

REINHOLD ENVIRONMENTAL Ltd.



**2014 APC Round Table  
& Expo Presentation**

July 14-15, 2014, in Louisville, KY / Hosted by LG&E/KU

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**Kline  
Consulting**

# MAXIMIZING ASH VALUE

**Joe Wong – ADA Carbon Solutions  
John Kline – Kline Consulting**

**Workshop at Reinhold APC Round Table  
July 14, 2014**

# Workshop Outline

- ⦿ Revenue and Costs – Why aren't I making money from MY ash?
- ⦿ Byproduct utilization potential
- ⦿ Cement/Concrete utilization drill down
  - Drivers and Limits
  - How cement works – the market
  - Flyash in cement and concrete today / future
  - Sorbent impacts
  - Management approaches
  - If there's time: CO2 avoidance potential; global markets

# Fly Ash Revenue

\$/ton

\$20.00

\$18.00

\$16.00

\$14.00

\$12.00

\$10.00

\$8.00

\$6.00

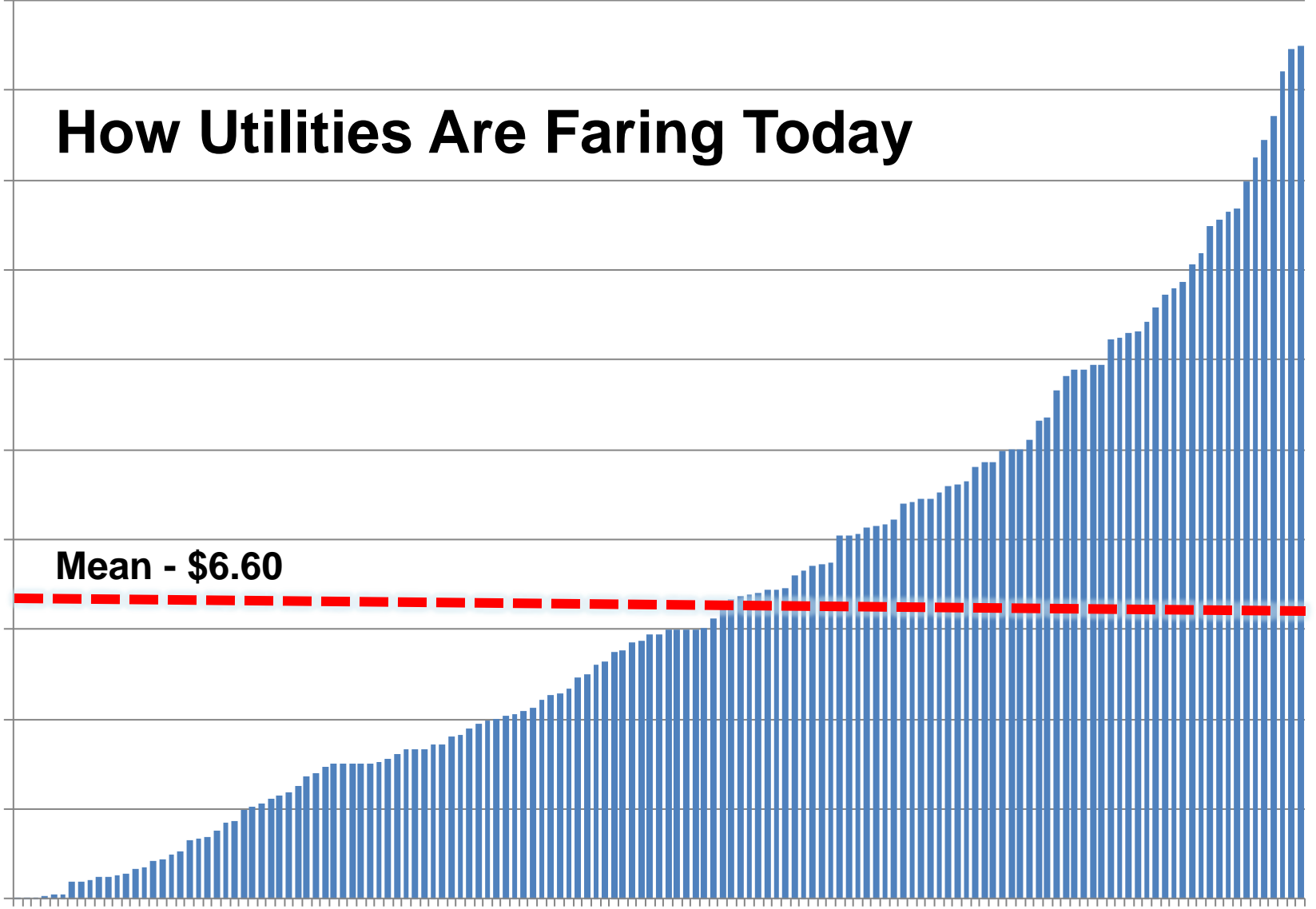
\$4.00

\$2.00

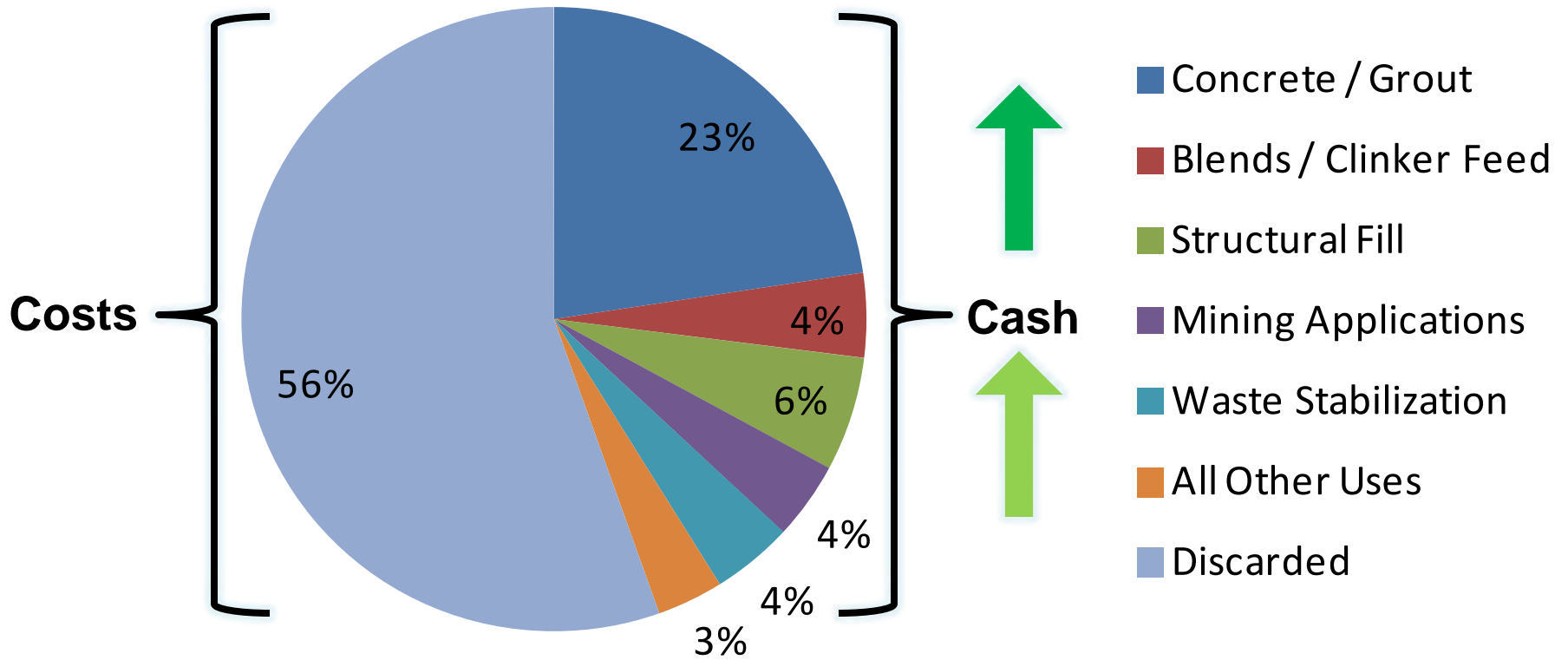
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## How Utilities Are Faring Today

