

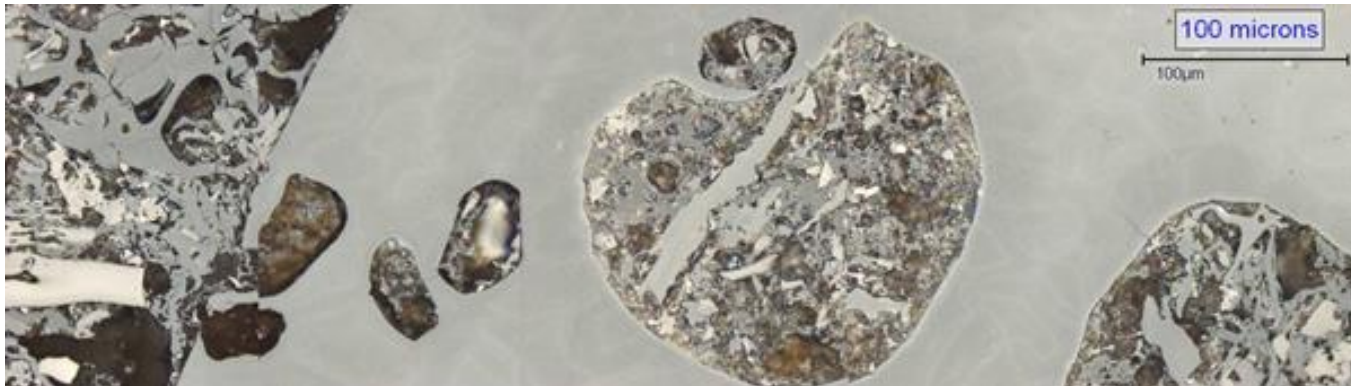
# THE SIGNIFICANCE OF COAL BEYOND ELECTRICITY GENERATION

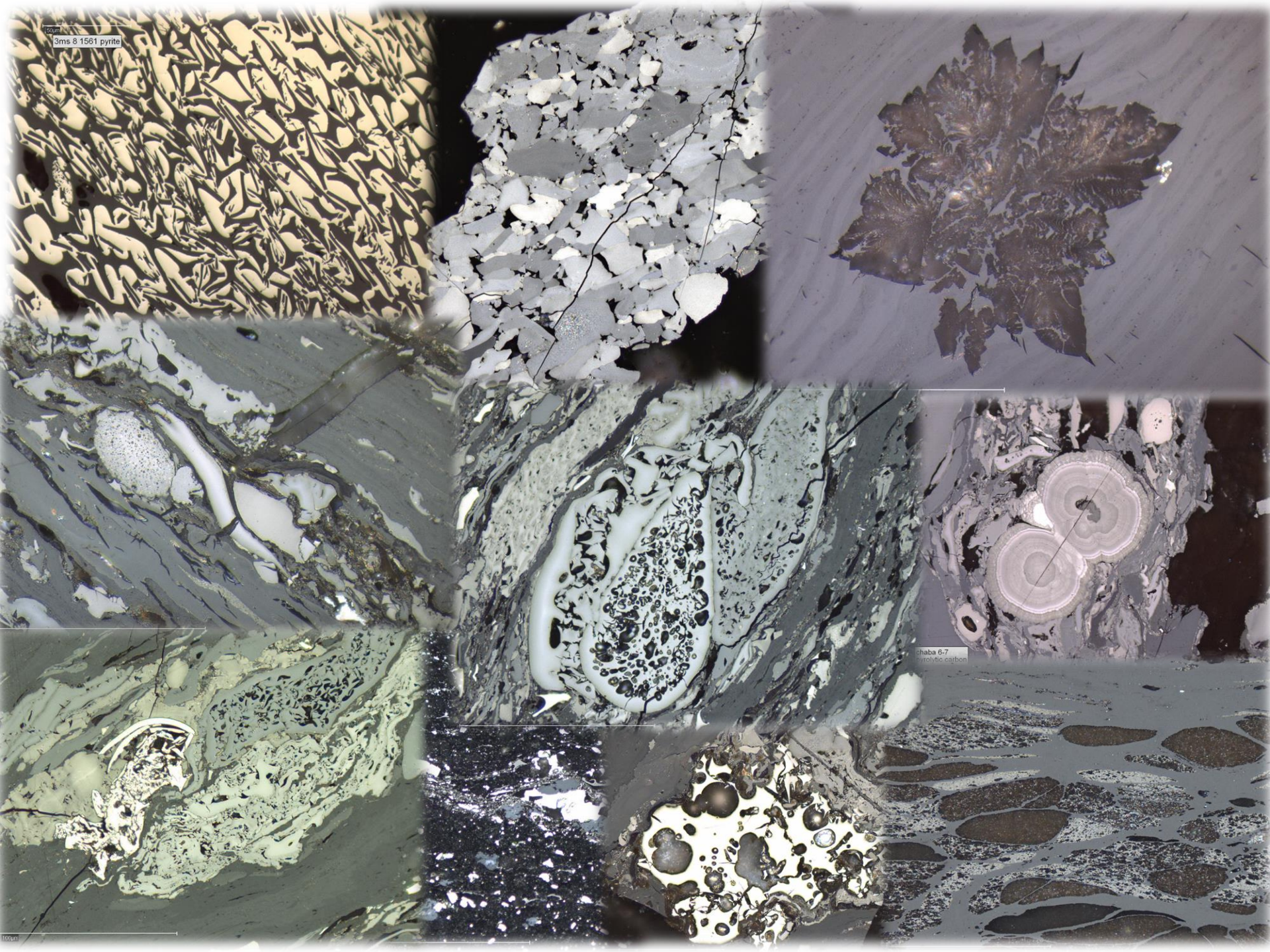
FFF Carbon Conference, Middelburg  
1 April 2022

Prof Nikki Wagner  
[nwagner@uj.ac.za](mailto:nwagner@uj.ac.za)

**cimera**

DSI-NRF Centre of Excellence for  
Integrated Mineral and Energy Resource Analysis





3ms 8 1561 pyrite

pyrolytic carbon

# OVERVIEW

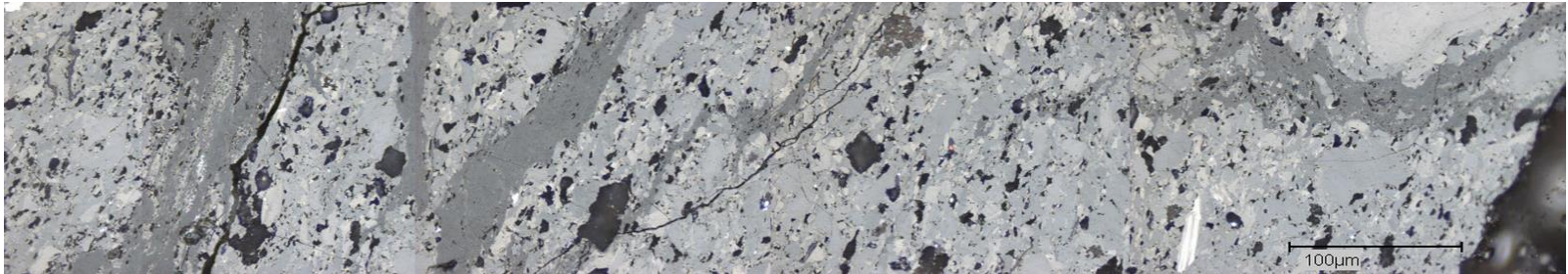
- Understanding coal
- Coal and global significance
- The significance beyond electricity generation

Coal is critical to our world, through its use in providing much-needed affordable electricity and also in building our societies through its use in steel and cement. 37% of the world's electricity and over 70% of the world's steel is produced using coal (World Coal Association, 2020)

Coal plays a significant role in the construction of renewable energy infrastructure and supporting these fuels on the grid.

AS A SOCIETY, WE NEED TO ENSURE THE SUSTAINABLE, ENVIRONMENTALLY RESPONSIBLE USE OF COAL. AND THIS BEGINS BY UNDERSTANDING THE GEOLOGICAL RESOURCE

# COAL: “that dirty black stuff”?



“mineral of fossilized carbon”

combustible sedimentary rock containing >50% by weight and +>70% by volume carbonaceous material formed from compaction of variously altered plant remains.

Composed of carbon, with variable hydrogen, sulphur, oxygen, nitrogen, and many other elements.

Rocks are comprised on mineral assemblages.

Coal is comprised of organic and inorganic (mineral) assemblages.

Organic building blocks are termed **macerals**.



