



THE OHIO STATE UNIVERSITY

Utilization of Coal Combustion Residues (CCRs): Current Status & Future Outlook

Dr. Tarunjit S. Butalia, P.E.
Research Associate Professor

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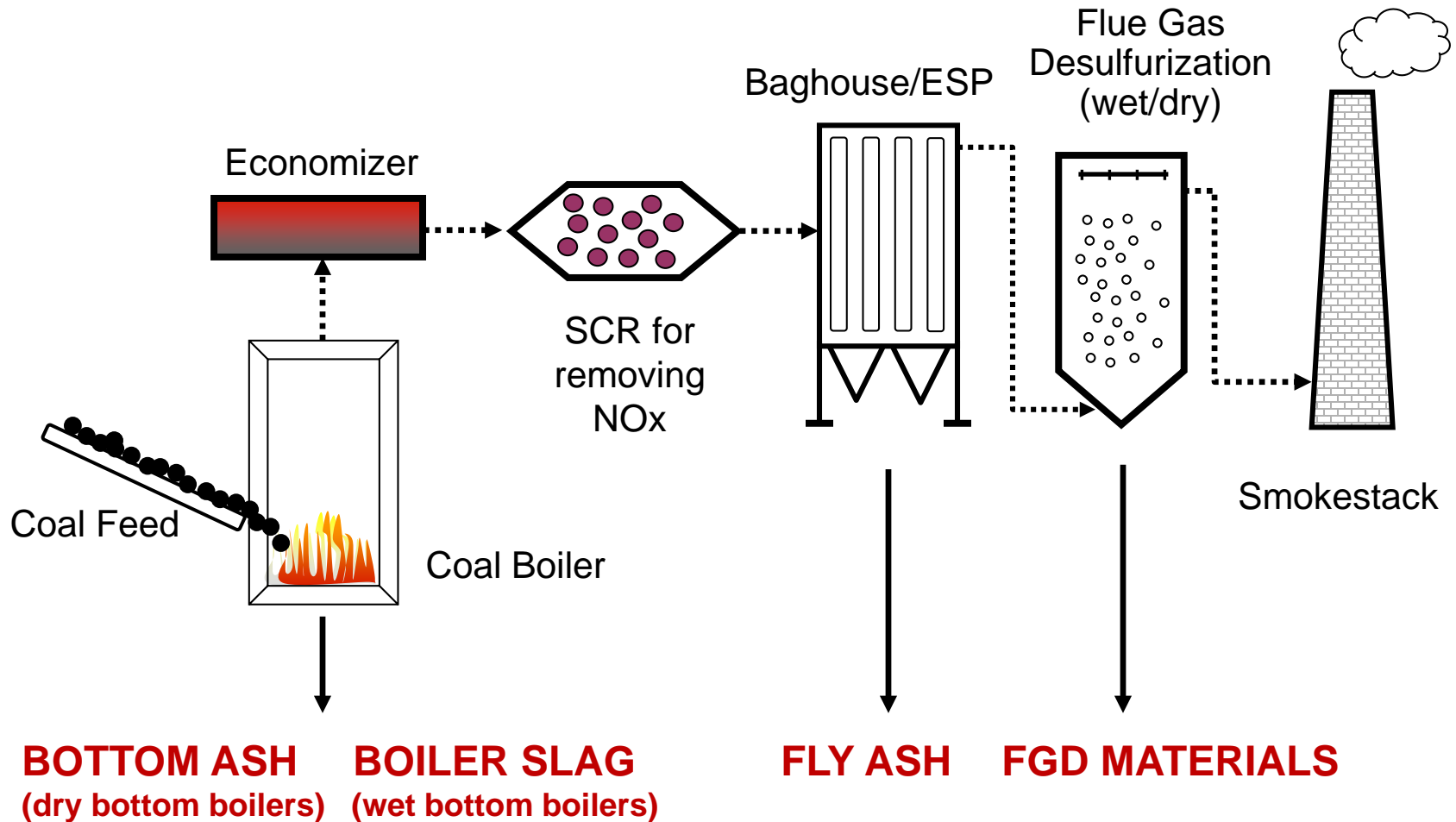
What are Coal Combustion Residues (CCRs)?

- CCRs are solid minerals that remain after pulverized coal is burned to generate electricity or steam
- US annual production: 110 million tons
- Types:
 - Fly Ash
 - Bottom Ash
 - Boiler Slag
 - Flue Gas Desulfurization (FGD) Materials





How are CCRs generated?



