Ash beneficiation on a large scale

March 2025

Agenda

1. Introduction
2. Definition of scale
3. Disadvantages of scale
4. Advantages of scale
5. High value fields
6. Summary: The Ash utilization model

Introduction: What drives development?

Why?

The need (short term)

- Johnson & Johnson (vaccine)

The opportunity (medium term)

- Telsa (electric cars)

The intent (Medium-Long term)

- Space X (space exploration)

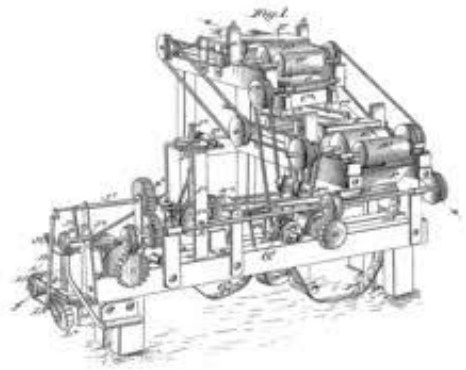
The Vision (long term)

- ABB (robotics)

How?

The Resources (people)
Knowledge and competency

The Assets
Quality of equipment impacts outcomes



The Time
Good research takes time

The Money
Knowledge is expensive

What?

Innovate
Creating new knowledge (IP & growth Strategy)

Grow
Develop new products, services, or processes (Increase Revenue)

Sustain
Improve existing ones (Stay competitive & reduce costs)

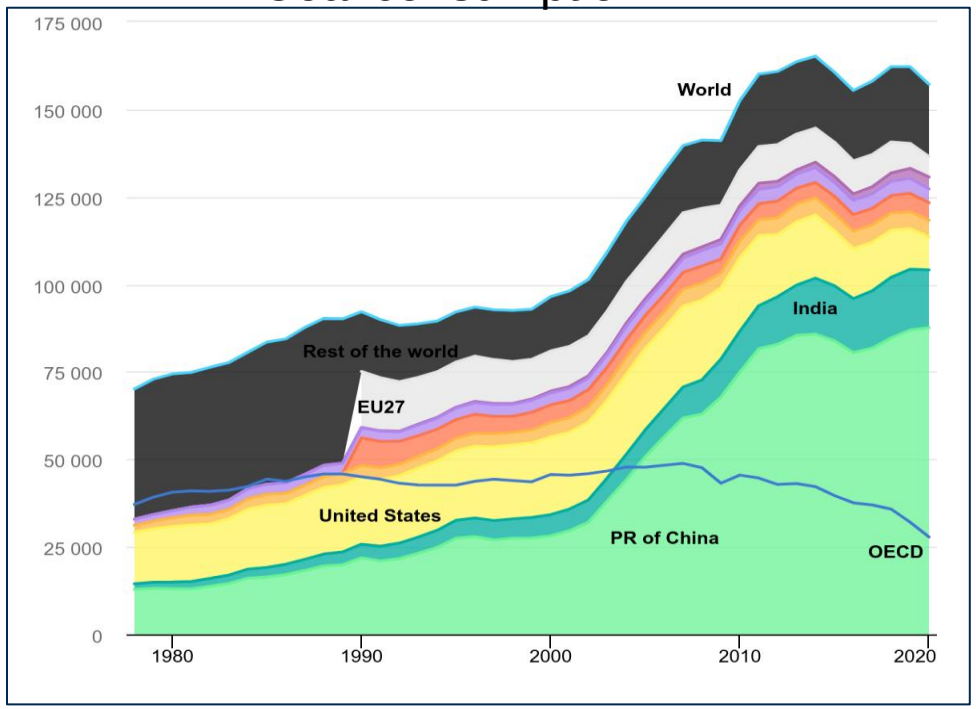
Who produces the most coal derived ash?

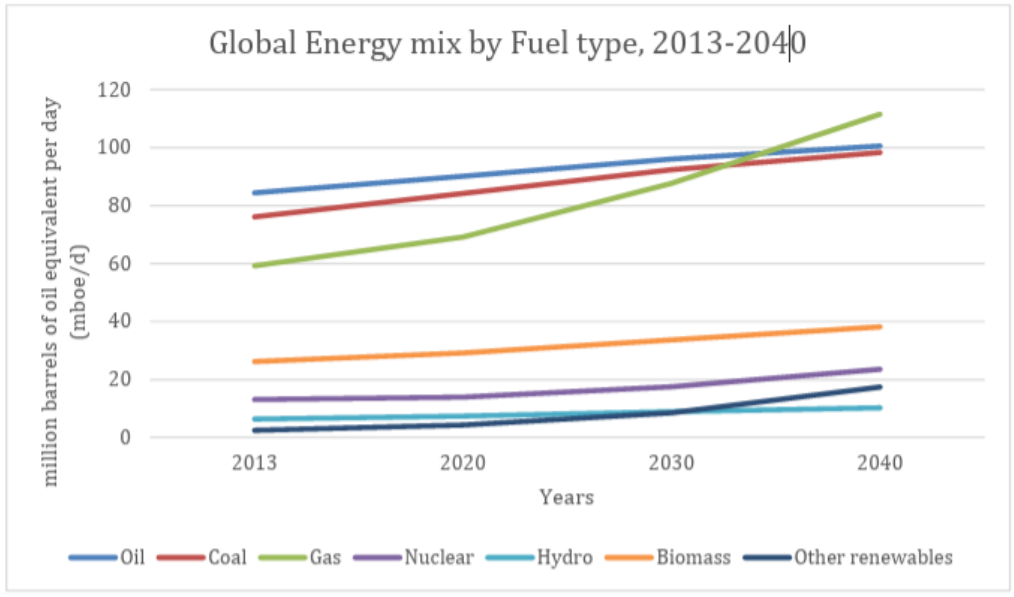
- China has the 4th largest coal reserves in the world

