

# **NON ENERGY PRODUCTS FROM COAL**

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**NCC 2019 FALL ANNUAL MEETING 11-12 SEPTEMBER**



**IEA  
CLEAN COAL CENTRE**

# PRESENTATION OUTLINE

**100 Mt of products from 400 Mt of coal  
high value compared to coal combustion  
and expanding markets**

**New carbon forms, chemicals, minerals,  
environmental applications and new materials**



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**DR IAN REID**

**PRINCIPAL ASSOCIATE**

Ian is a combustion technology specialist with over 30 years' experience in the gas, oil and petrochemicals industry. Ian has produced studies on lignite power plant technology, coal beneficiation and on Non-energy uses for coal.

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## THE IEA CLEAN COAL CENTRE

We are a **technology collaboration programme** organised under the auspices of the International Energy Agency. We are supported financially by national governments (contracting parties) and by corporate industrial organisations (sponsors).



# COAL AND CHEMICALS GLOBAL TRENDS

Thermal coal geographical shift to Asia (4Btce) and stranded resource

Energy Electrification – power and transport

Rising population (+ 60M pa), land fertility crisis and water shortage

Steel manufacture - EAF 25% share

Natural gas and oil– competition with coal



\$50/t vs - HB/lng



\$125-235 -



\$400/t



# OPPORTUNITIES FOR COAL PRODUCTS

**Coal tar and gasification chemicals** – gasification increasing – will overtake production of traditional tar based products

**Nano carbon materials** – how can coal be used?



Terbium



Neodymium

**Rare earth metals - REE from coal** – rising demand and restricted supply - coal as a mineral resource

**Carbon fibre** – high strength lightweight material for ground transport – now preferred in aerospace but remains high cost



**Carbon electrodes**  
- shortage of graphite as number of users increases

**Agrichemicals** – Latest UN report highlights global loss of soil fertility and desertification - how can coal contribute?

Many others:  
Activated carbon –  
carbon foams and  
composites – coal films –  
–carbon black.....  
+  
'The Hydrogen Road'

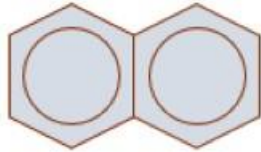


# TAR AND GASIFICATION CHEMICALS

Chemicals from coal tar and coal gasification are the dominant sectors for coal use making up most of 100 Mt but gasification is the sector that is rapidly increasing...

## coal tar chemicals

pharmaceuticals - insecticides – varnish – rayon – nylon – pigments – dispersants - polyurethane  
polyaromatic product safety; pitch costs doubling since 2016 >400 \$/t  
electric arc furnaces taking market share affects supply amid increased demand – pitch from low grade coal



Naphthalene derivatives



## 'oxygen blown' gasification of coal

methanol to olefins and polymers – polypropylene, polyethylene, polyester, ethylene glycol, fuel

250 million tonnes of products in progress – significant proportion already under construction in China  
significant environmental concerns: plastic waste and carbon dioxide intensity



# RARE EARTH ELEMENTS FROM COAL

La	Ce	Pr	Nd	Pm	Sm	<b>Eu</b>	<b>Gd</b>	<b>Tb</b>	<b>Dy</b>	<b>Ho</b>	Er	Tm	Yb	<b>Lu</b>
<b>Sc</b>	<b>Y</b>		LREE		HREE		Key elements in <b>bold</b>							

- REEs appear in almost all the high end engineering applications: aerospace; mobile phones; magnets for electric motors , energy storage; lighting; alloys... Neodymium example
- Economic recoverable resources restricted to a few countries.
- Coal typically 35ppm REE content, but certain deposits can exceed 300ppm - Extraction from coal as a by-product avoids mining costs, but must concentrate REE from a lower level
- Can take from raw coal waste streams, mine drainage water, lignite or from fly ash after combustion – AMD method can be part of site restoration
- Poor environmental record in China and Malaysia – toxic ‘Lake’ Baotou



