EP Power Minerals

Production of Low-GHG SCM’s from Legacy CCP Deposits

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Agenda

01 EP Power Minerals

02 Decarbonization

03 Production of low carbon SCM’s

01

EP Power Minerals

A Global Network of Experts in Cementitious Materials

European Market Leader with 40 years of experience in the management of coal combustion products and slag

First to market (1989) with the recovery and processing of landfill ash for use in concrete

International Trading Team spanning 3 continents connecting the largest SCM sources and markets

Global Technical & Project Development team of experts for the next generation of cementitious materials

EP Power Minerals

EP Power Minerals

Company

Since mid-2021, EP Power Minerals has been part of EP Holding - Energetický a průmyslový holding (EPH)

A Prague based European energy group covering the complete value chain of the energy sector

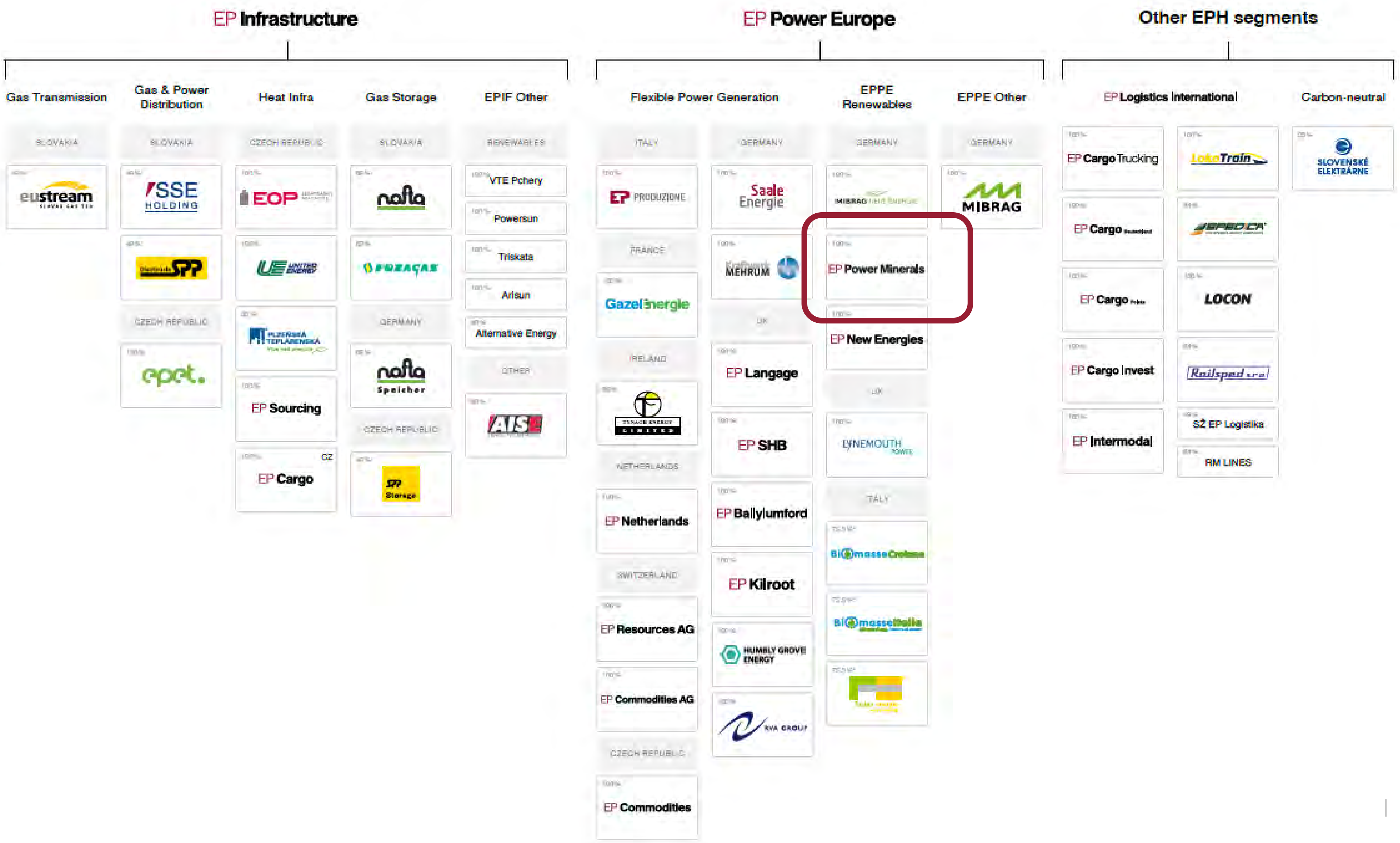
EPH owns and operates energy assets in **Czechia, Slovakia, Germany, Italy, Ireland, the UK, France, the Netherlands** and **Switzerland**.

EPH comprises more than **70 companies with over 10 thousands employees**, that are structured in three pillars:

EP Infrastructure,
EP Power Europe, and
EP Logistics International

EPH
KPI‘s 2022
Assets: EUR 30,5 bn
Revenues: EUR 37,1 bn
Adj. EBITDA: EUR 4,3 bn

EPH Company Structure



EP Infrastructure

- Gas Transmission
  - SLOVAKIA
    - eustream
- Gas & Power Distribution
  - SLOVAKIA
    - SSE HOLDING
    - Distribúcia SPP
  - CZECH REPUBLIC
    - epet.
- Heat Infra
  - CZECH REPUBLIC
    - EOP
    - UE United Energy
    - Plzeňská teplárenská
    - EP Sourcing
    - EP Cargo CZ
- Gas Storage
  - SLOVAKIA
    - nafta
    - POZAGAS
  - GERMANY
    - nafta Speicher
  - CZECH REPUBLIC
    - SPP Storage
- EPIF Other
  - RENEWABLES
    - VTE Pchery
    - Powersun
    - Triskata
    - Arisun
    - Alternative Energy
  - OTHER
    - AIS

EP Power Europe

- Flexible Power Generation
  - ITALY
    - EP PRODUZIONE
  - FRANCE
    - GazelEnergie
  - IRELAND
    - Tynagh Energy Limited
  - NETHERLANDS
    - EP Netherlands
  - SWITZERLAND
    - EP Resources AG
    - EP Commodities AG
  - CZECH REPUBLIC
    - EP Commodities
  - GERMANY
    - Saale Energie
    - Kraftwerk MEHRUM
  - UK
    - EP Langage
    - EP SHB
    - EP Ballylumford
    - EP Kilroot
    - Humbly Grove Energy
    - RVA Group
- EPPE Renewables
  - GERMANY
    - MIBRAG Neue Energie
    - **EP Power Minerals**
    - EP New Energies
  - UK
    - LYNEMOUTH POWER
  - ITALY
    - BiomasseCrotone
    - BiomasseItalia
- EPPE Other
  - GERMANY
    - MIBRAG

Other EPH segments

- EP Logistics International
  - EP Cargo Trucking
  - EP Cargo Deutschland
  - EP Cargo Polska
  - EP Cargo Invest
  - EP Intermodal
  - LokoTrain
  - SPEDICA
  - LOCON
  - Railsped s.r.o.
  - SŽ EP Logistika
  - RM LINES
- Carbon-neutral
  - SLOVENSKÉ ELEKTRÁRNE

EP Power Minerals

We care for a **solid** future.