Mean - \$6.60



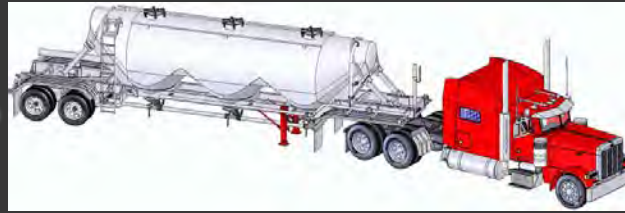
# Use of Fly Ash in US



ACAA 2012 Data



Power Plant



Cement  
Sand  
Aggregate  
Flyash  
Water



Limestone  
Clay  
Shale  
Sand  
Flyash  
Bottom ash  
Syngyp



Cement Plant



Concrete Plant



Structures



# The use of flyash in concrete & grout

## ⦿ Pros

- Improves concrete
- Reduces costs
- Reduces carbon footprint

## ⦿ Cons

- Reduces strength
- Reduces air entraining (freeze –thaw durability)

# Cement Plants Using Ash

## PORTLAND CEMENT PLANTS THAT USE FLY ASH AND/OR BOTTOM ASH AS A RAW MATERIAL



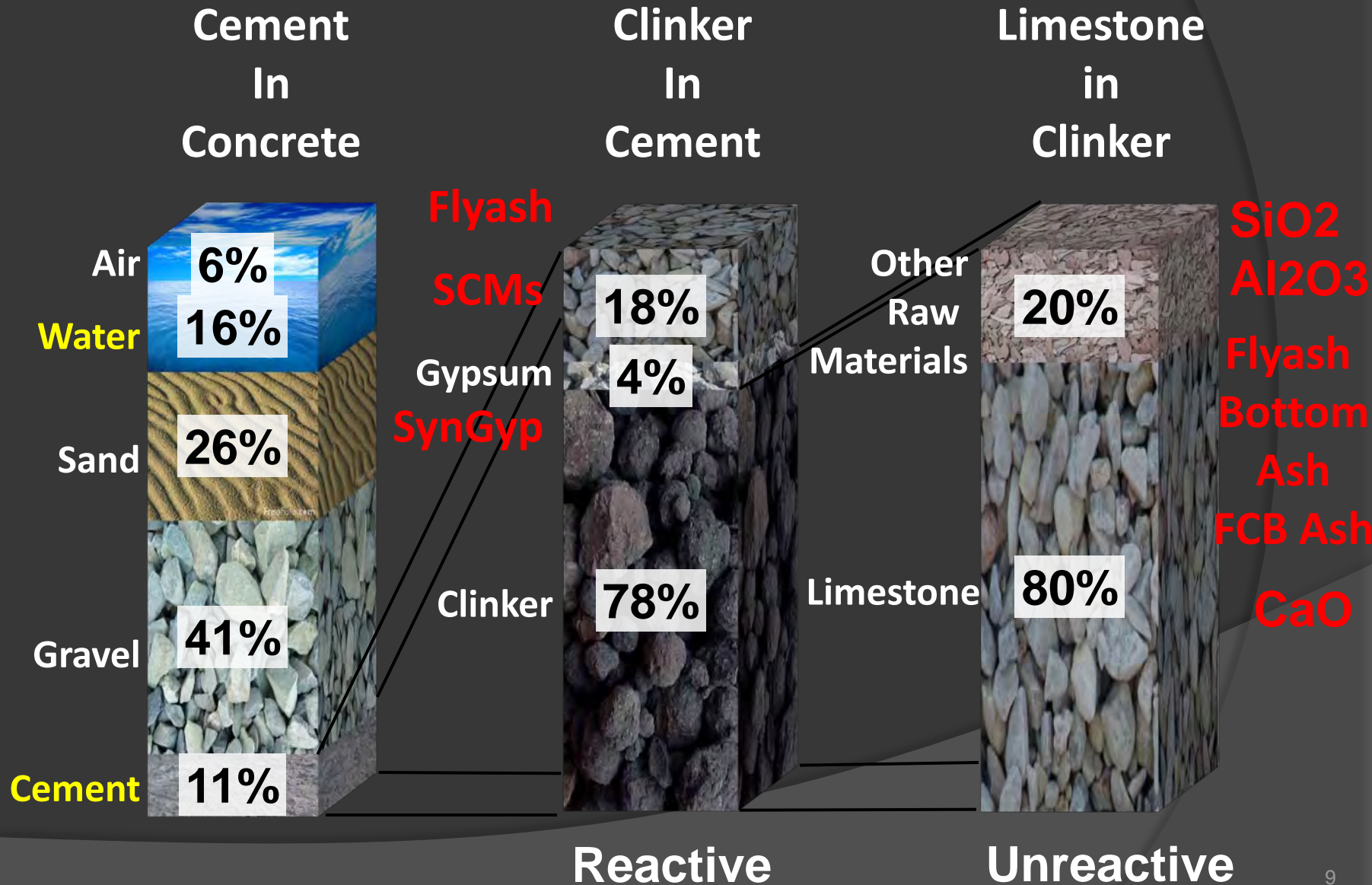
# How Cement Works

(The Simplified Version)



Calcium Silicate Hydrate  
Both the Calcium and Silica Oxides  
need to be in a reactive form

# The Use of Ash in Cement and Concrete



# Most Important Binder Materials

## Legend

C-Ash – ASTM Type C Flyash

F-Ash – ASTM Type F Flyash

L – Lime (Limestone -  $\text{CaCO}_3$ )