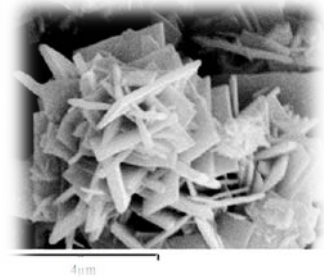


Flue Gas Desulfurization (FGD) Materials

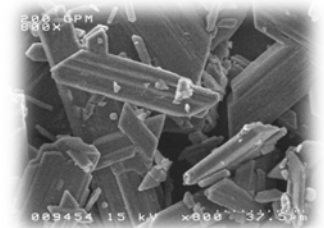
- Solid / semi-solid material obtained from flue gas scrubbers (for **SO₂ control** of high sulfur coals)
- Predominantly silt size particles
- May be wet or dry as well as sulfite or sulfate depending on process
- Types:
 - Dry FGD Materials
 - Wet FGD Materials
 - Sulfite (Stabilized FGD material)
 - Sulfate (FGD Gypsum)



Stabilized
FGD material



FGD
Gypsum





Major Beneficial Uses of CCRs

- **Concrete & concrete products**
- Cement production
- **Structural & flowable fills**
- **Road base**
- Mineral fillers
- Gypsum wallboard
- **Soil & waste stabilization**
- Snow & ice control
- Blasting grit & roofing granules
- **Aggregate**
- Agricultural
- **Mining**
- **Extraction of Minerals & REEs**





2017 Production & Use (ACAA)

- Production was slightly (4%) greater in 2017 vs. 2016
- Beneficial use increased to record level of 56% in 2016 to **64.4%** in 2017
- Use of fly ash remained roughly level with prior year in spite of high demand. Market data - gap between supply & demand to be about 30%.
- FGD gypsum use in wallboard increased to 60%
- Use of CCRs in structural fills continued its multi-year slide mostly due to regulatory issues
- *CCR use in pond closure activity impacted other beneficial uses as material normally put into other uses was diverted to closure.*

2017 Coal Combustion Product (CCP) Production & Use Survey Report

Beneficial Utilization versus Production Totals (Short Tons)

2017 CCP Categories	Fly Ash	Bottom Ash	Boiler Slag	FGD Gypsum	FGD Material Wet Scrubbers	FGD Material Dry Scrubbers	FGD Other	FBC Ash	CCP Production / Utilization Totals
Total CCPs Produced by Category	38,189,790	9,655,931	2,574,673	32,707,136	11,311,344	2,454,818	6,293	14,469,553	111,369,538
Total CCPs Used by Category	24,095,590	4,839,420	1,570,375	22,839,385	3,905,009	382,048	2,407	14,134,477	71,768,712
1. Concrete/Concrete Products /Grout	14,065,791	785,527	0	67,009	0	0	0	0	14,918,326
2. Blended Cement/ Feed for Clinker	4,579,724	1,622,612	132,183	2,317,445	0	51	0	0	8,652,015
3. Flowable Fill	86,379	0	0	0	0	0	0	0	86,379
4. Structural Fills/Embankments	465,653	871,875	0	0	0	0	0	0	1,337,529
5. Road Base/Sub-base	674,155	159,084	0	2,460	0	11,931	0	0	847,630
6. Soil Modification/Stabilization	360,796	48,876	0	0	0	0	0	0	409,673
7. Mineral Filler in Asphalt	59,317	0	0	0	0	7,019	0	0	66,336
8. Snow and Ice Control	69,192	276,989	4,220	0	0	0	0	0	350,402
9. Blasting Grit/Roofing Granules	0	17,705	1,412,685	44,981	0	0	0	0	1,475,371
10. Mining Applications	901,181	232,110	0	927,949	3,905,009	202,092	0	14,037,913	20,206,254
11. Gypsum Panel Products (formerly Wallboard)	0	0	0	15,859,606	0	0	0	0	15,859,606
12. Waste Stabilization/Solidification	1,065,993	48,964	0	3,026	0	114,646	0	96,564	1,329,193
13. Agriculture	0	0	0	1,157,877	0	35,121	0	0	1,192,998
14. Aggregate	0	10,237	21,287	0	0	0	0	0	31,524
15. Oil/Gas Field Services	78,716	0	0	0	0	11,188	0	0	89,905
16. CCR Pond Closure Activities	1,468,203	730,600	0	2,270,326	0	0	0	0	4,469,130
17. Miscellaneous/Other	220,489	34,840	0	188,705	0	0	2,407	0	446,442