Locally rooted and globally connected,

we are well positioned to serve our customers – the cement and concrete producers

supplying fly ash, granulated blast furnace slag, and other SCM’s –

delivered by our companies located in Europe, Asia or America

EP Power Minerals GmbH

SURSCHISTE

POWER MINERALS

EP Power Minerals Americas, Inc.

Euroment

HOANG SON
BUILD SUSTAINABLE VALUE

EP Energo Mineral

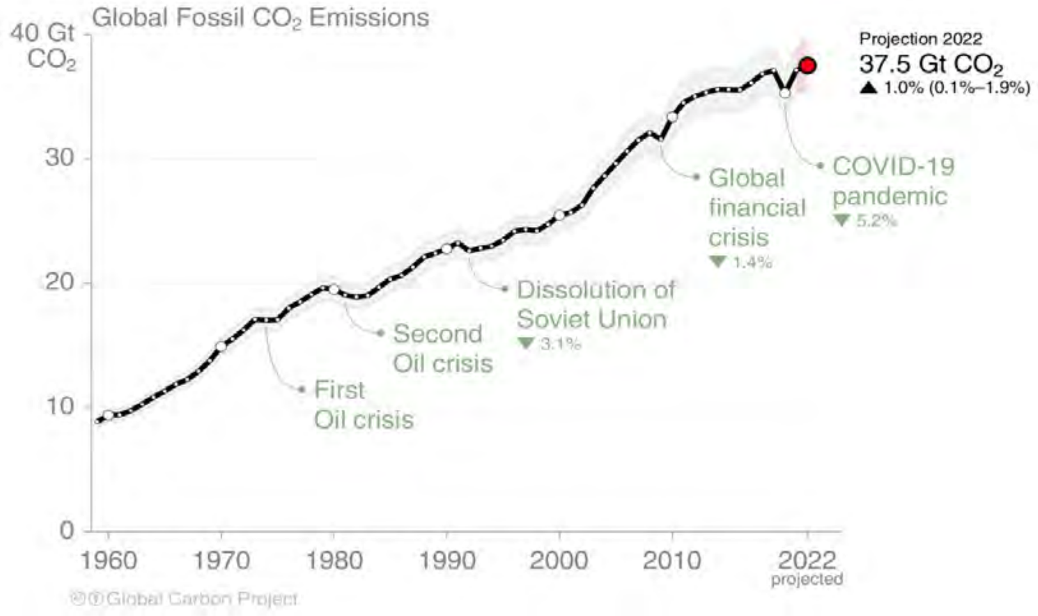
POWER MENT

02

Decarbonization

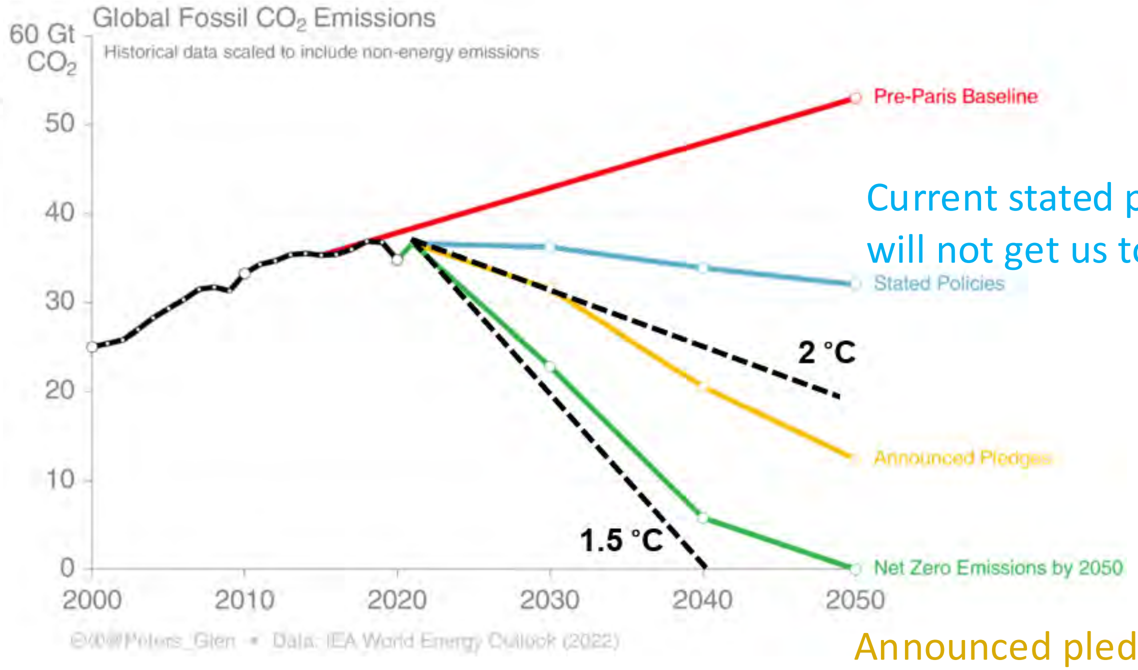
Global CO_2 Emissions & Impact of Global Initiatives

- Global CO_2 emissions have risen ~ 3% per year from1940s till 2000s, slowing to 0.5%/yr in recent years
- Current atmospheric CO_2 level of 420 ppm (2023) is ~50% more than the pre-industrial revolution of ~280 ppm (1750)
- Containing global average surface temperature rise to 1.5 – 2°C is important to avoid potentially catastrophic feedback loop



Global Fossil CO_2 Emissions

©ⓘ Global Carbon Project



Global Fossil CO_2 Emissions

Historical data scaled to include non-energy emissions

©ⓘ@Peters_Glen • Data: IEA World Energy Outlook (2022)

Current stated policies
will not get us to 2°C rise

Announced pledges are helpful,
but not even enough for 1.5°C

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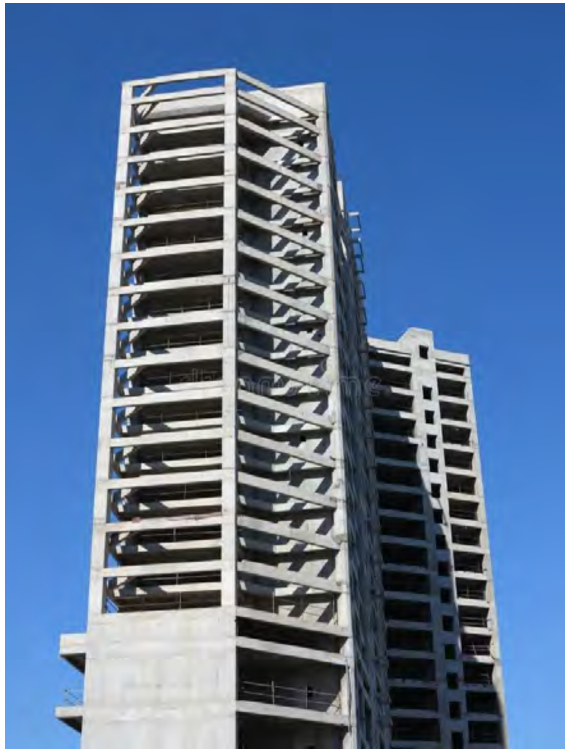
Concrete is the most abundant manufactured material on earth