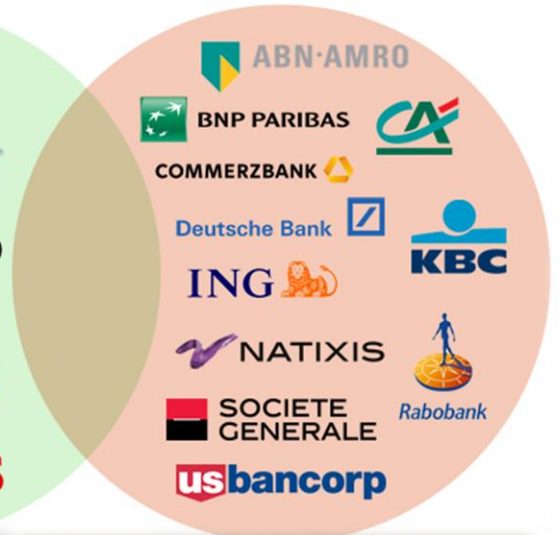
**ANTI  
COAL  
MINING**

**COAL = POISON**



Banks supporting UNEP-FI initiative on climate transparency

Banks not financing new coal mining or power projects



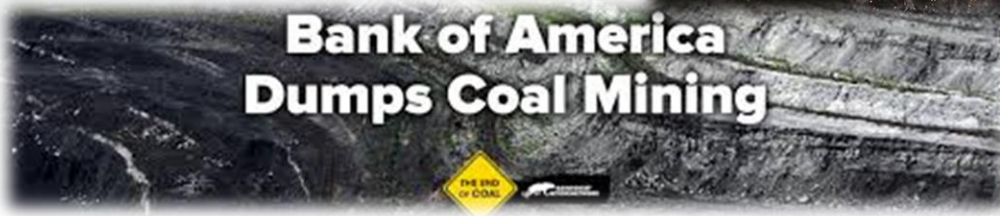
**COAL IS NOT  
OUR FUTURE**

#KEEPITINTHEGROUND

SINCE 2016  
THE BIG BANKS HAVE LOANED  
**\$35.5 BILLION**  
TO DIRTY FOSSIL FUELS  
FUELING THE CLIMATE CRISIS



**Bank of America  
Dumps Coal Mining**



# Understanding coal ...

- Geologist: how did coal form? (coal diagenesis)
- Geologist: where is coal? (coal exploration)
- Mining engineers: how can the coal be extracted? (mining)
- Process engineers: : how can the coal quality be upgraded? (beneficiation)
- Chemical engineers: how can the energy and carbon be harnessed?(conversion & advanced applications)
- Metallurgists: how can the properties be manipulated for ore reduction? (coking and reductant properties)
- Mineralogist: what can be recovered from coal discard and ash? (ash properties)
- Mechanical Engineers: how to improve efficiencies? (CCT)
- Environmentalist: what are the pollutants? (CCT)
- Accountants / CFO's / COO's: how can we make more money? (coal-value chain)
- Civil society: do we understand coal? (CCT, advanced applications)

**ORGANIC PETROLOGY FINDS RELEVANCE IN GEOLOGY, METALLURGY, CHEMICAL ENGINEERING, COAL SUSTAINABILITY ACROSS THE COAL VALUE-CHAIN**

# Basic understanding of coal ....

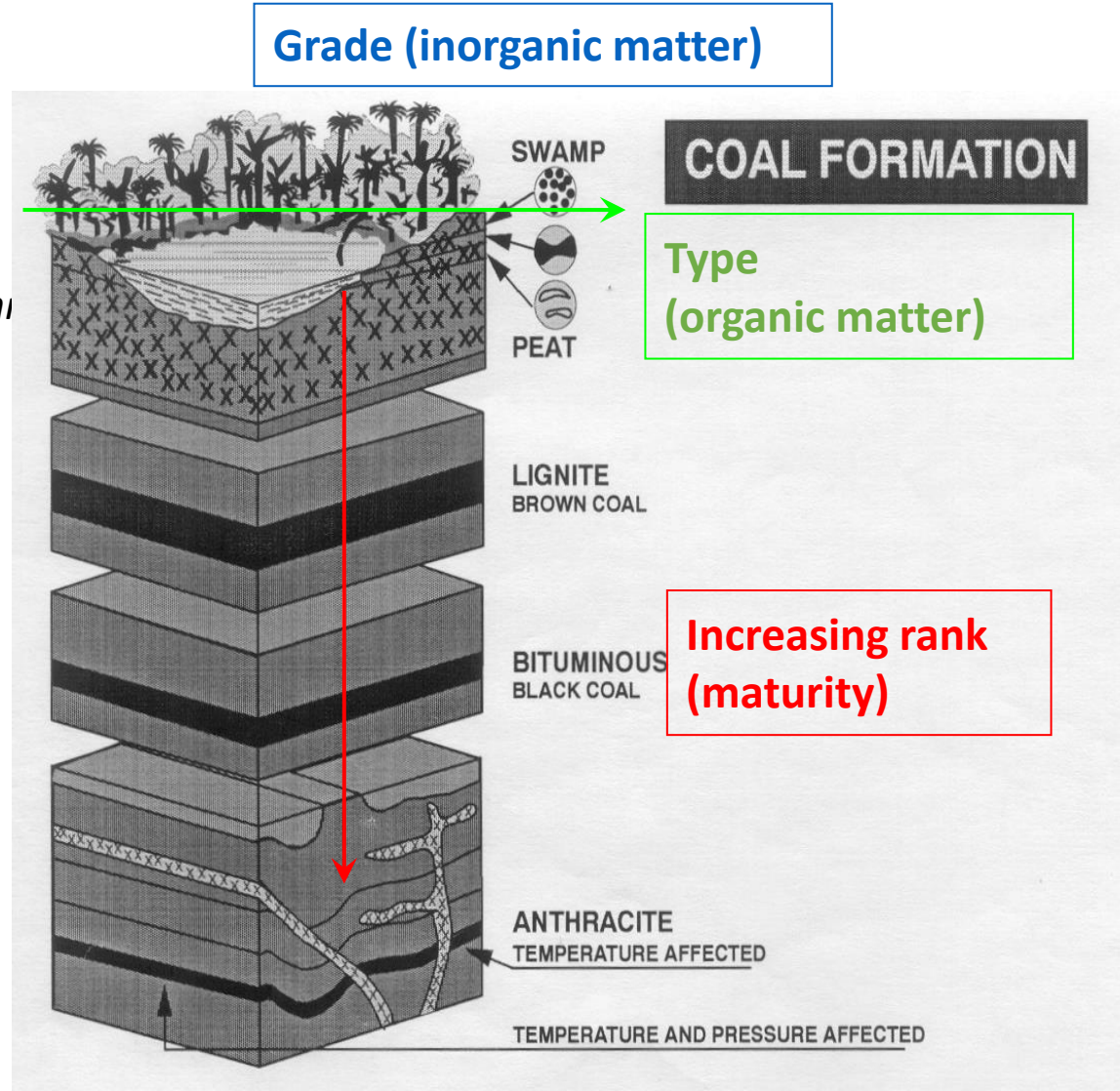
## **Petrographic aspects**

- **Type** - lithotypes / macerals
- **Grade** – minerals / ash
- **Rank** – maturity (lignite, bituminous, bituminous, anthracite)
- **Condition** – weathering / oxidation

## **Chemical aspects**

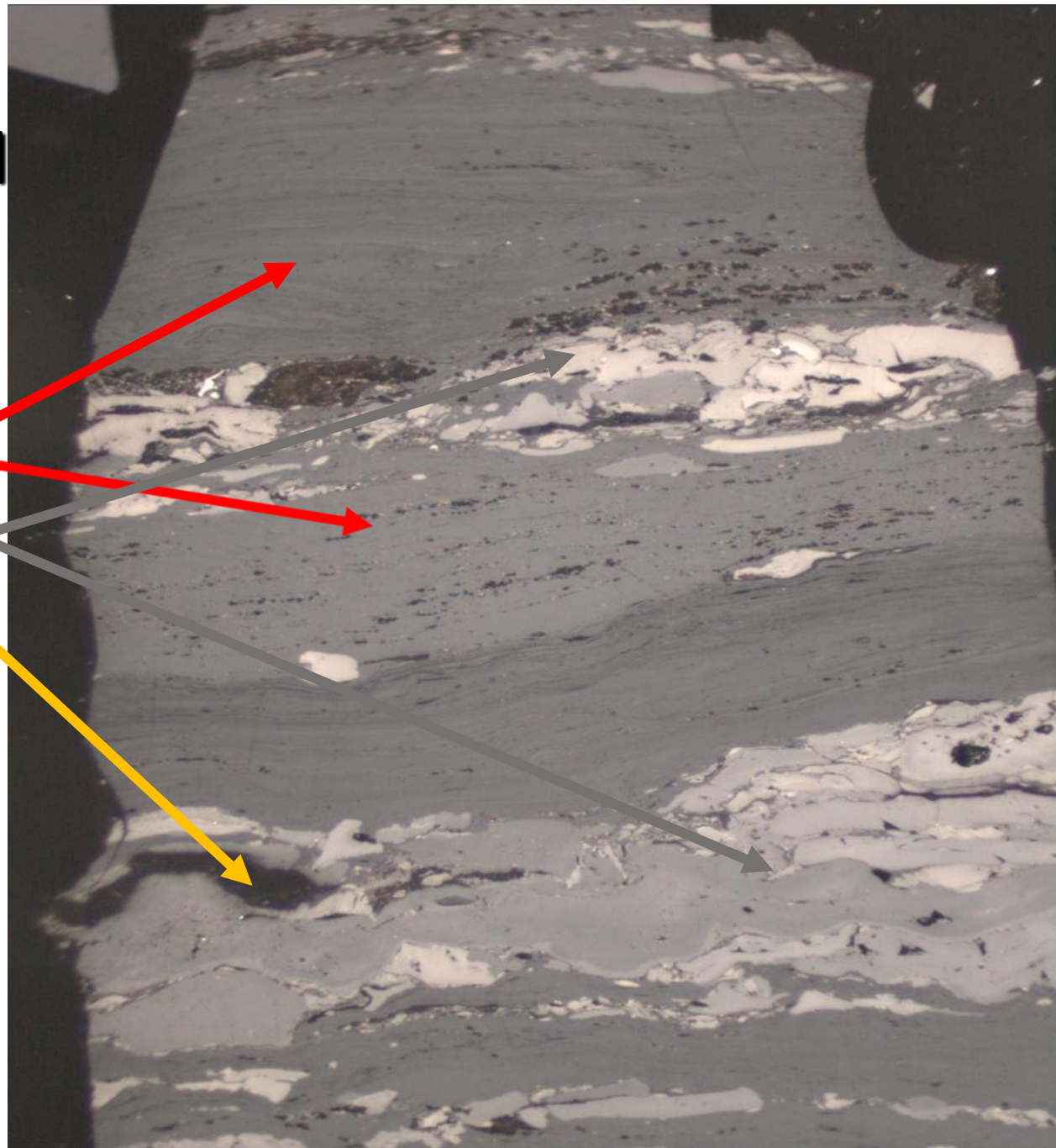
- Proximate analysis
- Ultimate analysis
- CV
- Ash oxide

