MONASH University

High Value Products from Victorian Brown Coal

Alan L Chaffee
Professor
School of Chemistry

Carbon to Products Seminar
7 February, 2018

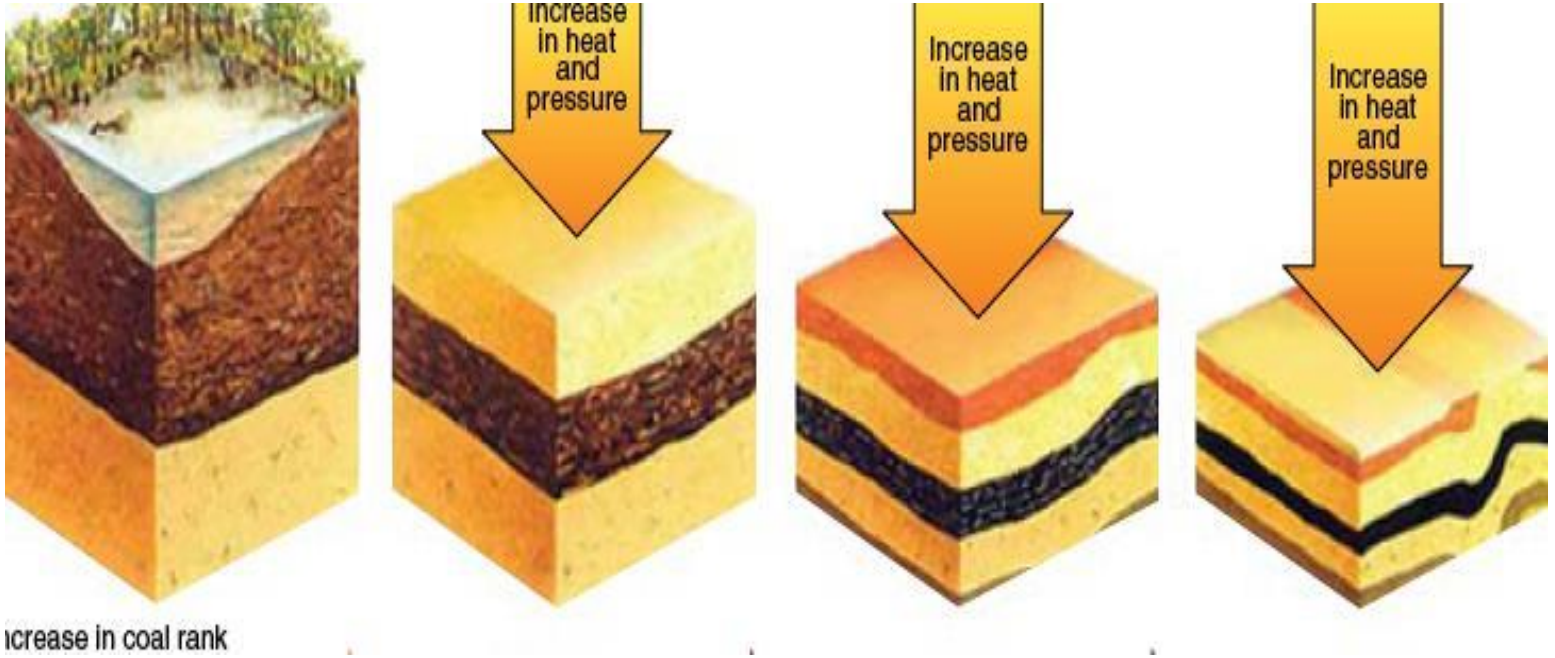
GROUP OF EIGHT AUSTRALIA

Contents

- CLEAN BROWN COAL
- Coke-like material
- Active carbon monoliths
- Road bitumen
- Agricultural products
- Other products

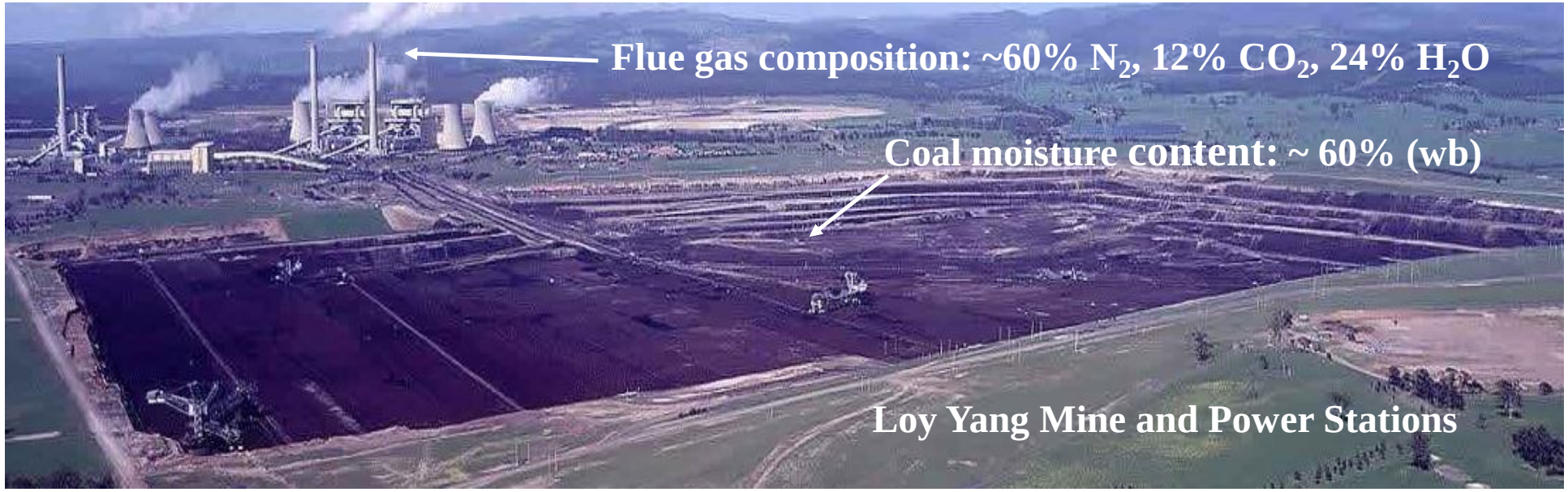
What is brown coal?

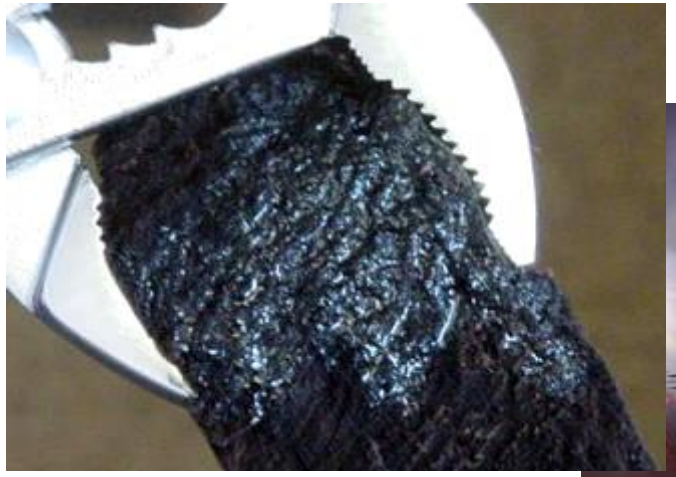
Coal Rank	Australian Terminology	European Terminology
Anthracite	Black Coal	Black Coal
Bituminous Coal	Black Coal	Black Coal
Sub-bituminous Coal	Black Coal	Brown Coal
Lignite	Brown Coal	Brown Coal