Coal Reserves

#	Country	Coal Reserves (tons) in 2016	World Share
1	United States	254,197,000,000	22.31%
2	Russia	176,770,840,800	15.51%
3	Australia	159,634,329,600	14.01%
4	China	149,818,259,000	13.15%
5	India	107,726,551,700	9.45%
6	Germany	39,802,209,480	3.49%
7	Ukraine	37,891,906,250	3.33%
8	South Africa	35,053,458,000	3.08%

Coal consumption





- Coal is expected to still be a significant energy source for the near future

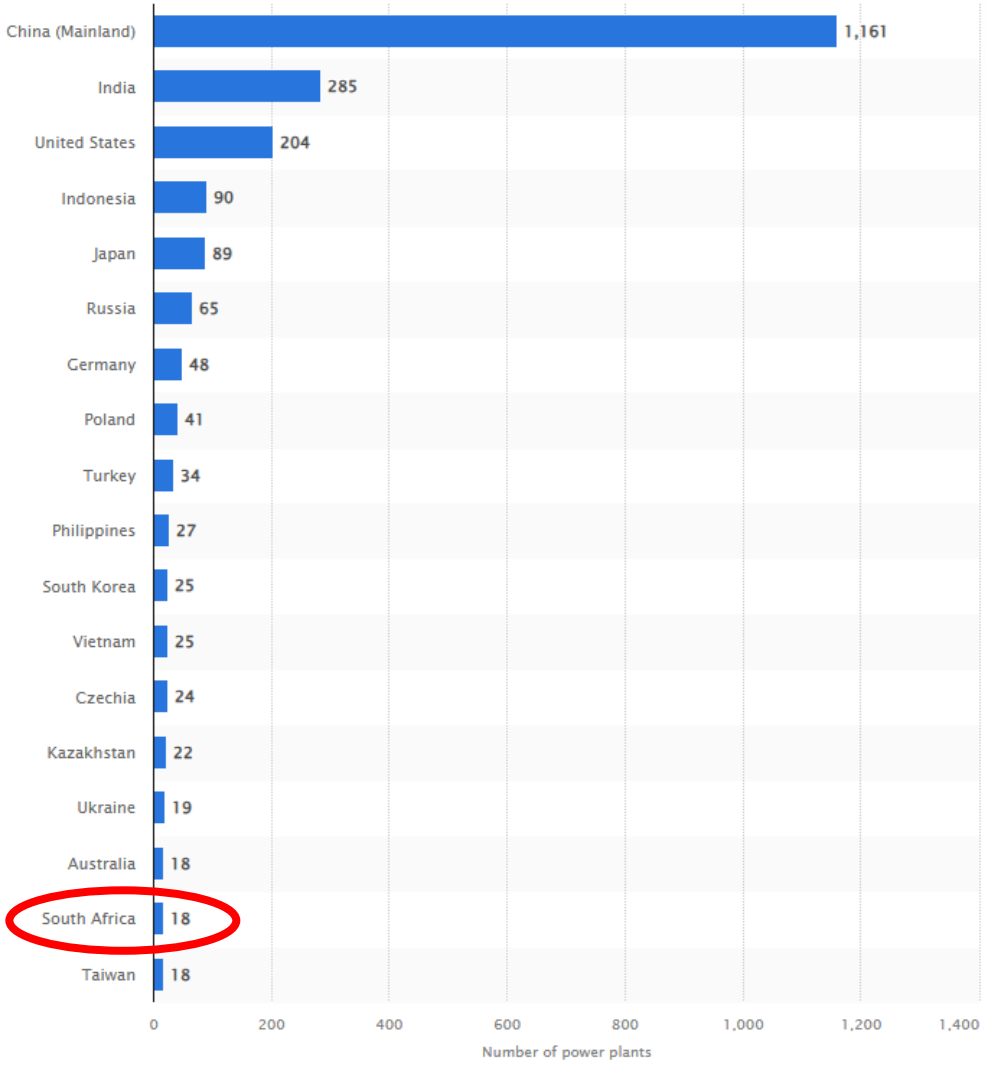
- China utilizes more coal than the rest of the world combined

[1] https://www.worldometers.info/coal/coal-reserves-by-country/#:~:text=Coal%20Reserves%20by%20Country%20%2D%20Worldometer,North%20Korea

[2] https://www.iea.org/data-and-statistics/charts/world-coal-consumption-1978-2020

[3] Organization of the Petroleum Exporting Countries, 2016. OPEC World Oil Outlook. October 2016. [Online] Available at: http://www.opec. org [Accessed 12 September 2024].

Definition of scale



- China has the greatest number of coal-fired power stations of any country or territory in the world. As of July 2024, there were 1,161 operational coal power plants on the Chinese Mainland [1].
- It's difficult to give a precise number of CTL (coal-to-liquids) plants in China. However, China has at least three large-scale coal-to-liquids (CTL) plants that utilize Fischer-Tropsch technology [2].
- China produces a large amount of coal ash, estimated at over 500 - 800 million tons annually [3], and its accumulated production exceeds **3 billion tons**. This significant volume is a result of China being the world's largest coal consumer, using it for over 60% of its energy needs [4].
- Most of this ash is coal fly ash (CFA) generated by coal-fired power plants [4].

[1] https://www.statista.com/statistics/859266/number-of-coal-power-plants-by-country/#:~:text=China%20has%20the%20greatest%20number,total%20global%20coal%20electricity%20generation.

[2]https://www.sciencedirect.com/science/article/abs/pii/S0957582022001835#:~:text=Coal%20combustion%20has%20generated%20large,et%20al.%2C%202021).

