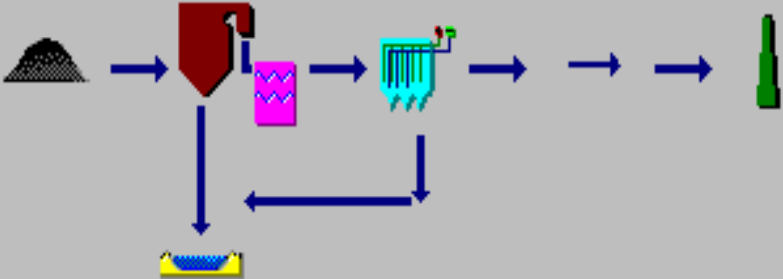
 

Flue Gas Treatment Solids
 Disposal Only
 Use in Commerce Only
 Disposal + Commerce

Fly Ash Management
 Mix w/ Bottom Ash
 Mix w/ FGD Solids
 No Mixing

Ash Pond Solids
 Disposal Only
 Use in Commerce Only
 Disposal + Commerce

Plant Diagram



Click on buttons 1 through 5 to describe your plant.


Configure Plant


Trace Species


Set Parameters


Get Results


Close Session

Trace Species

- | | |
|--|---|
| <input type="checkbox"/> 2,3,7,8-TCDD | <input checked="" type="checkbox"/> Naphthalene |
| <input type="checkbox"/> Aluminum | <input checked="" type="checkbox"/> Nickel |
| <input checked="" type="checkbox"/> Antimony | <input type="checkbox"/> Phosphorus |
| <input checked="" type="checkbox"/> Arsenic | <input type="checkbox"/> Potassium |
| <input checked="" type="checkbox"/> Barium | <input checked="" type="checkbox"/> Selenium |
| <input checked="" type="checkbox"/> Benzene | <input checked="" type="checkbox"/> Silver |
| <input checked="" type="checkbox"/> Benzo(a)pyrene | <input type="checkbox"/> Sodium |
| <input checked="" type="checkbox"/> Beryllium | <input checked="" type="checkbox"/> Thallium |
| <input type="checkbox"/> Boron | <input checked="" type="checkbox"/> Toluene |
| <input checked="" type="checkbox"/> Cadmium | <input type="checkbox"/> Vanadium |
| <input type="checkbox"/> Calcium | <input checked="" type="checkbox"/> Xylene |
| <input checked="" type="checkbox"/> Chloride | <input checked="" type="checkbox"/> Zinc |
| <input checked="" type="checkbox"/> Chromium | |
| <input checked="" type="checkbox"/> Cobalt | |
| <input checked="" type="checkbox"/> Copper | |
| <input checked="" type="checkbox"/> Fluoride | |
| <input checked="" type="checkbox"/> Formaldehyde | |
| <input type="checkbox"/> Iron | |
| <input checked="" type="checkbox"/> Lead | |
| <input type="checkbox"/> Magnesium | |
| <input checked="" type="checkbox"/> Manganese | |
| <input checked="" type="checkbox"/> Mercury | |
| <input checked="" type="checkbox"/> Molybdenum | |

Please select Trace Species for current session. When completed, select any of Configure Plant, Set Parameters or Get Results.

Hazardous Air Pollutants (HAPs)

Toxic Release Inventory (TRI)

Select All

Select All

Select Inorganics

Select Inorganics

Select Organics

Select Organics

Unselect All



Set Parameters

[TRI Case Study Plant] Plant Performance

To edit the Value, click on the red check mark (if any) to remove it, then double-click on Value.

	Parameter Description	Units	Unc	Value	Calc	Minimum	Maximum	Default
1	Gross Electrical Output	(MW)		692.2		1	3000	540
2	Gross Cycle Heat Rate	(Btu/kWh)		8833		7000	12000	8924
3	Net Electrical Output	(MW)		650.0		1	3000	492
4	Capacity Factor	(%)		65.00		0	100	75
5	Excess Air for Furnace	(% stoich.)		20.00	✓	0	40	Calc
6	Leakage Air at Preheater	(% stoich.)		19.00	✓	0	60	Calc
7	Ambient Air Temperature	(°F)		80.00		77	110	80
8	Unaccounted Boiler Losses	(%)		0.5000		0	4	0.5
9	Boiler Efficiency	(%)		89.03	✓	50	95	Calc
10	Gas Temp. Exiting Economizer	(°F)		700.0		250	1200	700
11	Gas Temp. Exiting Preheater	(°F)		300.0		150	400	300

← Return to Checklist

Print

?

Default





Set Parameters

- Plant -----
- 1. Fuel Properties
- 2. Plant Performance
- 3. Furnace Emission Factors
- 4. Stack Emission Constraints
- 5. Cold-Side ESP
- 7. Solid Waste Management
- 8. Cooling Water System
- 9. Water Treatment Systems
- Trace -----
- 1. Fuel Properties
 - 1.1. Fuel Properties: Coal
 - 1.2. Coal Pile Runoff
 - 1.3. Pyrite Rejects
- 2. Plant Performance
- 3. Furnace Emission Factors
- 4. Organics Emission Rates
- 5. Cold-Side ESP
- 7. Solid Waste Management
- 8. Cooling Water System
- 9. Water Treatment Systems

Click on a folder to open it. Click on a page to set or change parameters.

Plant parameters highlighted in blue indicate the most important site-specific parameters for TRI estimates.

All "Trace" parameters also are important for TRI.



Configure Plant / Get Results

Get Results

Options

- Trace Table
- Trace Diagram
- for **Antimony** ▼
- Perf. Diagram
- Gas Table
- Solids Table

Units

- System:
 ▼
- Diagram:
 ▼
- Table:
 ▼

Show Summary Tables

Show Plant Configuration

- Plant Diagram
- Water Diagram



Report Options

- Toxic Release Inventory
- HAPs Emissions

Uncertainty Distribution

- Off
- Selected Distributions Only
- On

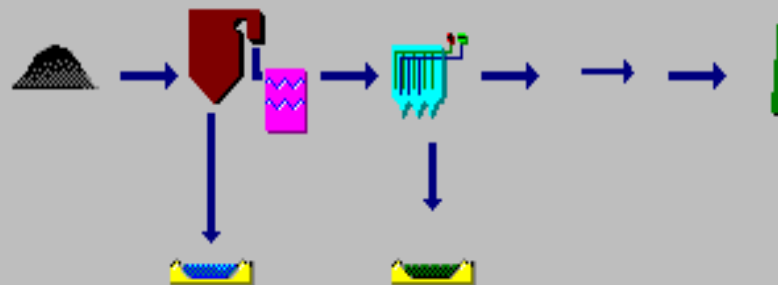
Graph Size:

Sampling Method

- Median Latin Hypercube
- Random Latin Hypercube
- Monte Carlo

Sample Size:

Plant Diagram



Click on an icon in the diagram to get a result.