2020

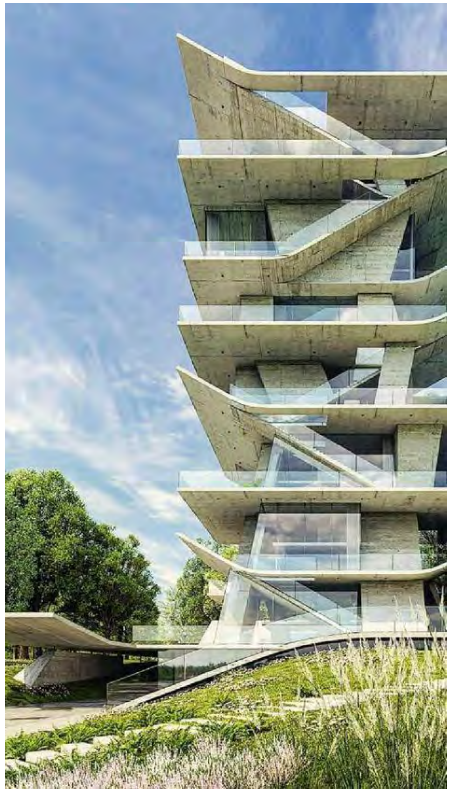
Global Concrete Production
14 billion cubic meters

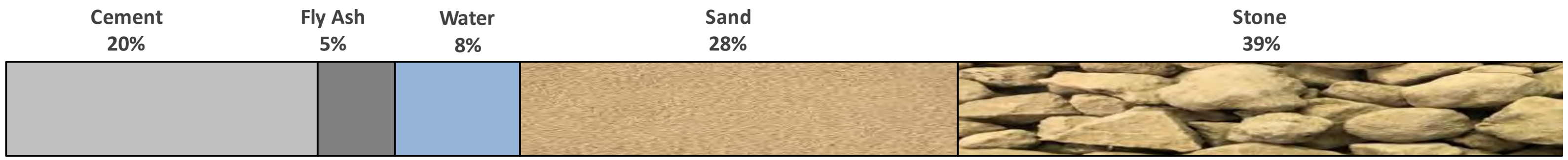
Percent in Residential Housing
40%

Global Cement Production
4.2 billion tonnes

Value of Cement/Concrete Products
$440 billion

Percent of Global CO2 Emissions
7%~8%





Decarbonization of Cement & Concrete Production

Concrete
DECARBONATION
Pathways

- More efficient use of cement in concrete (mix optimization, admixtures, etc.)
- Absorption of CO_2 into cementitious materials – Carbonation
- **Carbon Capture and Sequestration (CCS) of cement kiln CO_2 emissions**
- **Replacement of cement with lower carbon footprint materials (SCM's)**

There are many SCMs
Traditionally, residual wastes or by- products
Others are emerging

Global Supplementary Cementitious Materials Market by Type, Application, End User Industries and by Region, Global Trends and Forecast from 2019 to 2028

Market is expected to grow faster in next decade with more than double digit growth. 11.44%

Phasing out of Coal based power plants is a major restraint for the Supplementary Cementitious Market.

Increasing construction activities after Covid-19 have helped the growth of Supplementary Cementitious Materials market.

Global SUPPLMENTARY CEMENTITIOUS MATERIALS Market

Opportunities and Forecast, 2021-2030

Global Supplmentary Cementitious Materials Market is expectedto reach $39.9 Billion by 2030.

Growing at a CAGR of 7.2% (2021-2030)

nature communications

Article

https://doi.org/10.1038/s41467-022-33289-7

Cement substitution with secondary materials can reduce annual global CO_2 emissions by up to 1.3 gigatons

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Izhar Hussain Shah[1], Sabbie A. Miller[2], Daqian Jiang[3] & Rupert J. Myers[1]

Population and development megatrends will drive growth in cement production, which is already one of the most challenging-to-mitigate sources of CO_2 emissions. However, availabilities of conventional secondary cementitious materials (CMs) like fly ash are declining. Here, we present detailed generation rates of secondary CMs worldwide between 2002 and 2018, showing the potential for 3.5 Gt to be generated in 2018. Maximal substitution of Portland cement clinker with these materials could have avoided up to 1.3 Gt CO_2-eq. emissions (~44% of cement production and ~2.8% of anthropogenic CO_2-eq. emissions) in 2018. We also show that nearly all of the highest cement producing nations can locally generate and use secondary CMs to substitute up to 50% domestic Portland cement clinker, with many countries able to potentially substitute 100% Portland cement clinker. Our results highlight the importance of pursuing regionally optimized CM mix designs and systemic approaches to decarbonizing the global CMs cycle.

technical (energy, emissions, and material efficiency) measures, of which cementitious materials (CMs) substitution (including complete and partial substitution) is one of the most promising[10].

Substitution of cement constituents (e.g., clinker), cement, binder, and concrete/mortar are possible. However, substitution in the binder (including cement and its constituents) (Fig. 1) is especially important since: (a) most of the environmental impact in the CMs cycle arises from clinker production[10]; (b) it provides many opportunities for environmentally, technically, and economically beneficial treatment of industrial by-products[11]; and (c) extensive substitution of cement with non-cementitious materials such as steel, bricks, timber, etc., is unlikely in the foreseeable future given the huge global scale needed. For instance, steel and bricks have higher greenhouse gas emissions per unit mass than concrete[12,13] while for timber, a massive expansion of production[3] is needed to achieve comparable substitution rates of timber for concrete[14] to those for clinker substitution in cement (~25 mass%[15]). Concerns related to sustainable forest management provide another barrier to the expansion of timber use. We thus focus on material substitution in cementitious binders here.

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Nature Communications | (2022)13:5758

1

- SCMs have a lower CO_2 footprint than portland cement
- SCM's can partially substitute for cement in concrete and can improve concrete performance & strength

- Emission avoidance is expected to drive demand for SCM's as CCS is the most-costly option to zero carbon

Available Technologies to Produce Low-Carbon Concrete

High Impact/Low Cost

- Concrete Optimization
- High Quality SCM's (25%~ 75% PC Replacement)

High Impact/High Cost

- Carbon Capture & Sequestration (~2025)
- SCM based (>90%) Novel Cements (~2040)

Coal Fly Ash

GGBF Slag

Silica Fume

Natural Pozzolans

& others

Low Impact/Low Cost

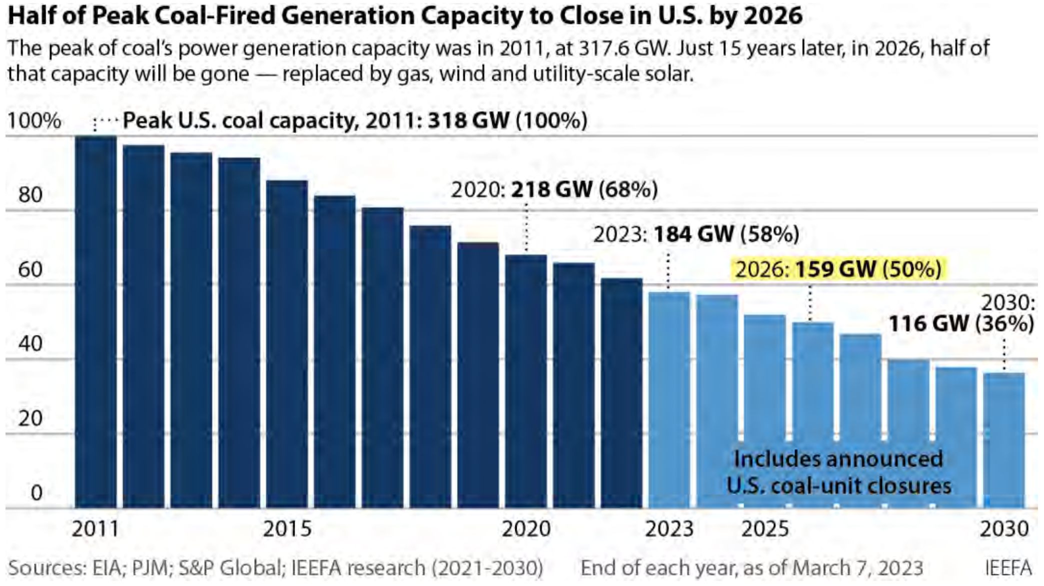
- Improved Efficiency (cement production)
- Conventional SCM's (<25% PC replacement)

Low Impact/High Cost

- Zero Carbon Kiln Fuel (~2030)
- High carbon footprint SCM's

Decarbonization of Electricity (U.S.)