[3] chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/http://www.cityu.edu.hk/phy/appkchu/Publications/2021/21.48.pdf

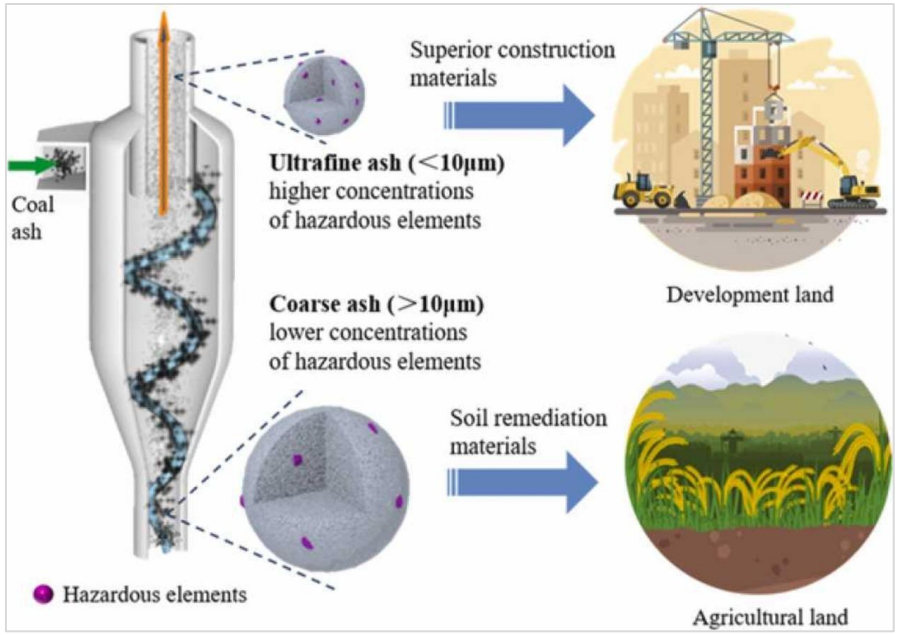
[4] https://www.frontiersin.org/journals/environmental-science/articles/10.3389/fenvs.2022.887837/full

Disadvantages of scale: The need

- Firstly, large areas of land are occupied for the storage of coal ash [1].
  - While specific figures on the total area covered by coal ash in China are difficult to pinpoint, estimates suggest that 3.3 to 41.7 thousand hectares of land are occupied by fly ash, indicating a considerable land footprint [2].
  - For context, the Sasol Secunda industrial complex site is 17.371 thousand hectares in total
- Secondly, there are certain amounts of hazardous elements (HEs) such as: As, Cd, Cr, Hg, Pb, etc. in coal ashupon contact with water and if there is no barrier, may leach into the ground [1].
- Thirdly, the dry coal ash is prone to drift with wind and pollute the air [2].

[1] https://www.sciencedirect.com/science/article/abs/pii/S0957582022001835#:~:text=full%2Dsize%20image-,Introduction,the%20storage%20of%20coal%20ash.
[2] https://www.sciencedirect.com/science/article/abs/pii/S1364032115017281
[3] https://en.wikipedia.org/wiki/Secunda,_South_Africa
[4] https://www.anz.veolia.com/services/recycling-waste-services/hazardous-waste/solid-hazardous-waste/dust-fly-ash
[5] https://www.nationalgeographic.com/science/article/110815-safer-ways-to-reycle-fly-ash-from-coal

Advantages of scale: Utilization



A. Building materials production, including cement, fly ash bricks, fly ash ceramic and fly ash blocks;

B. Building works, including produces concrete, mortar, etc.;

C. Road construction, including the embankment, pavement base and pavement;

D. Backfill, including the structure backfill, construction backfill, filling in low-lying area and wasteland, filling with mines, coal mining subsidence area, building materials factory to take pits, tidal marsh, etc.;

E. Agriculture field application, including soil improvement, compound fertilizers production and land reclamation;

F. Recycling useful raw materials, including hollow microsphere, Al_2O_3, Fe_2O_3, SiO_2, carbon granules, etc.

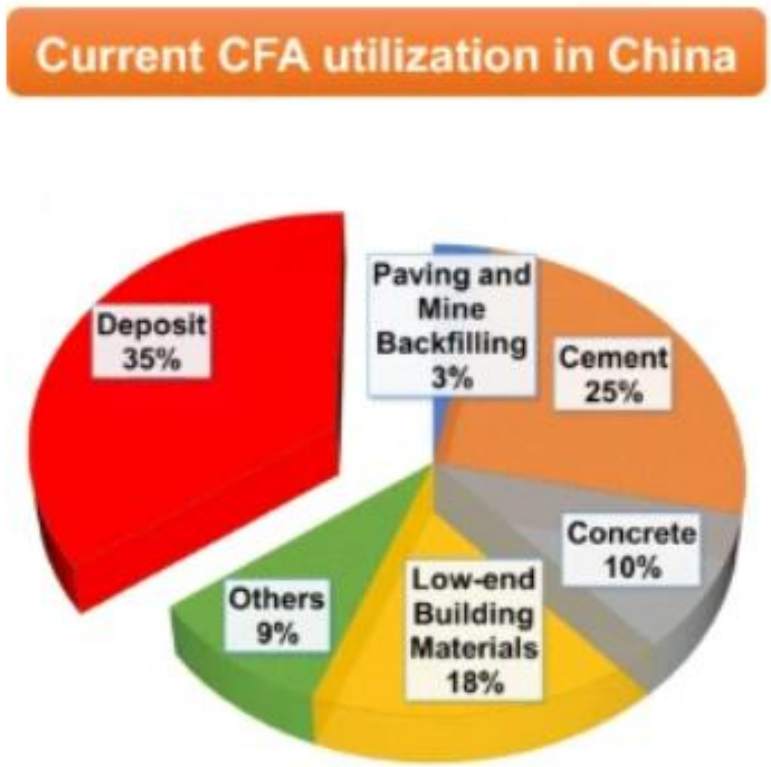
[1] https://www.sciencedirect.com/science/article/abs/pii/S0957582022001835#:~:text=full%2Dsize%20image-,Introduction,the%20storage%20of%20coal%20ash.
[2] https://daswell.com/blogs/fly-ash-properties-source-advantages-uses/