# REE FROM COAL WASTE STREAMS – PROCESS AND IP

Key first target – match mineral ore concentration >2%

Feedstock: Coal tailings, AMD, lignite, ash

(Patent China 2014)

Grind coal and mix with  $\text{Na}_2\text{CO}_3$

Roast, water leach and filter

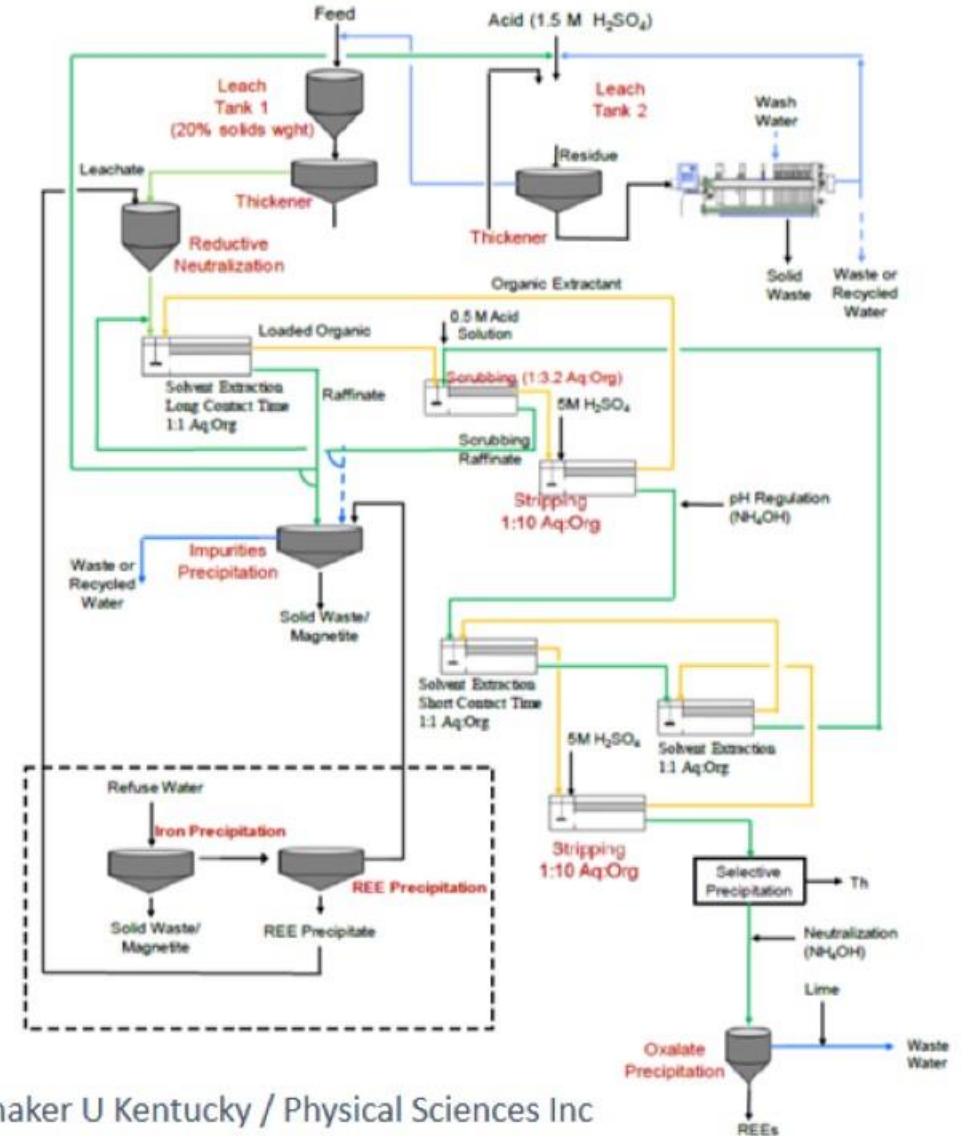
Staged HCl leaching forming chlorides

REE purification

Closer to mine ore process

*Separation Strategies can be thermal using additives such as aluminium phosphate (US Patent 2017), or new acid –solvent route....*