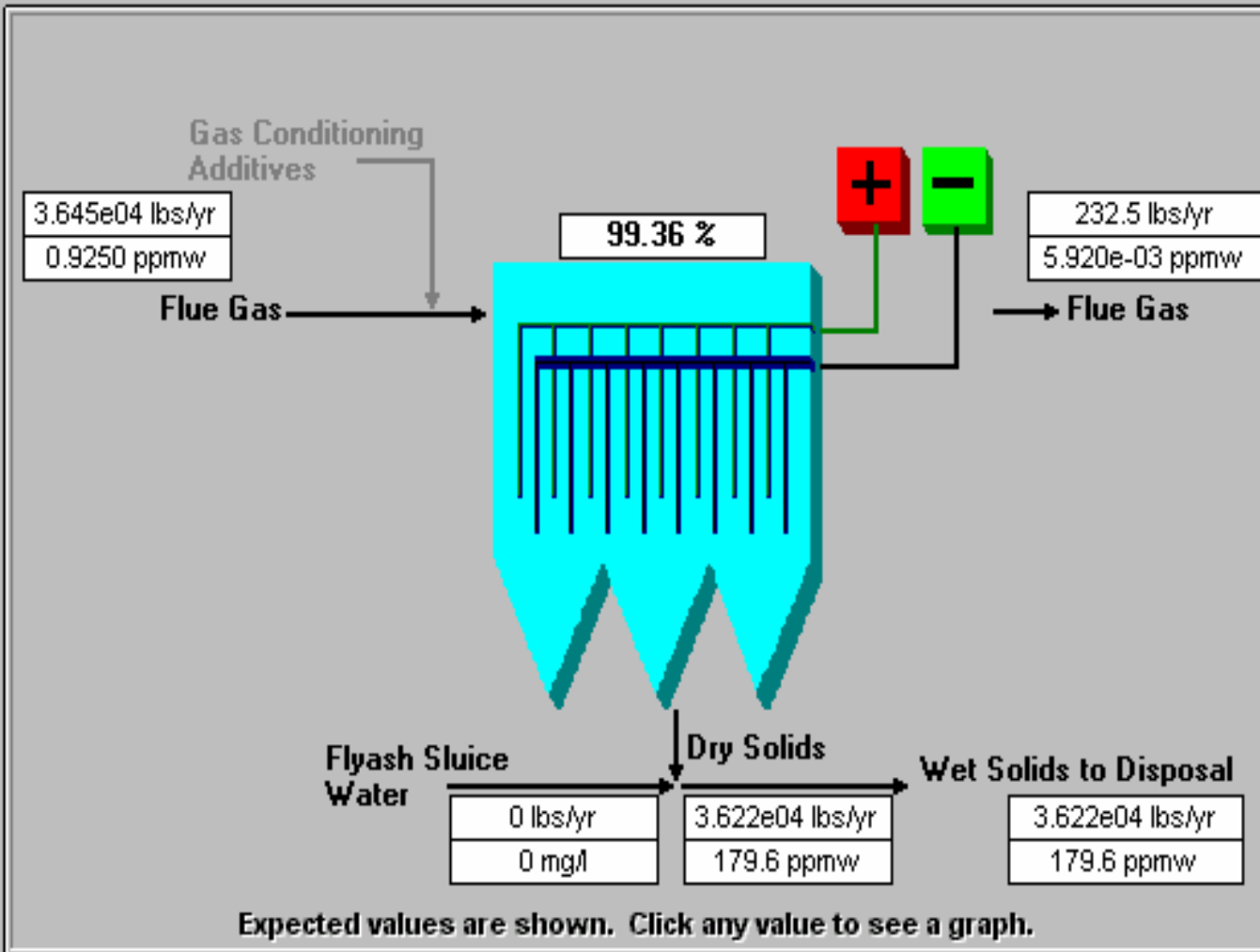
Particulate Removal -- ESP

[TRI Case Study Plant] Cold-Side ESP System: Trace Species

- Options**
- Trace Table
 - Trace Diagram
- for **Chromium**
- Plant Diagram
 - Gas Table
 - Solids Table

- Units**
- System: **English**
- Diagram: **Annual Avg.**
- Table: **Annual Avg.**

- Print**
- Copy to Clipboard**
- Return**





Plant Summary

[TRI Case Study Plant] Threshold Test for Coincidental Manufacture (lbs/yr)

Options

Flows:

- Plant Summary
- Entering Plant
- Exiting Plant

Trace Species:

- Entering Plant
- Exiting Plant
- TRI Threshold
- TRI Releases

Units

System:

English

Table:

Annual Avg.

Print

Copy to Clipboard

Return

Substance (Median Values)	Quantity	Threshold
Antimony	2519	2.083e04
Arsenic	2.430e04	1.894e04
Barium	2.278e05	2.239e04
Benzene	0	2.500e04
Benzo(a)pyrene	0	2.500e04
Beryllium	3026	9009
Cadmium	1276	2.189e04
Hydrochloric Acid	2.050e06	2.500e04
Chromium	4.458e04	1.912e04
Cobalt	1.532e04	1.966e04
Copper	4.983e04	2.221e04
Hydrogen Fluoride	1.819e05	2.500e04
Formaldehyde	0	2.500e04
Lead	1.940e04	2.321e04
Manganese	5.376e04	1.937e04
Mercury	312.8	2.500e04
Molybdenum	7647	2.500e04



Plant Summary

[TRI Case Study Plant] Summary of TRI Releases: Coincidentally Manufactured Species (lb/yr)

Options

Flows:

- Plant Summary
- Entering Plant
- Exiting Plant

Trace Species:

- Entering Plant
- Exiting Plant
- TRI Threshold
- TRI Releases

Units

System:

English

Table:

Annual Avg.

Print

Copy to Clipboard

Return

Substance (Median Values)	Total Release	Air Release	Land Release	Water Release	Transfer Offsite
Antimony	0	0	0	0	0
Arsenic	2.433e04	1111	2.052e04	2701	0
Barium	2.279e05	883.2	2.103e05	1.673e04	0
Benzene	0	0	0	0	0
Benzo(a)pyrene	0	0	0	0	0
Beryllium	0	0	0	0	0
Cadmium	0	0	0	0	0
Hydrochloric Acid	1.996e06	1.996e06	0	0	0
Chromium	4.470e04	238.7	4.354e04	928.8	0
Cobalt	0	0	0	0	0
Copper	4.994e04	222.8	4.917e04	549.3	0
Hydrogen Fluoride	1.645e05	1.645e05	0	0	0
Formaldehyde	0	0	0	0	0
Lead	0	0	0	0	0
Manganese	5.435e04	192.6	5.250e04	1658	0
Mercury	0	0	0	0	0