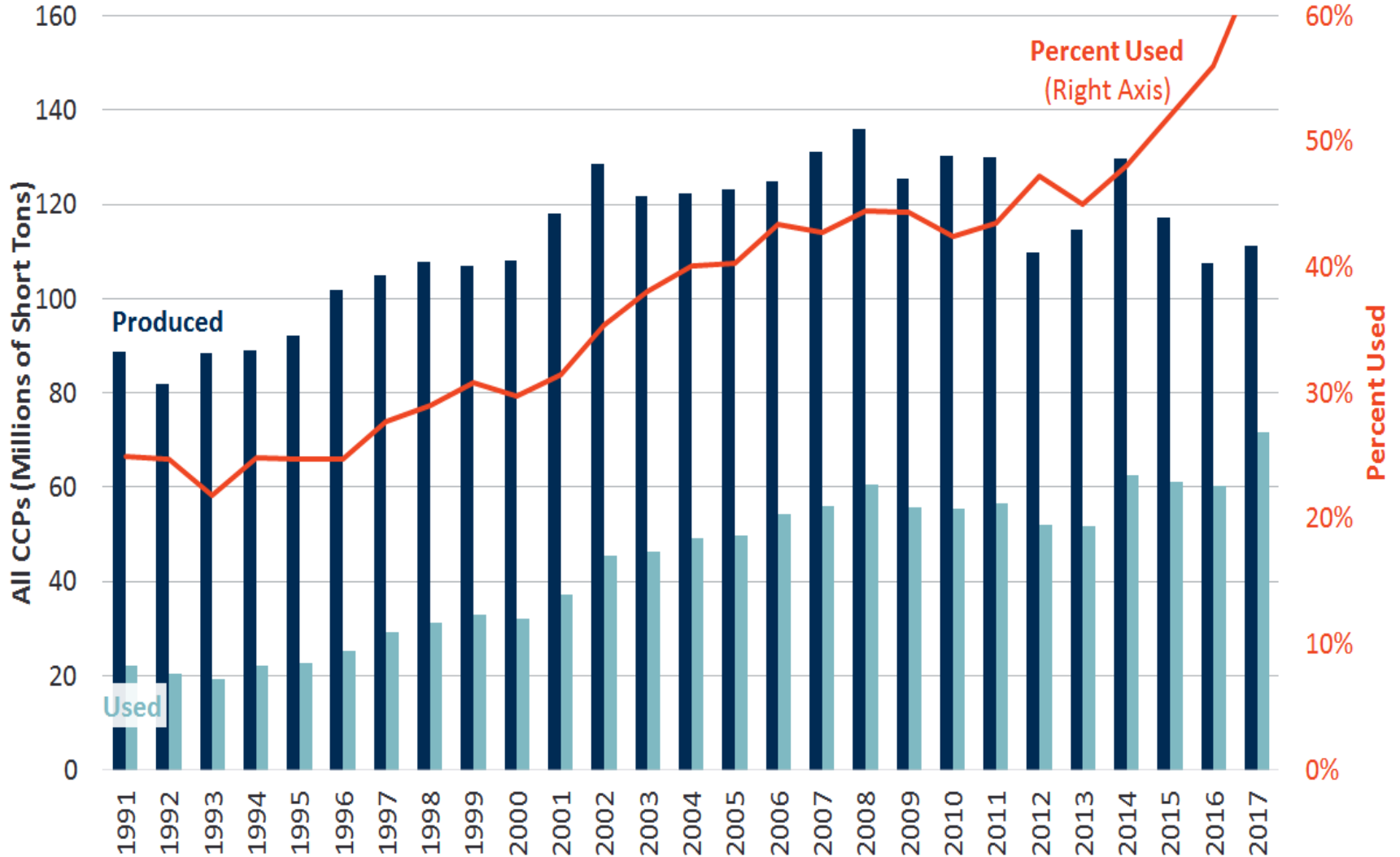
Summary Utilization to Production Rate

CCP Categories	Fly Ash	Bottom Ash	Boiler Slag	FGD Gypsum	FGD Material Wet Scrubbers	FGD Material Dry Scrubbers	FGD Other	FBC Ash	CCP Utilization Total
Totals by CCP Type/Application	24,095,590	4,839,420	1,570,375	22,839,385	3,905,009	382,048	2,407	14,134,477	71,768,712
Category Use to Production Rate (%)	63.09%	50.12%	60.99%	69.83%	34.52%	15.56%	38.25%	97.68%	64.44%