Retirements of significant U.S. coal-fired generation capacity have been underway

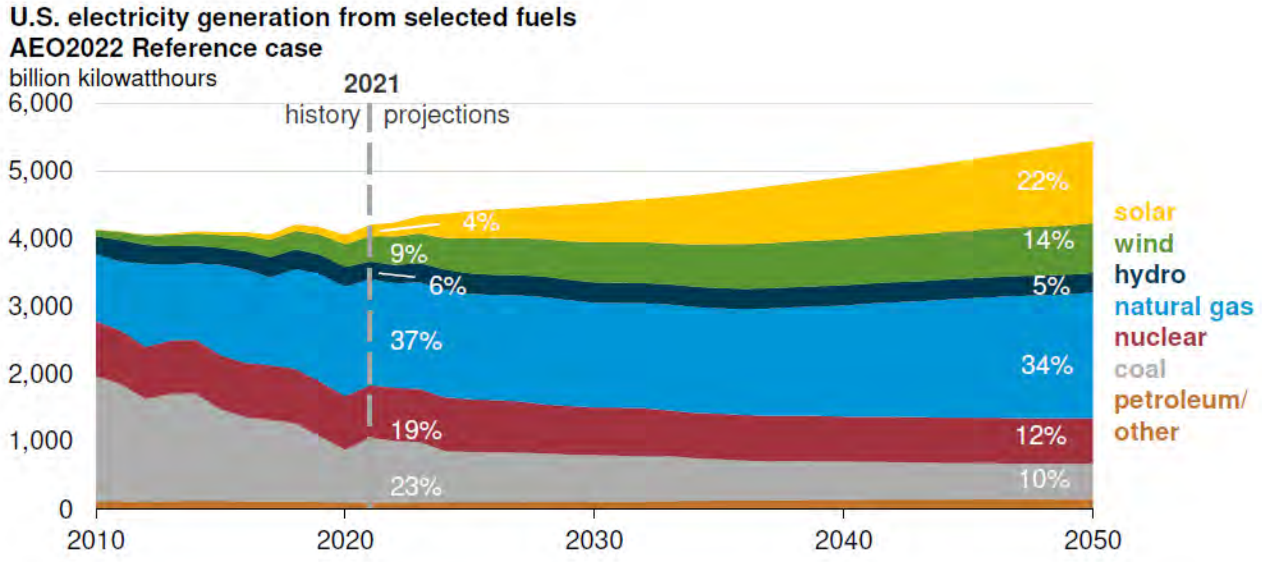


Half of Peak Coal-Fired Generation Capacity to Close in U.S. by 2026

The peak of coal's power generation capacity was in 2011, at 317.6 GW. Just 15 years later, in 2026, half of that capacity will be gone — replaced by gas, wind and utility-scale solar.

Sources: EIA; PJM; S&P Global; IEEFA research (2021-2030) End of each year, as of March 7, 2023 IEEFA

But many coal-fired units (nearly 200) remain



U.S. electricity generation from selected fuels
AEO2022 Reference case

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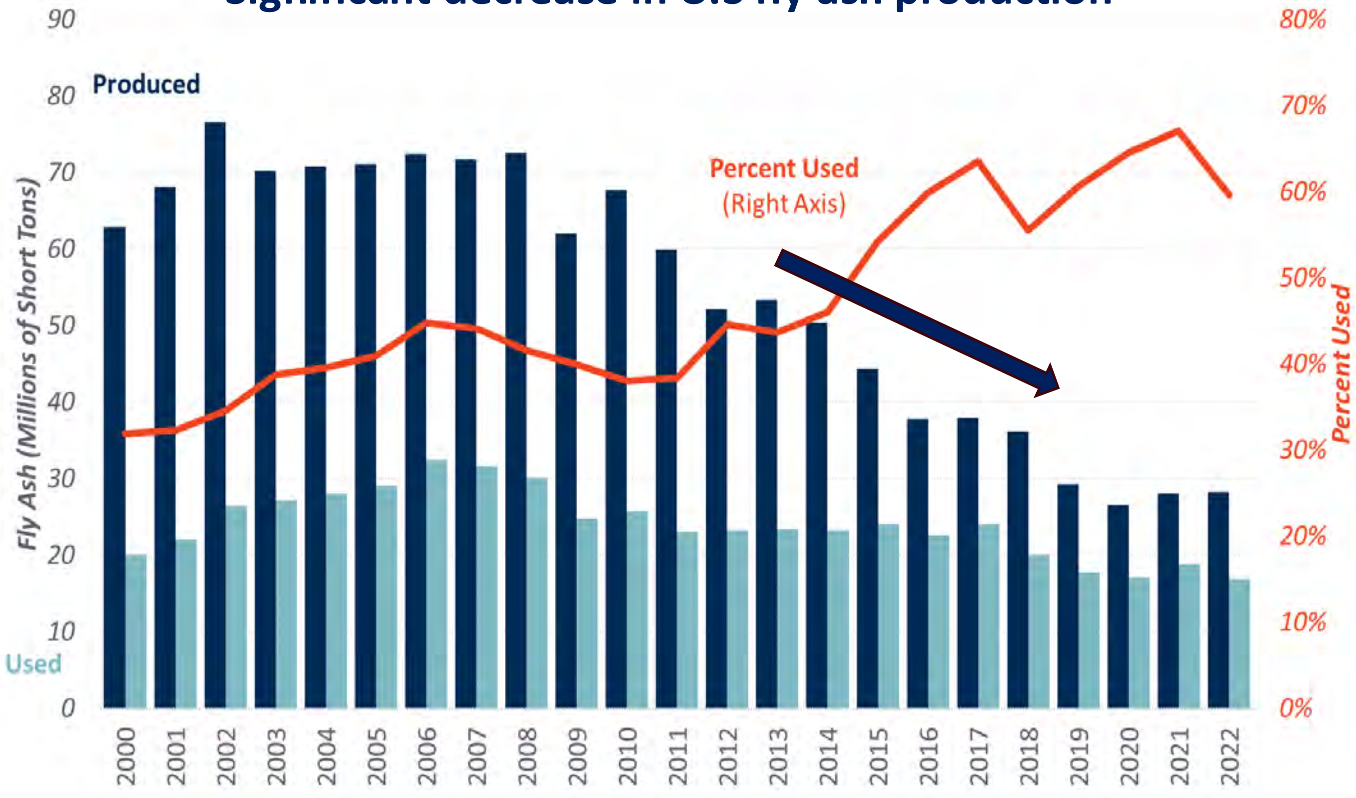
Impact of Electricity Decarbonization

Significant decrease in U.S fly ash production



Reduction in Use: seasonal/regional disparities and closure of large producers of quality fly ash

Similar story in Europe and Australia

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03

Production of Low Carbon SCM’s

EP Power Minerals - SCM Global Sourcing Strategy

Current production fly ash

- Sourcing inTurkey, India, Vietnam, Japan and other excess producing regions

GGBFS

- Trading in (G)GBFS between Asia, Europe & the U.S.