*Currently most REE Minerals processed In China*



Honaker U Kentucky / Physical Sciences Inc  
>90wt% REO products at lab scale





# CARBON FIBRE

## Current applications:

Sports  
Civil construction  
Aerospace  
Robotics  
Automotive

Aerospace and electric  
transport needs

High strength at low mass

Carbon 2.1 t/m<sup>3</sup>

Steel 7.1 t/m<sup>3</sup>

Typical prices \$100000/t

2018 \$8 billion total sales

Pitch fibre 10% of market

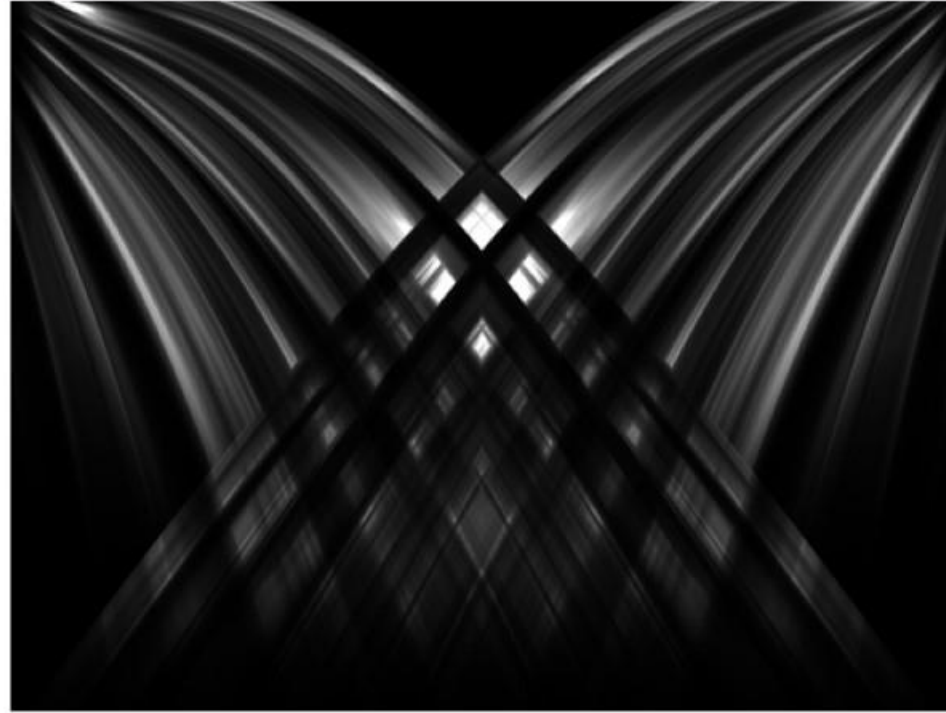


Image: Bigstock.com

## Details on Mitsubishi pitch fibre Dialead™

High end product: high tensile modulus 4 \*  
steel (900 Gpa) and thermal conductivity 3 \*  
aluminium (620 W/mK), no heat expansion

## Pitch fibre issues

- Mitsubishi main supplier with proprietary knowledge
- Quality issues encountered may be due to insoluble components in pitch
- Longer term - coal pitch feed source from coking plants linked to blast steel industry



# COAL USE IN ELECTRODES – PITCH AND SYNTHETIC GRAPHITE



Limits on **Li ion** battery life

Carbon gradually forms a path between electrodes (dendrites) that can cause a short circuit  
Potential role for graphene to stabilise electrodes

## Industrial uses of graphite

**steel production moving to EAF and battery electrodes for mobiles and computing- electric vehicle market impact**

Price Peak at \$30,000 now eased to \$4-8,000/t as demand falls  
expectation is \$5000 floor

Industry: Steel electric arc furnaces – also aluminium & silicon

## Synthetic graphite

Synthetic graphite is normally made from pet needle coke.

