

ALTERNATIVE USES FOR COAL in the changing energy landscape

Alan Flavelle

- The basic cost of energy.
- If I need a gigajoule of energy.
- Victorian Brown Coal: \$1.00
- Collie Coal: \$2.50
- Petrol: \$12.50
- Electricity: \$28.00

- We need to go back to the beginning. and think about the origins of coal.
 - Fossilized and preserved plants.
 - But not every part of the plant
 - Plants are mainly cellulose and lignin
- Coal is the preserved plant lignin and natural processes have removed the cellulose.
- “New coal” is lignin plus water plus some waste matter such as sand—called lignite.
- This new coal is slowly buried and heated and some of the lignin molecules get transformed—black coal.

- THE LUCKY COUNTRY
- VICTORIAN BROWN COAL [VBC]: BILLIONS OF TONNES OF IT, CLOSE TO THE SURFACE WITH VIRTUALLY NO WASTE MATTER.
- CHEMICALLY INDISTUISHABLE FROM LIGNIN
- CELLULOSE REMOVED BY NATRUAL PROCESSES.
- COLLIE COAL [CC]: ONE OF THE MOST CHEMICALLY REACTIVE BLACK COALS THERE IS.

TRADITIONAL USAGE


1. A source of energy. We burn it to obtain heat energy mainly for driving turbines which in turn drive electricity generators and until recently for transport—ships and trains.
2. Heating for town gas and chemicals.

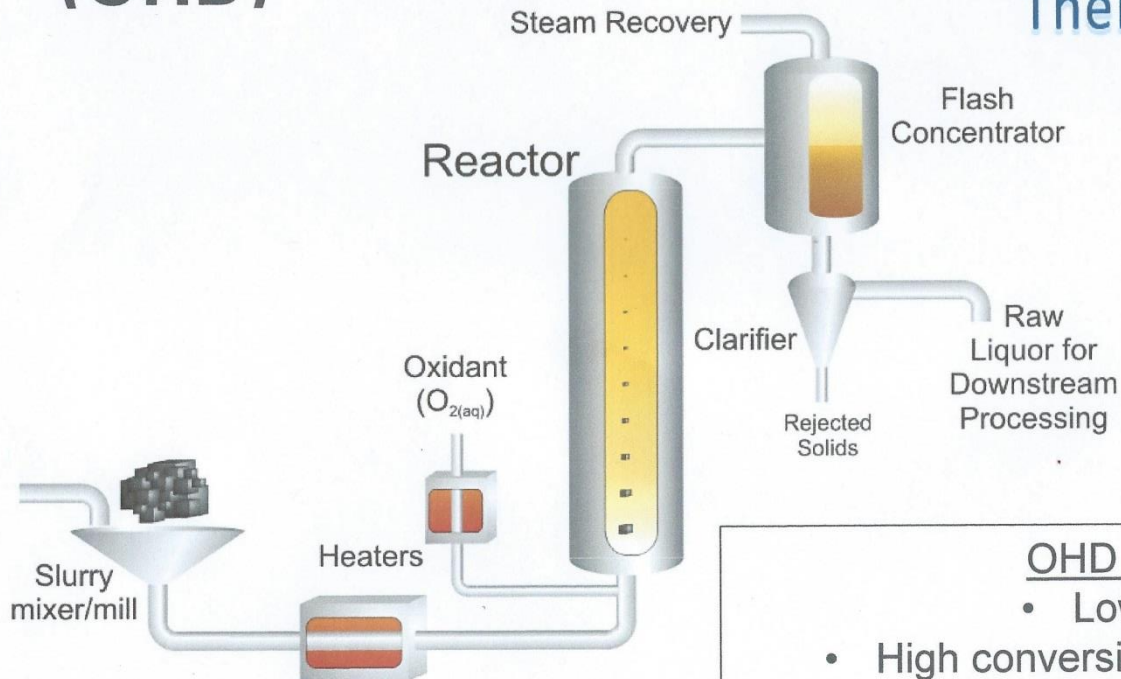
ALL THE ABOVE IS ACCOMPANIED BY
THE GENERATION OF SIGNIFICANT CARBON
DIOXIDE-EMIITED TO THE ATMOSPHERE.

THERE IS ANOTHER WAY.

1. IF A MIXTURE OF COAL, WATER AND LIQUID OXYGEN IS BROUGHT TOGETHER AT THE APPROPRIATE TEMPERATURE AND PRESSURE THEN ALL THE CARBON WILL BE TRANSFORMED INTO A RANGE OF LOW MOLECULAR WEIGHT ORGANIC COMPOUNDS.
2. THE PROCESS IS CALLED *OXIDATIVE HYDROTHERMAL DISSOLUTION* **OHD**.