## **Mineralogy**



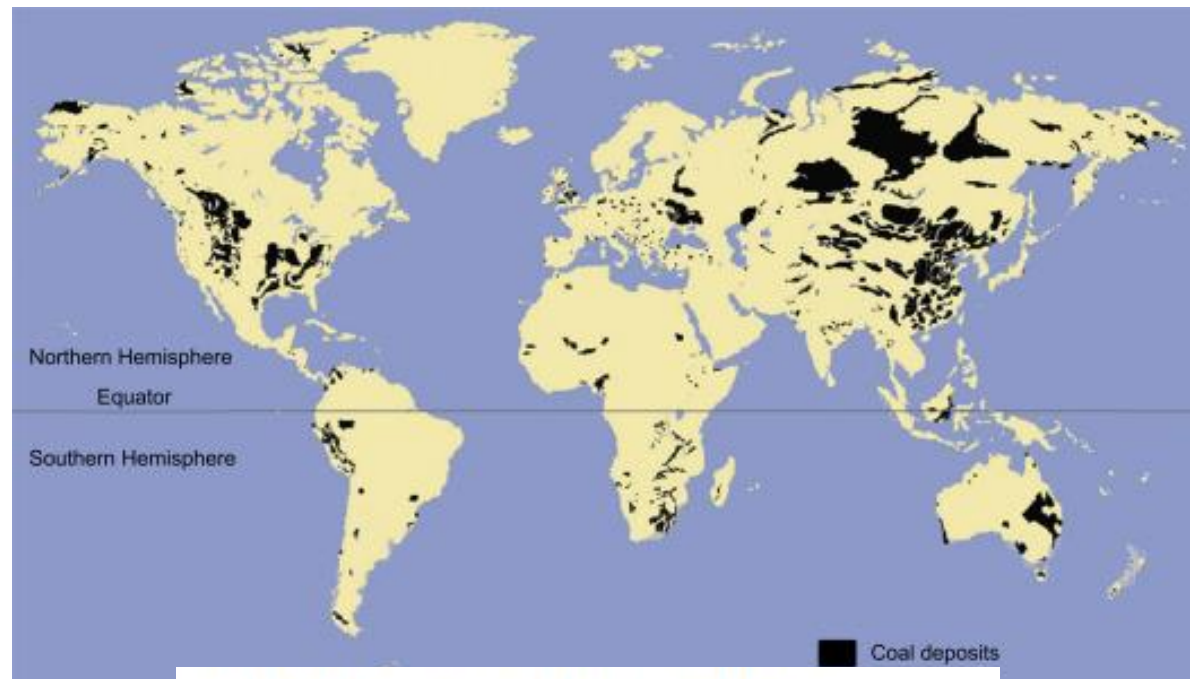
# Three Main Organic Maceral Groups

- Vitrinite group
- Inertinite group
- Liptinite group





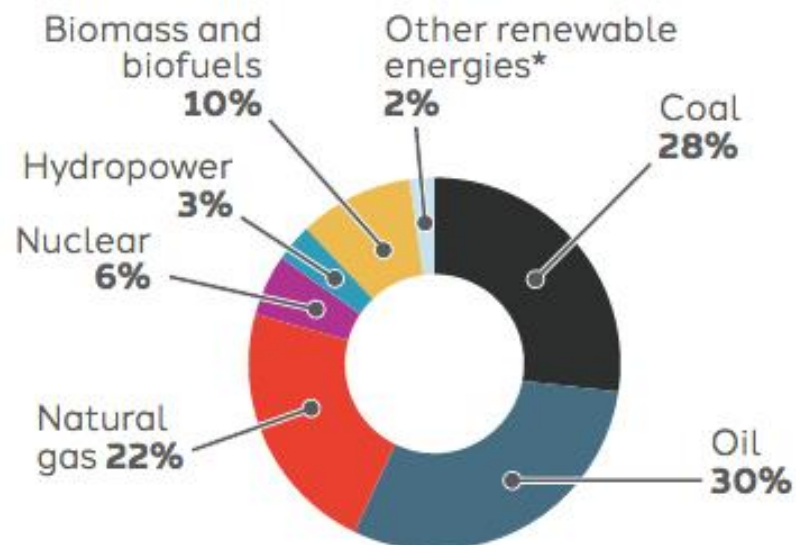
# GLOBAL SIGNIFICANCE



- 1.06 trillion tonnes of proven coal reserves worldwide (World Coal Association)
- Equates to close to **132 years** of future supply at current rates of production
- Distributed more evenly than other fossil fuels
- Accounts for 28% of global primary energy

## Global Energy Mix in 2020

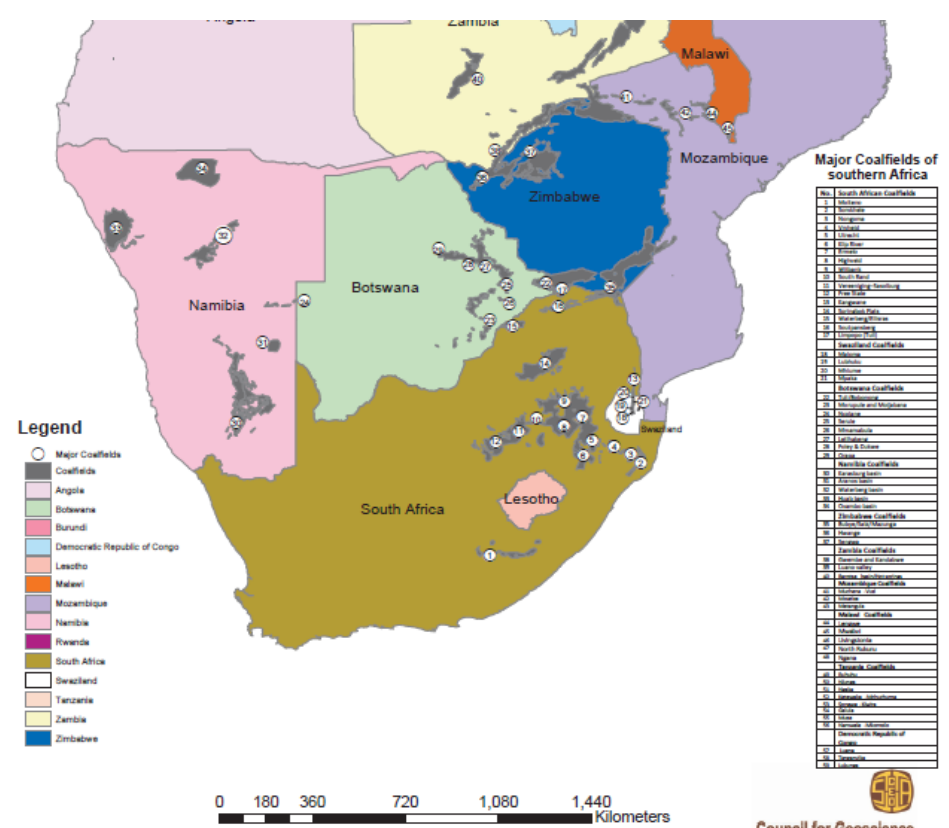
(source International Energy Agency)



# SA COAL FACTS

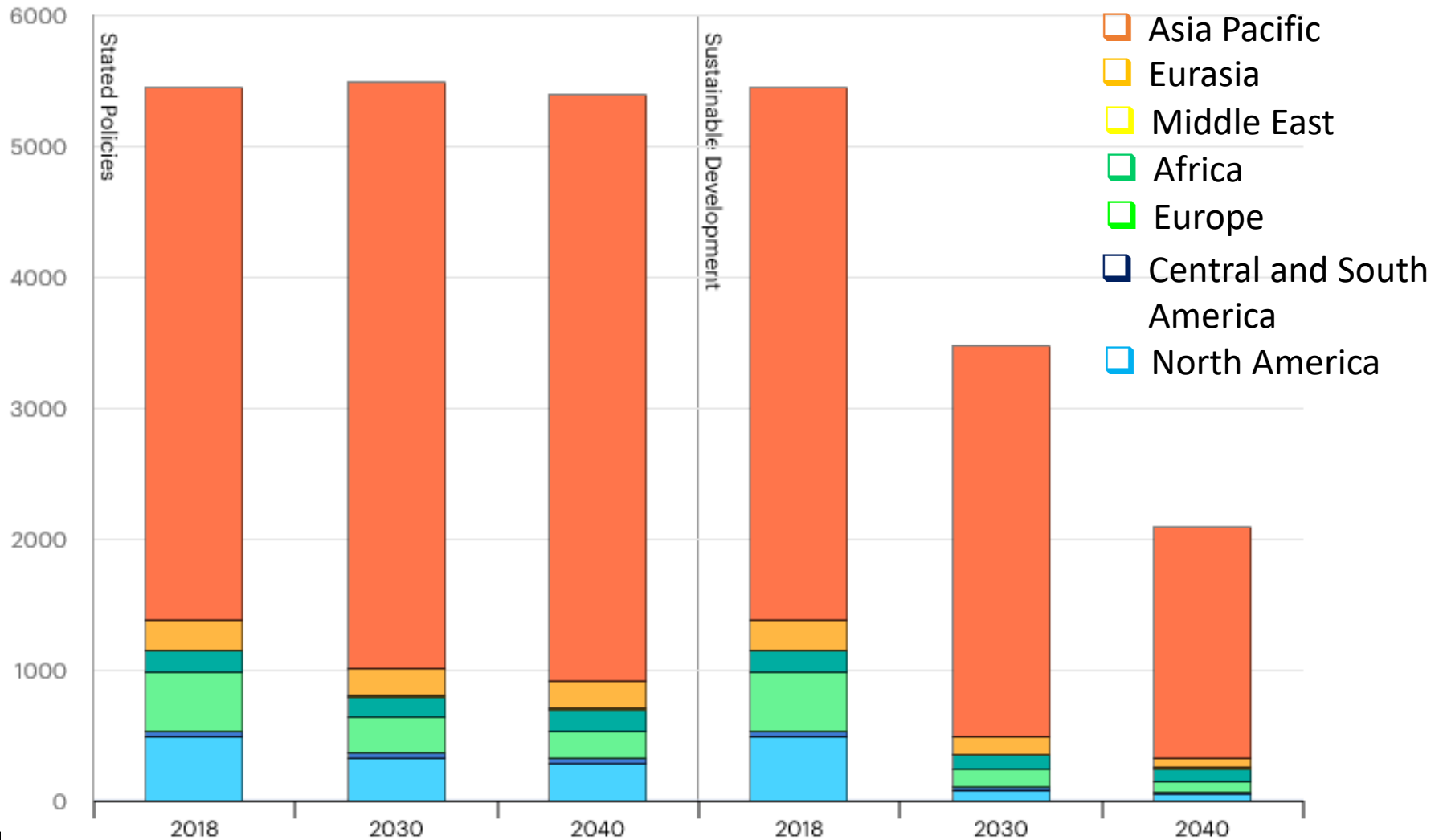
- South Africa is the
- 7th largest producer of coal
- 5th largest exporter of coal
- 8% of world coal reserves