Natural Pozzolan

- Iceland (150 million tons) & other deposits/materials such as calcined clays & calcined shale

Other industrial by-products

- Non-coal derived pozzolans from mining and mineral processing

Recovery & processing of legacy coal ash deposits

- EPH utility sites and other third party deposits with initial focus on Europe & the U.S.

Legacy Fly Ash Deposits (U.S.)

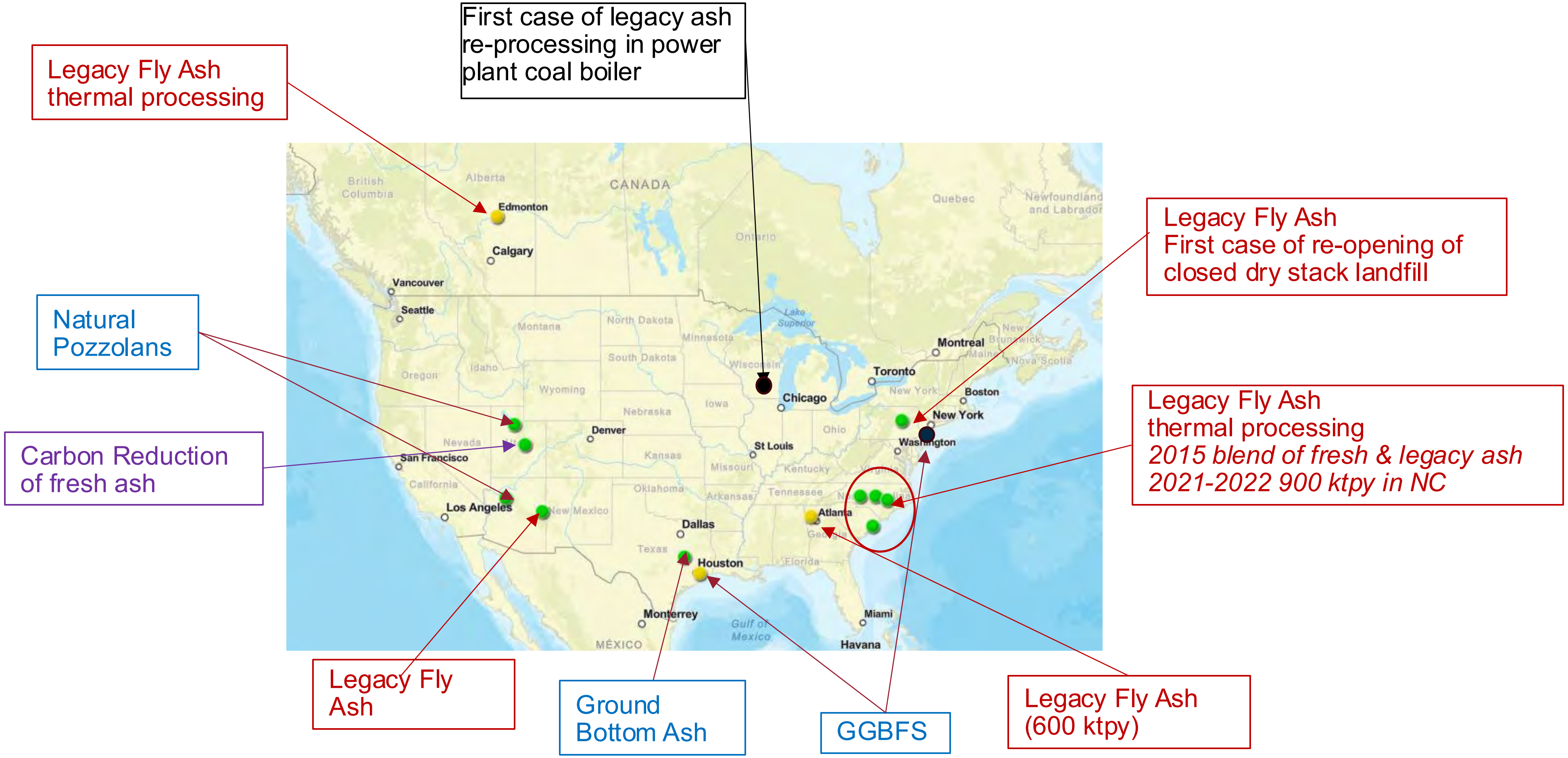
Nearby 2 billion tons of fly ash have been discarded in over 1,000 landfills and other wet disposal units

Complex regulatory framework and varying quality of materials

For Example: The largest single deposit in the U.S., Little Blue Run, with over 100 million tons of coal ash & FGD materials has no marketable value

However, there are numerous deposits with recoverable materials & manageable regulatory framework

New SCM Resource Developments in North America



Legacy Fly Ash
thermal processing

First case of legacy ash
re-processing in power
plant coal boiler

Legacy Fly Ash
First case of re-opening of
closed dry stack landfill

Natural
Pozzolans

Carbon Reduction
of fresh ash

Legacy Fly Ash
thermal processing
2015 blend of fresh & legacy ash
2021-2022 900 ktpy in NC

Legacy Fly
Ash

Ground
Bottom Ash

GGBFS

Legacy Fly Ash
(600 ktpy)

Source: Press Releases and public announcements

Anatomy of an SCM Production Project

10 Key considerations in evaluating new opportunities:

- Market Conditions - long term supply/demand dynamics
- Logistics – connecting the dots
- Product Positioning – competitive advantage (FA vs NP), pricing, carbon footprint, etc.
- Quantity – size of the ash deposit or recoverable pozzolan relative to market demand
- Permitting - regulatory constraints including landfill closure timeline
- Material Science - quality and variability of feedstock and finished product
- Techno economic & environmental feasibility: Processes to improve LOI, fineness, GHG, others
- Infrastructure – availability of utilities, especially heat for drying
- Seasonality - Production and demand (storage of feedstock and finish product)
- Disposition – by-products & rejects

The Conversion Process

The feedstock:

- Saturated (ponded) vs wet (dry stack). Fresh or salt water.
- Unburned Carbon (LOI) and other key quality parameters
- Segregation (particle size) & homogeneity of the deposit (presence of bottom ash, other CCP's & trash)
- Handling characteristics (stickiness, consistency, abrasiveness, presence of tramp metal, etc.)

The Process:

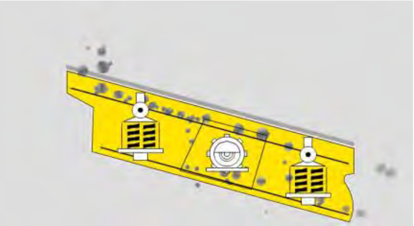
- Basic sorting & screening
- Drying - selection of equipment suitable for feedstock and post-processing
- More on drying – fuel, multipurpose (drying, de-agglomeration, transfer) & efficiency (energy & carbon footprint)
- Processing for LOI reduction – current options (electrostatic separation, wet flotation and combustion)
- Material Fineness – classification, attrition/classification or milling/classification
- Advanced processing – removal of chlorides, sulfates and alkalis present from seawater or desulfurization processes

The Others:

- Disposition of the by-products & rejects
- Material storage
- Environmental and many other design considerations

Basic Processing

Pre-Screening



Reclaimed wet fly ash is pre-screened at 6 to 12 mm (¼” ~ ½“) to remove debris & coarse particles
Very low electric consumption. Produces a reject stream.