Incentive based motivation

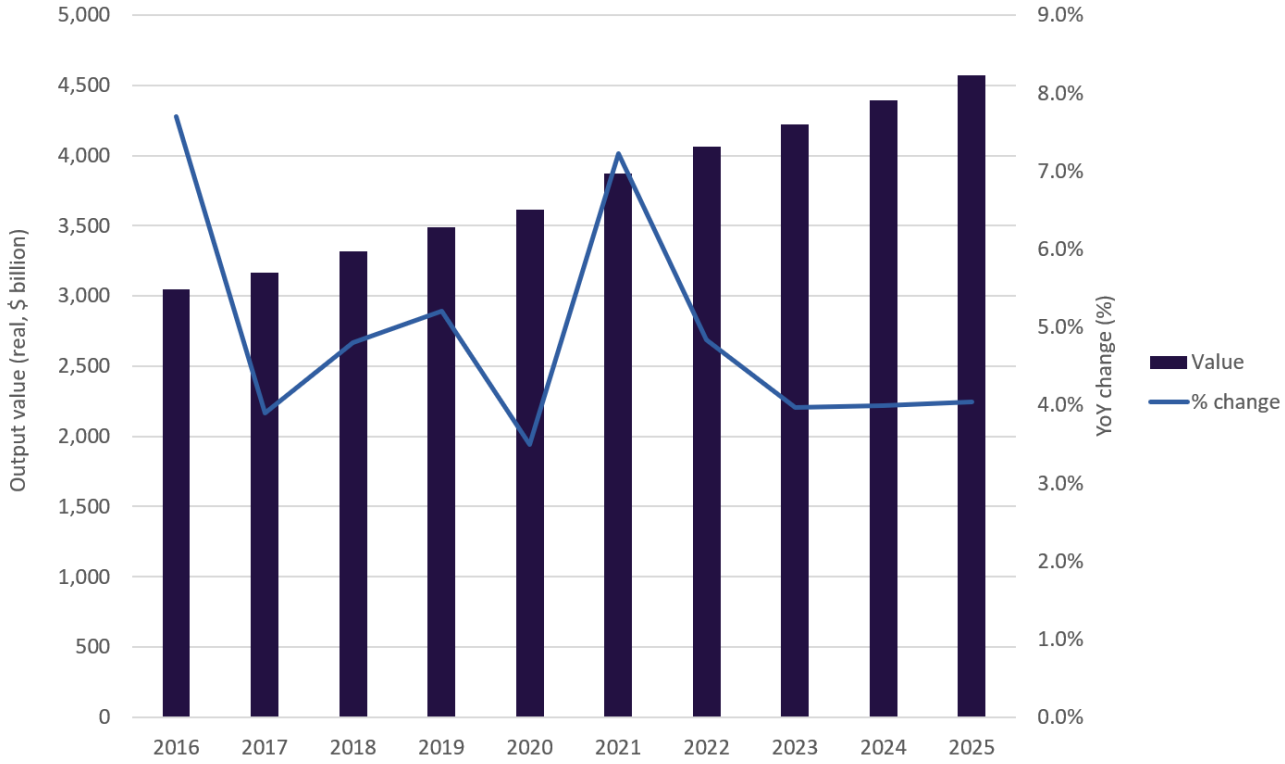
- China has established the guideline “based on usage” clearly for fly ash and introduced a series of preferential measures, such as funding or tax breaks for projects using fly ash.
- “Management Measures for Comprehensive Utilization of Fly Ash”
  - National Development and Reform Commission takes charged in the organization, coordination, supervision and inspection of fly ash comprehensive utilization in China, and the relevant departments under the state council provide assistances within their own mandates.
- “Major Industrial Solid Waste Comprehensive Utilization”
  - To achieve the target of comprehensive utilization rate of 70%
- Legal and Regulatory Review
  - Designed to facilitate and removed regulatory huddles (within standards) to beneficiation

- Proximity of producer and end user
- Demand of specific products
- Rate of development of specific area
- Slower development due to Environmental considerations

Demand and Utilization relationship



- China has highest average CFA utilization of 65%
  - 39% in the US and 47% in Europe
  - global average is estimated to be close to 25%
- ca. 80% of that utilization goes into constructed related materials
- There has been improvement in the utilization of CFA into high value fields in the last 5 years (improving from 3% to 9% utilization



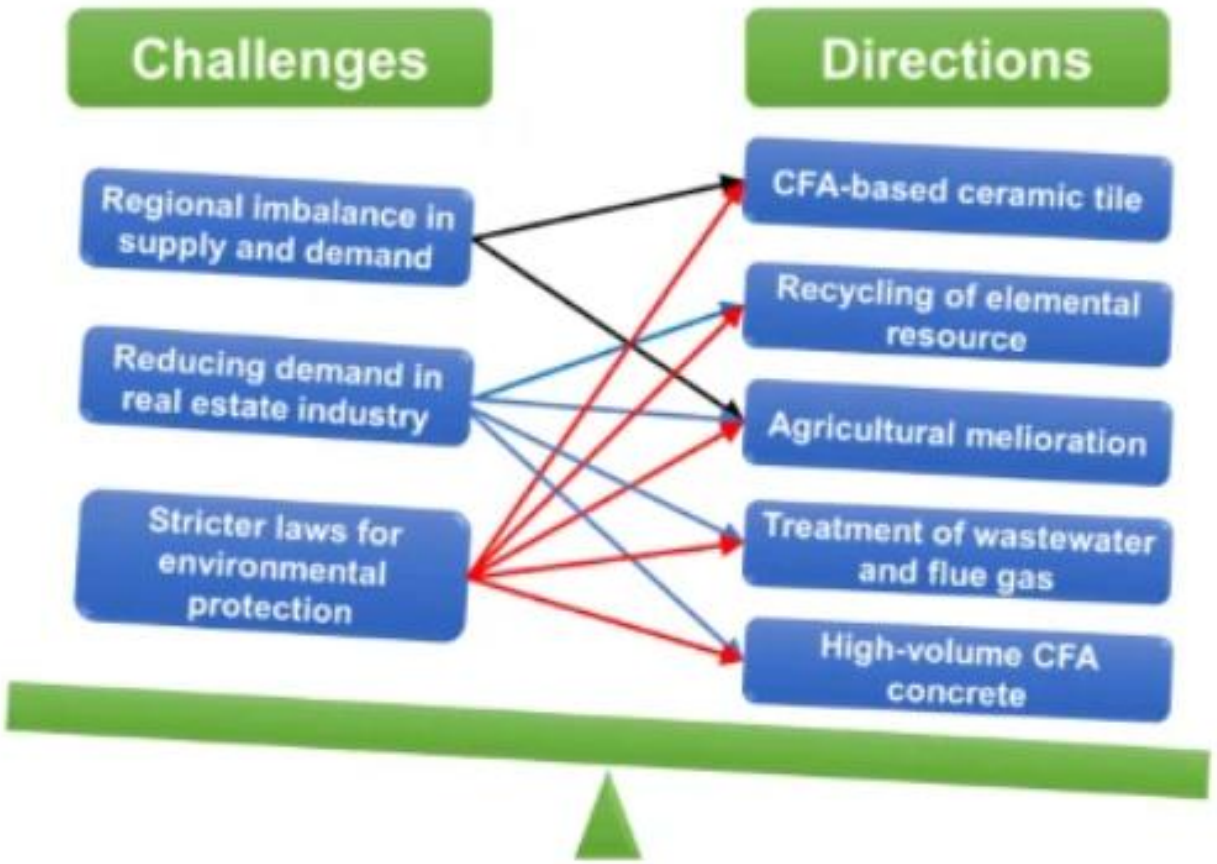
- China has the highest infrastructure growth in the world
- However, while the demand of construction material is still high, the growth rate (year on year) has stabilized in the last three years.