MK – Metakaolin

PC – Portland Cement

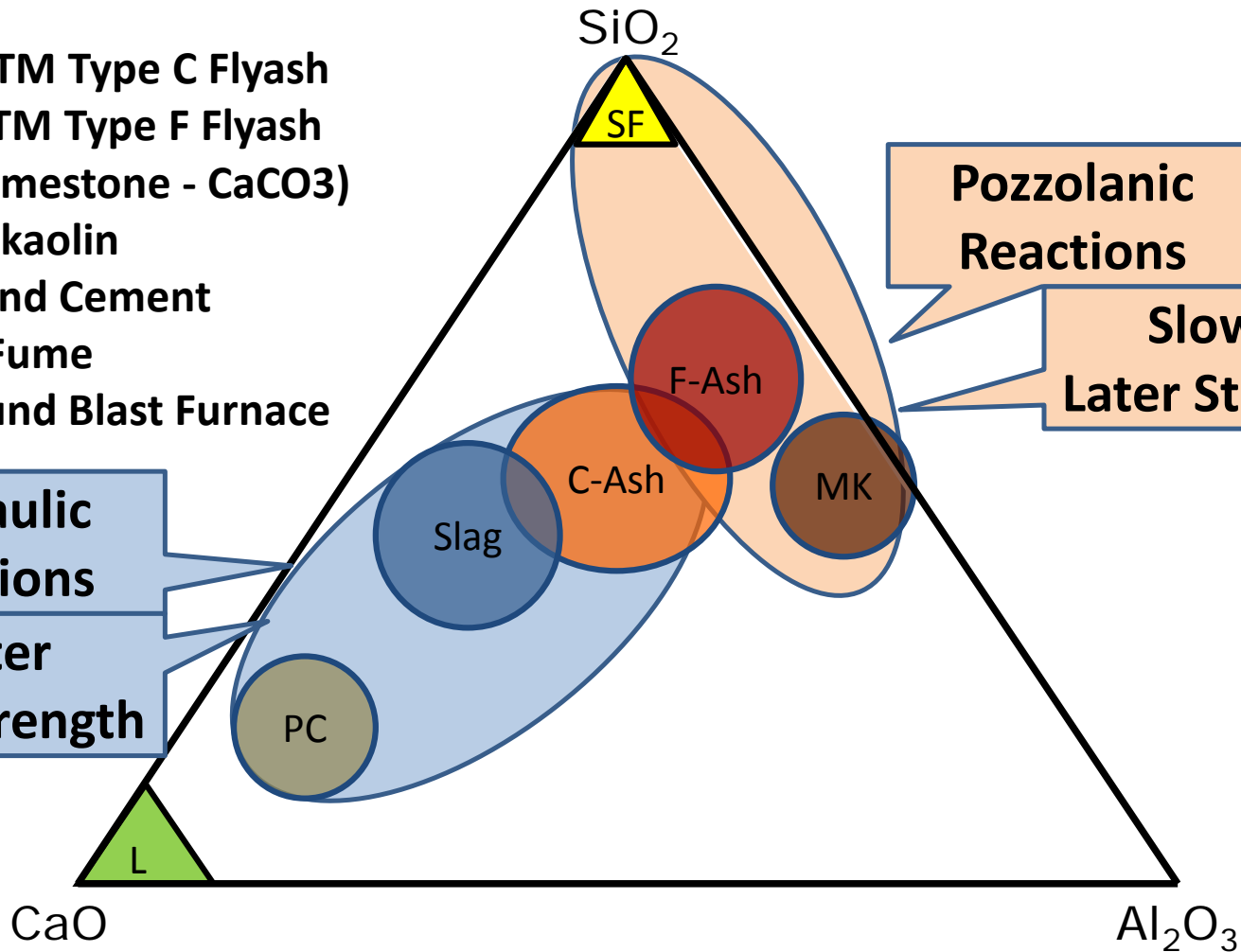
SF – Silica Fume

Slag – Ground Blast Furnace

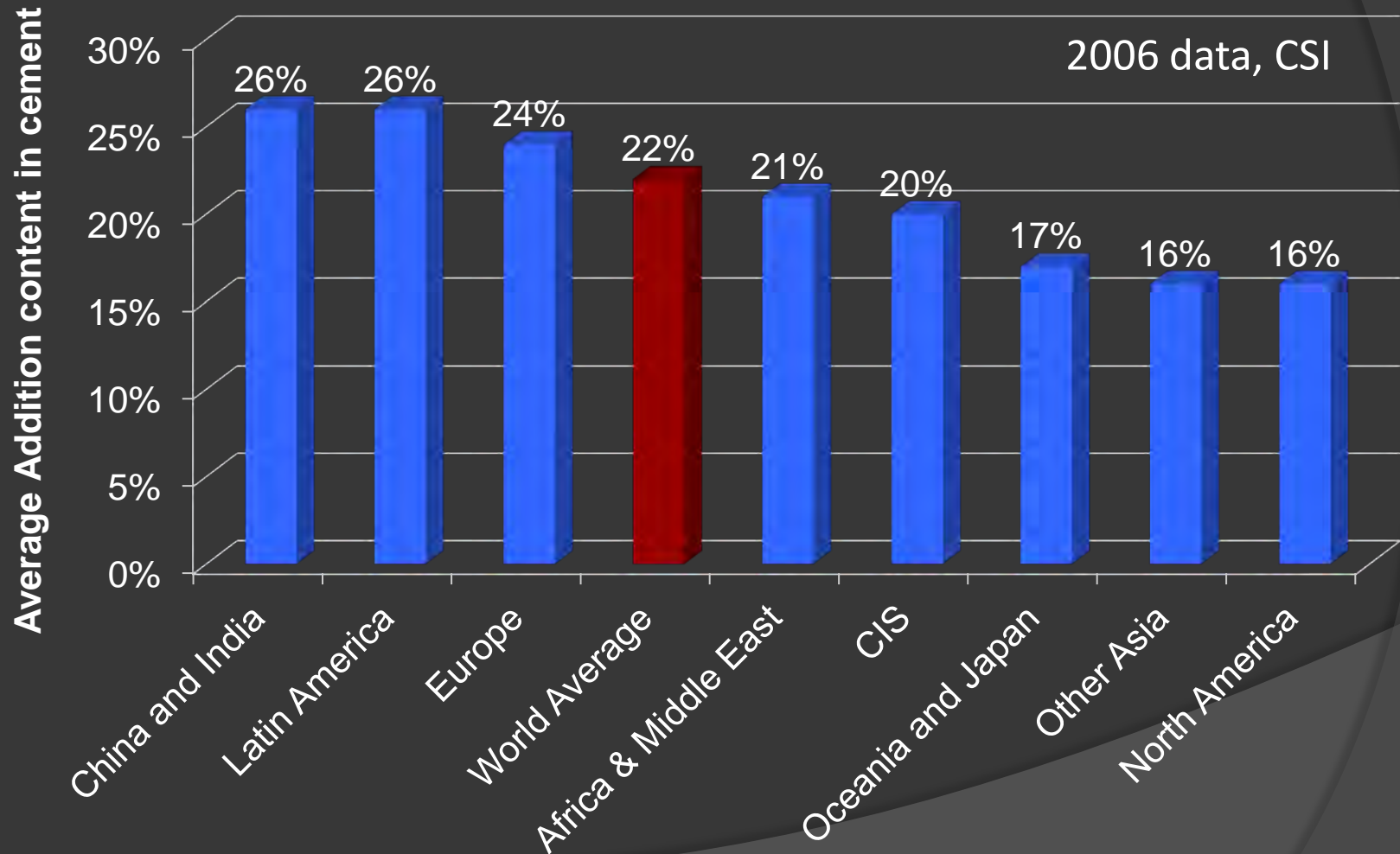
Hydraulic  
Reactions  
Faster  
Early Strength