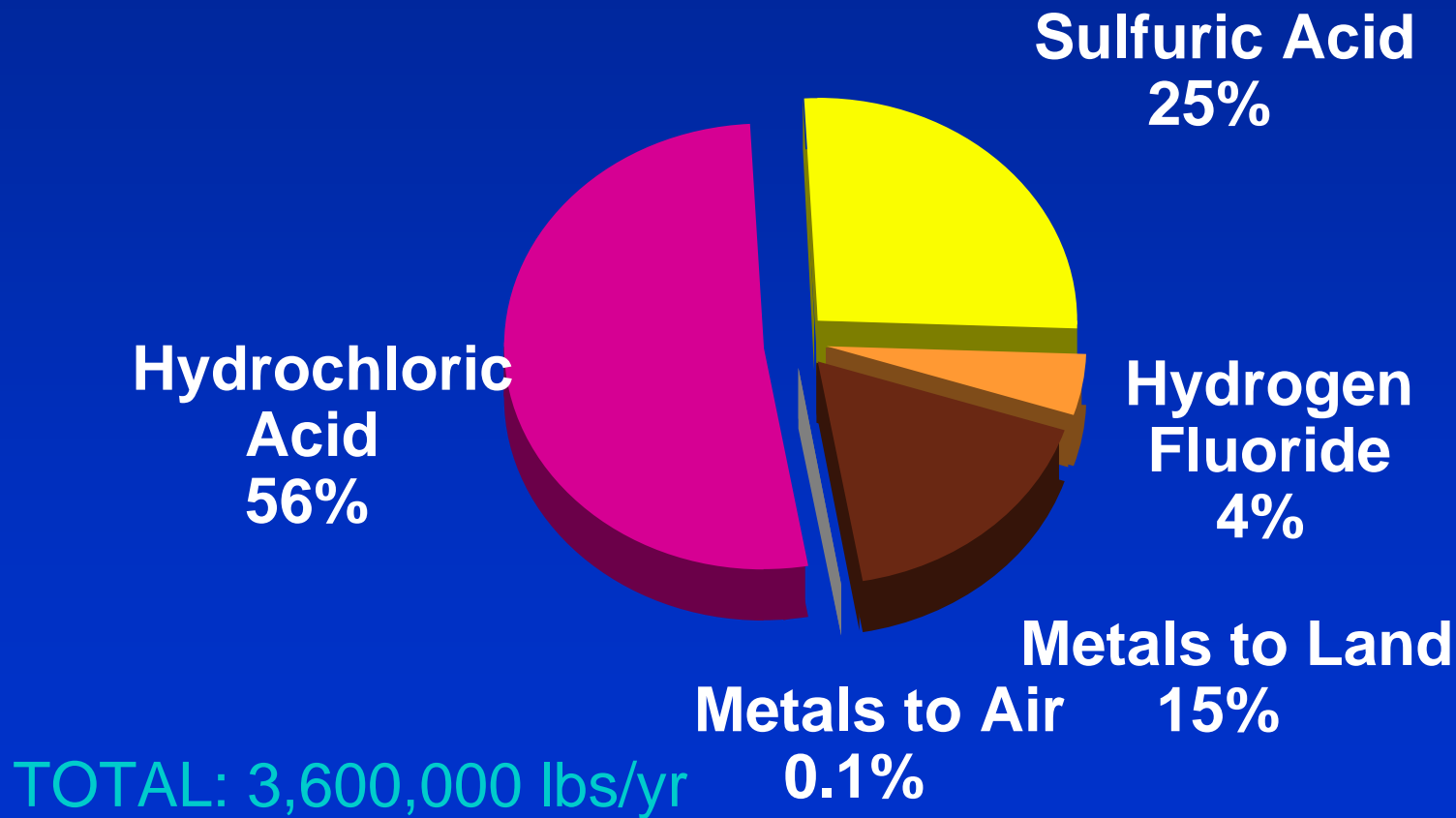
TRI Case Study

- 650 MW (net) facility
- Tangentially fired boiler
- Bituminous coal, 2.5 lb SO₂/MBtu
- Cold-side electrostatic precipitator
- Dry flyash disposal on-site
- Zero wastewater discharge
- 65% capacity factor

Summary of Reportable TRI Releases for Case Study (650 MW, 65% CF, Zero Wastewater Discharge)

Chemical	Air Releases	Land Releases	Total Releases
Hydrochloric Acid	2,000,000	0	2,000,000
Sulfuric Acid	890,000	0	890,000
Barium	910	250,000	250,000
Hydrogen Fluoride	160,000	0	160,000
Manganese	190	60,000	60,000
Zinc	470	58,000	59,000
Copper	220	55,000	55,000
Chromium	250	49,000	49,000
Nickel	200	43,000	43,000
Arsenic	1,100	25,000	27,000
Total	3,100,000	540,000	3,600,000

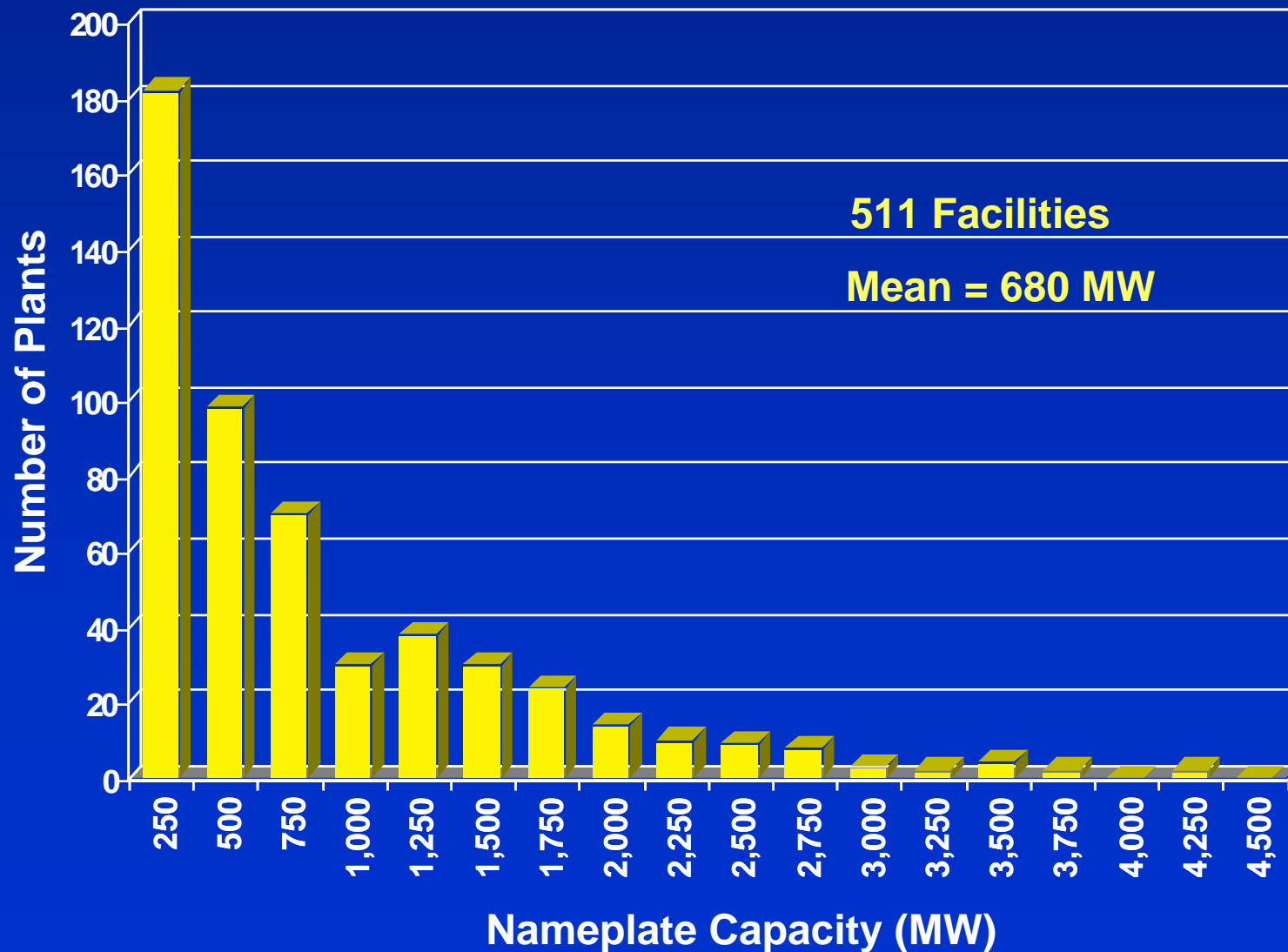
Reportable TRI Releases (650 MW Case Study Plant)