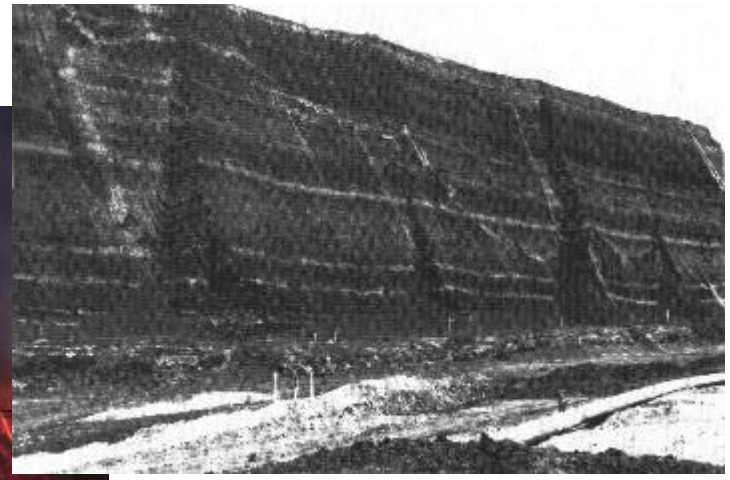


Australian Coal Association 2009

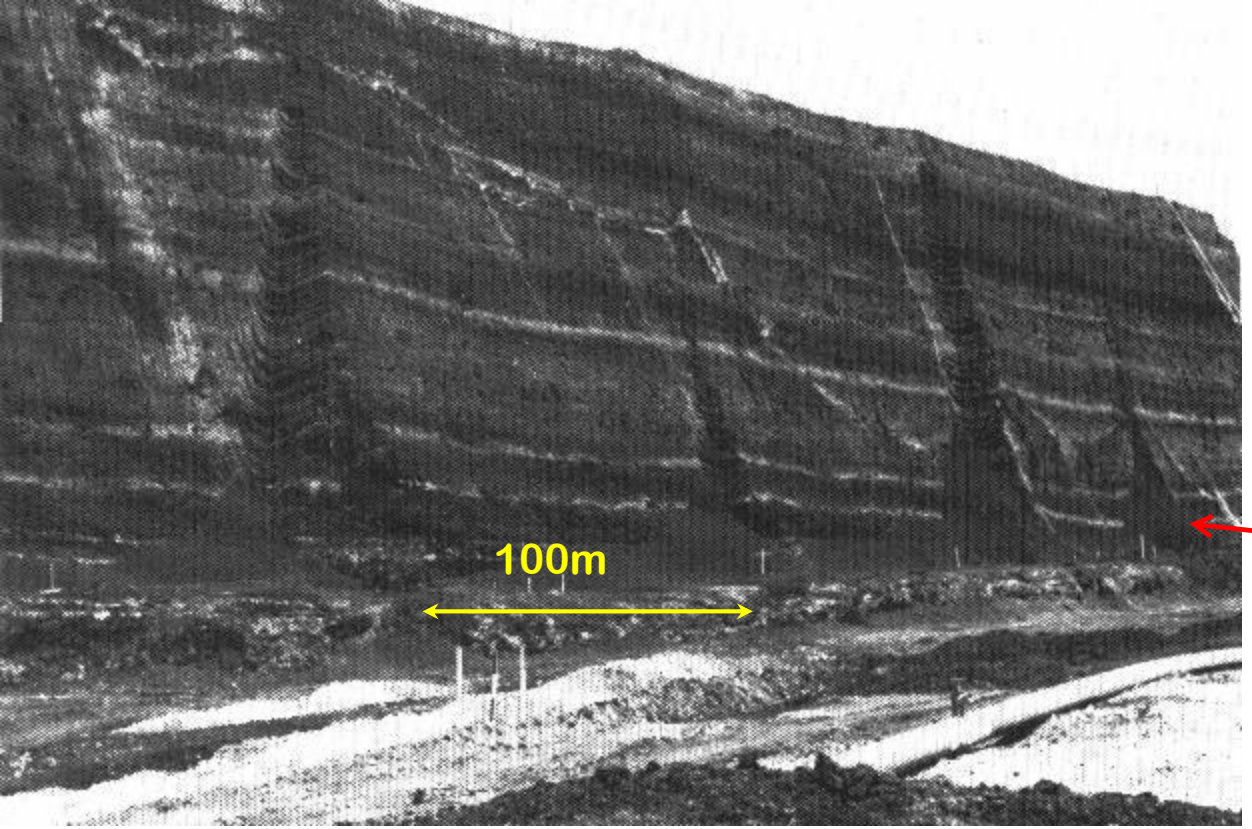
Vast Reserves, Cheaply Mined, Wet, Reactive







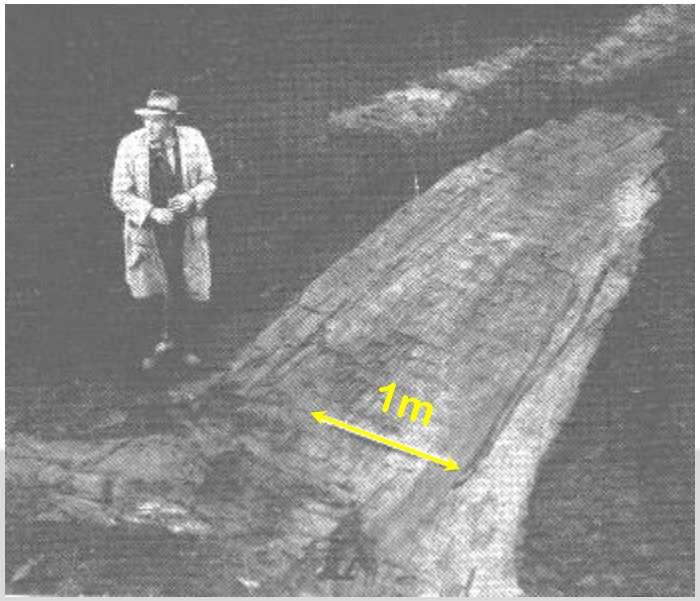
Victorian Brown Coal is a heterogeneous material

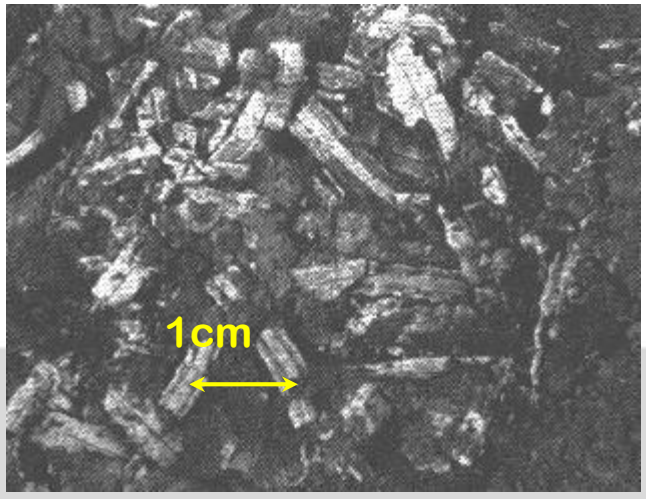


Lithotypes:

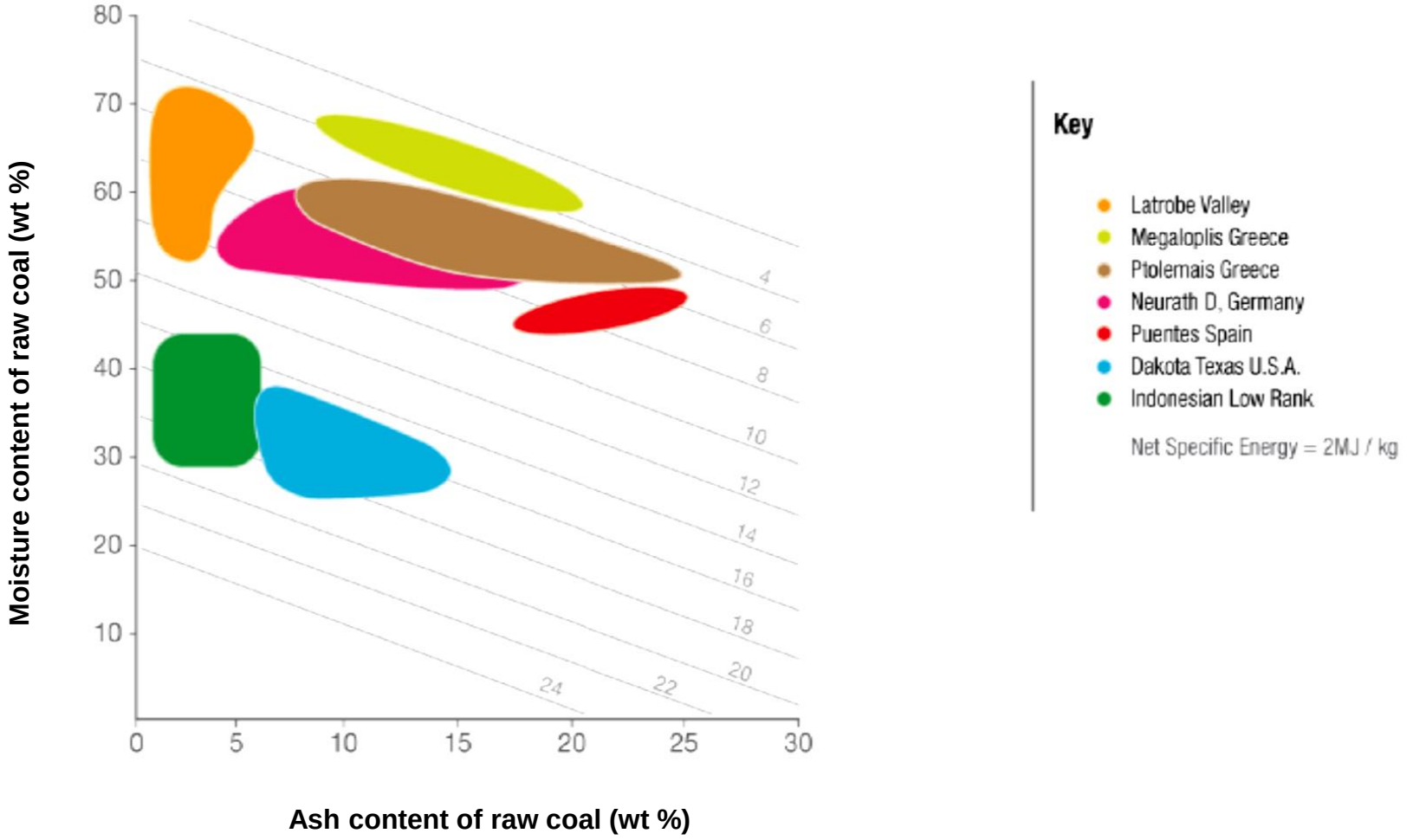
- Pale
- Light
- Medium Light
- Medium Dark
- Dark