- Coal in South Africa accounts for
- 1<sup>st</sup> / 2<sup>nd</sup> highest foreign exchange earnings in the country
- 2<sup>nd</sup> largest mining income-earning commodity, beating gold
- 70% of SA primary energy production
- **>90% of carbon reductants in the metallurgical industry**
- **>40% of petrol and diesel requirements**
- **>200 major chemicals for 1000s of carbon-based products**

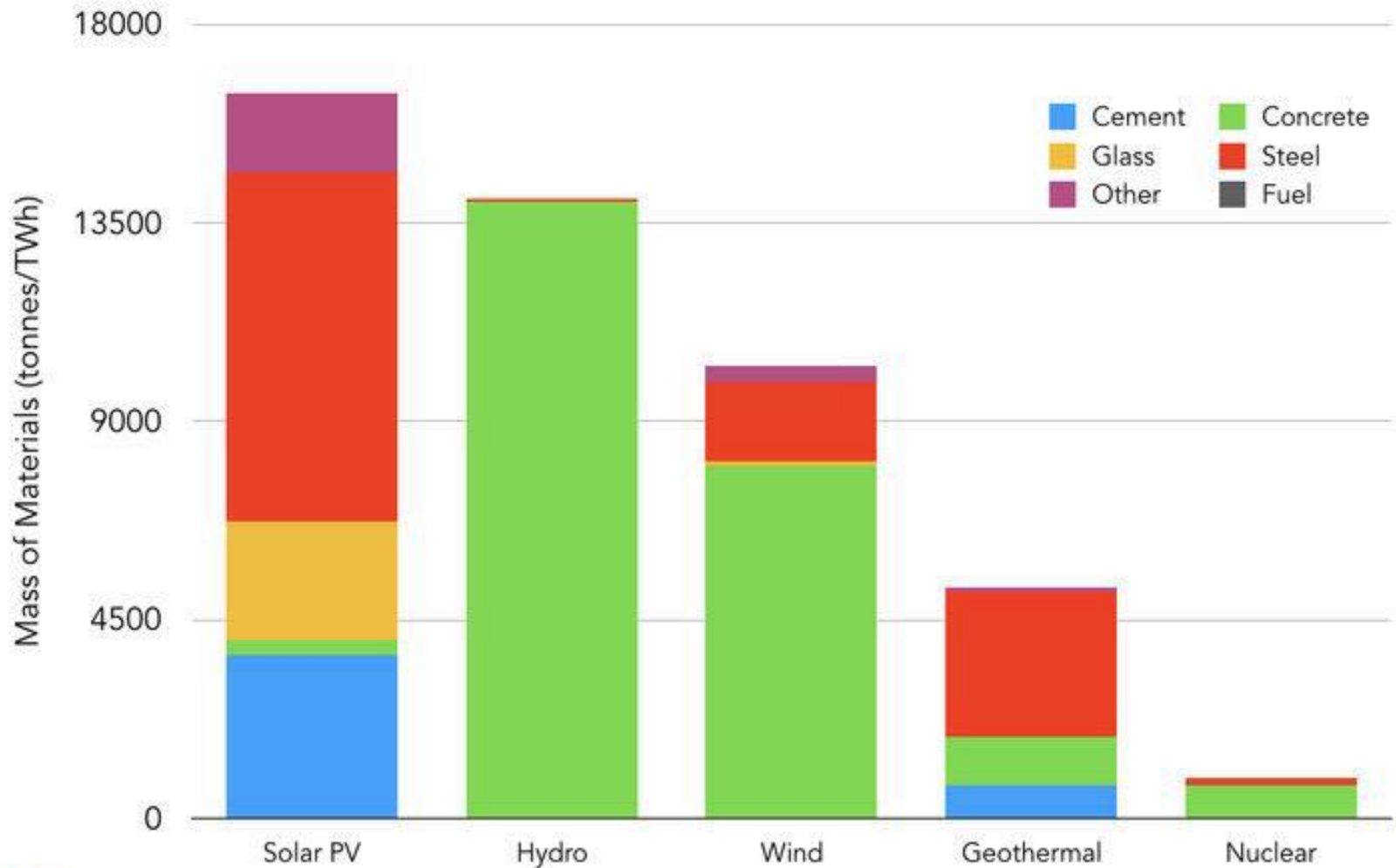


# Coal demand by region and scenario, 2018-2040

Last updated 21 Nov 2019; IEA



# Materials Throughput for Each Energy Source



Sources: DOE Quadrennial Technology Review, Table 10.4

Murray, Raymond L. Holbert, Keith E.. (2015). Nuclear Energy - An Introduction to the Concepts, Systems, and Applications of Nuclear Processes (7th Edition). Elsevier. page 97

# INDUSTRIAL USES OF COAL



## The significance of coal in the transport sector.

Liquid fuel ← 1

Hybrid vehicles

Hydrogen

Aluminium ← 2

Carbon fibers

## The significance of coal in the infrastructure sector.

Steel ← 3

Cement ← 4

Bricks

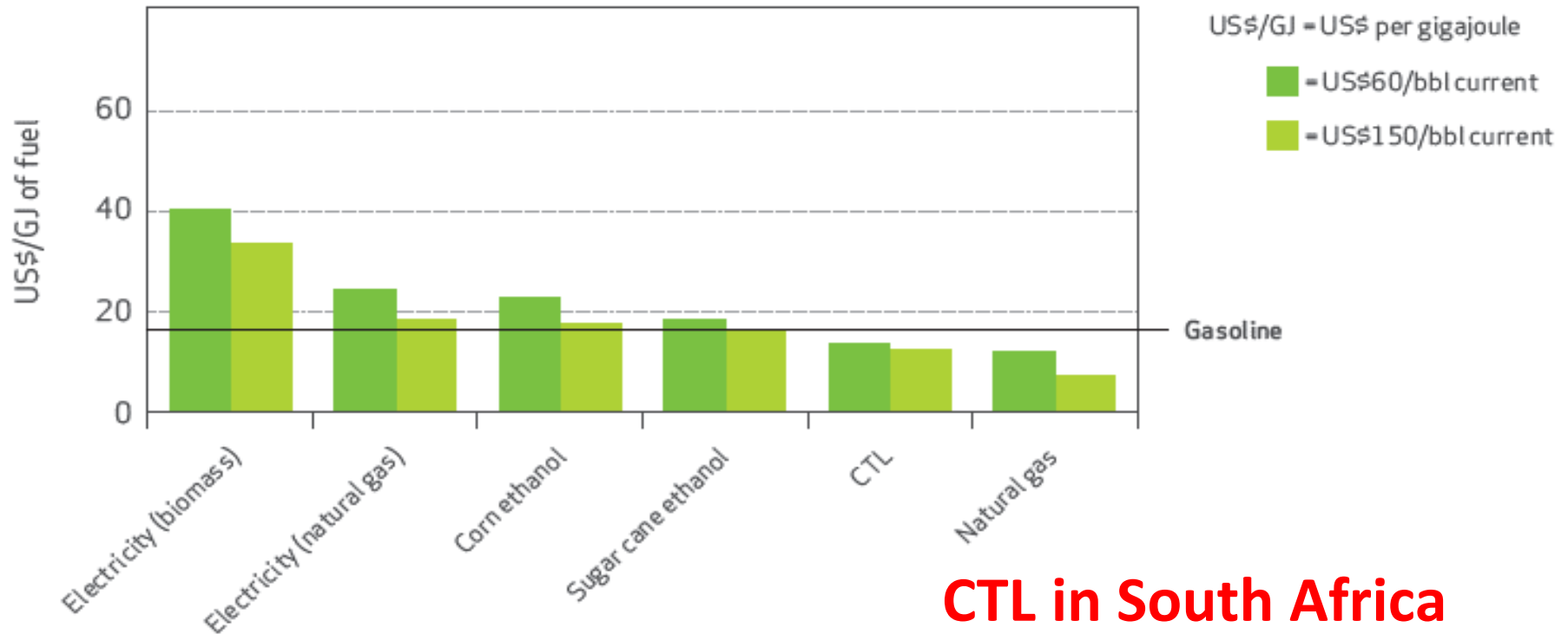
## The significance of coal in the clean energy sector.