Pozzolanic  
Reactions

Slower  
Later Strength



# Clinker Substitution



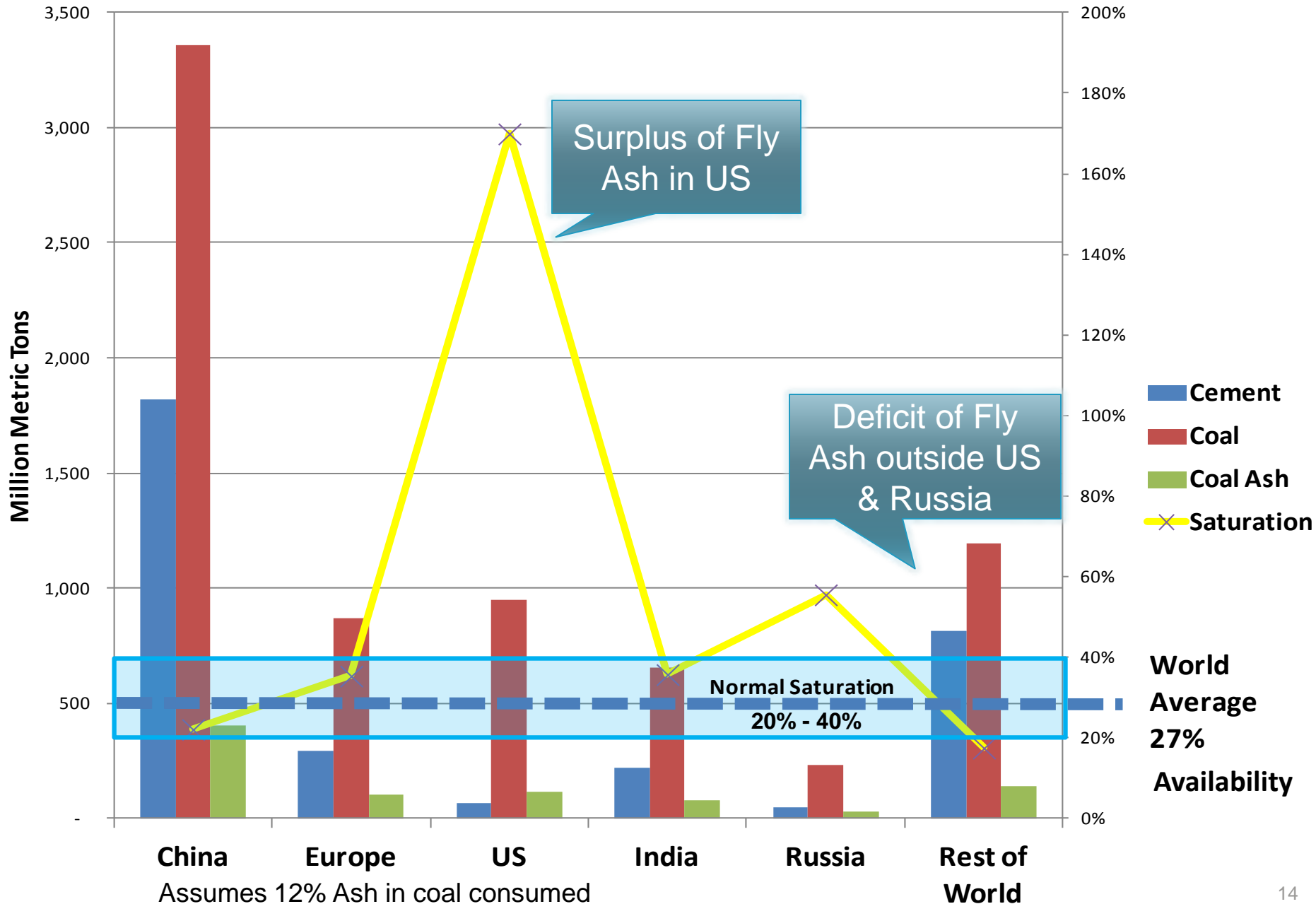
# Clinker Substitutes

- ⦿ Portland cement is made up primarily of calcium silicates
  - These react with water
- ⦿ Other Produced and Natural Materials also contain calcium and silica oxides
  - Blast furnace slag
  - Flyash
  - Pozzolans (Natural and Artificial)
  - Also known as “Supplemental Cementing Materials” (SCMs)

# Keys to Fly Ash Use in Concrete

- ⦿ Chemistry and purity of the Fly Ash
- ⦿ Reactivity of the Fly Ash
  - Calcium in CaO form
  - Amorphous silica
  - Small particles (high surface to weight)
- ⦿ Availability of the Fly Ash
- ⦿ Local specifications and norms
  - Most locations opening up to more SCMs

# Coal Ash to Cement Balance



# Global Potential to Increase Flyash

	Today		Potential	
Clinker	2780	77.2%	2780	68.6%
Gypsum	120	3.3%	120	3.0%
<b>Flyash</b>	<b>250</b>	<b>6.9%</b>	<b>500</b>	<b>12.3%</b>
Slag	150	4.2%	200	4.9%
Pozzolan	150	4.2%	300	7.4%
Limestone	150	4.2%	150	3.7%
Total Binder	3600	100.0%	4050	100.0%

# Quantity of Flyash Usage

- ⦿ Historically usages has been between 15 – 25% of the binder content
- ⦿ Usage rates depend on:
  - The application
  - The properties of the flyash
  - Specification limits
  - Geographic location
  - Climate
- ⦿ Higher percentages (30 – 50%) have been used in massive structures, such as foundations and dams

# Flyash Usage in Concrete

In order for fly ash to be used beneficially, it must adhere to the specifications imposed by the ultimate product. These specifications may include requirements on, among others:

- Size
- Carbon Content / LOI
- Foam Index Activity
- Chemical Composition
- Color
- NH<sub>3</sub> (ammonia)
- Hg (Mercury)

# The Value of “Good” Fly Ash

- The average price of cement today is around \$90/t (USGS)
- To qualify as an SCM, fly ash should meet 75% of the strength of cement
- Therefore as a substitute material, maybe \$70/t maximum
- However, if / when the cost of cement and CO<sub>2</sub> increases, the value of fly ash also increases
- Flyash and bottom ash as a cement raw material have a maximum value of \$15/t delivered

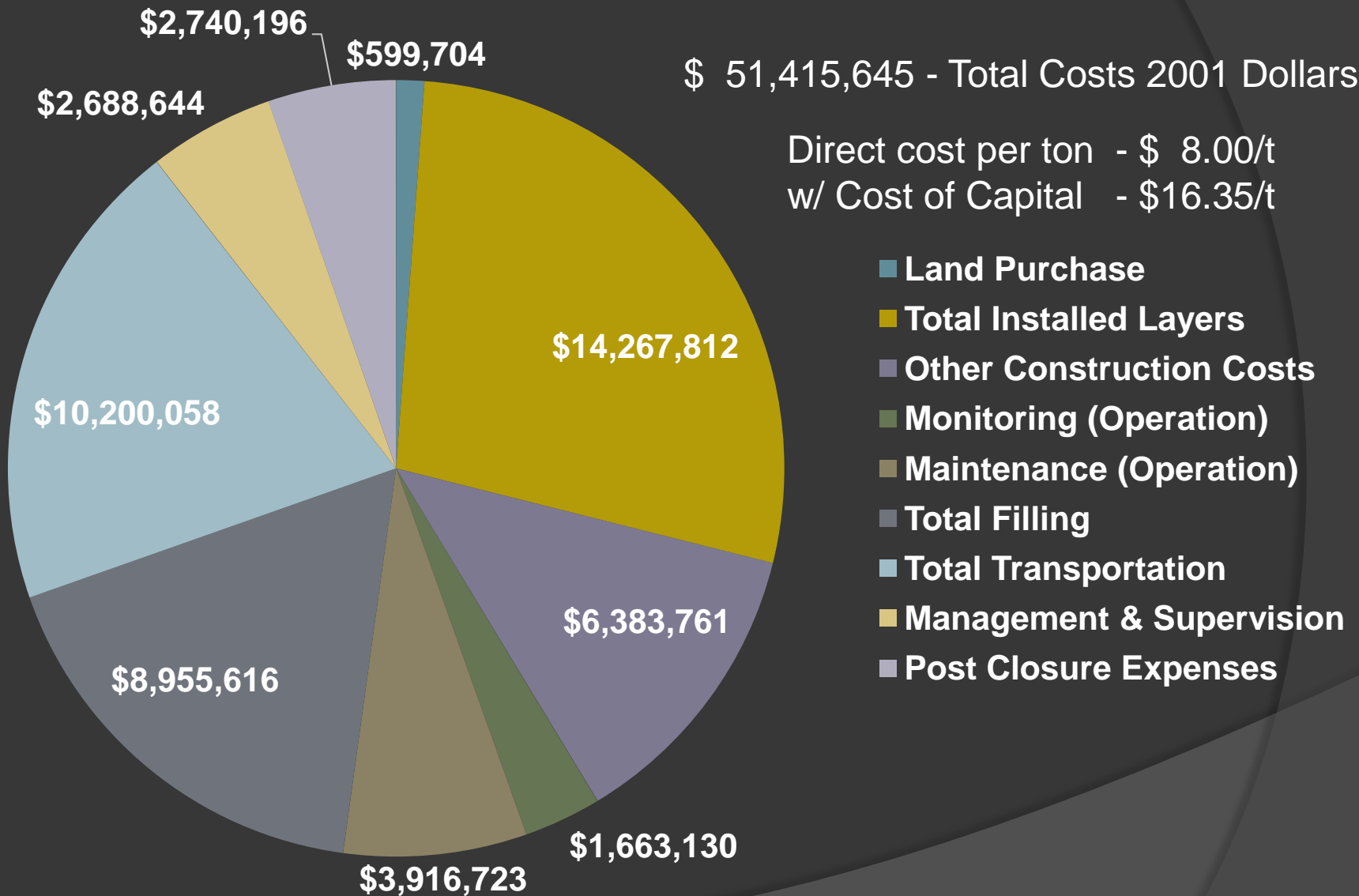
# What about the Cost Side

- ⦿ Disposal Costs are Increasing
  - Land costs
  - New Landfill Regulations
  - Landfill liners
  - Water monitoring
  - Seepage collection systems
- ⦿ Landfills create a future liability