[1] https://link.springer.com/article/10.1007/s11356-020-08864-4#:~:text=CFA%20is%20the%20major%20solid,the%20urgent%20issues%20in%20China.

[2] https://www.globaldata.com/data-insights/construction/chinas-construction-industry-set-to-grow-by-7-in-real-terms-in-2021/

[3] https://www.sciencedirect.com/science/article/abs/pii/S0016236112002335

Balancing the Utilization to support environment



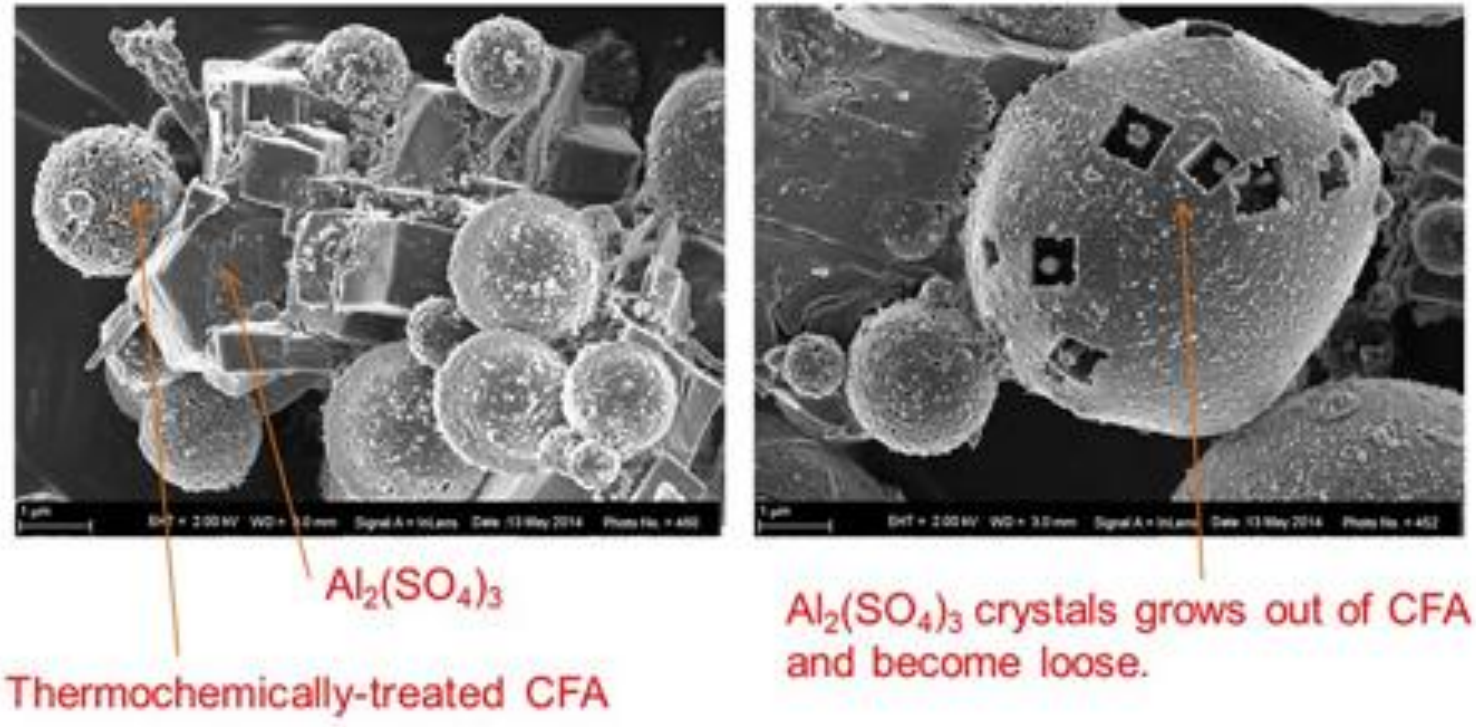
- Regional imbalance in supply and demand
- Reducing demand in the real estate industry
- Stricter laws for environmental protection

- The Utilization of CFA into the construction space will remain the highest utilization mode in China for the next 10 years
- Environmental laws are driving the utilization of CFA into carbon capture and waste treatment industries
- High value utilization of CFA increasing year-on-year and currently makes up ca. 10% of Utilization.
- China is focusing on reduction of dependency on imports, for example Alumina extraction from CFA as a substitute for bauxite imports.