Materials of construction

CRM and REE ← 5

# 1. SIGNIFICANCE OF COAL IN TRANSPORT FUELS

## Production costs of alternative transport fuels



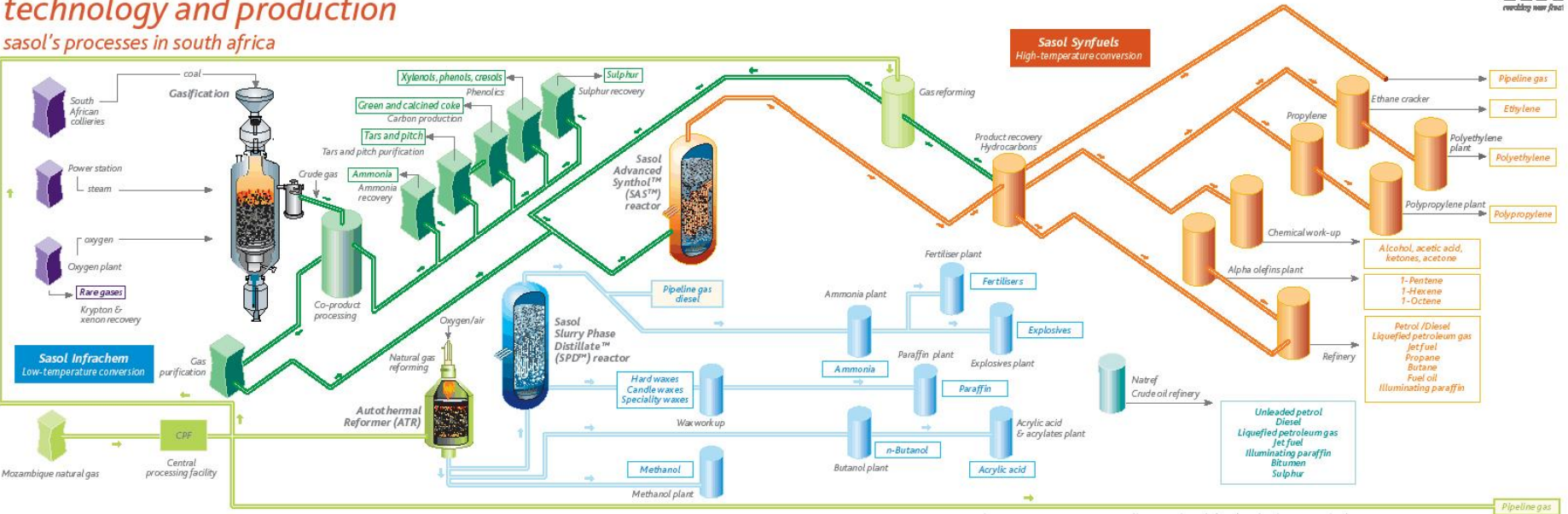
**CTL in South Africa**  
**20% SA transport fuel**  
**7.5% SA jet fuel**

# Sasol gasification CTL process

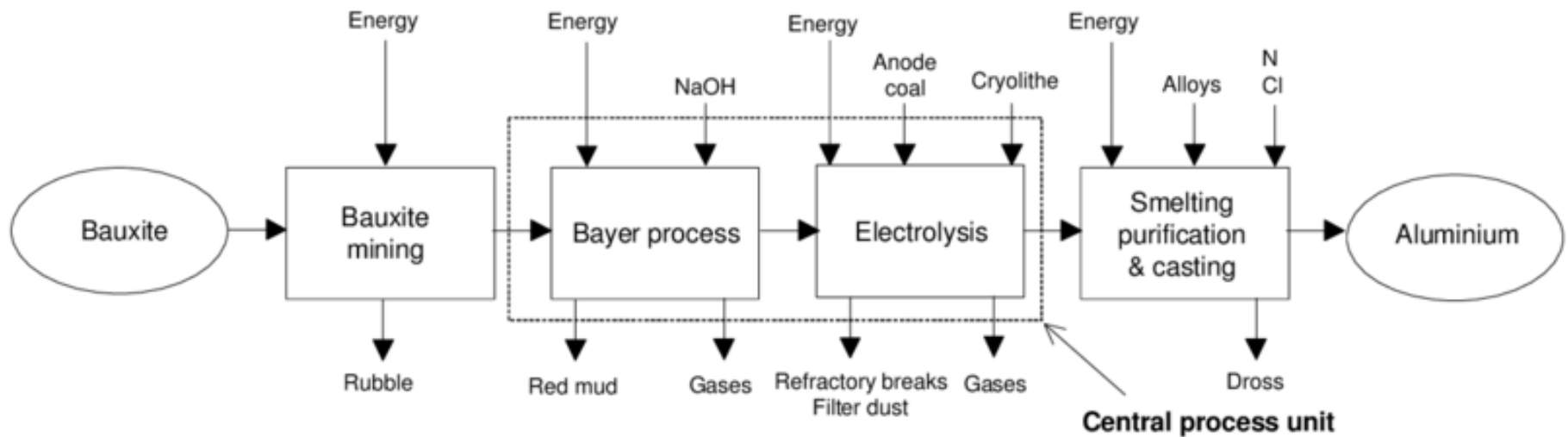


## technology and production

sasol's processes in south africa

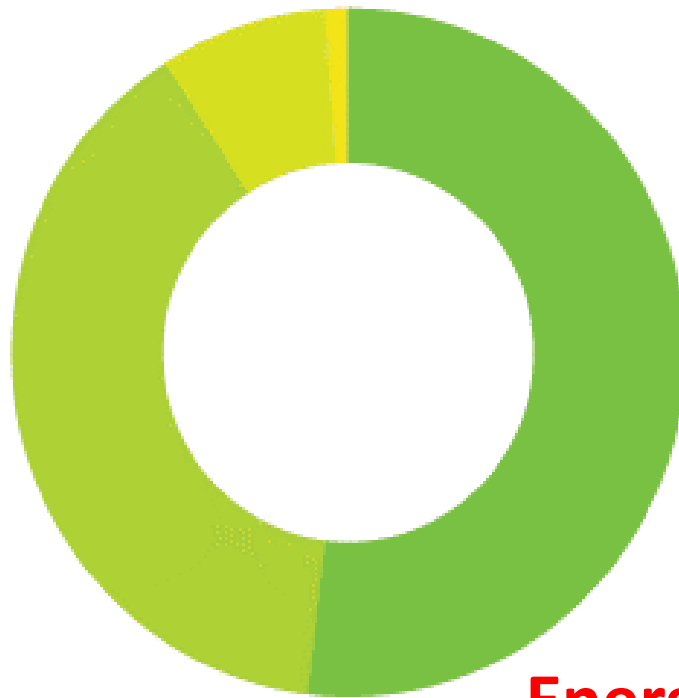


# 2. SIGNIFICANCE OF COAL & CARBON IN THE ALUMINIUM INDUSTRY





## Primary aluminium smelting power consumption



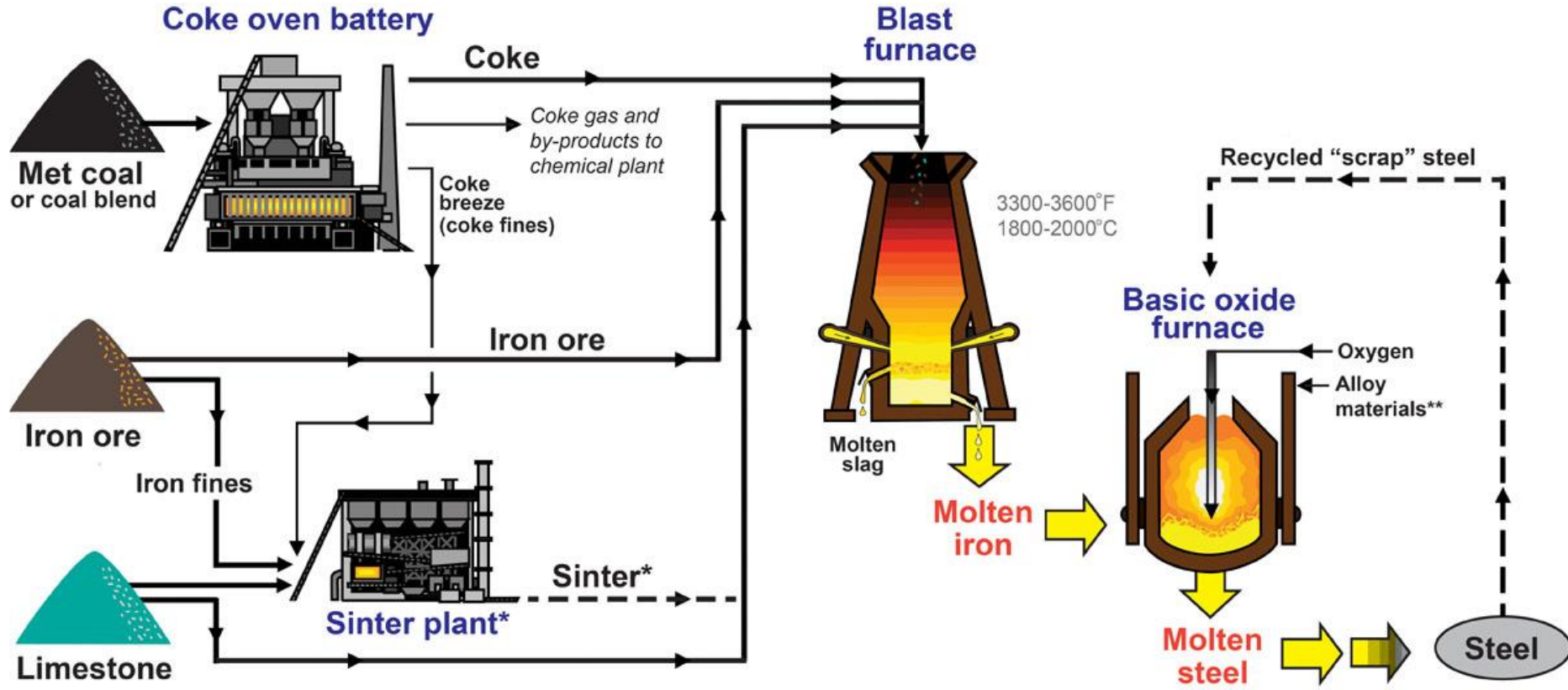
- 52% Coal
- 39% Hydro
- 8% Natural gas
- 1% Nuclear