# Landfill Costs (6.5 million tons - 20 years)

\$ 51,415,645 - Total Costs 2001 Dollars

Direct cost per ton - \$ 8.00/t  
w/ Cost of Capital - \$16.35/t



Ohio State University Model

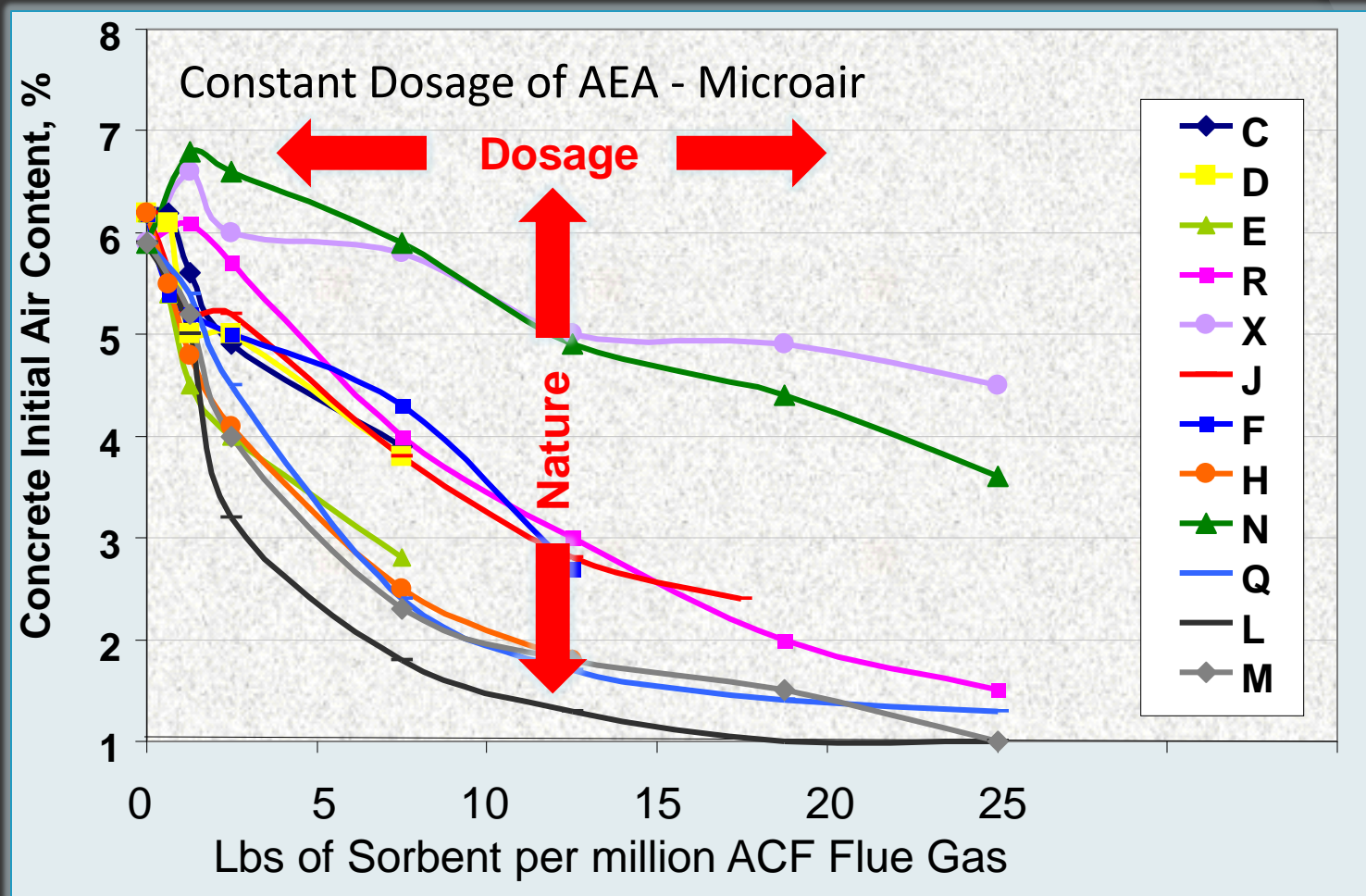
# The Challenge

- ⦿ The value of good ash is increasing
- ⦿ While, the cost of disposal is also increasing
- ⦿ However, maintaining a marketable ash is becoming more difficult

# Challenges to Fly Ash Value

- ⦿ Quality and consistency of the fly ash
  - Reactive
    - Fresh Ash
    - F-Ash can be reclaimed
    - C-Ash can not be reclaimed
  - Clean
    - Low Carbon [consistent / steady levels? – admixture impacts]
    - Low Sorbents
- ⦿ Oversupply of the market (US today)
- ⦿ The addition of various sorbents for environmental controls

# Impact of dosage on concrete air content



Concrete air content strongly depends on **nature** and **dosage** of AC

Data from *EUEC Conference, Phoenix, January 2013*



# Sorbents for SO<sub>x</sub> & HCl Reduction

- ⦿ Limestone is inert and does not overly impact cement or concrete quality when included in small doses (<5%)
- ⦿ Lime is more reactive and can also be added to cement and concrete in small doses (<5%)
- ⦿ Calcium sulphate can be used in wallboard and cement production, calcium sulfite needs to be oxidized (wet scrubbers)
- ⦿ Sodium based sorbents include alkali (Na) and can impact the quality of cement and concrete, sodium additions should be kept to a minimum

# Sorbents for Mercury Reduction

- ① Field of Sorbents
- ① Powdered Activated Carbon
  - Consistency and stability of the ash product
  - Time effect
  - Improvements to consistency
  - Fly ash beneficiation