Their composition and chemistry differ





Quality Comparison of Low Rank Coals

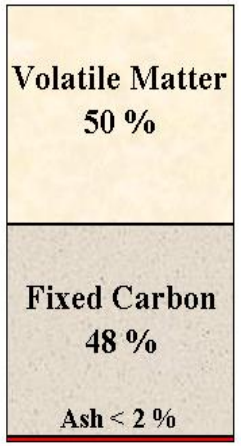


From: Allardice Consulting

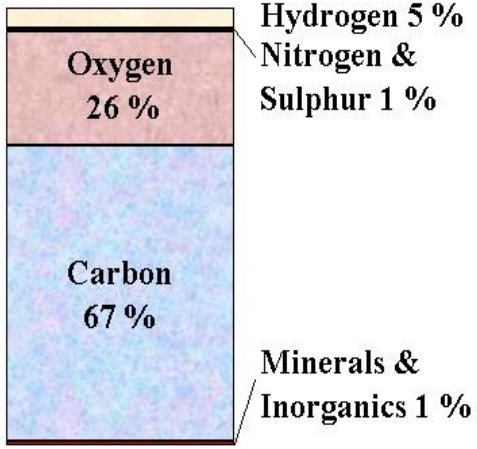
Composition of Victorian Brown Coal

Positives: Low N, Low S, Low Ash, Cheap
Negatives: High Moisture, High O,
Low Specific Energy (wet),
Spontaneous Combustion

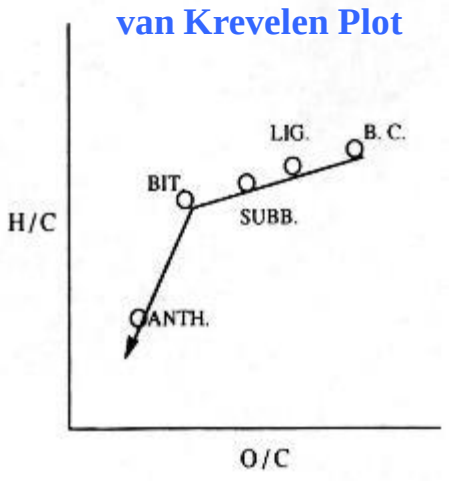
Proximate Analysis



Ultimate Analysis



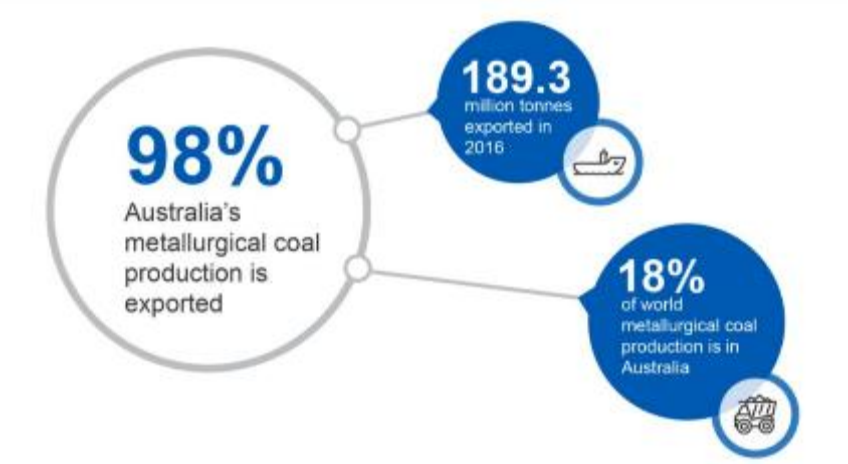
van Krevelen Plot

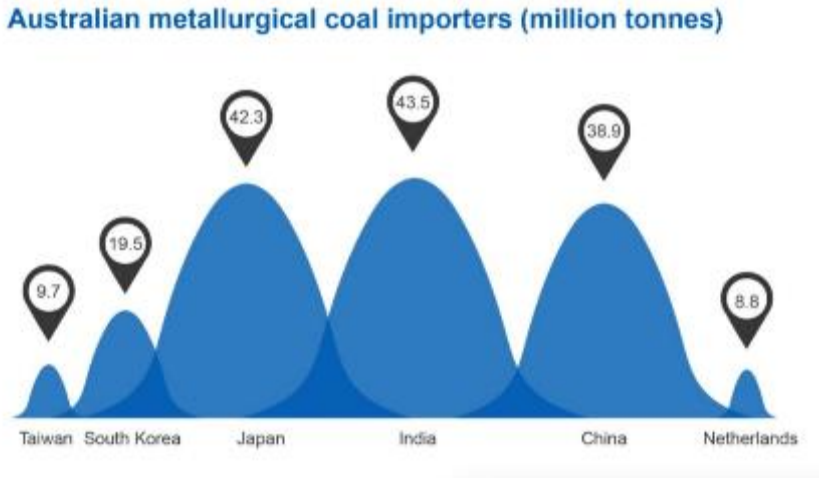


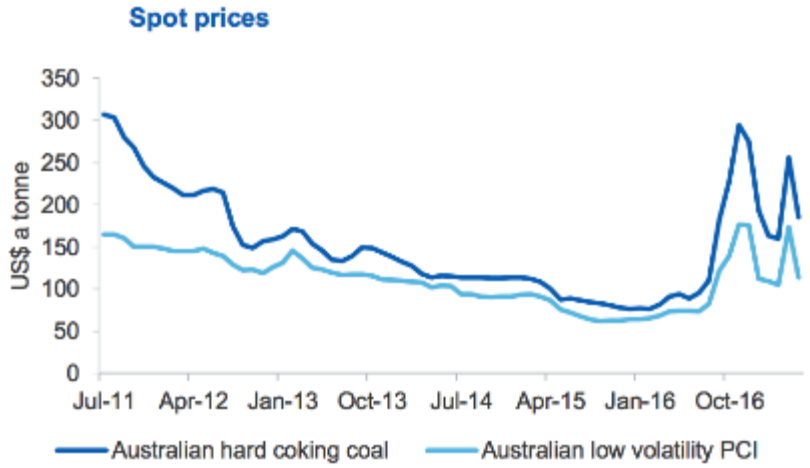
Contents

- Clean brown coal
- COKE-LIKE MATERIAL
- Active carbon monoliths
- Road bitumen
- Agricultural products
- Other products

Metallurgical Coal







- 70% of the steel produced today relies directly on metallurgical coal
- R&D and Investment decisions are driven by:
  - high prices,
  - reducing coke quality,
  - concerns over supply/demand

COKE-LIKE MATERIAL FROM VBC

Coking Coal

- Some bituminous coals
- Higher rank coal
- **Melts** on carbonization
- **Resolidifies** at higher temperature to form **Coke**