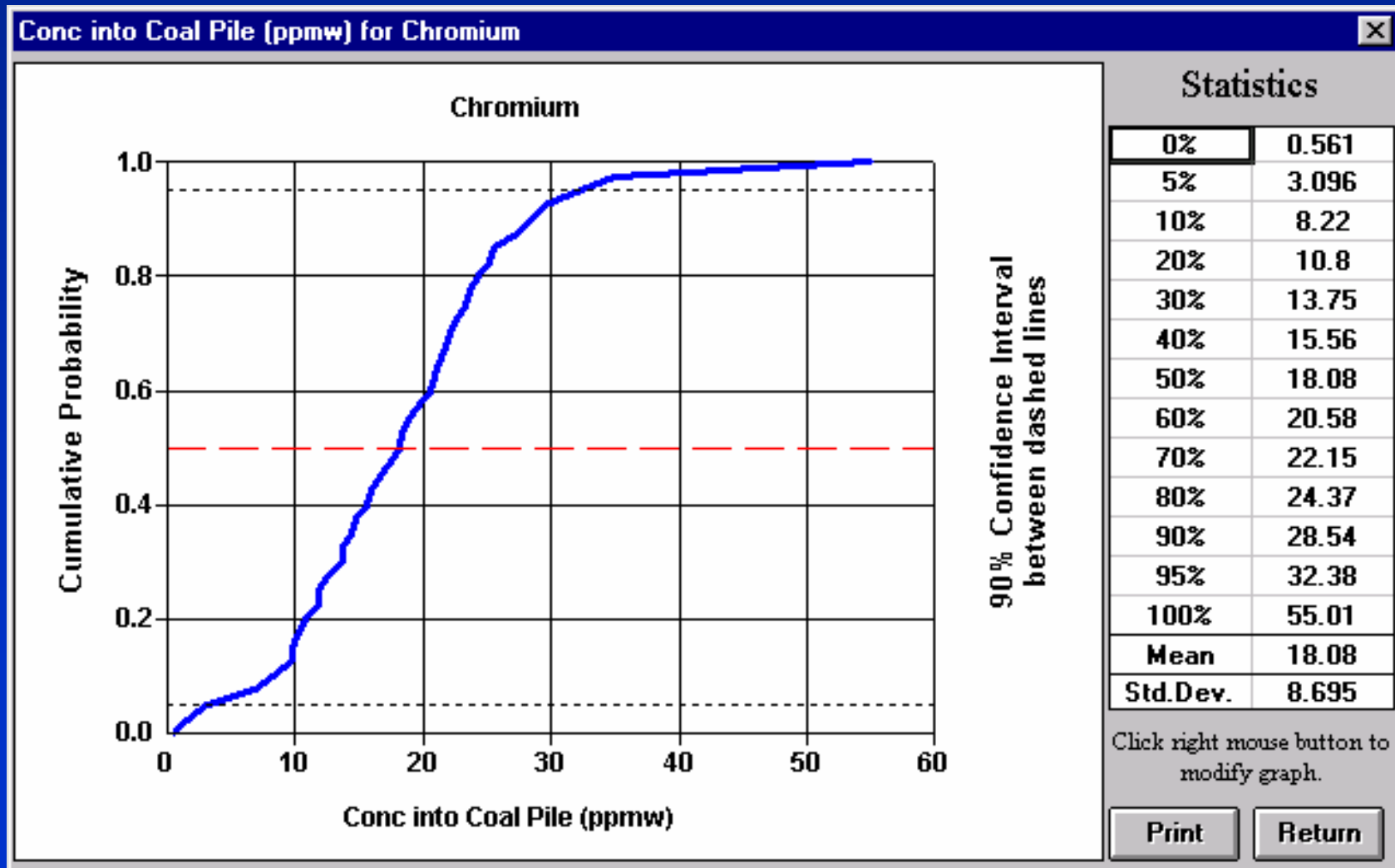
Factors Affecting TRI Releases

- Plant Size and Operation
- Fuel Properties
- Plant Configuration
- Plant Operating Practices