2017 Cenospheres Sold (Pounds)	147,958	Data in this survey represents 145.20701 GWs of Name Plate rating of the total industry wide approximate 263.0478 GW capacity based on EIA's July 2017 Electric Power Monthly.
CCPs Imported in 2016 (Short Tons)	0	
CCPs Exported in 2016 (Short Tons)	0	

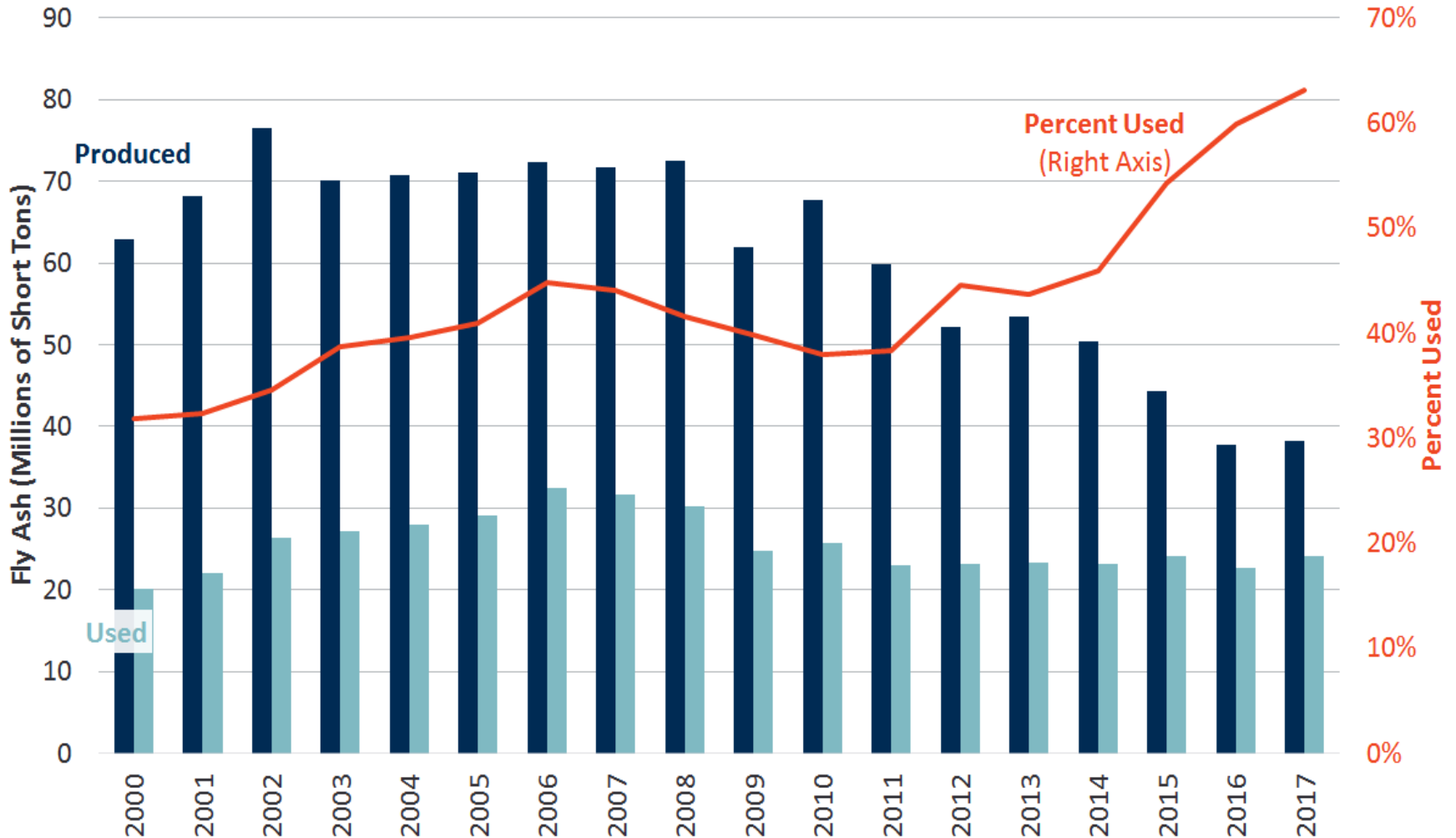