In Japan coal tar sourced needle coke is used to make synthetic graphite electrodes are used for lower intensity EAF applications – main issue is sulphur content.

EAF electrodes take 3 months to make and 8hrs to consume, explaining slow response to high prices.

All industrial graphite electrodes use a pitch binder - coal tar pitch makes up 20% of the electrode - 0.5 kg consumed per ton of EAF steel = 200,000 t



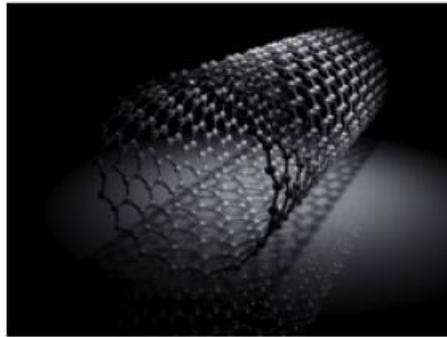
# CNTS & GRAPHENE

## Carbon nanotubes

Established product

Main use in composites

Limited success in manufacture from pitch but can use CO or acetylene in CVD



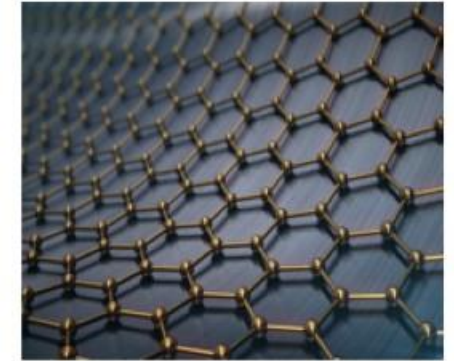
## Graphene Quantum Dots

quantum dots from coal for VDU and medicine – using the crystalline/amorphous structure of coal

*chemical extraction*

colour filters are \$260 for 5mg

Graphene sheets from coal  
Despite scepticism!



Fragments of graphite/graphene  
already present in bituminous coal

- *Electrochemical method (C2G, Ohio)*
- *Thermal molten salt route (NETL)*

-many new applications emerging in construction, electrodes, composites, textiles...

latest –gas separation?

- expected to reach 1/10<sup>th</sup> CNT market by 2023



# LIGNITE SOIL IMPROVER

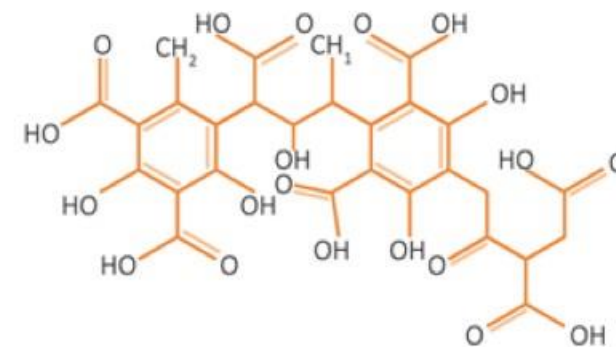
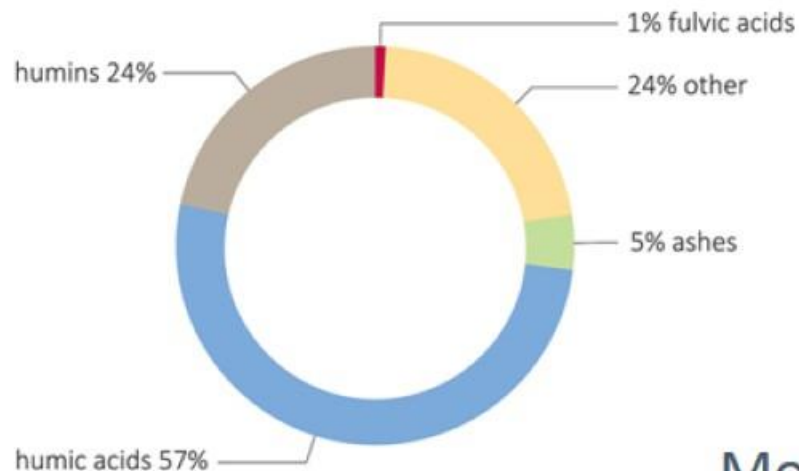
**Issues:** a growing population, food shortages, desertification, carbon loss from soil, nitrogenous fertiliser pollution and water shortages.