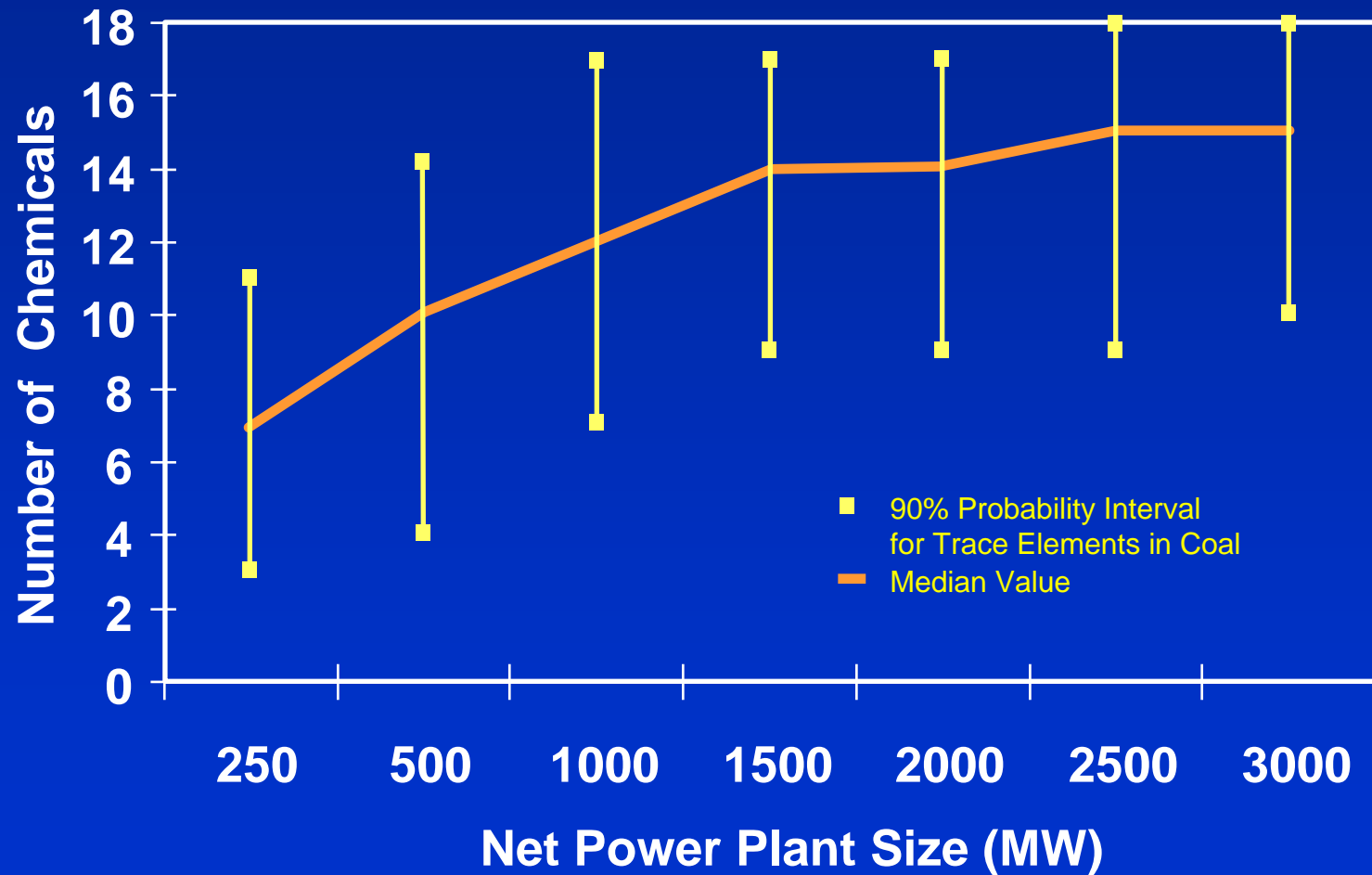
Size of Coal-Fired Power Plants



Variability of Trace Species in Coal



Effect of Plant Size and Fuel Composition on Number of Reportable TRI Chemicals Manufactured During Combustion





Configure Plant



Trace Species



Set Parameters

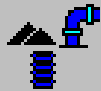


Get Results



Close Session

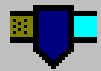
Configure Plant / Get Results



1. Fuel Type



2. Combustion



3. Flue Gas Cleanup



4. Water System



5. Waste Management

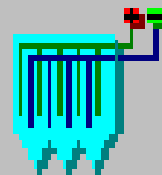
Plant Diagram

Water Diagram



SO2 Removal

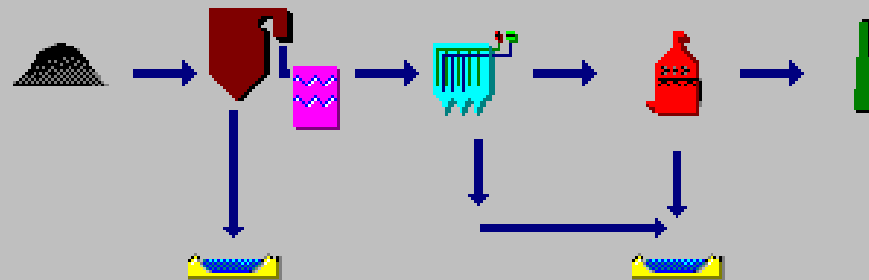
- Wet Lime/Limestone
- Lime Spray Dryer
- None



Particulate Removal

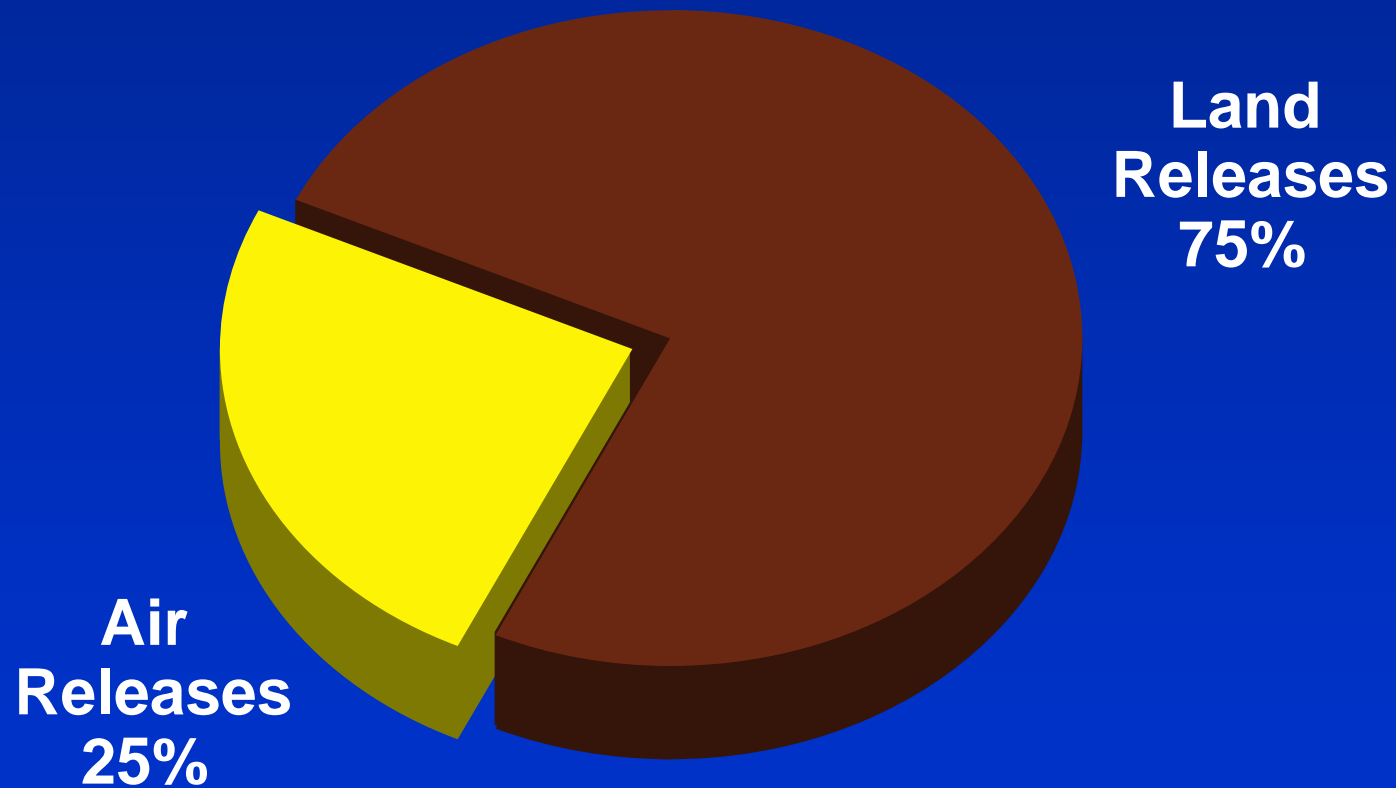
- Cold-Side ESP
- Fabric Filter
- None

Plant Diagram



Click on buttons 1 through 5 to describe your plant.