Total Production & Use



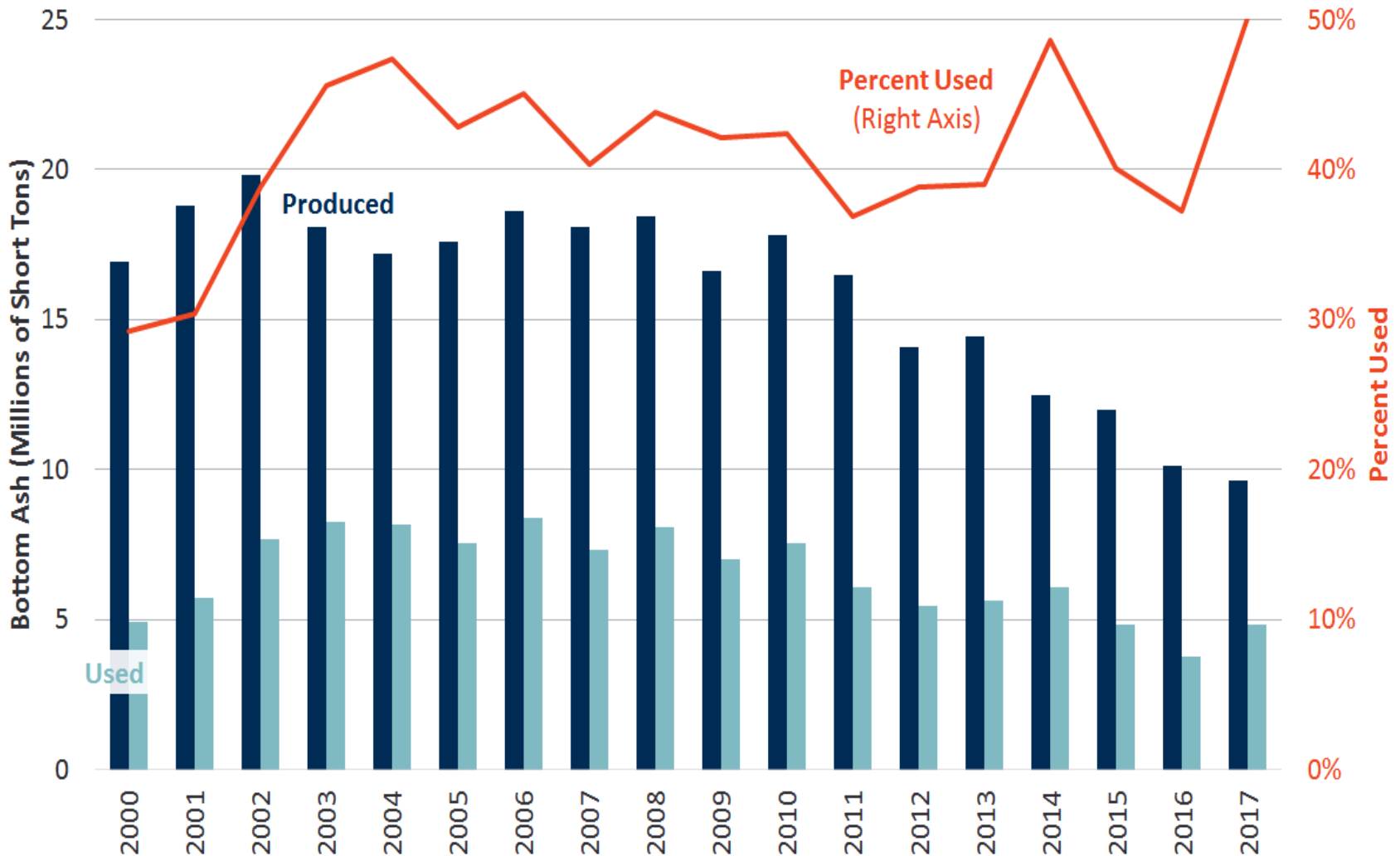


Fly Ash Production & Use



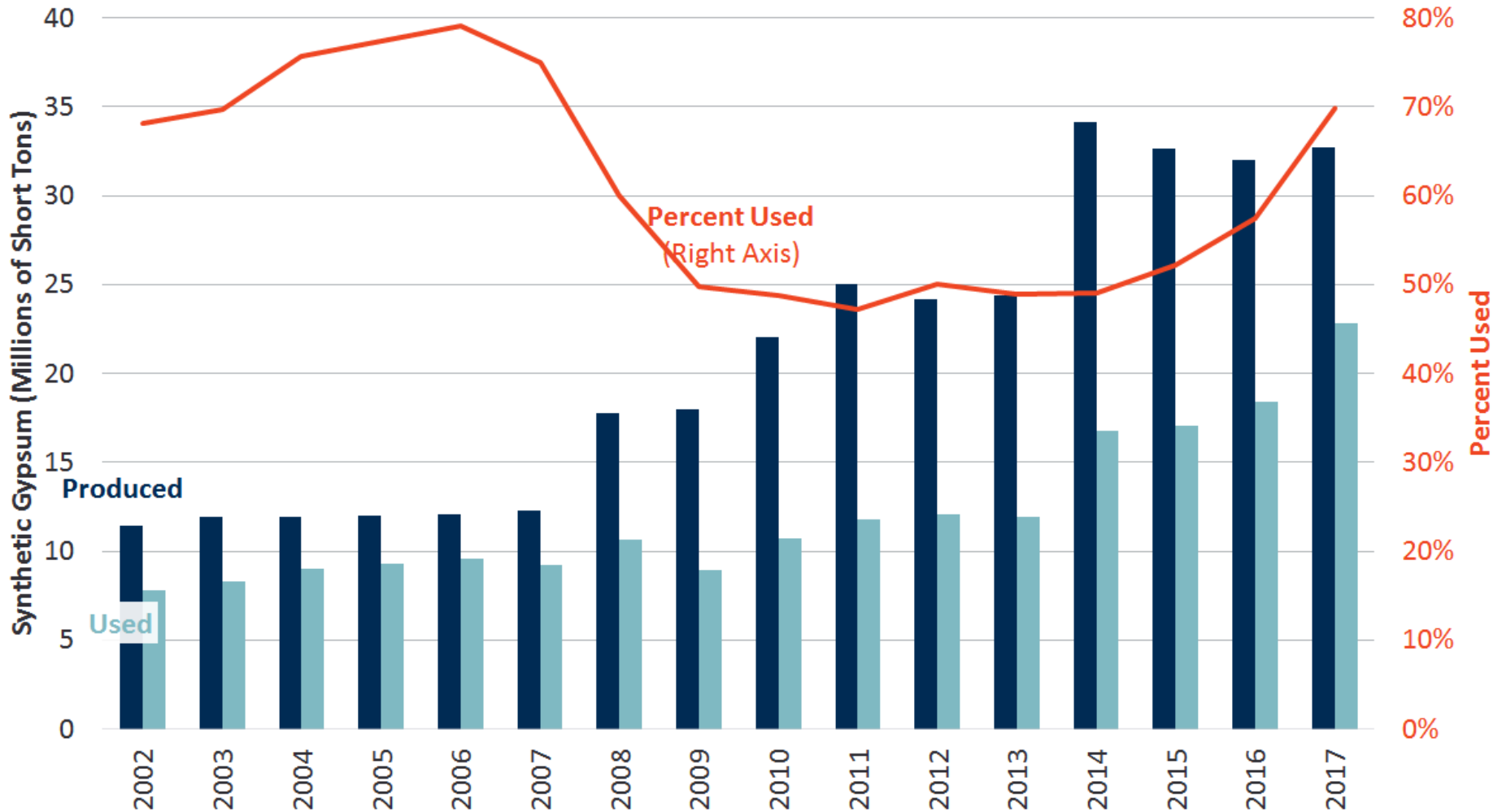


Bottom Ash Production & Use





FGD Gypsum Production & Use





Future Outlook

- CCR beneficial use applications which will flourish are those that are:
 - *environmentally responsible*
 - *technically sound*
 - *commercially competitive*
 - *sustainable*
- Types of applications:
 - **Large volume, low value** (eg. mine reclamation)
 - **Large value, low volume** (eg. extraction of REEs)
 - **Medium value, large volume** (eg. fly ash concrete, FGD gypsum wallboard)