Drying Technologies

Deployed for wet fly ash:

- flash pneumatic dyers
- mechanically agitated rapid dryers
- fluid bed dryers
- rotary dryers

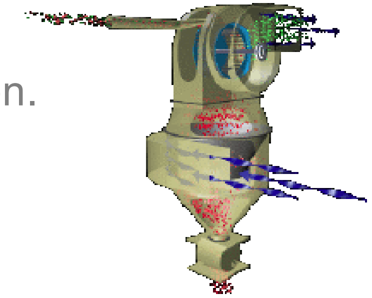
Demonstrated at pilot scale:

- attrition dryer (Already deployed for other materials)
- heated paddle/auger dryer (Already deployed for other materials)
- low temperature pneumatic (kinetic dryer) Novel Technology

Wide range of fuels and energy source options: natural gas, propane, fuel oil, biomass, steam or recovered heat from host industrial processes, renewable electricity, etc. Emissions include CO_2 and other combustion gases.

Air Classification

Similar in function to screening; but is often used for finer particle separation.
Uses more electricity for motors than screens. Produces a reject stream.



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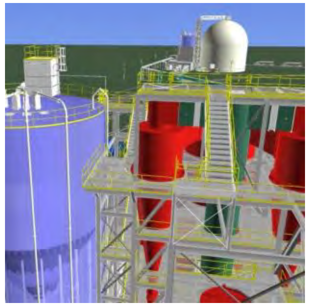
Carbon (LOI) Reduction

Electrostatic Separation

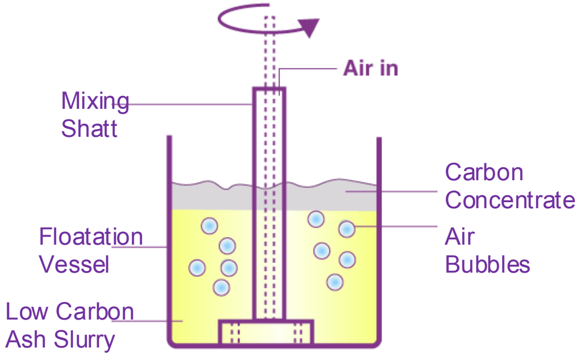
Dry processing of high carbon ash to reduce the LOI content
Produces a high carbon by-product that can be beneficially used

Thermal Carbon Reduction



High temperature process to ignite and reduce the residual carbon
Some systems require supplementary fuel to sustain combustion
Can have a significant CO_2 footprint

Carbon Flotation (Wet Processing)

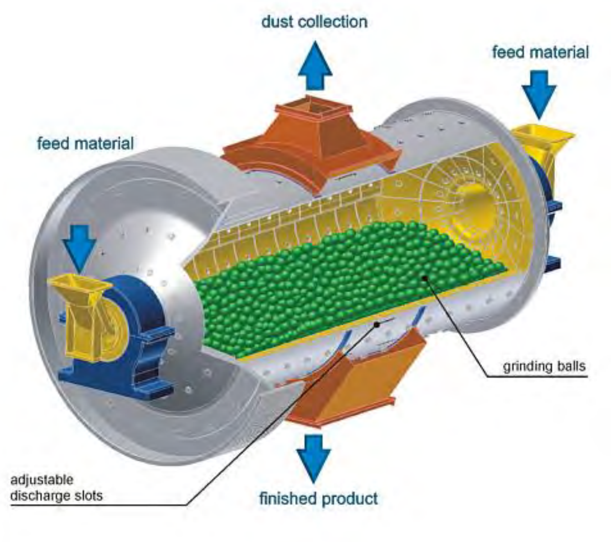


Mature technology for mineral processing - not deployed for fly ash yet
Requires chemical reagents for separation of carbon
Produces a high carbon by-product that can be beneficially used
Suitable for reducing dissolved solids content (salt)

Fineness Reduction & Other Performance Enhancement

Grinding/Milling

Applicable to bottom ash, agglomerated fly ash and natural pozzolans
Mills are typically integrated with a classifier
NP’s and bottom ash might need to be “finer” than spec requirement



Reagents/Activators

Numerous ‘technologies” are being promoted for enhanced SCM performance
To improve concrete strength and increase cement replacement levels
“Near” 100% replacement of portland cement with geopolymer based chemistry
Basic concepts include alkali activation, water reduction and cement strength acceleration
Reagents can be “pre-applied” to the SCM or added into the concrete mixture

TOP SECRET

CONFIDENTIAL

Let’s talk about drying Technologies

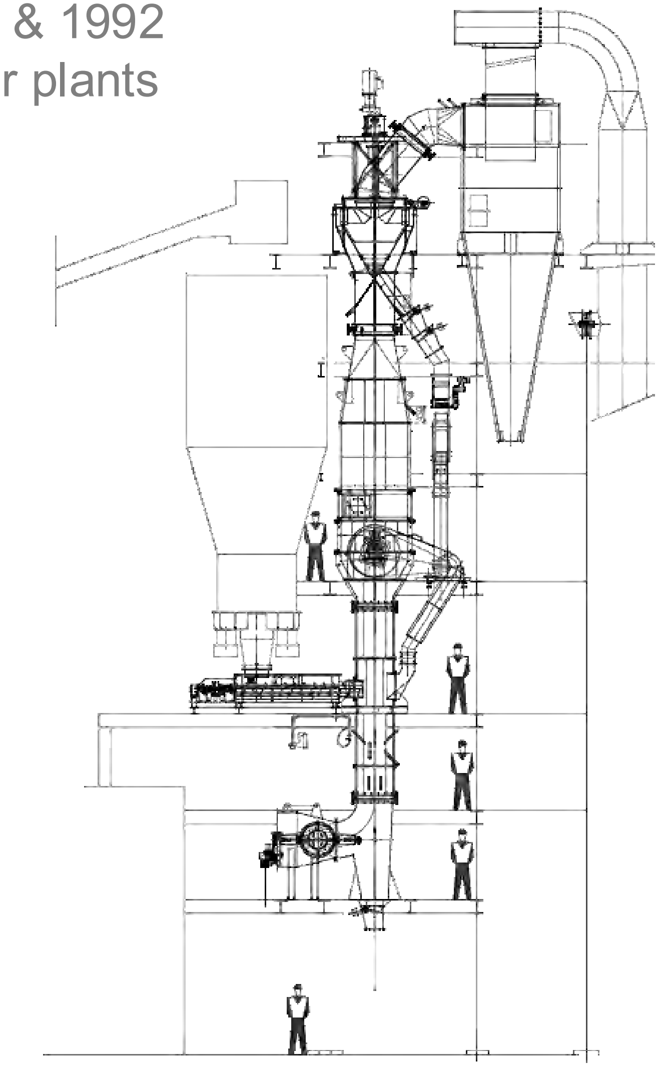
Deployed for wet fly ash:
- flash pneumatic dryers
- mechanically agitated rapid dryers
- fluid bed dryers
- rotary dryers

Demonstrated at pilot scale:
- attrition dryer
- heated paddle/auger dryer
- low temperature pneumatic (kinetic dryer)

Novel drying concepts:
- solvent displacement

Flash Dryers at EP Power Minerals/Surchiste (France)

- First two (2) installations to recover fly ash from landfills established in 1989 & 1992
- 30+ years of reclaiming ash from landfills at Hornaing and Saint Avold power plants
- Processed over 6 million tons of fly ash for the concrete market