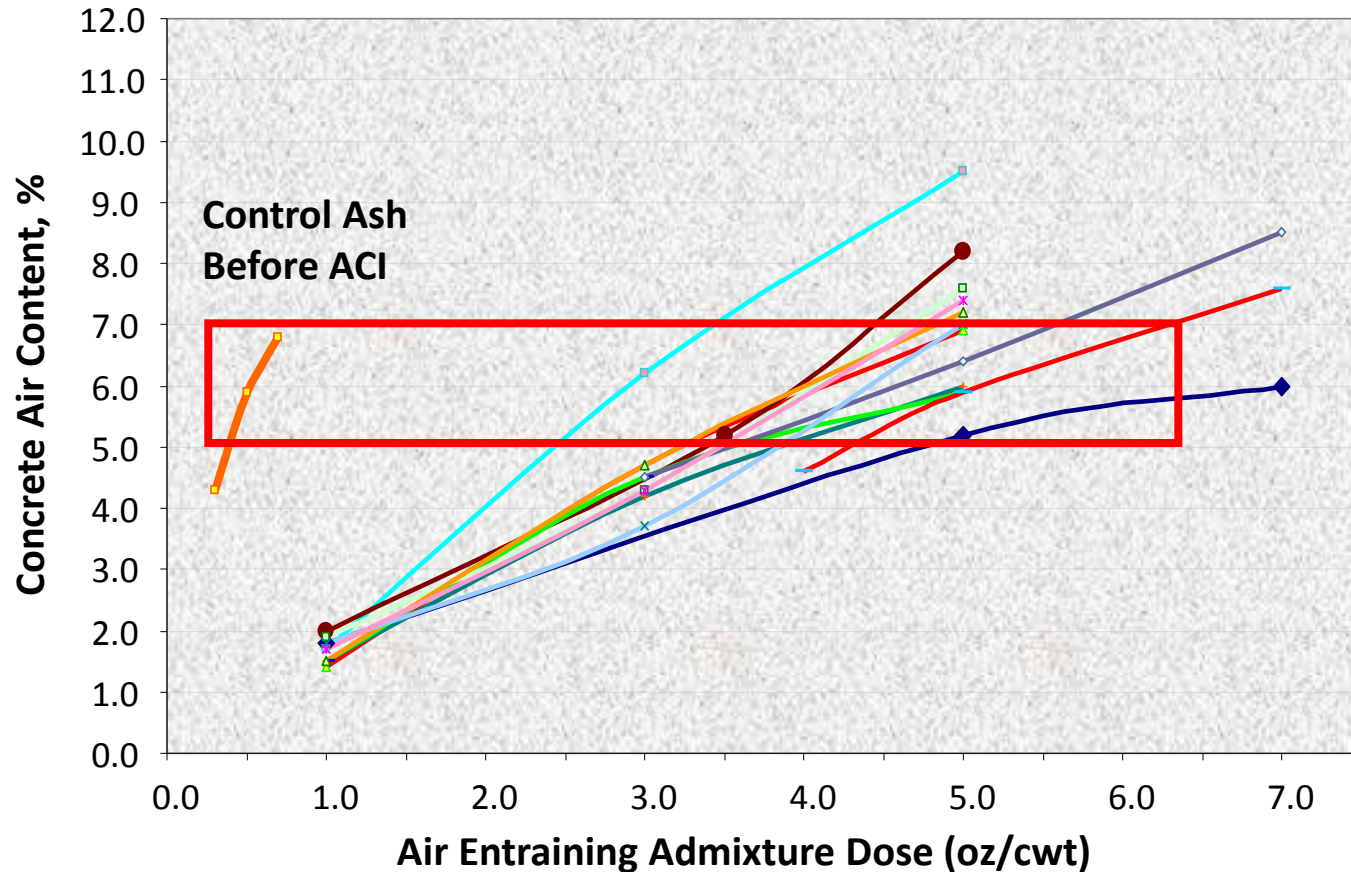
# Impact of Reagents on Ash Usage

Reagent 	Usage 	Cement Raw Materials	Cement Component	Concrete Additive
Lime		Large Amounts	Medium Amounts	Small Amounts
Limestone		Large Amounts	Medium Amounts	Medium Amounts
CaBr <sub>2</sub>		Large Amounts	Small Amounts	Small Amounts
Mercury		Very Small Amounts	Large Amounts	Large Amounts
Activated Carbon		Large Amounts	Very Small Amounts	Very Small Amounts
Trona		Small Amounts	Very Small Amounts	Very Small Amounts
Sodium Bicarbonate		Small Amounts	Very Small Amounts	Very Small Amounts

All reagents play a role in the usage and value of CCPs !

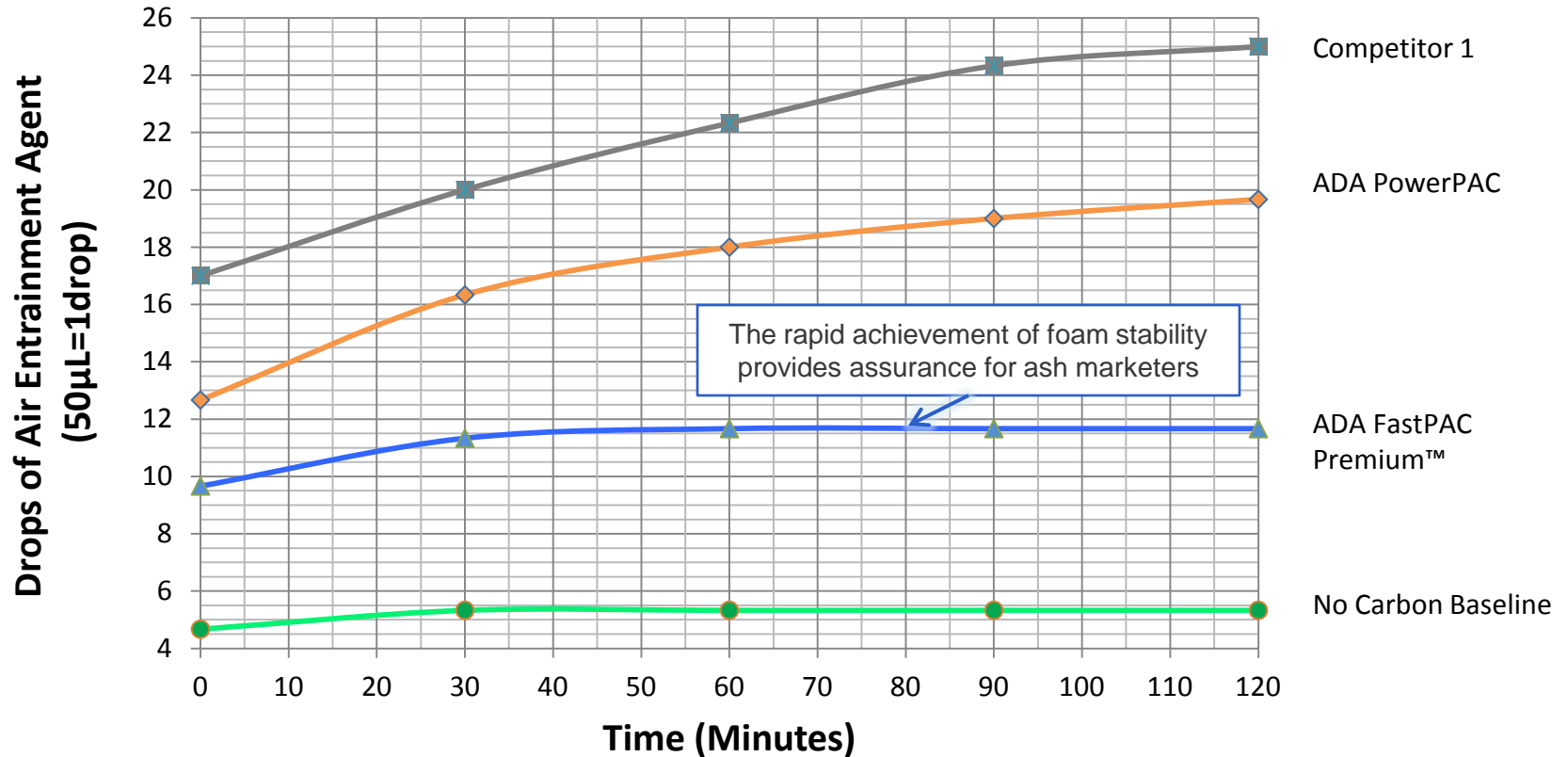
# Consistency is KEY!