**0.2kg carbon for every  
2.2 kg aluminium  
produced**

**Energy – coal can be replaced**  
**Cathodes – no current alternative to coal**  
**Anodes – no current alternative to coal**

Source: International Aluminium Institute 2012

# 3. SIGNIFICANCE OF COAL IN THE STEEL INDUSTRY



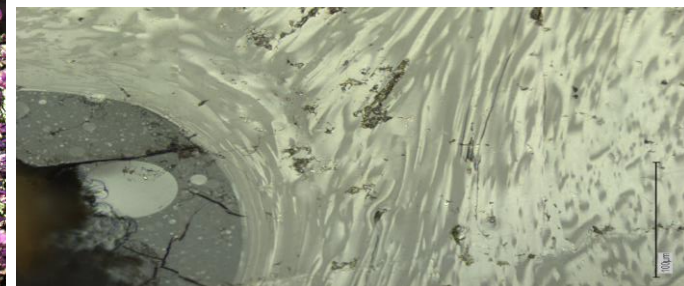
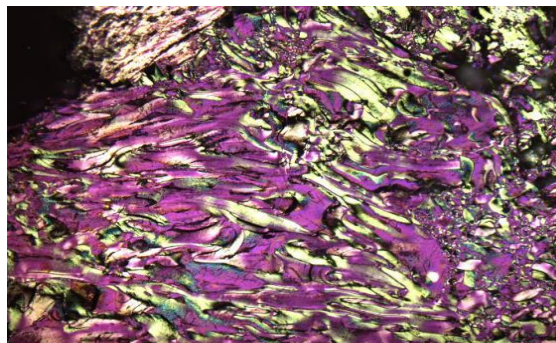
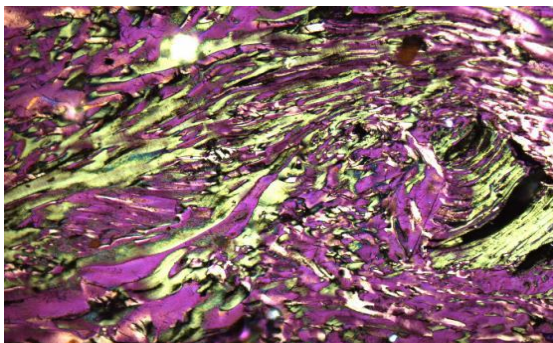
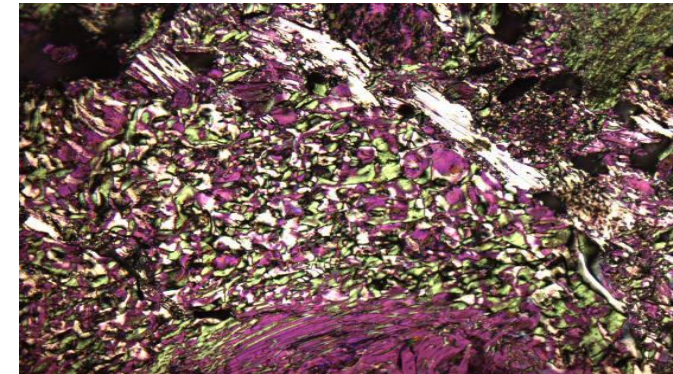
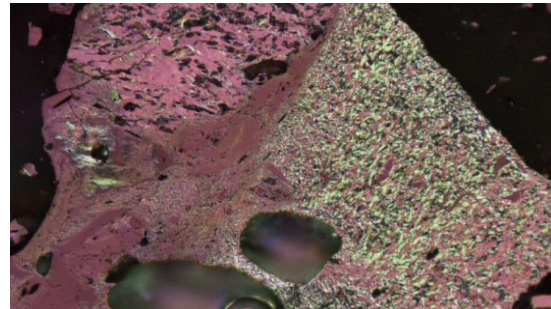
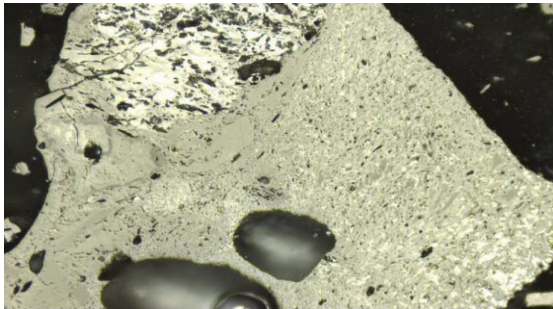
# IMPACT OF ORGANIC MATTER COMPOSITION ON INDUSTRIAL PLANT - METALLURGICAL PROCESSES -

A CHANGE IN THE PROPORTION OF ORGANIC MATTER  
COMPOSITION IN COAL CAN AFFECT:

- REACTIVITY – RATE OF CARBON CONSUMPTION
- RESISTIVITY -
- POROSITY AND PERMEABILITY
- STRENGTH



Cokes for metallurgical applications in ferrochrome production / steel manufacture



## Crude steel production by process



- 70% Integrated route based on coal
- 29% Electric arc furnace route
- 1% Open hearth route

### Blast furnaces:

770kg coal + 1400kg iron ore + 150kg limestone + 120kg recycled steel  
= 1 ton crude steel

### Electric arc furnaces:

880kg recycled steel + 150kg coal + 43kg limestone  
= 1 ton crude steel

Source: World Steel Association, 2011

(World Coal Association, 2020)

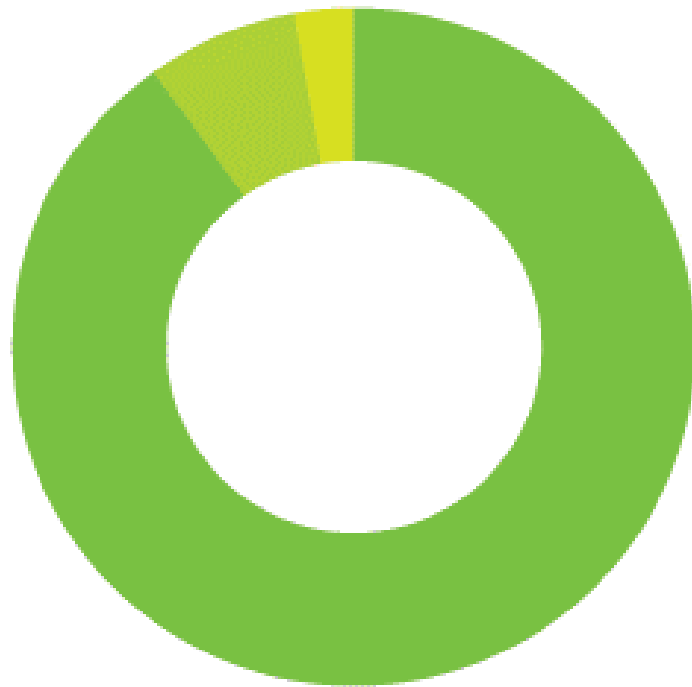
80% of all the materials in a single wind turbine are steel



# 4. SIGNIFICANCE OF COAL IN THE CEMENT INDUSTRY

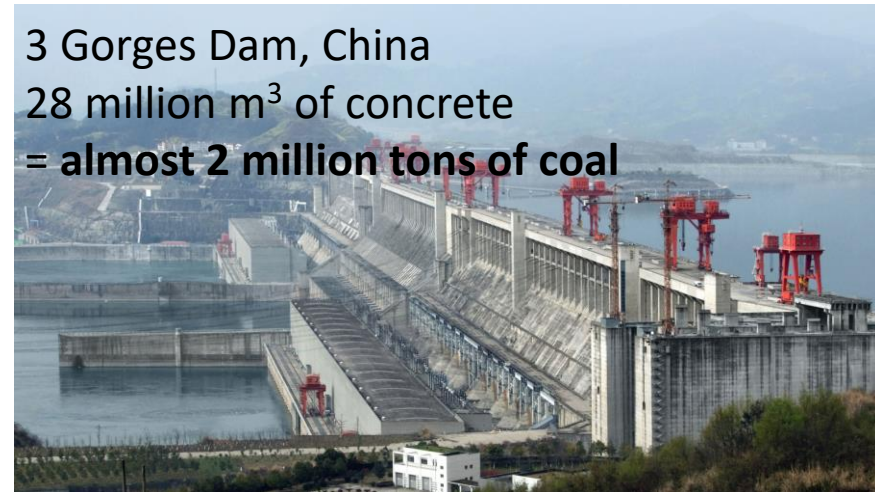
Total fuel consumption by cement kilns

200kg coal = 1 ton cement  
300-400kg cement for  
1m<sup>3</sup> concrete



- 90% Conventional fuel (mainly coal)
- 7% Alternative fuel (includes a variety of wastes, discarded tyres, oil, plastics, solvents, textiles and waste biomass)
- 3% Biomass