[1] https://link.springer.com/article/10.1007/s11356-020-08864-4#:~:text=CFA%20is%20the%20major%20solid,the%20urgent%20issues%20in%20China.

Advantages of Scale: High-value fields

- A raw material for alumina extraction
  - It is estimated that only 10% of China's fly ash contains more than 30% alumina and is otherwise a scarce alternative of bauxite
  - Acid leaching process is commonly used - high recovery rates (over 80%) however lower quality due to other impurities such as iron oxide and calcium oxide, etc., which are difficult to remove during the leaching process
  - High-value elements (Li, Ga, Ge, rare earth elements, etc.) can be extracted from coal ash [2], making it an attractive mineral resource.



[1] https://www.researchgate.net/publication/285851228_Current_status_and_prospect_of_fly_ash_Utilization_in_China
[2] chromeextension://efaidnbmnnnibpcajpcglclefindmkaj/https://uknowledge.uky.edu/cgi/viewcontent.cgi?article=1675&context=woca#:~:text=Aluminum%20extraction%20from%20coal%20fly,2SO4)%20combined%20to%20aqueous%20leaching.

Advantages of Scale: High-value fields

- Production of inorganic fiber
  - Fly ash is heated to a high temperature of ~1600°C to be molten. Then the melting magma is cooled by high-pressure energetic gas in the vertical direction of magma flow. Thus, an ultrafine fiber with a 3-6μm diameter is produced
  - Used as an advanced heat insulating material and flame-resistant wall materials since there is no organic matter in the fiber product
  - Applications in paper manufacturing industry, and as fillers in the rubber or plastic industry

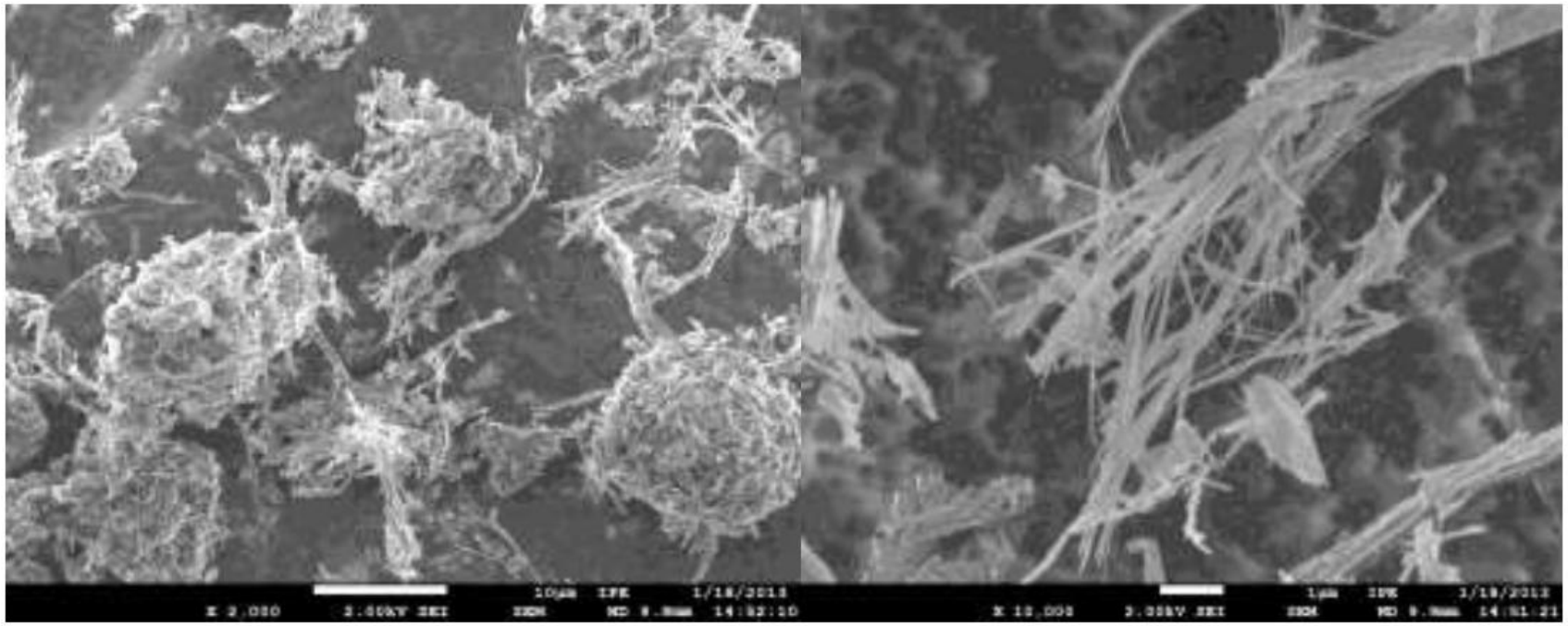
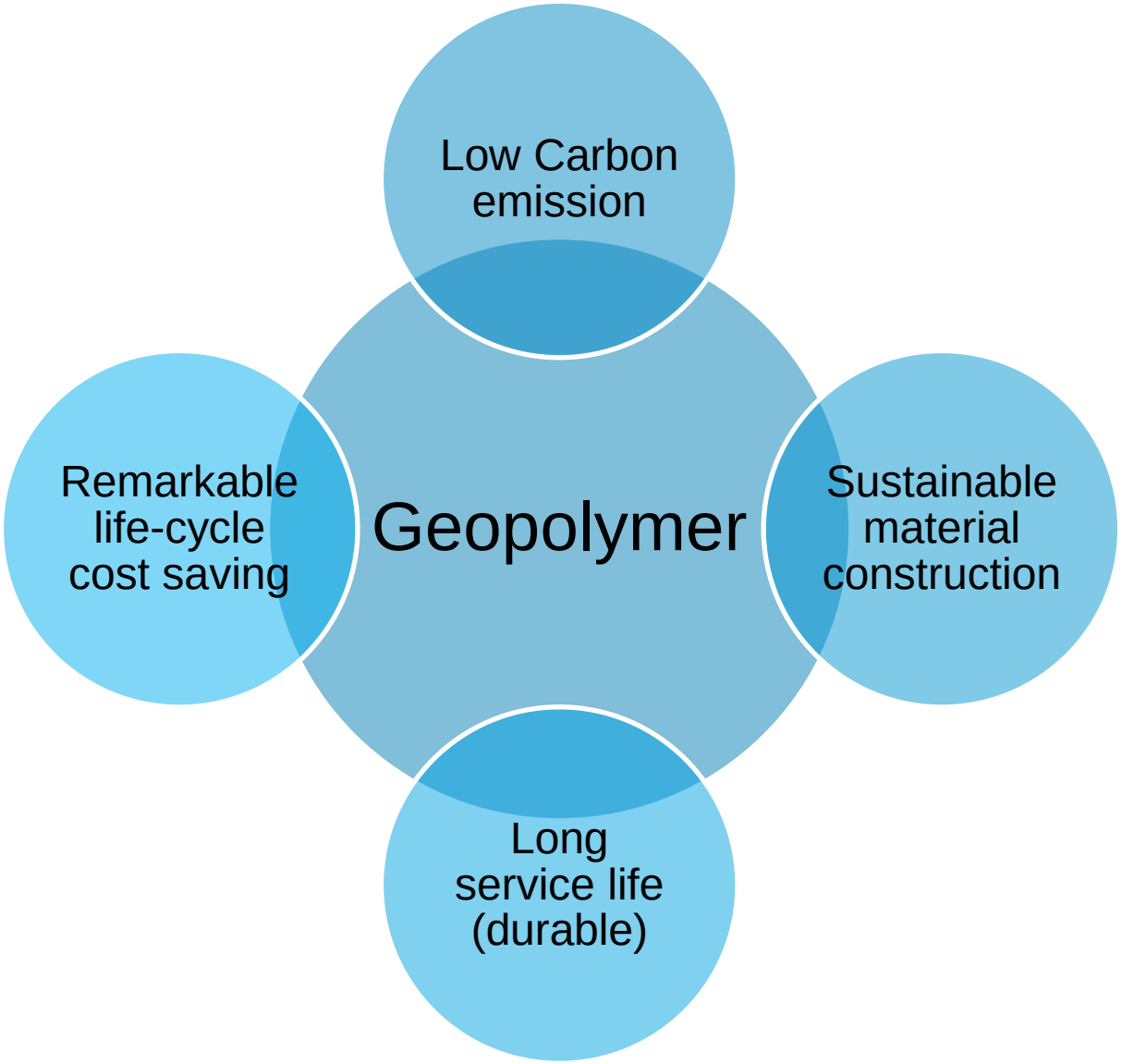