BUT, Limited reserves and increasing demand

- Becoming more expensive

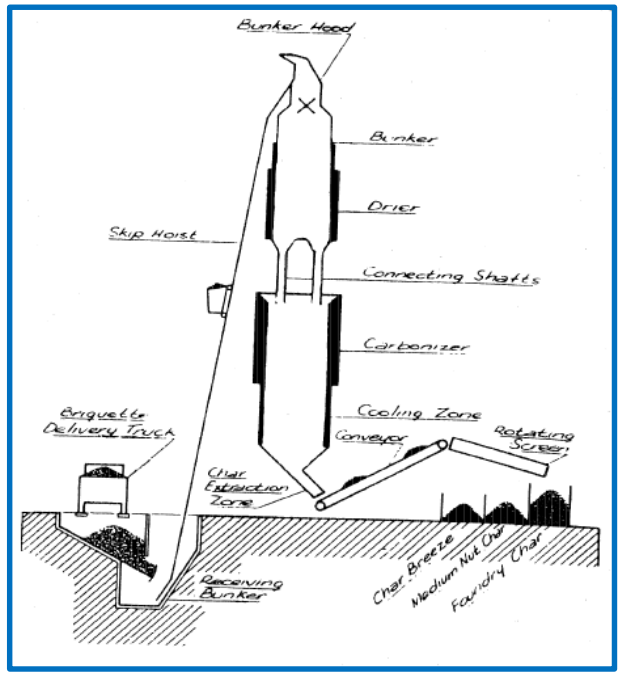
Victorian Brown Coal (VBC)

- **Low rank** coal
- Large reserves
- Very accessible, **very cheap**
- Very low concentrations of mineral **impurities**
- Therefore a very **attractive feedstock** for iron and steel industry

BUT

- Does not have coking properties; does not melt on heating
- Therefore, does not produce coke
- Only produces a char on carbonization
- **The char is too reactive to be used in a blast furnace**

Previous Studies: Gas & Fuel Corp



Auschar plant, Latrobe Valley, Victoria (1958 - 2014)

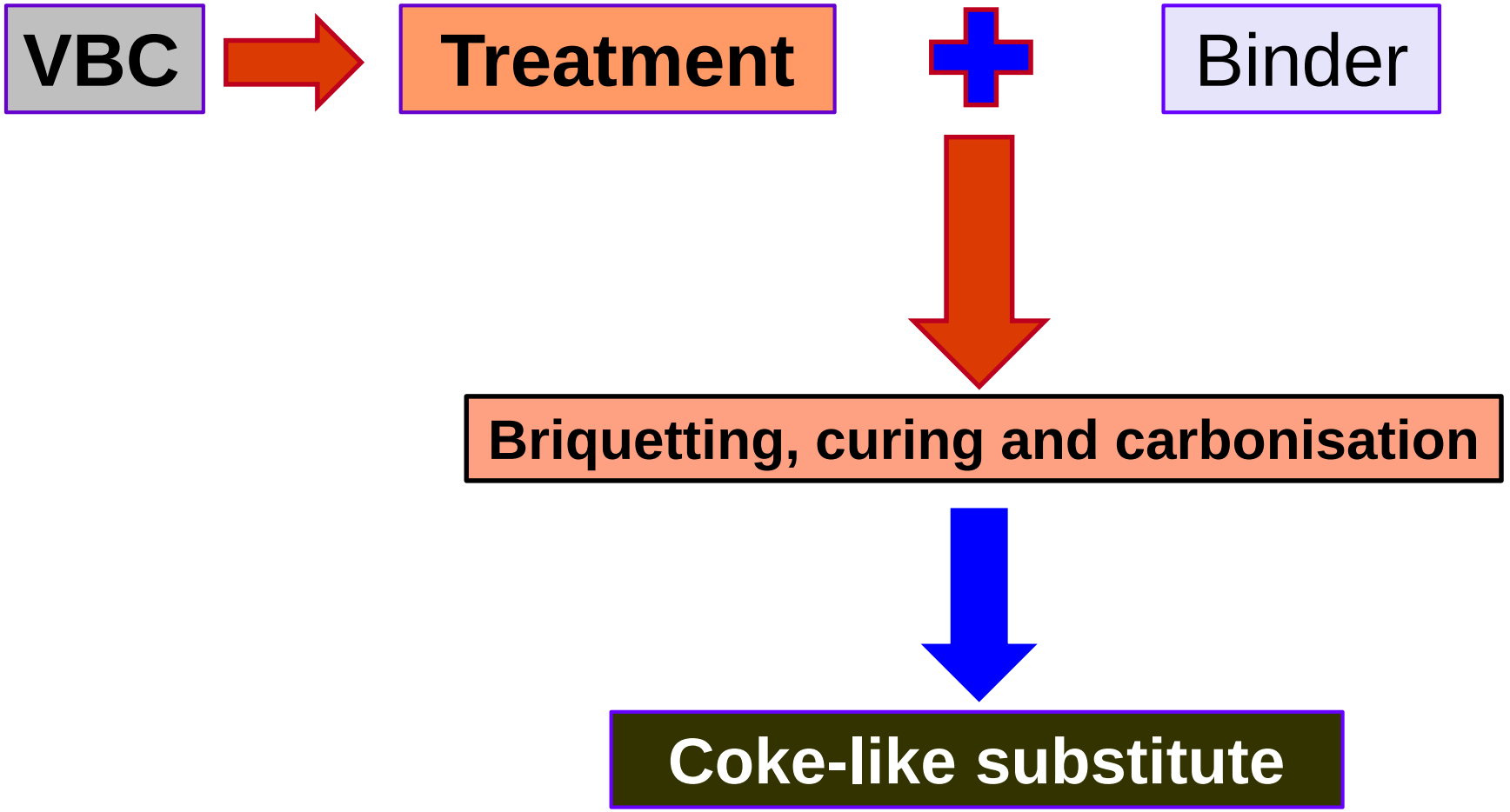
2.3 t briquettes

1 t hard **CHAR**

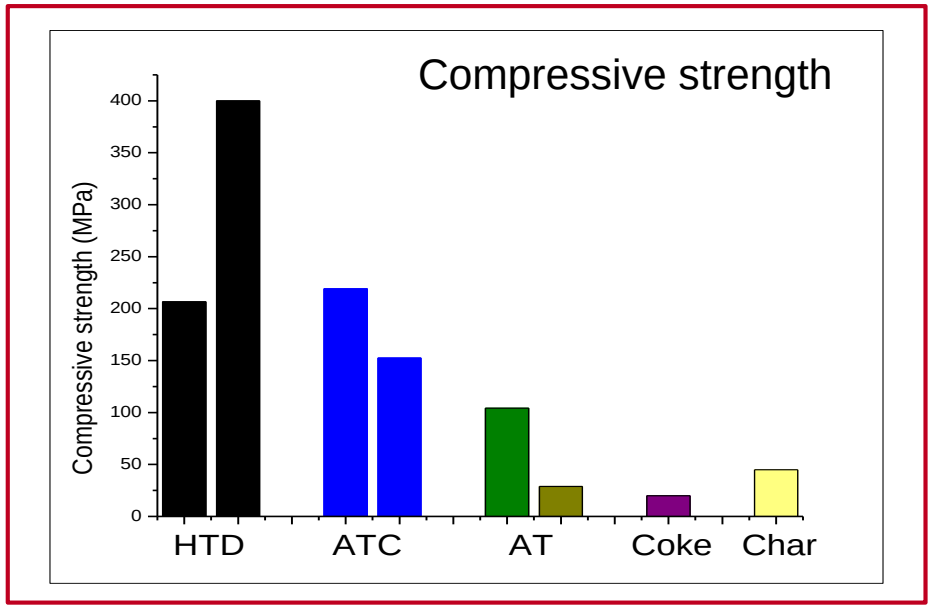
Very strong product
Too reactive for blast furnace