Issues Facing CCR Industry

- USEPA Rulemaking
- Demand
- Supply
- Ash Pond Closures
- Harvesting of CCRs from ash ponds & landfills



USEPA CCR Regulation

- Rulemaking started in 1976
- Published on April 17, 2015
- Subtitle C preference
- Litigation continues
- More rulemaking in progress: Oct 2, 2019
Public hearing on proposed changes to CCR regulations (eg. **Boron triggers corrective action**)



Demand

- Fly ash for use in concrete & FGD gypsum use in wallboard products at historic levels
- FGD gypsum use in agriculture weak due to low crop prices
- Other CCP uses unsteady
- Cenosphere use collapsing



Supply

- Natural gas prices
- Moderate weather
- Logistics
- Combustion injections
- Specifications
- Reclaiming of ash ponds
- Harvesting from landfills & ponds



Specifications are Evolving

- ASTM C 618 and AASHTO M 295 used for concrete mixtures
- Proposals under consideration which will increase supply of compliant fly ash
- Combustion stream injections recognized
- Blending being considered



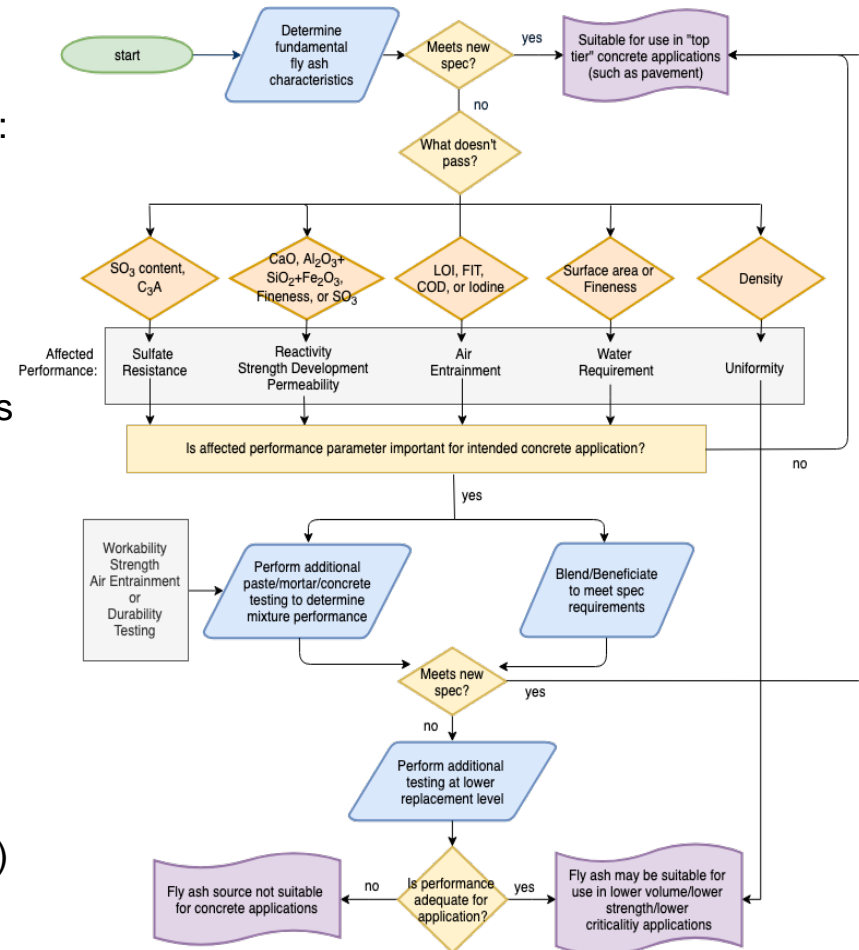
Harvesting Stored Fly Ash

- Historic activity at relatively low volumes
- SEFA, Boral, and ASHCOR technologies are promising developments
- Pond closures creating new interest
- States have considered mandates



Existing Needs:

- Better understanding of these 'unconventional' materials:
 - Reactivity and effects on durability
 - Adsorption of admixtures
 - Source **VARIABILITY**
- Better understanding of links between material properties and larger scale concrete performance
- Better (or maybe just different?) tests and testing approaches to quantify material properties
- Specifications that allow for exceptions based on application needs
- Collaboration between fly ash suppliers, utilities, researchers, concrete producers, and owners (i.e. DOTs) for continued testing and knowledge creation