**Concrete Friendly Sorbent  
Sampling over a 3 week period**



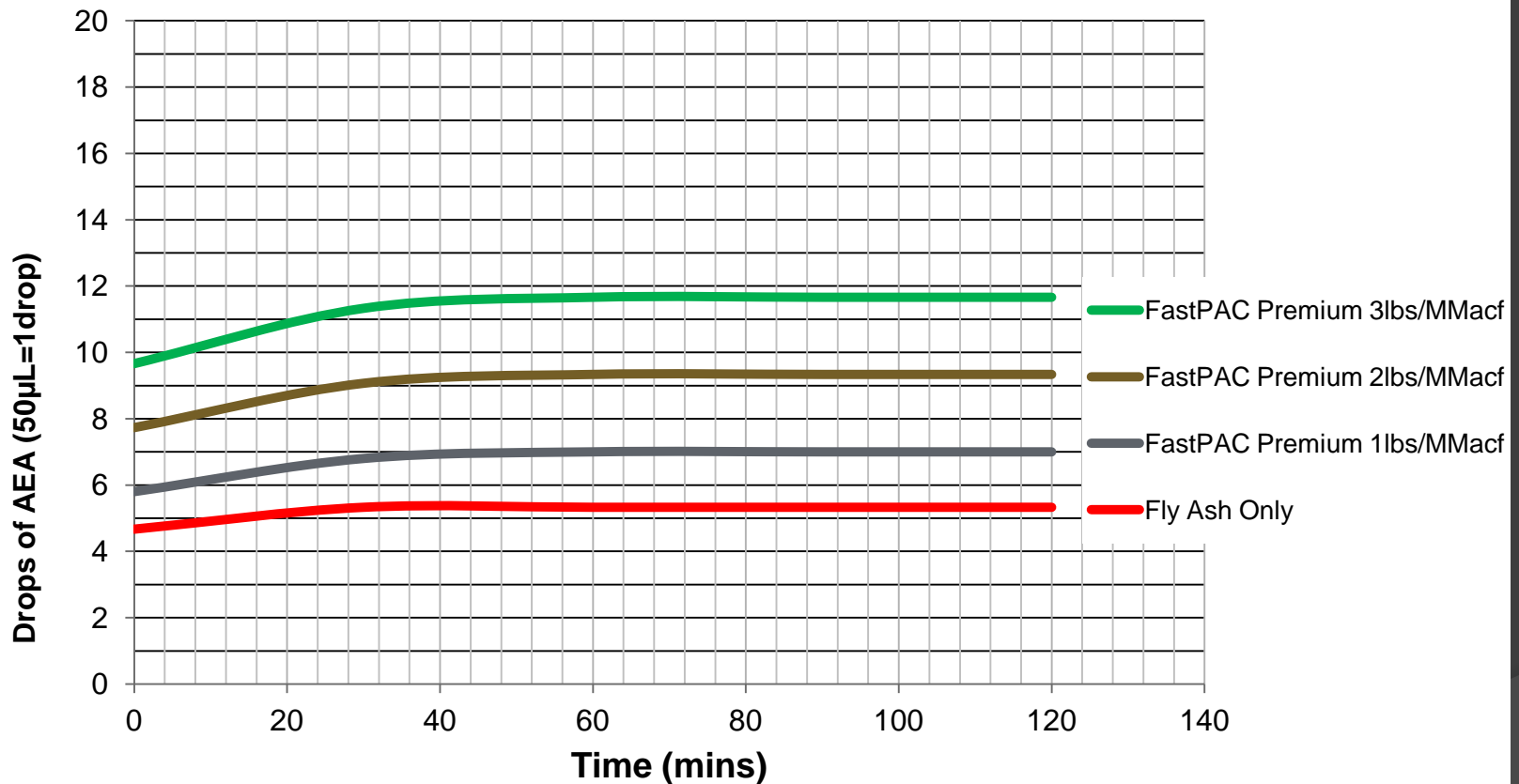
**Small variations in PAC content  
severely impacts air requirement**

# Advances in Concrete Compatibility From Generation 2 FastPAC™ PACs



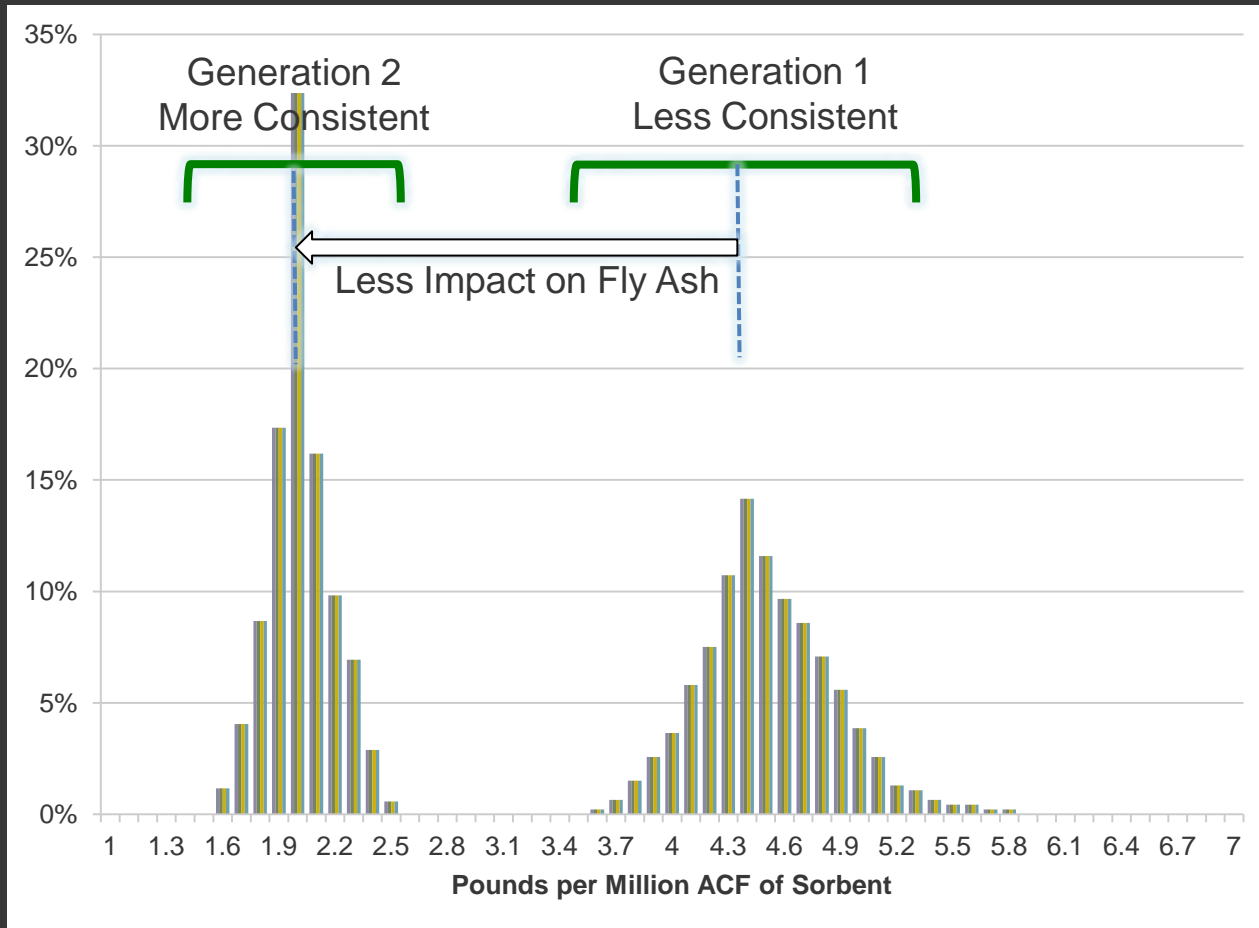
Our patent-pending FastPAC™ products conserve Air Entrainment Agent Usage and provide Rapid Foam Stability. These curves represent the initial AEA required and foam stability over time for various sorbents at an injection rate of 3 lb/MMacf

# Advances in Concrete Compatibility From Our FastPAC™ Products



Our patent-pending FastPAC™ products require lower ACI injection rates to achieve Hg capture targets, thus reducing the relative levels of carbon in fly ash and resulting in low initial AEA dosing combined with excellent foam stability over time.