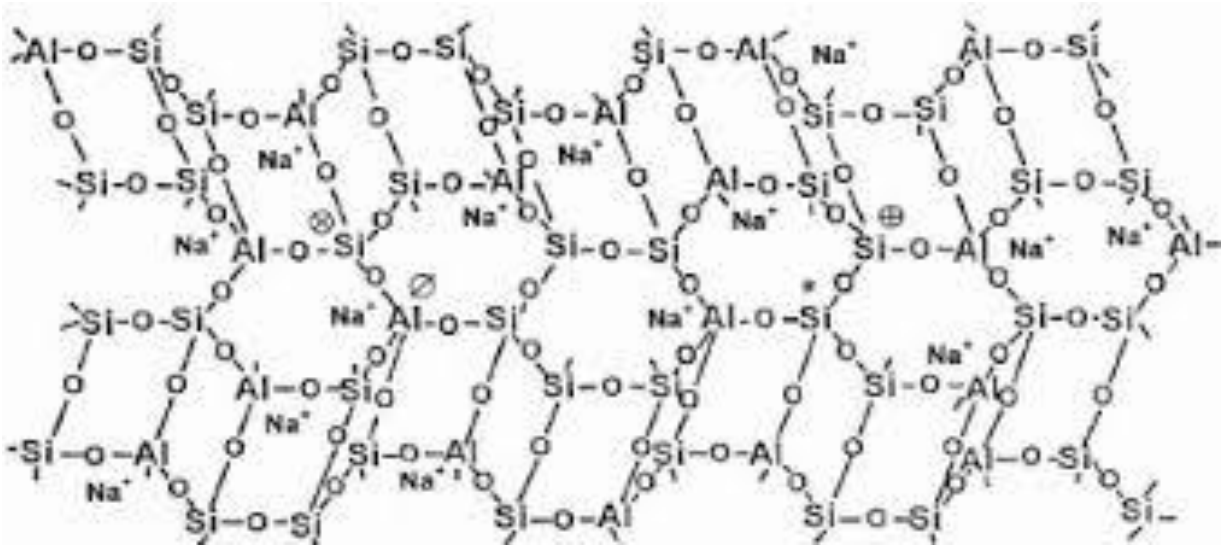
Fig. 3 SEM of produced inorganic fiber

[1] https://www.researchgate.net/publication/285851228_Current_status_and_prospect_of_fly_ash_Utilization_in_China

Advantages of Scale: High-value fields



- Production of geopolymer
- Inorganic compounds containing AlO_4 and SiO_2 connected each other in a hollow net structure.
- The polymer has excellent absorption capacities for almost all toxic metal ions, low energy consumption, and carbon dioxide emission, etc.
- Treatment applications of hazardous water and gas



[1] https://www.researchgate.net/publication/285851228_Current_status_and_prospect_of_fly_ash_Utilization_in_China