Research by Higgins, Kennedy et al
Gas and Fuel Corporation of Victoria

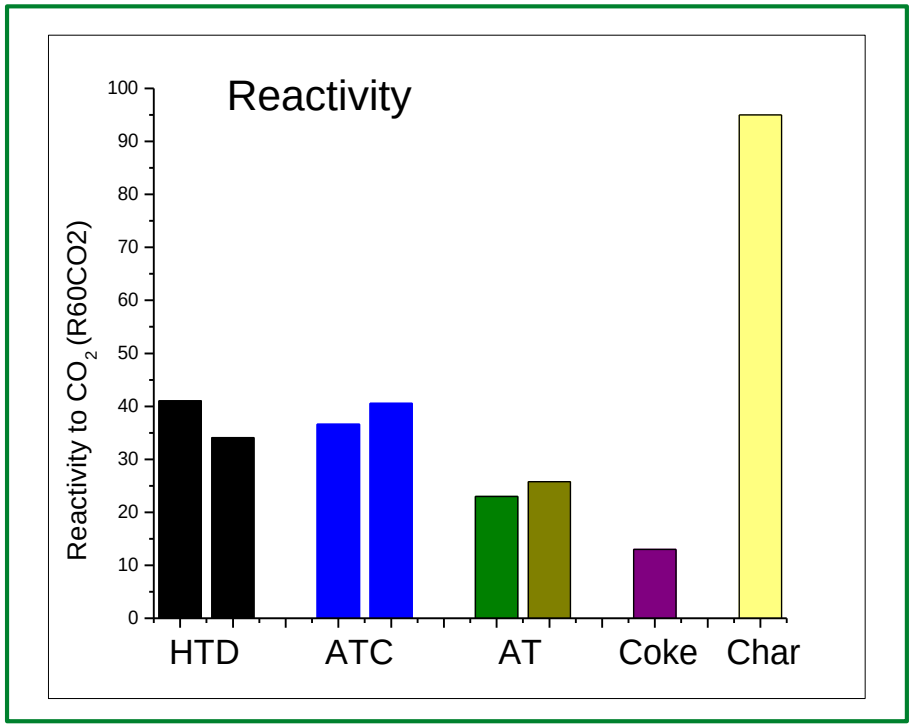
Approach


VBC
Treatment
Binder
Briquetting, curing and carbonisation
Coke-like substitute

Properties Comparison

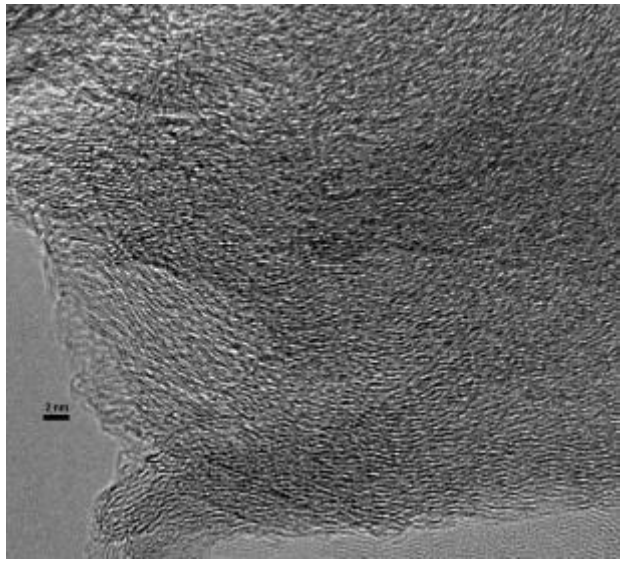


All carbonised products, including char, were stronger than BF coke

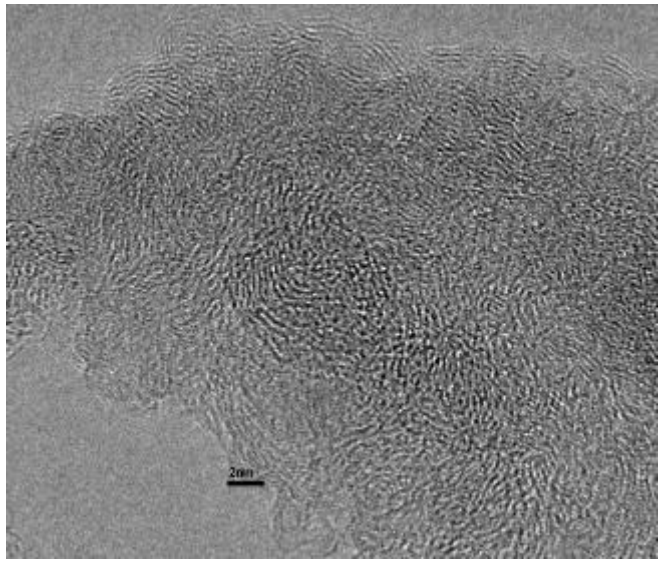


Least reactive samples approached the reactivity of BF coke

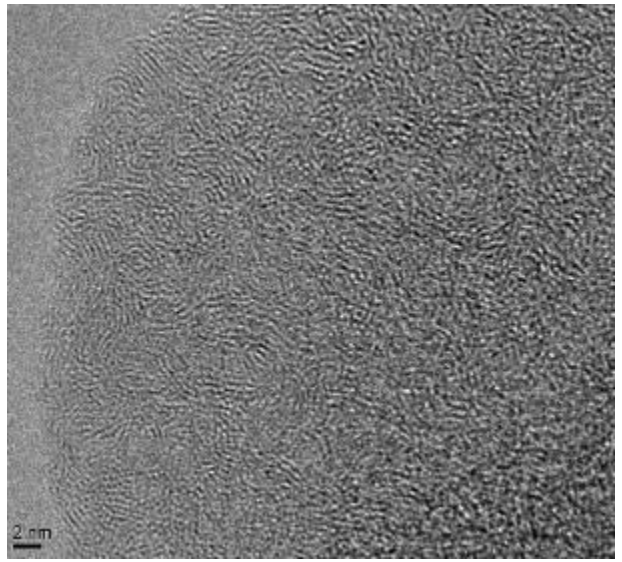
Transmission Electron Microscopy Images



BF coke



Coke-Like Product



VBC Char

- **BF coke:** Significant proportion of well-ordered regions
- **Coke-Like Product:** Developing ordered regions
- **VBC Char:** Poorly ordered, largely ‘amorphous’

COKE-LIKE MATERIALS FROM VBC

A procedure has been developed for preparing Coke-Like Materials that:

- are adequately **hard**
- have **low reactivity** approaching that of a BF coke

- There was **no relationship between strength and reactivity** in our products
- There was a strong **inverse correlation between reactivity and graphitic structure**

Monash University is **seeking partners** to further develop and commercialise this VBC product as a blast furnace coke substitute

Australian PCT: 2017/903985

Contents

- Clean brown coal
- Coke-like material
- ACTIVE CARBON MONOLITHS
- Road bitumen
- Agricultural products
- Other products

Active Carbon Monoliths

Conventional activated carbons:
powdered or granulated

Issues in use:
high pressure drop, plugging,
agglomeration, particle entrainment

Australian PCT: AU2016/901978

Active Carbon Monoliths

Conventional activated carbons: powdered or granulated

Issues in use:
high pressure drop, plugging, agglomeration, particle entrainment

Carbon honeycomb monolith : a structured activated carbon

Features :
- ✓ high void fraction
- ✓ large surface area
- ✓ high mass transfer rate
- ✓ regenerable

Australian PCT: AU2016/901978

Active Carbon Monoliths

Carbon honeycomb monolith :
a structured activated carbon

Features :

✓ high void fraction
✓ large surface area
✓ high mass transfer rate
✓ regenerable

Global activated carbon market:

- 1.6 million tonnes (2016)
- ~ USD 3 billion
- Annual growth rate > 12 %

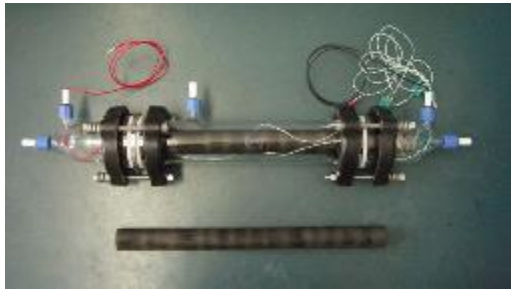
Granulated activated carbon:

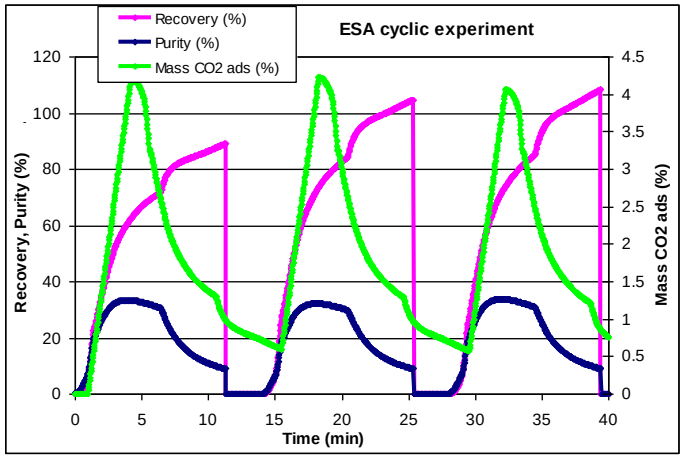
- typical market value: ~2000 USD/t.