Reportable TRI Releases for Case Study Plant with FGD



TOTAL: 830,000 lbs/yr

Ash Pond

[TRI Case Study Plant] Ash Pond System: Trace Species

Options

Trace Table
 Trace Diagram
 for **Chromium**

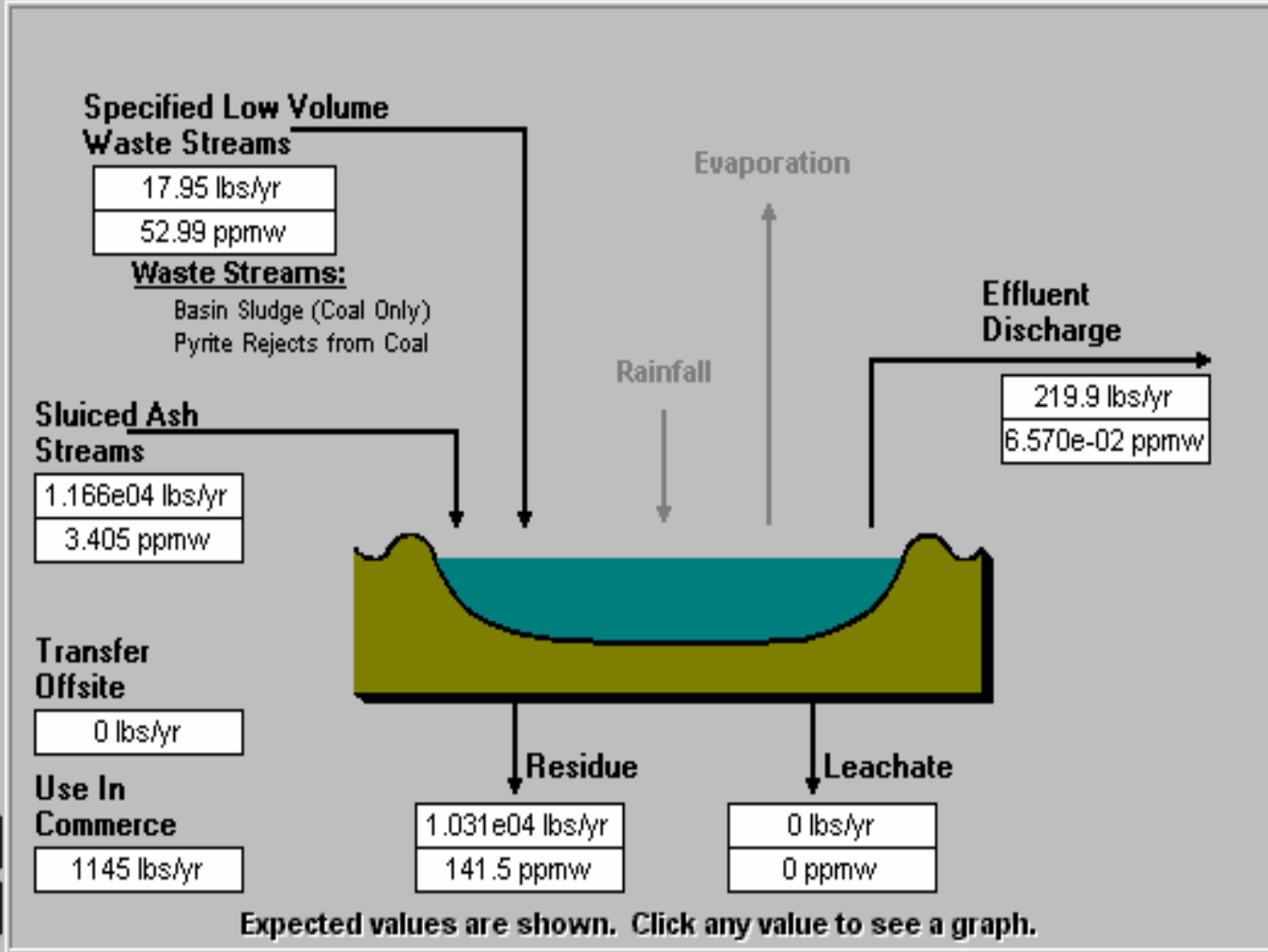
Plant Diagram
 Gas Table
 Solids Table

Units

System: **English**

Diagram: **Annual Avg.**

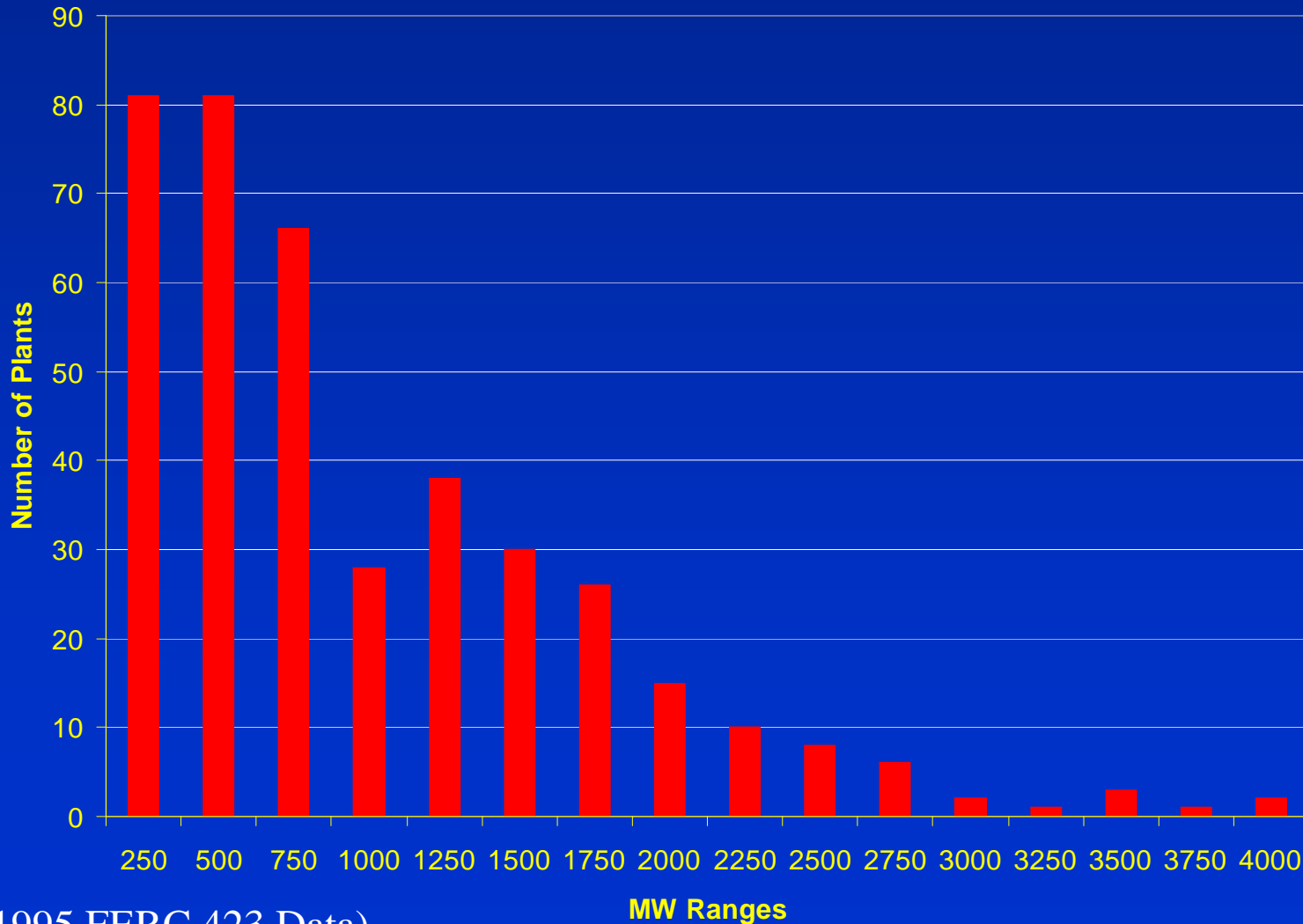
Table: **Annual Avg.**



Summary of Reportable TRI Releases for Case Study (650 MW, 65% CF, NPDES Discharge)