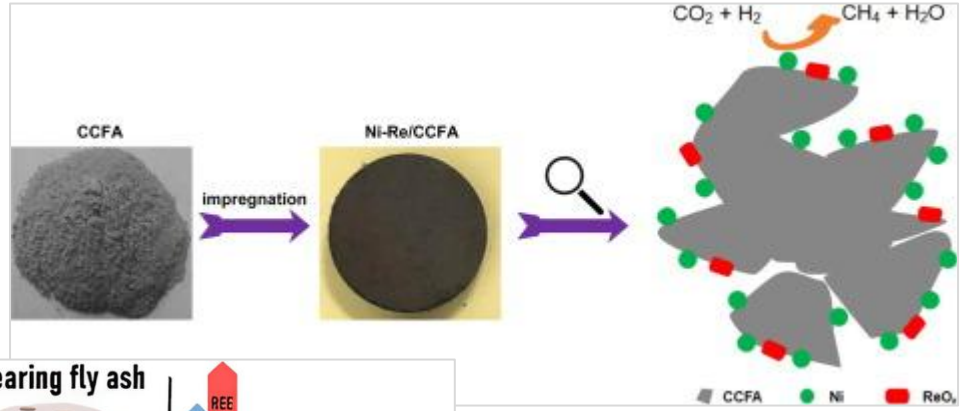
Advantages of Scale: High-value fields

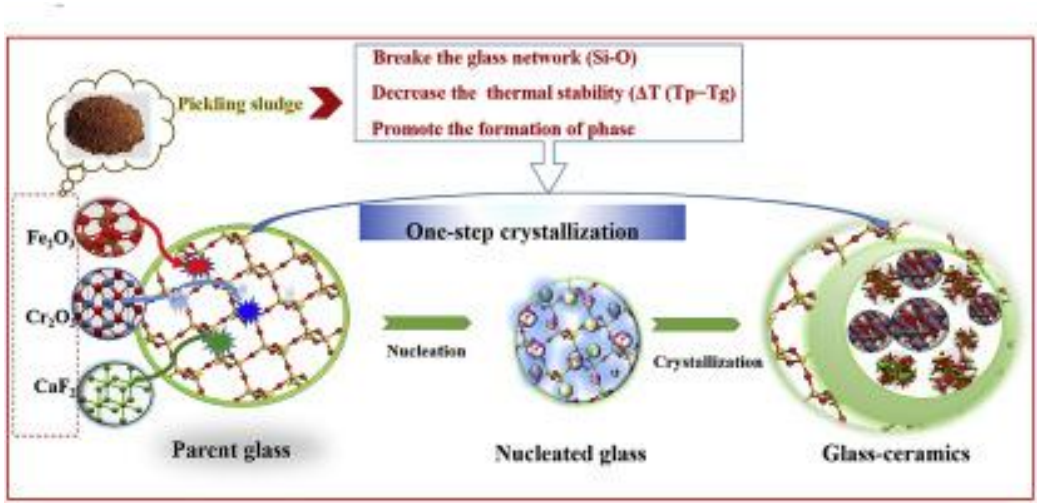
1. Manufacture of glass and ceramics,

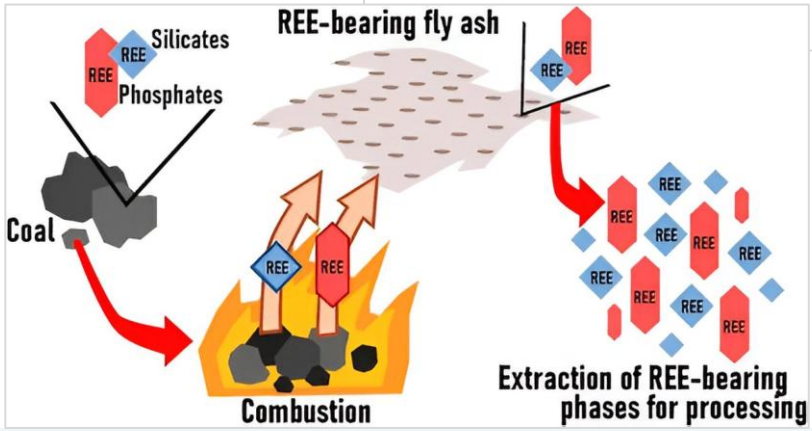
2. The production of zeolites,

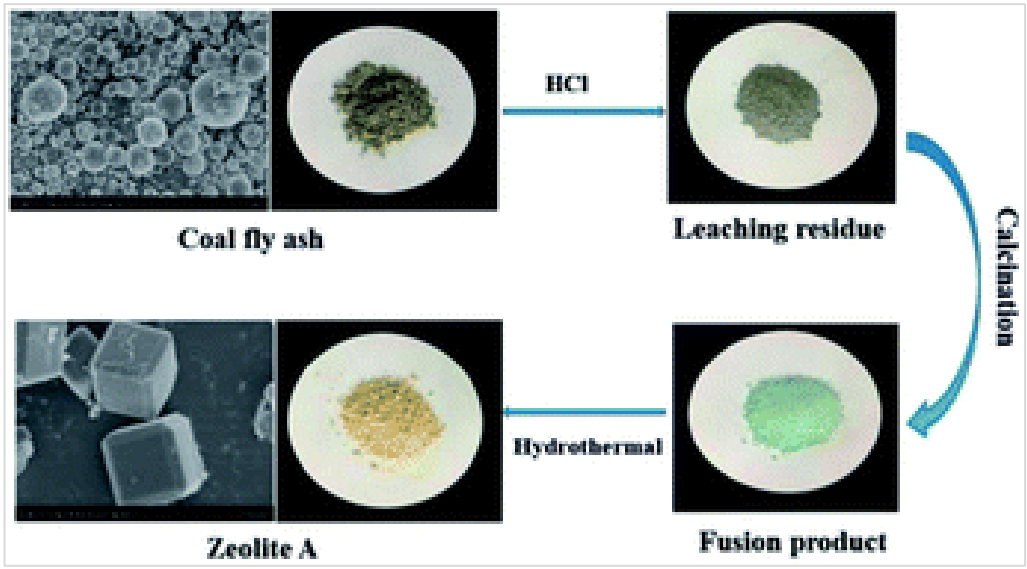
3. Use as catalysts and catalyst supports,

4. The extraction of metals.









Summary