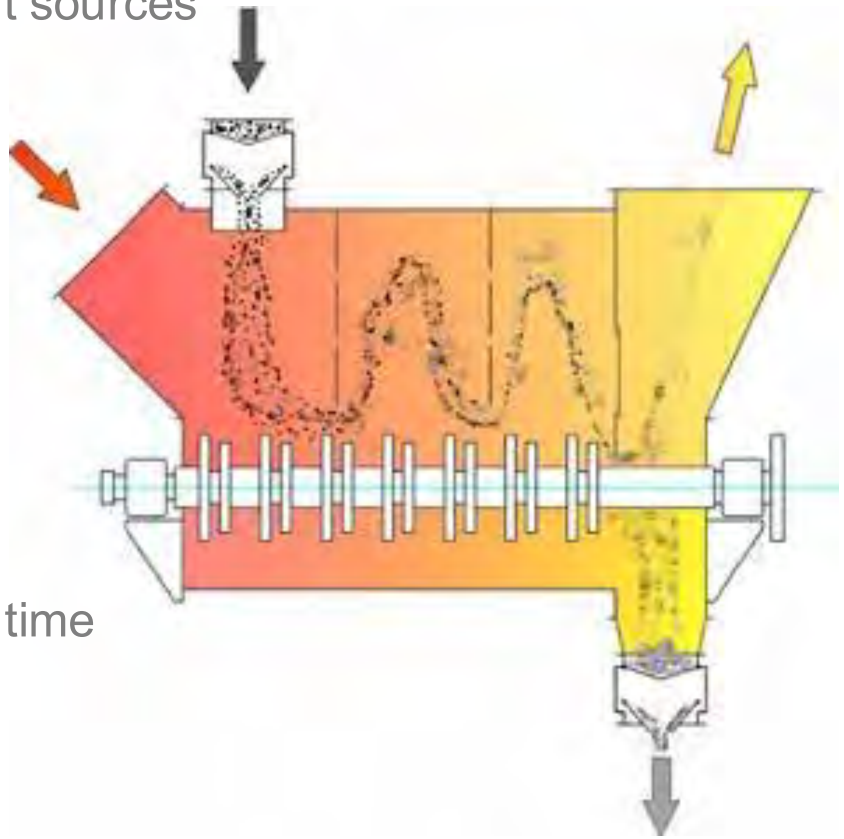
Fives Flash Dryers at the Surchiste Facilities:

- 40 & 80 metric tph
- 18% ~ 22% moisture feed
- 300°C air stream from NG burner
- 10-30 m/sec gas velocity (10X rotary dryer)
- 230 KWh/mt Heat (NG)
- 8 KWh/mt Electrical

- Ideal for fine grained/powdered material
- A cage mill or hammermill might be needed to break agglomerates
- Very large cyclone and bag houses (much larger than rotary drum)
- Consideration for abrasion & high wear from high velocities

Rapid Dryer at EP Power Minerals in Lunen (Germany)

- Another early entrant in the wet fly ash drying space
- 20+ years processing 15% moisture ash from multiple powerplant sources



Hazemag Rapid Dryer at the Lunen Facility:

- 50 metric tph
- 15% moisture feed
- 700°C air from NG burner
- 140°C dryer temperature
- 200 KWh/mt Heat (NG)
- 10 KWh/mt Electrical

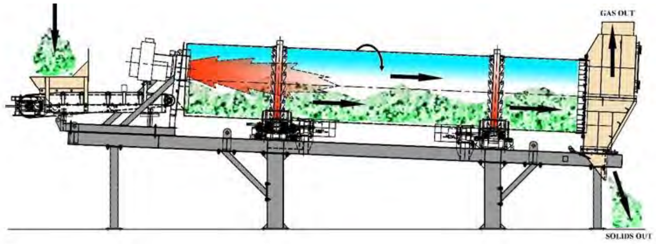
- Agitated chamber to enhance turbulence and reduce residence time
- Gravity discharged and flue gas entrained products
- System include hammer mill & classifier
- Cyclone & baghouse for product collection

Rotary Dryers

- The “workhorse” of the industrial drying industry (Aggregates, fertilizers and other minerals)
- First known landfill fly ash drying installation in the U.S. (2018)

Rotary Dryer (Tarmac design parameters):

- 36 metric tph (40 stph)
- 20% moisture
- 120°/150°C solids/gas
- 8.5’ dia x 50’ long drum
- 20 MM Btu/hr
- > 300 KWh/mt heat (NG)
- 8 KWh/mt Electrical



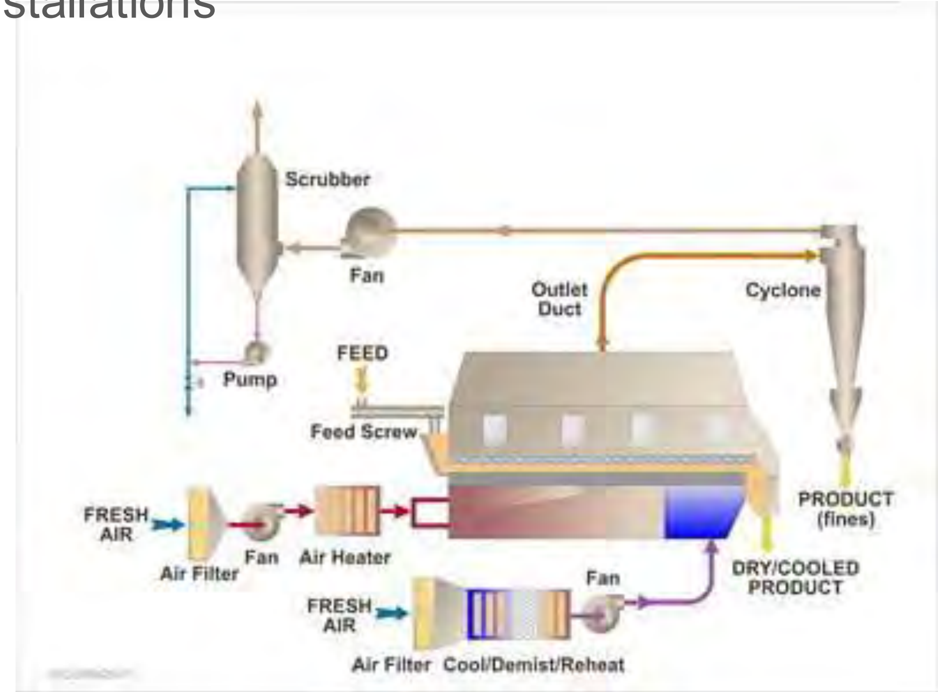
- High production capabilities (up to 90 tph)
- Ability to accept significant variability in feedstock moisture
- Low turbulence (agitation by lifters) and high residence time
- Can be mobile for 10 to 25 tph production

Fluid Bed Dryers

- Fluid bed reactors have been used for carbon in ash reduction (CBO$^{\text{TM}}$ and STAR$^{\text{TM}}$)
- Use for drying ash as part of the STAR$^{\text{TM}}$ carbon combustion installations
- No known stand-alone fluid bed dryers for landfill fly ash

Fluid Bed Dryer (design estimates):

- 23 metric tph (25 stph)
- 20% moisture
- 500~600 °C
- 260 KWh/mt Heat
- 12 KWh/mt Electrical



- High residence time – typical for material with slow drying rates/long reaction time
- Mostly suited for uniform material with particle size exceeding 100 micron
- High excess air to lift the material and expand bed
- Higher power consumption than flash or rotary dryers