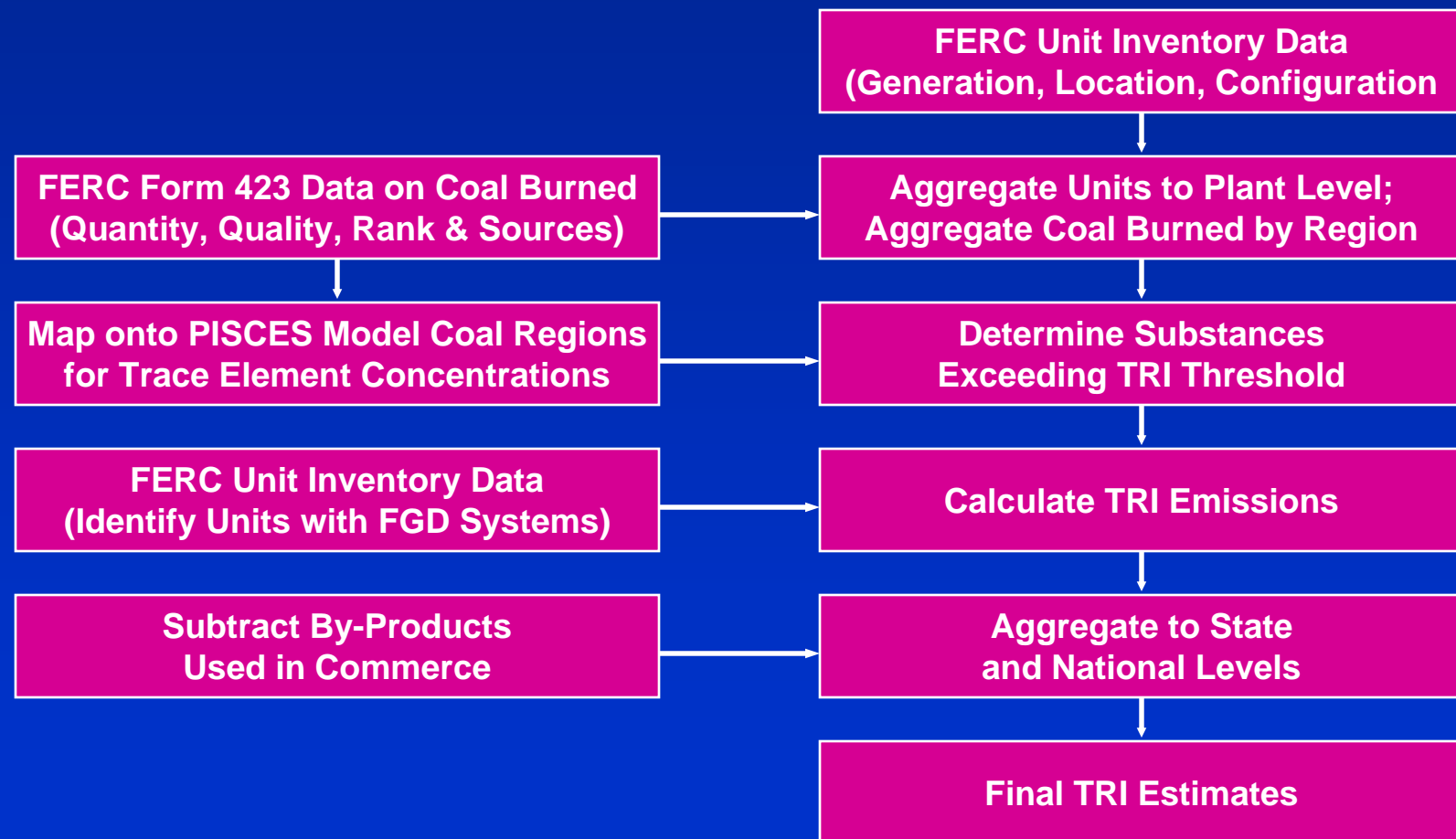
Chemical	Air Releases	Land Releases	Water Releases	Total Releases
Hydrochloric Acid	2,000,000	0	0	2,000,000
Sulfuric Acid	890,000	0	0	890,000
Barium	910	230,000	17,000	250,000
Hydrogen Fluoride	160,000	0	0	160,000
Manganese	190	58,000	1,700	60,000
Zinc	470	57,000	1,300	59,000
Copper	220	55,000	1,400	56,000
Chromium	250	48,000	930	49,000
Nickel	200	41,000	1,900	43,000
Arsenic	1,100	23,000	2,700	27,000
Total	3,100,000	510,000	27,000	3,600,000

Size Distribution of Coal-Fired Power Plants Modeled in this Study



(Source: 1995 FERC 423 Data)

Schematic of Study Methodology



Base Case Estimates of Total Power Plant Releases for 1995 (millions of pounds)

TRI Chemical	Air	Total
Hydrochloric acid	553.5	553.5
Barium compounds	< 0.4	142.3
Sulfuric acid	129.6	129.6
Hydrogen fluoride	55.4	55.4
Manganese compounds	0.2	29.3
Zinc compounds	0.2	19.2
Copper compounds	0.1	12.2
Nickel compounds	0.1	11.7
Chromium compounds	< 0.1	9.9
Lead compounds	< 0.1	6.8
Arsenic compounds	< 0.2	6.0
Molybdenum trioxide	< 0.1	4.7
Cobalt compounds	< 0.1	3.6
Antimony compounds	< 0.1	1.5
Selenium compounds	0.3	0.7
Thallium compounds	< 0.1	0.4
Beryllium compounds	< 0.1	0.3
Total	740.	987.