3 Gorges Dam, China  
28 million m<sup>3</sup> of concrete  
= **almost 2 million tons of coal**



Source: IEA 2009

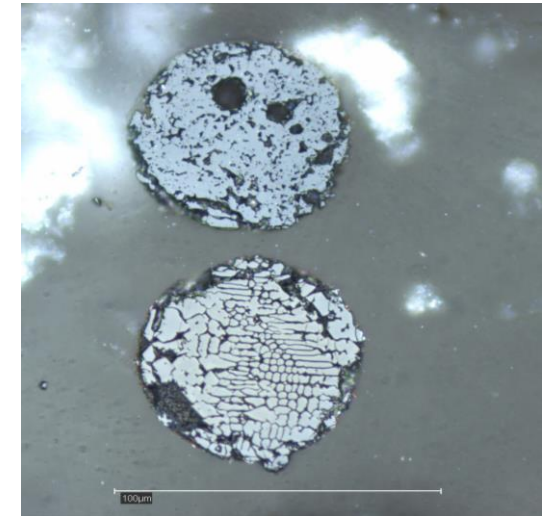
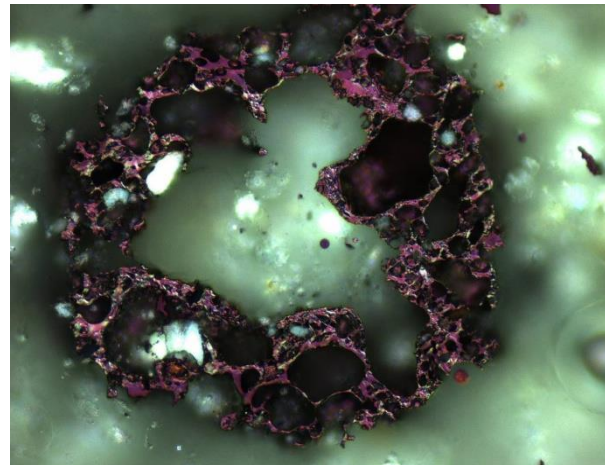
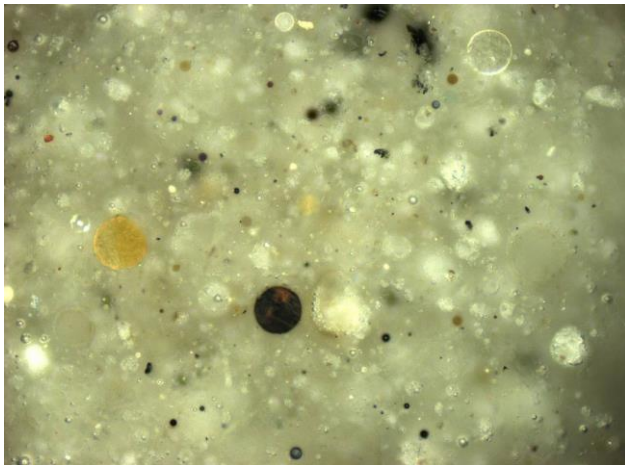
(World Coal Association, 2020)

## CONSIDER ASH AS A RAW MATERIAL

SIZE, AND RECOVER CHAR AND OTHER MINERALS, OR USE ASH AS IS

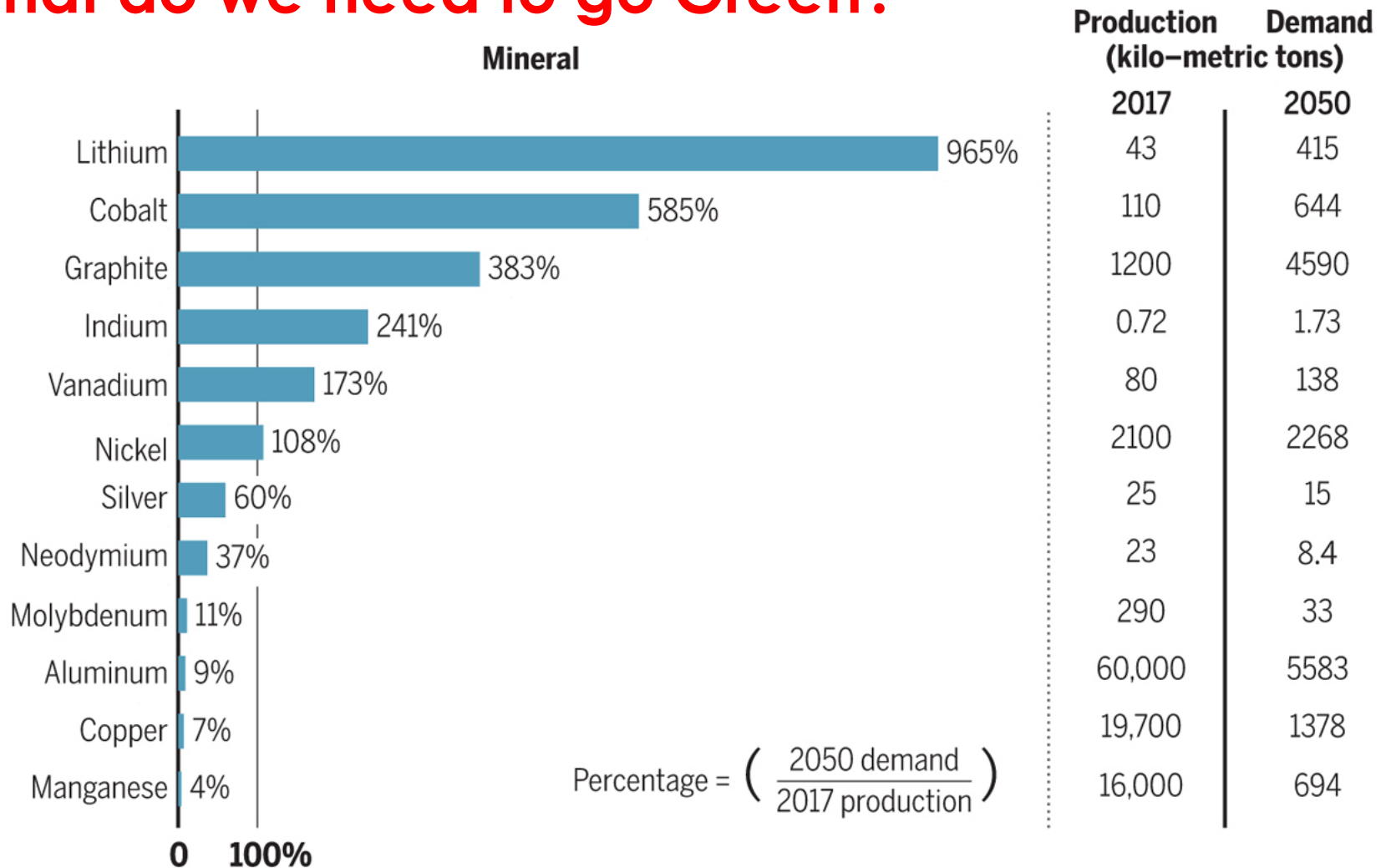


- ❖ Largest use of ash is in cement and concrete.
- ❖ Also used in mine reclamation, roads, infilling voids
- ❖ Gypsum used in wallboard manufacture
- ❖ Cenospheres are recovered and used in electromagnetics (fillers in composite materials and paints)



# 5. SIGNIFICANCE OF COAL IN THE CLEAN ENERGY INDUSTRY: CRITICAL RAW MATERIALS

## What do we need to go Green?



# CRITICAL RAW MATERIALS....

## 2020 Critical Raw Materials (new as compared to 2017 in bold)

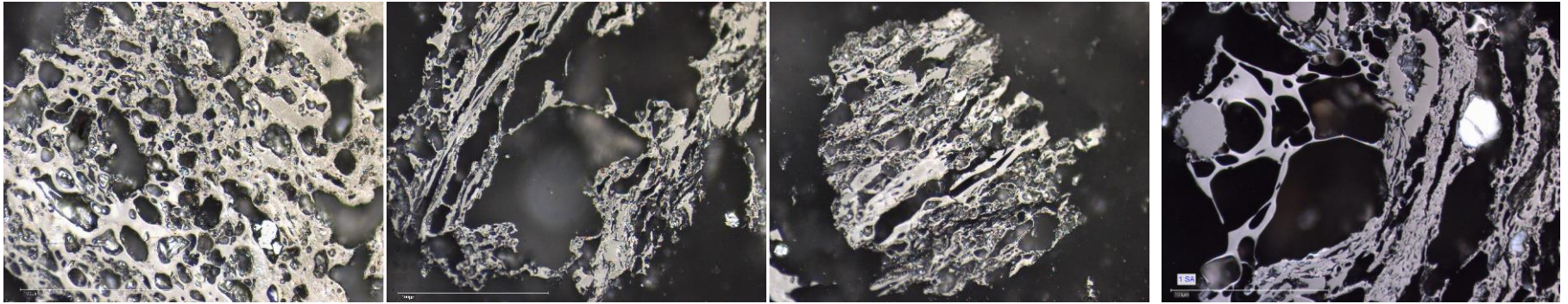
Antimony	Hafnium	Phosphorus	
Baryte	Heavy Rare Earth Elements	Scandium	
Beryllium	Light Rare Earth Elements ★	Silicon metal	
Bismuth	Indium	Tantalum	87%
Borate	Magnesium	Tungsten	44%
Cobalt	Natural Graphite ★	Vanadium	82%
Coking Coal ★	Natural Rubber	Bauxite	64%
Fluorspar	Niobium	Lithium	73%
Gallium	Platinum Group Metals	Titanium	67%
Germanium ★	Phosphate rock	Strontium	57%
			87%
			nite 69%
			ck 44%
			58%
			66%
			61%
			84%
			53%
			95%
			95%