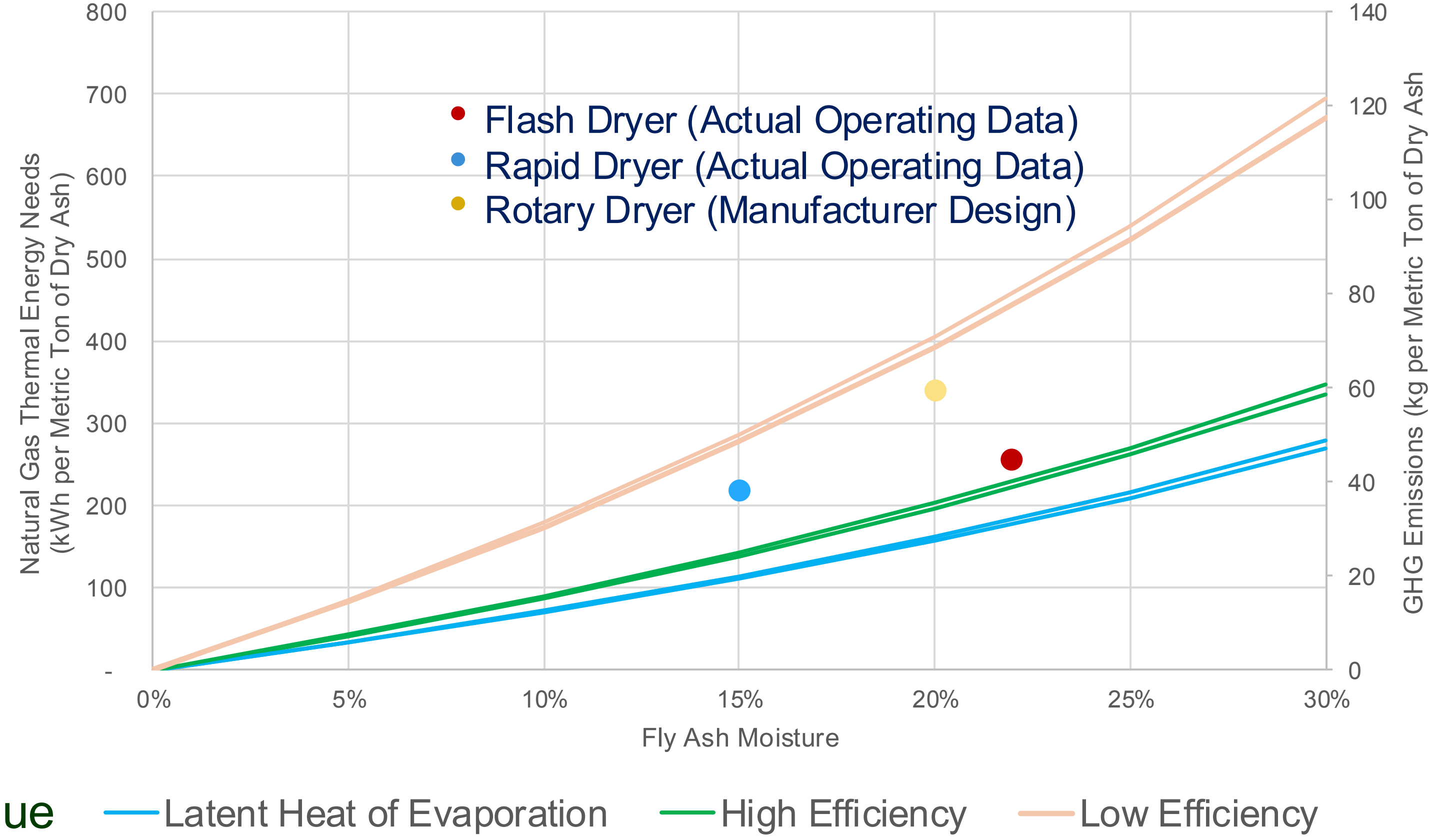
Drying Efficiency and GHG Emissions

Many drying options are available to process ash - from simple rotary to multi functional (drying & attrition)

- Capex & Opex are system specific and highly dependent on ancillary functions and scalability (some are modular)

In general terms,
A very high-efficiency gas dryer uses:
200 kwh per 1000 kg ash (20% w/w)

A BMW i7 uses:
200 kwh per 1000 km (2 full charges)
That's enough to drive from Paris to Prague

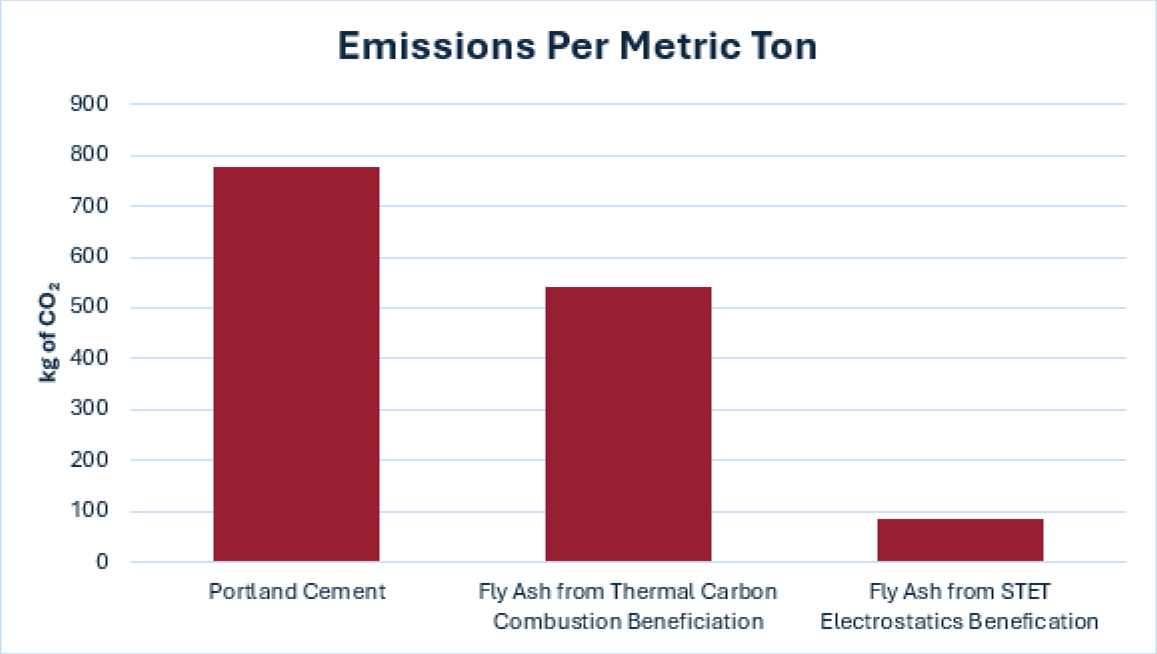


GHG emissions are based on US EPA factors for NG combustion: 0.181 kg CO_2 eq KWh

GHG Emissions relative to Portland cement

Carbon footprints:

- Electrostatic separation and classification add minor carbon footprint burdens
- Thermal activation of pozzolans (clay & shale) further increase the carbon footprint of SCM's
- Thermal combustion of unburn carbon in ash significantly increases the SCM carbon footprint



References: EPA & EPRI

ALL known & viable SCM production processes result in lower carbon footprint than portland cement

EP **Power Minerals**

“We will always be a strong partner for the concrete and cement industry – even when coal-fired power generation will have come to an end.”

Ljósmynd:
Þórir N.K.

Rafic Minkara, Ph.D., P.E.

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Thank you.