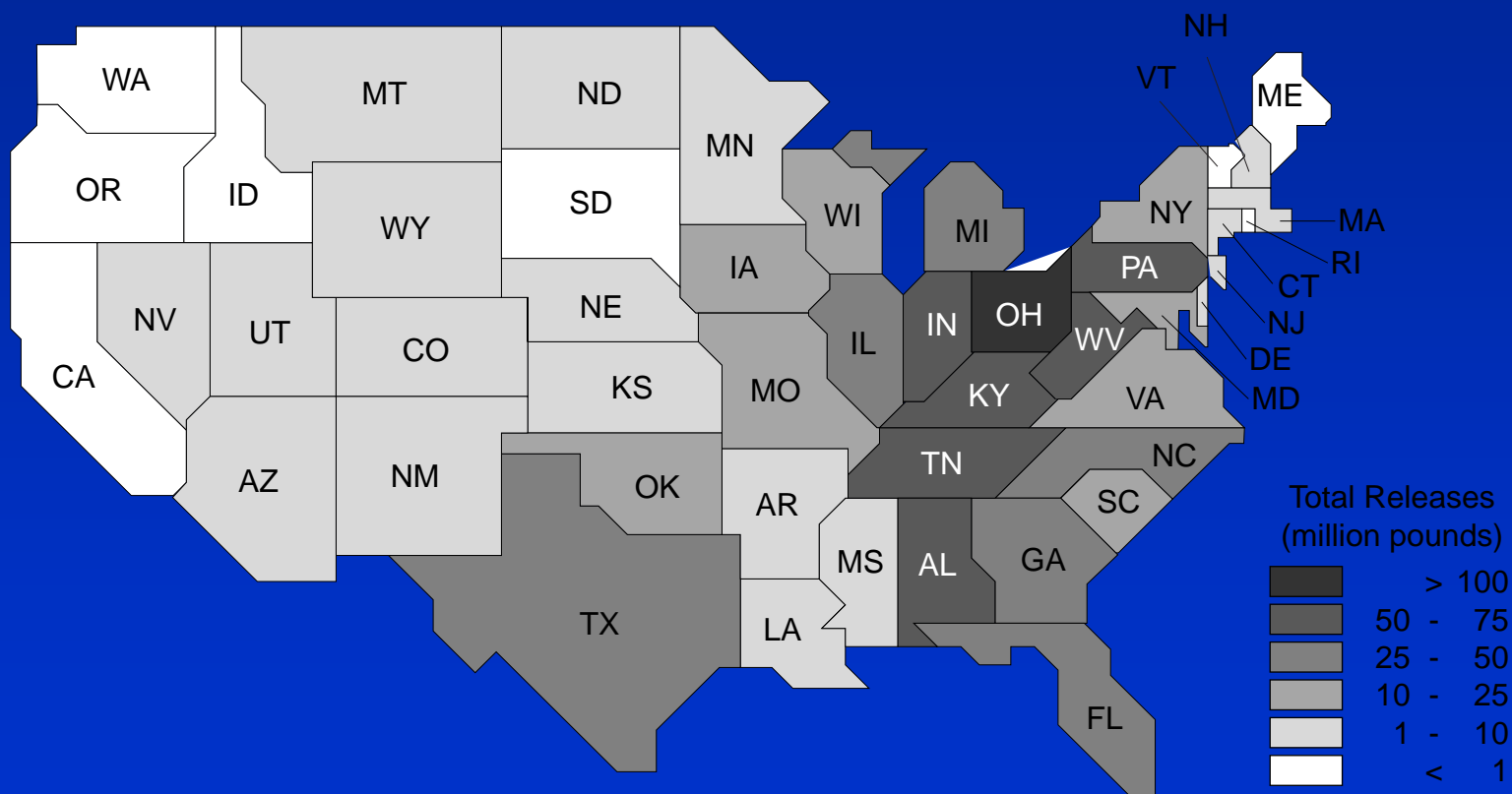
Figures for metal compounds refer to weight of elemental metal.

Totals Include on-site and off-site releases.

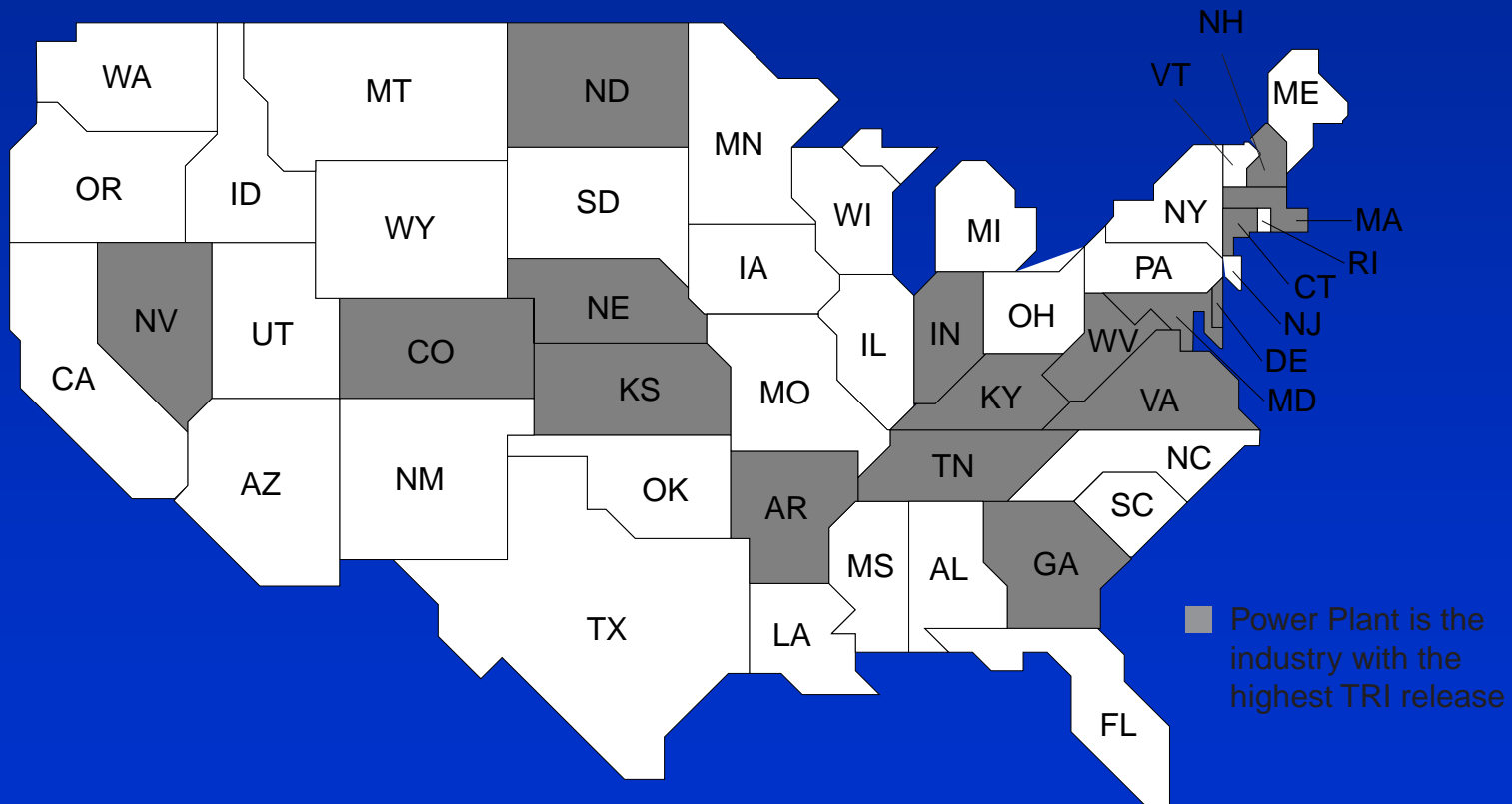
Uncertainty Estimates for Total 1995 Releases from Coal-Fired Power Plants (millions of pounds)

Substance	<u>Air Releases</u>		<u>Total Releases</u>	
	Base	Bound	Base	Bound
HCl aerosol	553	1147	553	1147
H ₂ SO ₄ aerosol	130	287	130	287
Hydrogen fluoride	55	135	55	135
Metal compounds	< 2	2	249	311
Total	740	1541	987	1880

Base Case Estimates of TRI Releases from Coal-Fired Power Plants for 1995



States Where Power Plant Releases Dominate Other Industries (1995)



Policy Implications

- Electric utility industry likely to head the 1998 TRI
- Coal-fired plants = “most toxic”
- HCl replaces methanol as largest toxic release
- Need for risk communication activities (utilities + EPA)
- Efforts to reduce TRI emissions likely
- International impact on Pollutant Release Transfer Registers (PRTR)