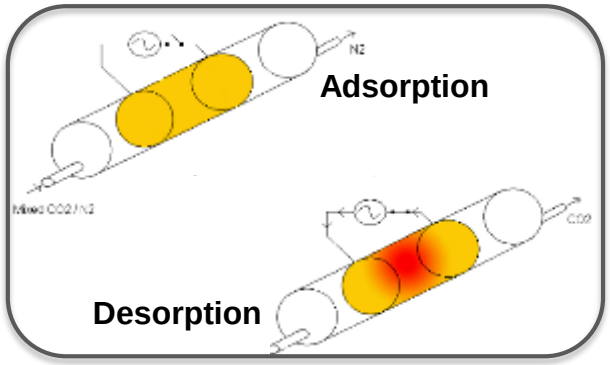
Carbon monoliths have far higher value:
Benchmark price: 130 USD / 10 cm
(Experimental material)

Australian PCT: AU2016/901978

Active Carbon Monoliths for CO_2 Capture





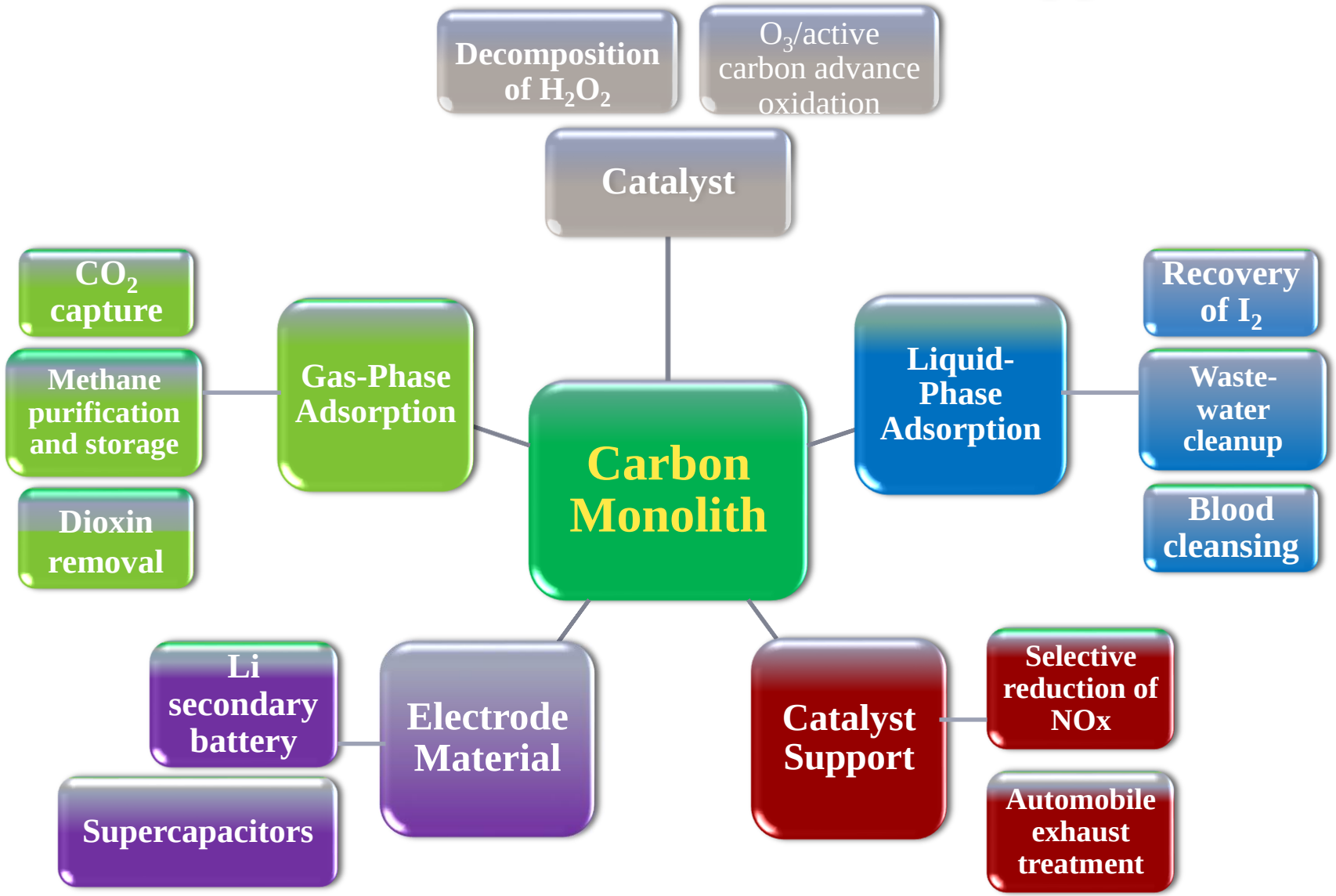


Monoliths can be repeatedly used: regeneration by **Electrical Swing Adsorption (ESA)**

- Monolithic carbons capture CO_2 and can then be regenerated by **ESA**
- Previous work utilised monoliths prepared from expensive precursor materials (resins)
- VBC derived adsorbents are now prospective for CO_2 capture and many other applications
- Heat is generated at the surface, just where it is needed

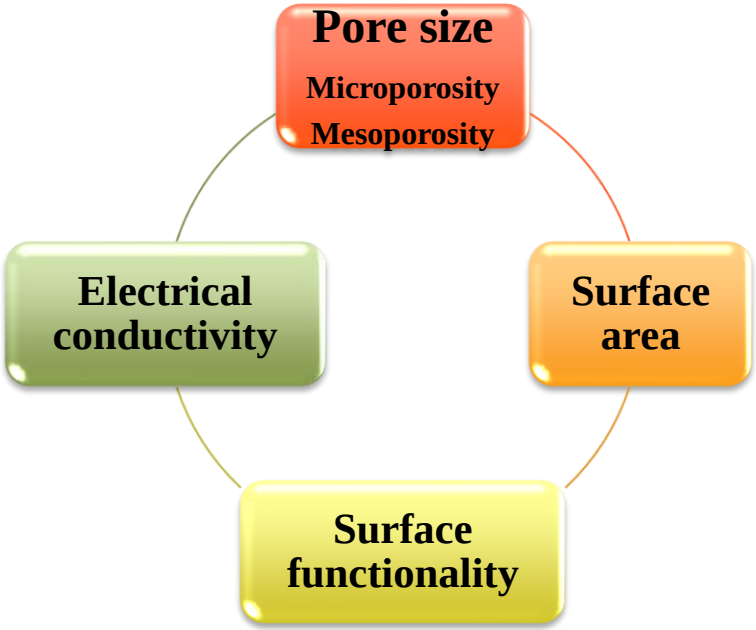
S Delaney, PhD Thesis, Monash University, 2009

Applications



Active Carbon Monoliths

Tailorable Properties



Facile Manufacture

ENVIRONMENTAL CLEAN TECHNOLOGIES LIMITED

We are now seeking to demonstrate a range of applications for this VBC product and are looking out for interested parties.

Australian PCT: AU2016/901978

Contents

- Clean brown coal
- Coke-like material
- Active carbon monoliths
- ROAD BITUMEN
- Agricultural products
- Other products

Road Bitumen

- Bitumen requires very specific properties
- Only heavy fractions from certain crude oils work
- Australia imports most of it (~700 kt/a)
- Value of finished product is ~ $1000/t
- Alternative materials are sought

SPECIFICATIONS/APPROVALS

AS 2008	Class 170

TYPICAL CHARACTERISTICS

DESCRIPTION	UNITS	METHODS	TYPICAL
Viscosity at 60° C	Pa.s	AS 2341.2	170
Viscosity at 135° C	Pa.s	AS 2341.2	0.35
Pen at 25° C	dmm	AS 2341.12	min 62
Flashpoint	° C	AS 2341.14	min 250
Viscosity of residue at 60° C (% of original)	Pa.s	AS 2341.2	max 300

Road Bitumen

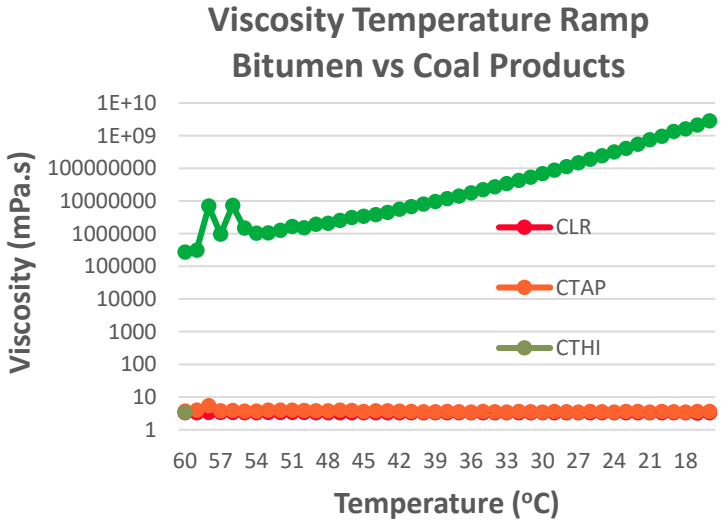
Brown coal liquids are being investigated as potential precursor materials

- Tar is polymerised at elevated temperature and pressure
- Physiochemical properties of the tar are evaluated.