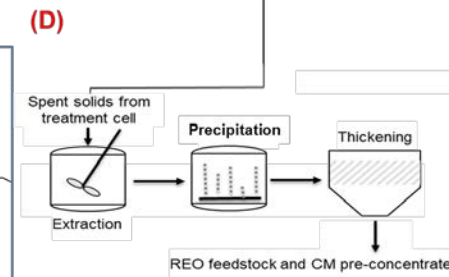
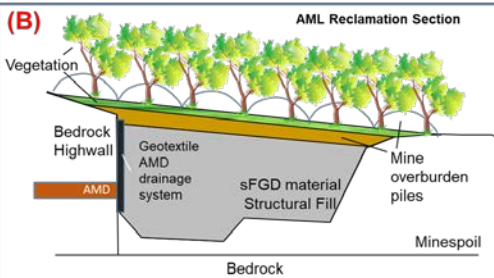
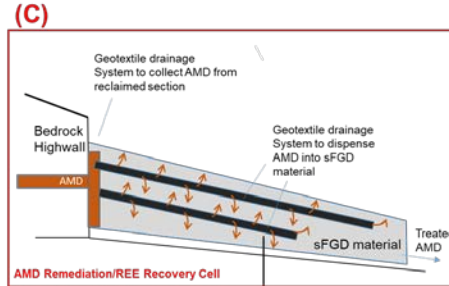
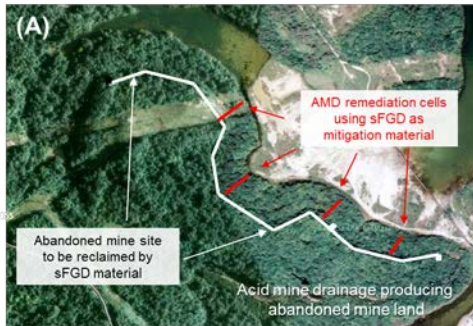
In progress: NCHRP 10-104: Recommendations for Revision of AASHTO M 295 Standard Spec to Include Marginal and Unconventional Source Coal Fly Ashes

NCHRP Team: Chris Shearer SDSM
Lisa Burris OSU
Prannoy Suraneni U of Miami
Doug Hooton U of Toronto





Recovering Rare Earth Elements from Acid Mine Drainage Using CCRs



- The trap-Extract-Precipitate (TEP) process uses alkaline by-products from coal flue gas desulfurization (sFGD) and lime softening in water treatment (WTP Sludge) to treat acid mine drainage (AMD) and recover rare earth elements (REEs).
- We have demonstrated that these materials are effective in trapping AMD REEs (over 95%).
- Non-acid base extraction process extracts over 90% entrapped REEs and concentrated them in extract.
- Precipitates containing over 7 wt.% total REE can be recovered from the extract using a process without addition of chemicals
- The process is ready to be tested in a larger scale.



Coal Combustion Products Program

Ohio State's Coal Combustion Products Program focuses on sustainable, high-volume beneficial uses of coal combustion products (CCPs), primarily from sulfur dioxide scrubbing processes, in construction, reclamation, infrastructure rehabilitation, manufacturing and agricultural applications. This program advances the beneficial uses of CCPs from sulfur dioxide scrubbing processes as well as more traditional byproducts, including fly ash, bottom ash, boiler slag and fluidized-bed combustor ash. Re-use of CCPs provides a low-cost raw construction material; extends the life of landfills, and lessens the need for new ones; and helps keep energy production costs in check.





Funded by the Ohio Coal Development Office, Ohio State University, Ohio coal-fired utilities, ash marketers, private businesses and trade and farming organizations, the Coal Combustion Products Program Improves and discovers technically sound, environmentally friendly and commercially competitive uses of CCPs in many interdisciplinary sustainable applications.

The program aids the CCP industry through research, education, technology transfer and outreach in its efforts to:

- expand uses in proven areas, such as highway and agricultural applications;
- remove or reduce regulatory and perceptual barriers to use;
- develop new or under-used large-volume market applications, such as mine land reclamation; and
- place greater emphasis on sulfate and sulfite flue gas desulfurization byproducts utilization.



More than 500 animal feeding pads in more than 12 Ohio counties are made from coal combustion products, including feeding pads at The Wilds in Muskingum County.



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