**Leonardite** is a natural mineral formed from lignite exposed to the air used for centuries

The geologic process that converted peat to lignite can be partially reversed to form synthetic humate that can be deployed for soil improvement

**Oxidative Ammonolysis** - adding O and N back into lignite

modest conditions 130°C & 3 bara ; EU backed and over 100 field trials



Molecule is re-oxidised  
lignite humic acid





# NON ENERGY COAL PRODUCTS CONCLUDING REMARKS

The versatility of coal carbon...

- **Coal to chemicals** – massive expansion of industry in progress – but profitability dependent on oil & gas prices but survived threshold \$oil may now be lower
- **REE** – can obtain REE from coal. Demonstrated can achieve mineral ore content and economic processing under development. Could be combined with mine site remediation
- **Carbon fibre** – high quality pitch fibre available and Mitsubishi has doubled production. Issues are production cost and knowhow for melt spinning. Need low cost pitch. Recyclable material.
- **Activated carbon and electrodes** – water, Hg and CCS; high cost of graphite and pet needle coke for electrodes – fall in steel demand has lowered prices but new users entering market
- **New technologies – CNTs, graphene** – rapidly growing areas that would benefit from cheaper feedstocks as demand increases – graphene has a broader range of application
- **Humates** – a potential high volume use for lignite that avoids emission problems of ammonia based fertilisers



# RECENT DEVELOPMENTS IN AUSTRALIA AND JAPAN

## Japan's Hydrogen Road

Battery powered vehicles are the basis for transport electrification –

Shortage of battery materials (cobalt, lithium, nickel)

Alternative approach is to develop a hydrogen infrastructure using fuel cell power

Currently >3000 FCV (Honda and Toyota) and aiming for >150 hydrogen stations

Aiming to showcase at Tokyo Olympics with 100 FCV buses (111 KW)

electrolysis with renewable power still too expensive – gasification of coal to H<sub>2</sub> half the cost

### Australia to Japan

stranded lignite resource: gasification - shift catalysis - hydrogen cryogenic transport -CCUS

160 t lignite for 3t of hydrogen and 100t CO<sub>2</sub> - \$350M demonstration project (3 moles H<sub>2</sub> to 4 CO<sub>2</sub>)

Project potentially \$2 billion per annum industry based on recent production.

**China** - China Hydrogen production cost \$2.5/kg coal/CCUS (IEA)

**USA and EU** - FCV and natural gas replacement

**Hydrogen storage and transport issues partially solved**



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**THANK YOU**

ANY QUESTIONS?

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## COFIRING 9 IN JAPAN

- The *9<sup>th</sup> International Workshop on Cofiring Biomass with Coal* will be co-hosted by IEACCC and NEDO Japan in Kokura, Japan, on 25-27 February 2020
- A leading international event covering the latest developments on the policies and practical measures which ensure the successful implementation of cofiring biomass with coal
- Join around 70 experts and senior policy makers from industry, research institutes, and government
- Visits to Kitakyushu Laboratory of Nippon Steel Engineering Co. and Shin Onoda Power Station
- <https://www.cofiring-workshops.org>