Coal tar and Additives

Polymerisation

Bitumen substitute *or* Blending material



A PhD project is underway

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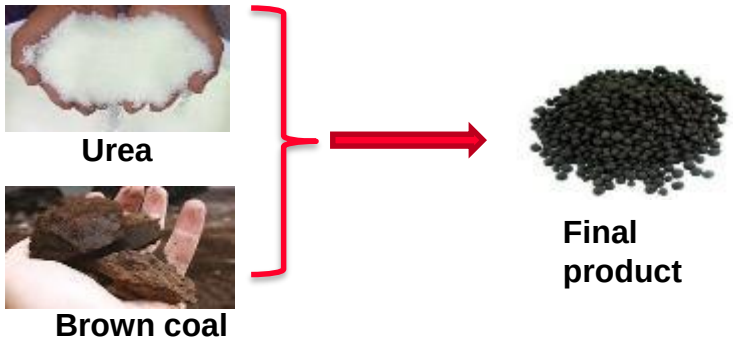
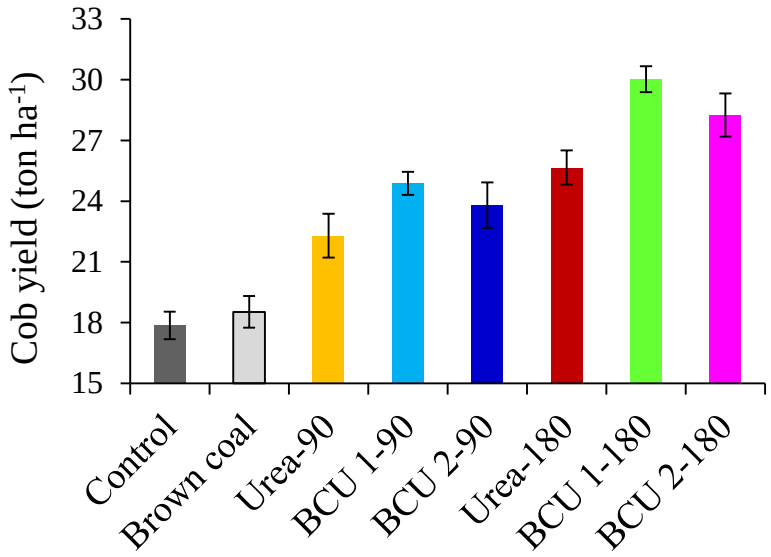
- AGRICULTURAL PRODUCTS
- Other products

Agricultural Products

Brown Coal Fertiliser blends





MONASH University

Contact: tony.patti@monash.edu

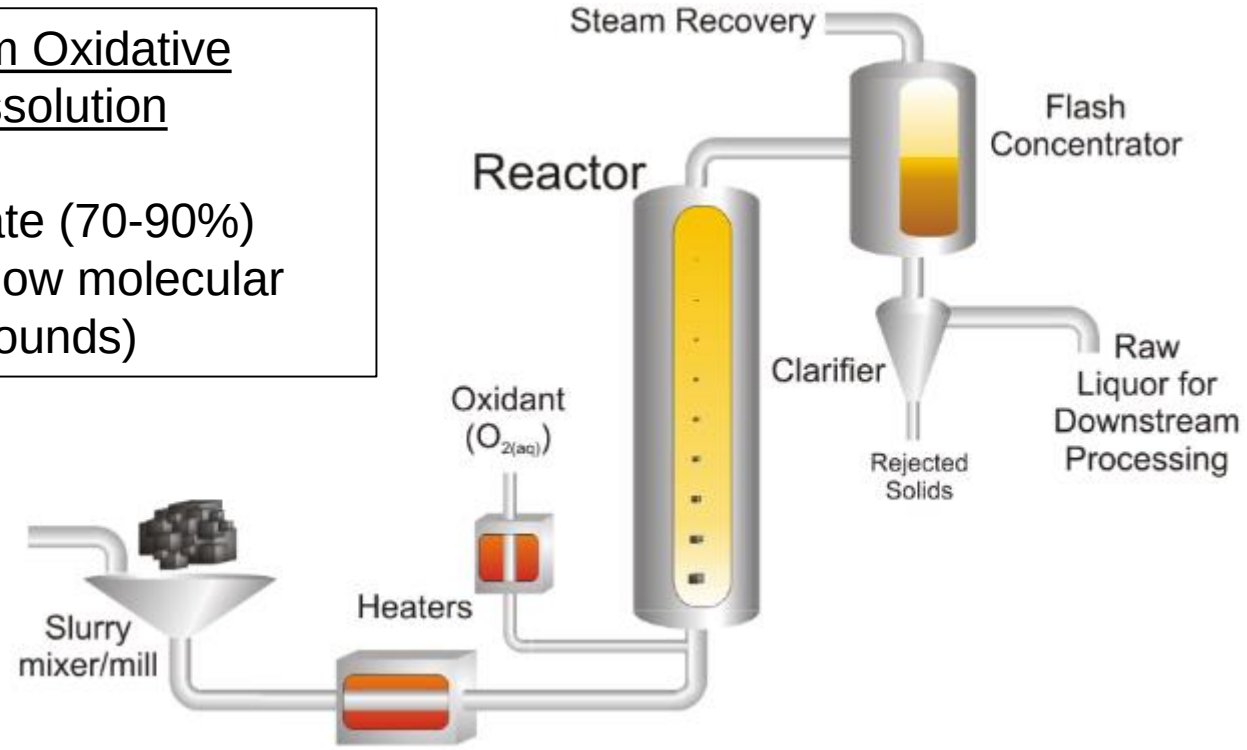
Agricultural Products

Biostimulant from Victorian lignite coal

Liquid produced from Oxidative Hydrothermal Dissolution

Low cost

- High conversion rate (70-90%)
- Fulvic-like product (low molecular weight compounds)



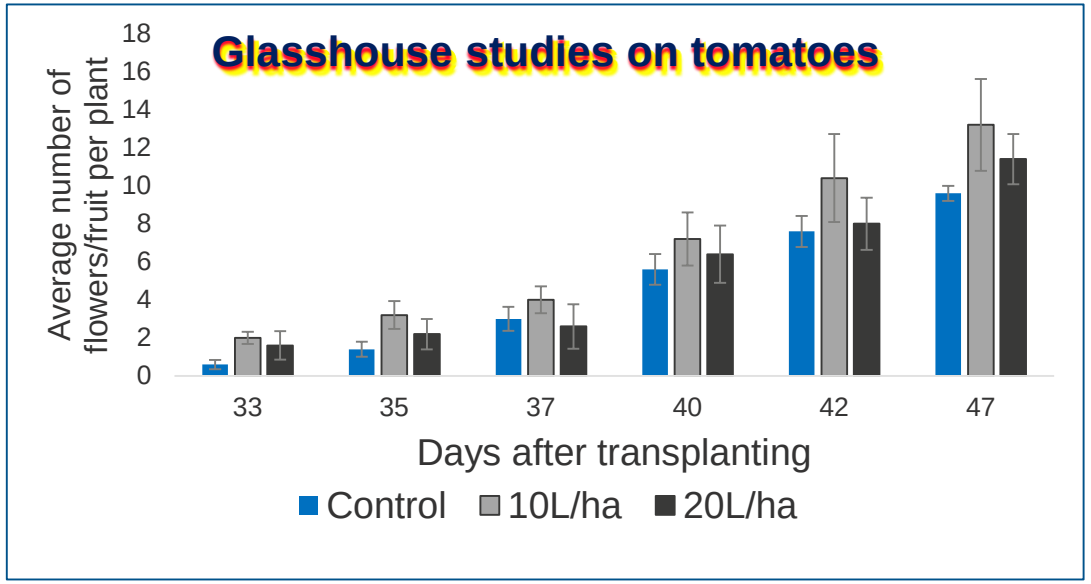
greenpower ENERGY

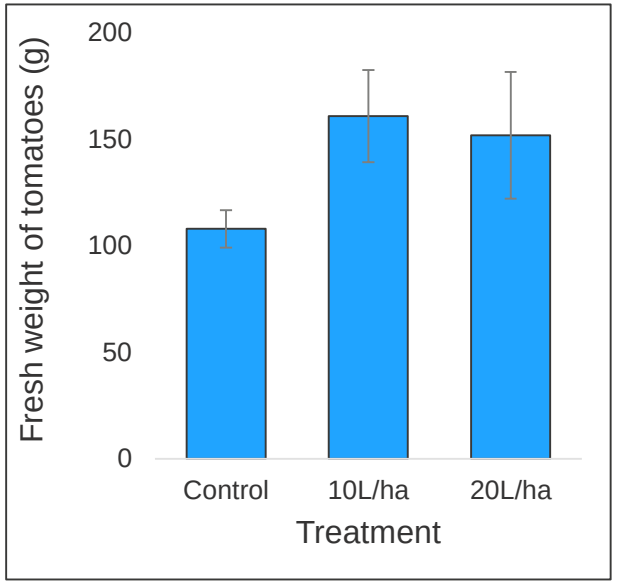
Thermaquatica

Contact: tony.patti@monash.edu

Agricultural Products

Biostimulant from Victorian lignite coal





- Decreased incidence of blossom end rot
- Hydroponic trials for fresh tomato markets
- Field trials for tomato processing industry