# Gen 2 FastPAC™ Products Achieve Consistent Fly Ash Properties



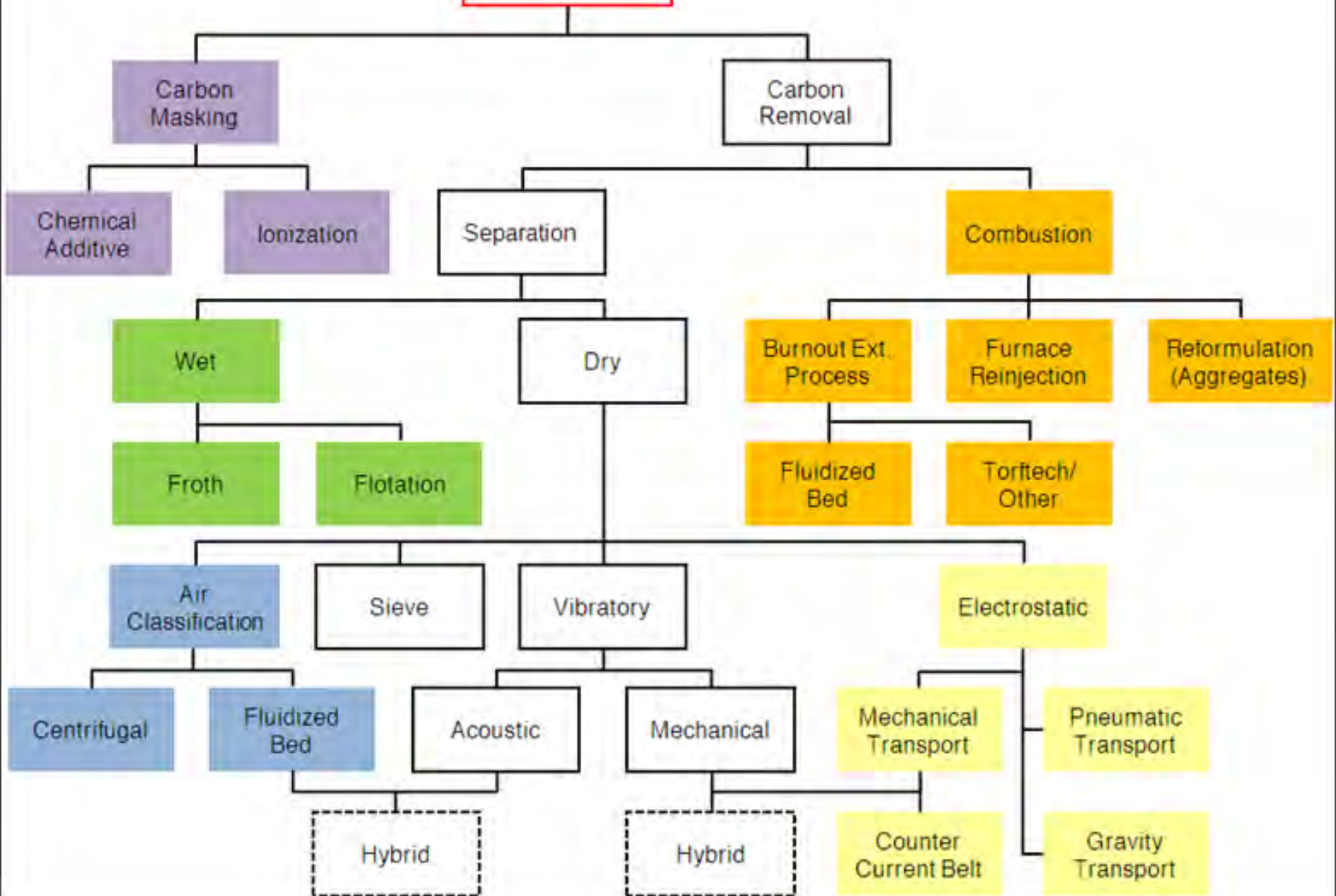
Lower injection rates and a tighter control range mean improved repeatability of fly ash AEA demand. Our Gen 2 FastPAC Premium™ allows low PAC injection for high Hg capture and greater active engineering control (steeper capture curves), resulting in more consistent fly ash properties.

# Ash Additives

## ◎ Masking

- Works on native and carbon based sorbents
- Low capital costs
- Can be added at load-out (process as needed)
- Chemicals can be expensive
- IP controlled by fly ash marketers
- Chemicals are proprietary
- Over / under dosing could be an issue

# Fly Ash Beneficiation



# Relative Cost and Product Quality for Ash Beneficiation Technologies (EPRI)

Technology Basis	# of Output Products	Primary Product (Low Carbon)	Yield	Secondary Product	Initial Ash Quality	Cost Range (\$/Ton)
Carbon Masking	1	Same LOI as initial ash	100%	NA	<6% LOI	\$2.00 - \$7.00
Wet Processes	Multiple	NA	NA	NA	NA	NA
Aerodynamic Classification	2	10 - 40% Reduction in LOI	50 - 90%	Variable LOI (typically > 30%)	No Limit	\$1.00 - \$3.00
Sieving	2	15 - 50% Reduction in LOI	50 - 90%	Variable LOI (typically > 30%)	No Limit	\$2.00 - \$4.00
Electrostatic (Belt)	2	1.5 - 3.0% LOI	60 - 85%	Variable LOI (typically > 30%)	<20% LOI	\$4.00 - \$7.00
Electrostatic (Pneumatic)	2	30 - 60% Reduction in LOI	35 - 70%	Variable LOI (typically > 30%)	<10% LOI	\$5.00 - \$8.00
Combustion	1	1.5 - 2.5% LOI	80 - 95%	NA	>8% LOI	\$10.00 - \$20.00

# Fly Ash Value

- ⦿ If your fly ash was good before sorbents it may very well still be marketable
- ⦿ If your fly ash was not good before, well more work will be required

# The Path Forward

- ◎ Know your fly ash
  - Strengths
  - Weaknesses
  - Environmental requirements
  - Results of specific tests such as foam index, stability, slump
- ◎ Know your competition
  - Who else is marketing ash in your area
  - Their strengths and weaknesses
  - Their environmental compliance strategy

# Path Forward

- ⦿ Define your target market
  - End use
  - Quality required
  - Quantity required
  - Target price
- ⦿ Define your approach
  - Marketer
  - Direct Sales

# Path Forward

- ◎ Select / adjust your environmental compliance strategy
  - Target One: Cement / Concrete market (highest margin)
    - Avoid sodium based sorbents
    - Minimize activated carbon variability/ restrict type
    - Lime / limestone OK
  - Target Two: Cement Raw Materials
    - Limited amounts of sodium based sorbents
    - Minimize mercury content
    - Activated carbon OK
    - Lime / limestone OK

# Path Forward

- ◎ Select / adjust your environmental compliance strategy
  - Target Three: Structural fill / Soil Stabilization / Mine backfill
    - Activated carbon OK, minimize HM leaching
    - Trona OK
    - Lime, check PH issues / limits

# The Future of Flyash in Concrete

- ⦿ There is a need in most of the world
- ⦿ Flyash value will increase with CO2 costs / constraints
- ⦿ Substitutes may be limited
  - Finite amount of slag available
  - Natural pozzolans not available globally
  - Artificial pozzolans require processing
- ⦿ Cost of disposal is increasing
- ⦿ Careful planning is therefore required

# The Future of Flyash

- ⦿ Globally there is not enough flyash
- ⦿ Locally there is too much flyash
- ⦿ CO<sub>2</sub> reduction will increase the value of “clean” Flyash
- ⦿ Utilities that market flyash will need to consider their path forward carefully
  - Mercury
  - Carbon / sorbents
  - Trona / sodium bicarbonate



Thank You

Kline  
Consulting

◎ Joe Wong

◎ John Kline

[Joe.wong@ada-cs.com](mailto:Joe.wong@ada-cs.com)

[johnpkline1@gmail.com](mailto:johnpkline1@gmail.com)

(303) 962-1967

(484) 602-3474