**SO, HOW DO WE FIND THESE VIP RAW MATERIALS?**

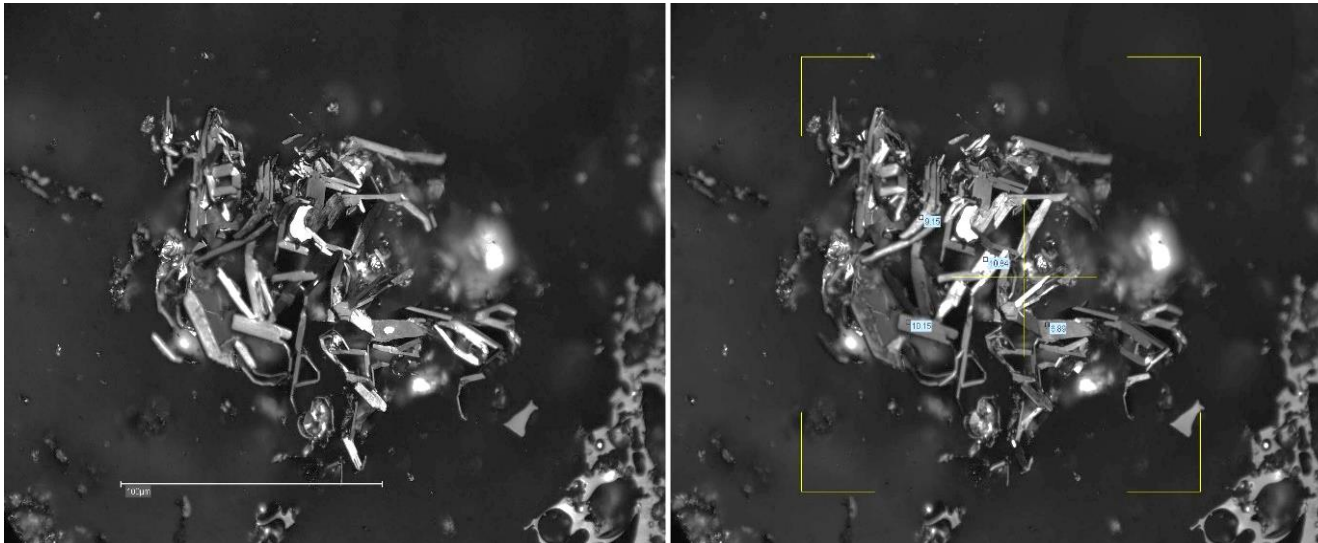


# Coal as an alternative source of graphite

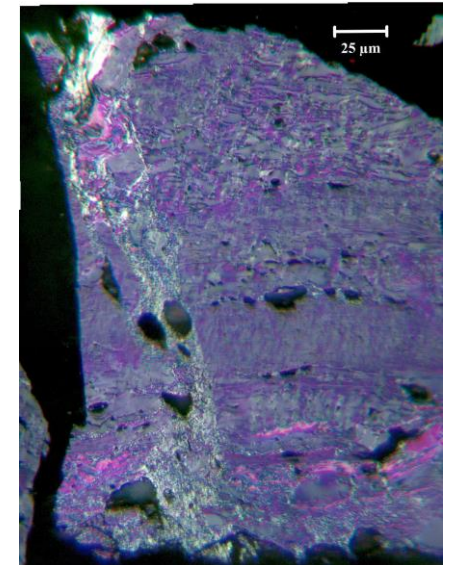
ERA-MIN CHARPHITE project



Char concentrate



Graphitised char



Natural graphite



# Rare Earth and Critical Elements from Coal-Based Materials

Mary Anne Alvin  
*NETL REE Technology Manager*

**Critical Minerals and Materials  
– Committee on Earth Resources –**

*Collaborative Solutions for Developing the US  
Resource – Panel Discussion*  
Washington, DC | May 9, 2018

Solutions for Today | Options for Tomorrow



USA Rare Earth Element Advanced Coal Technology Act (2019)  
Annual budget of \$23 million to 2027  
Department of Energy and the National Energy Laboratory (NETL)

# Input of REY into coal: Examples from Fire Clay coal

Basal bench    Tonstein    Top bench

*Organic* interactions with minerals and REY-bearing fluids throughout depositional history of Fire Clay coal

*Terrigenous* influences continued through time of deposition

*Terrigenous:*  
Monazite, zircon, etc.

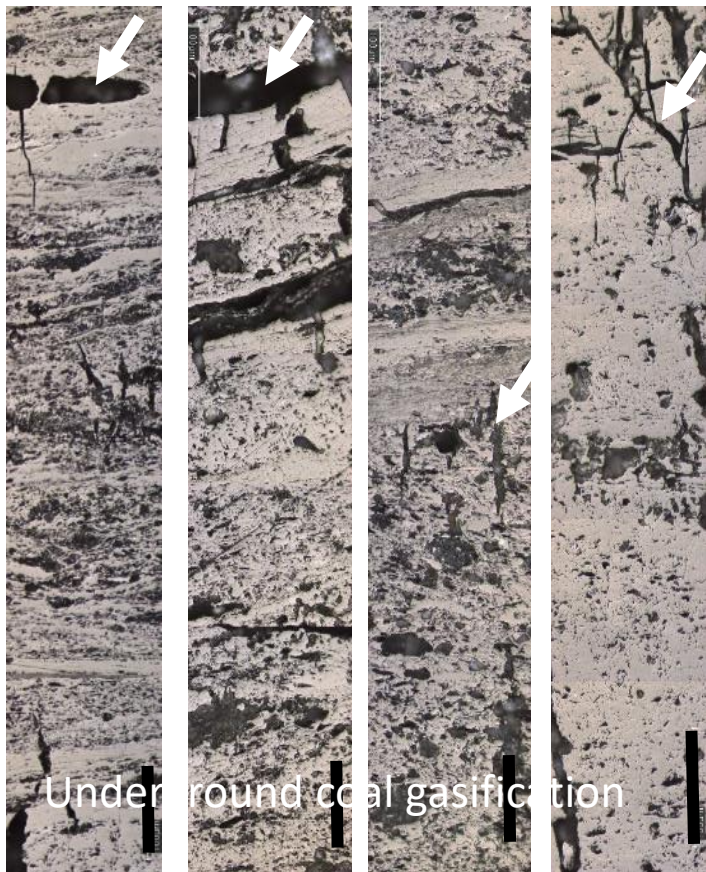
*Infiltration* from underclay

*Tuffaceous:*  
Volcanic ash fall

*Infiltration* from overlying sediments  
*Infiltration* from Ash-fall tonstein

*Infiltration* from Ash-fall tonstein

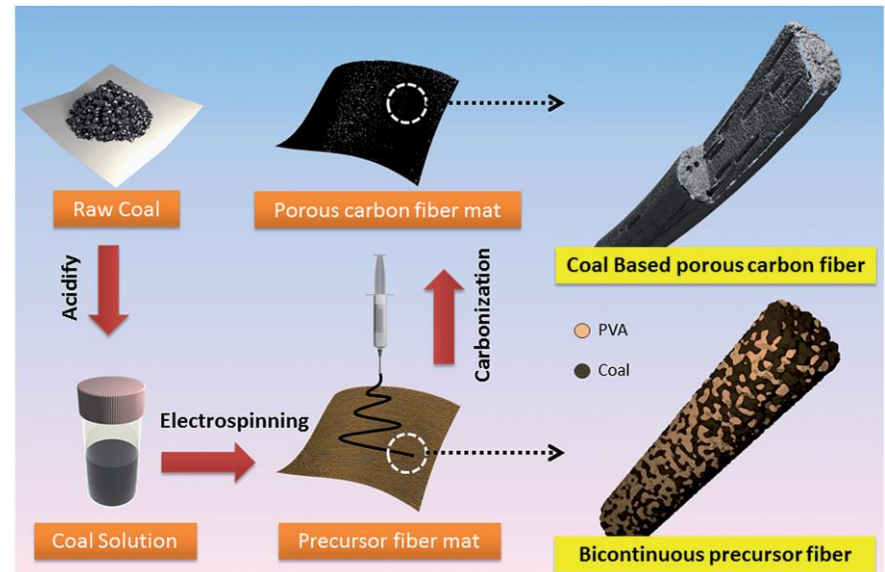
*Hydrothermal:*  
Fluids related to emplacement of Pine Mountain thrust



## Many additional uses:

- Paper manufacture
- Brick manufacture
- Small scale industries
- Ammonia gas from coke ovens
- Activated carbons
- Silicon metal
- Carbon nanotubes
- Hydrogen
- Light weight composite materials

Underground coal gasification



**CARBON FIBRES: STRONG, LIGHT WEIGHT COMPOSITE MATERIALS**

# SUMMARY

- ✓ Coal is primarily used for coal combustion – pf combustion
- ✓ Multitude of coal utilization options beyond electricity generation
  - ✓ Transport sector: liquid fuels; vehicles; infrastructure
  - ✓ Clean energy: infrastructure; CRM
- ✓ Coal utilization is related to the type, grade, and rank of coal, as well as the chemical composition of macerals
- ✓ Coal properties are a result of coal origin and formation, & subsequent processes
- ✓ Coal petrography enhances the understanding of coal deposits and coal utilization

Coal is significant in our daily lives  
And should be used in a socially responsible manner



Dr Klaus Brendow (World Energy Council): Coal's global image does not reflect the realities of the industry

# Thank you