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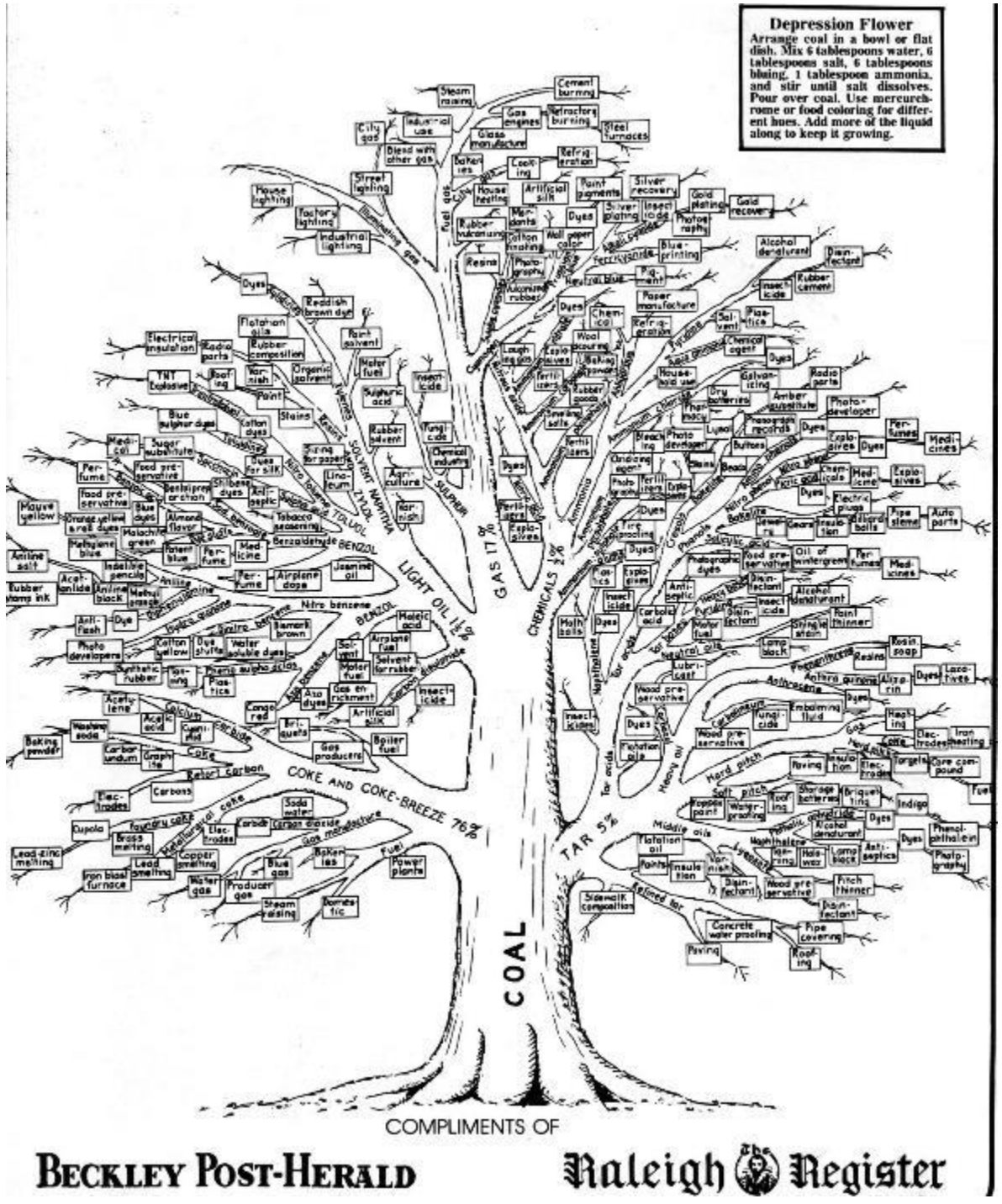

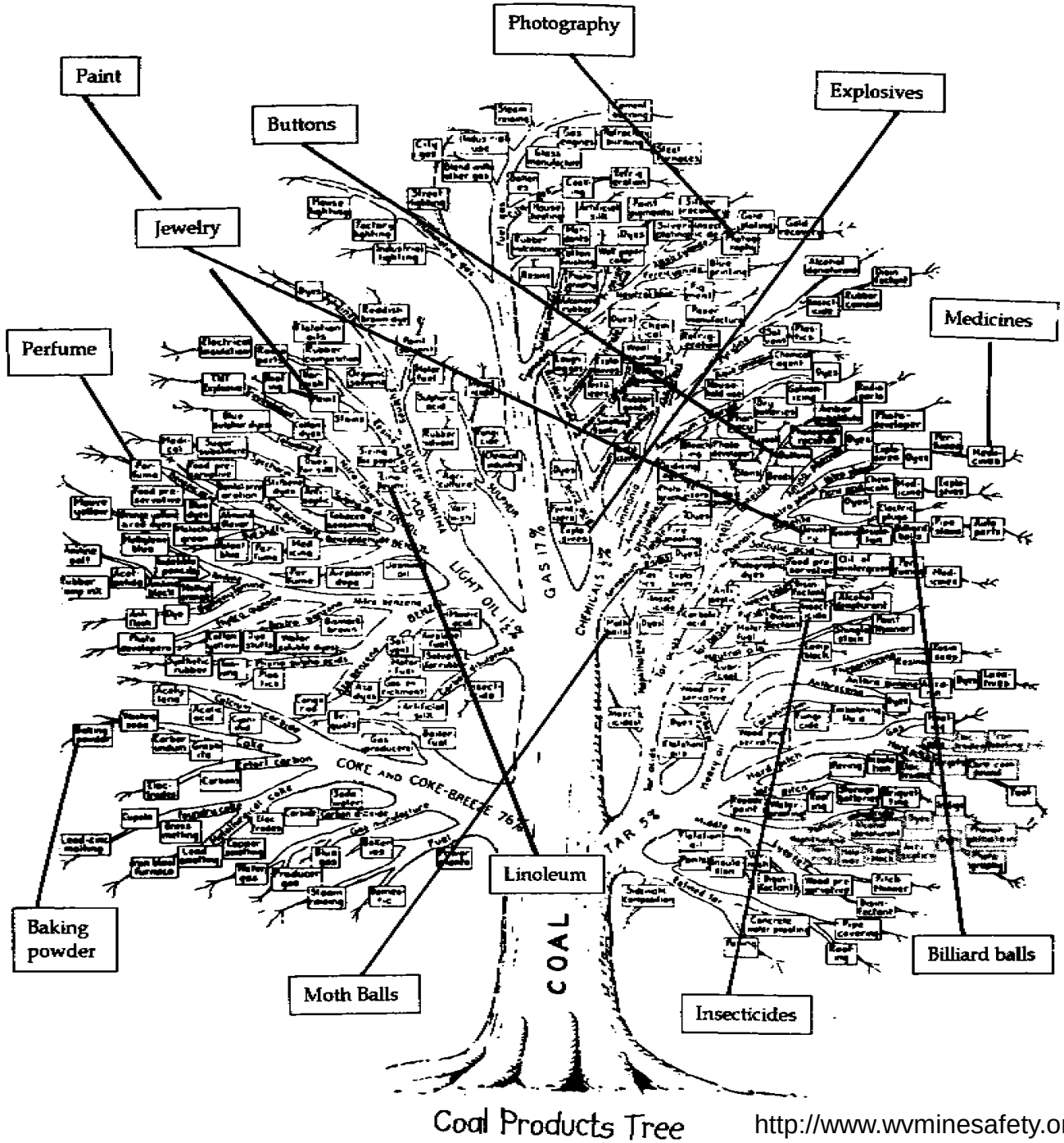

Coal Products Tree

http://www.wvminesafety.org/COALTREE.htm

Acknowledgements

BROWN COAL INNOVATION AUSTRALIA
anlecr&d
State Government Victoria
THE UNIVERSITY OF MELBOURNE
MATESA
CO2CRC
Fraunhofer IKTS

Thank You !

Some of the team at Monash University