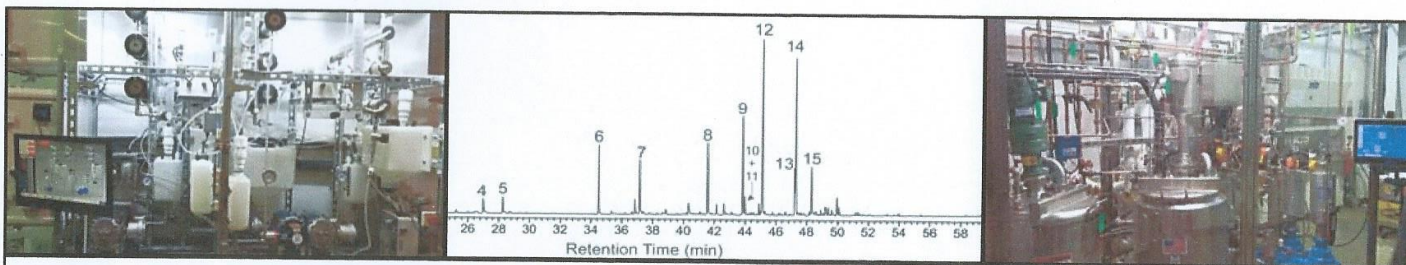
Oxidative Hydrothermal Dissolution (OHD)

Thermaquatica 



OHD liquor

- Low cost
- High conversion rate (70-90%)
- Fulvic-like product (low molecular weight products)



Integrated, Non-Catalytic Process for the Production of High Value Chemicals from Low Rank Coal by Oxidative Hydrothermal Dissolution (OHD)

Francois Botha, Ken Anderson, Derek Perry and Madhav Soti

Thermaquatica, Inc., Carbondale, Illinois, U.S.A.

Thermaquatica 

OHD is Environmentally Friendly

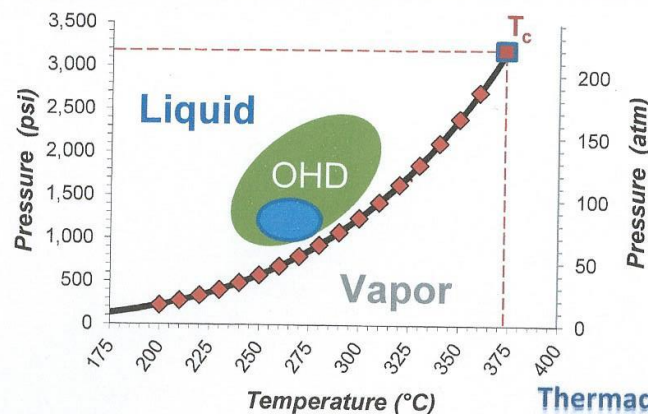
- 💧 **Uses only water and oxygen.**
- 💧 **Requires no exotic solvents, enzymes or catalysts, nor pretreatment of the feed.**
- 💧 **Moisture content of the feed is irrelevant – great for lignites.**
- 💧 **Typical reaction times (pulverized feed) are of the order of a few 10s of seconds.**
- 💧 **Readily achieves very high conversion of the solid.**
- 💧 **High recovery (typically 75-90+%) of the products as solubilized, low molecular weight chemicals.**
- 💧 **Produces very little CO₂ or other gases.**

What is Oxidative Hydrothermal Dissolution (OHD)?

OHD is a novel, continuous, hydrothermal process to convert macromolecular organic solids into low molecular weight chemicals, using only elevated temperature (200-370°C), high pressure, liquid water (subcritical) and molecular oxygen.

Important Parameters:

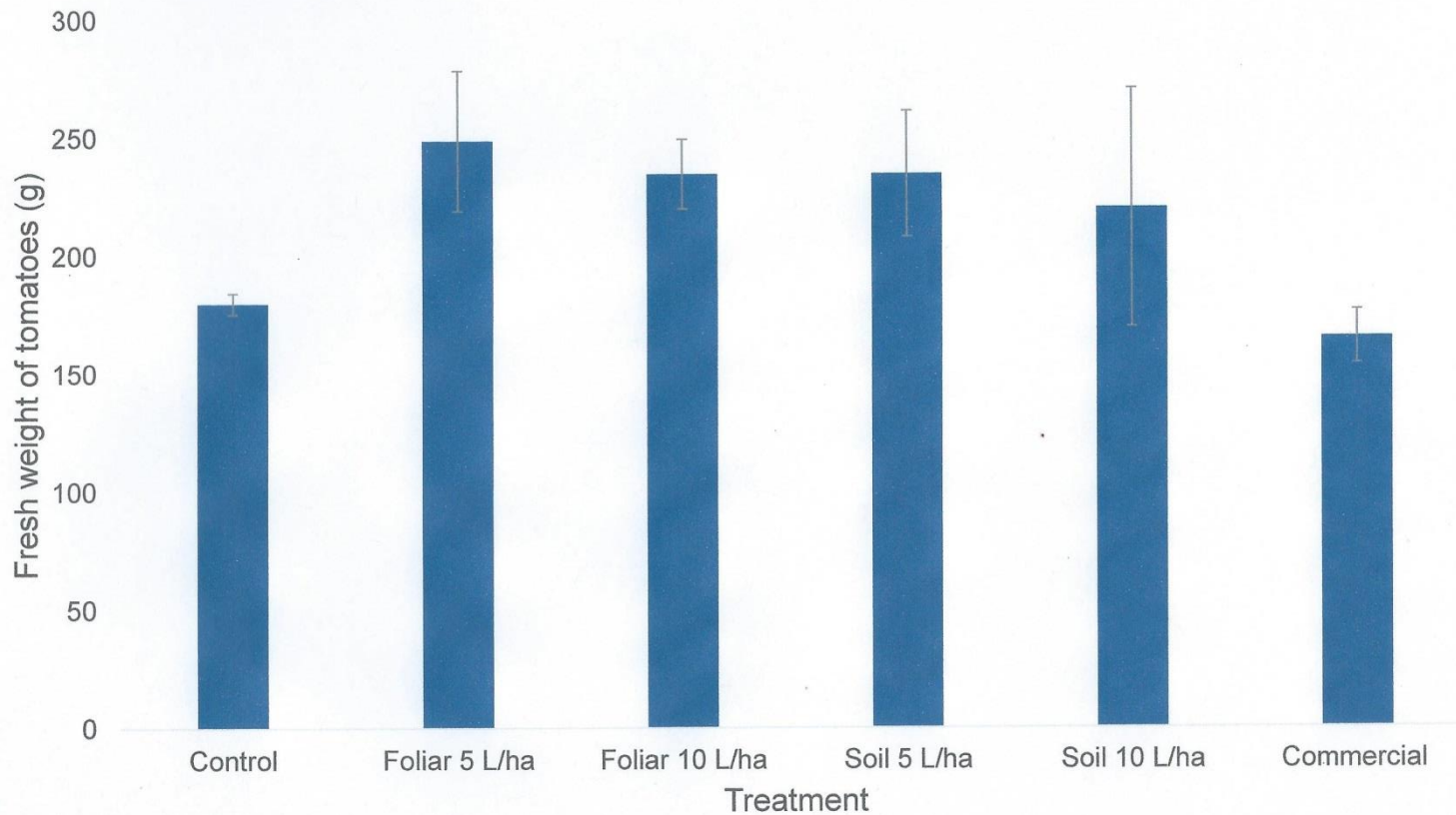
- ✓ Temperature (coals: 250-300 °C)
 - ✓ Oxidant Loading
 - ✓ No gas phase
 - ✓ Continuous flow
 - ❖ Pressure
- } reaction
} process



Pk.	Rt.	% of total	Compound	CAS#
1	18.184	1.75%	Anisole (Methoxybenzene)	100-66-3
2	35.581	12.83%	Methyl 3-methoxybenzoate (mHB)	5368-81-0
3	37.119	7.18%	Methyl 4-methoxybenzoate (pHB)	121-98-2
4	40.992	1.61%	Dimethyl Terephthalate	120-61-6
5	41.498	4.36%	Dimethyl isophthalate	1459-93-4
6	42.744	1.07%	6,7-Dimethoxy-m-cymene (?)	
7	43.293	4.79%	Methyl 3-hydroxybenzoate	19438-10-9
8	43.424	4.84%	Methyl 3,5-Dimethoxy benzoate	
9	44.07	2.42%	Methyl 3,4-Dimethoxy benzoate	24812-90-6
10	44.407	2.43%	Unassigned (?)	
11	44.764	7.63%	Dimethyl 2-Hydroxy Terephthalate	
12	47.766	5.82%	C3 alkyl hydroxy methoxy benzoate (unknown isomer)	
13	48.401	9.81%	1,7,7-trimethyl-2(1H)-Naphthalenone, octahydro-4A-(hydroxymethyl)- (*)	
14	49.612	1.74%	C16 FAME	
15	50.075	1.93%	Dimethyl 4-Methoxy Terephthalate	120-61-6
16	51.703	1.64%	Trimethyl trimellitate (1,2,4-Benzenetricarboxylic acid trimethyl ester)	2459a-10-1
17	52.816	28.15%	Trimethyl trimesate (1,3,5-Benzenetricarboxylic acid, trimethyl ester)	2672-58-4
		100.00%		
		Collie		

* Peak 13 is a terpenoid derived product reflecting the probable presence of minor amounts of fossil resin within the coal

Study 2 – Tomato yield



Possible mechanisms

- Chelation of nutrients in soil
- Hormone effects – auxin/cytokinin ratio
- Increased exudation of compounds into root zone and stimulation of the microbial community

Further studies

- Timing of application
- Hydroponic
- Effects on the soil microbial community
- Other crops including wheat, cotton
- Hormone study



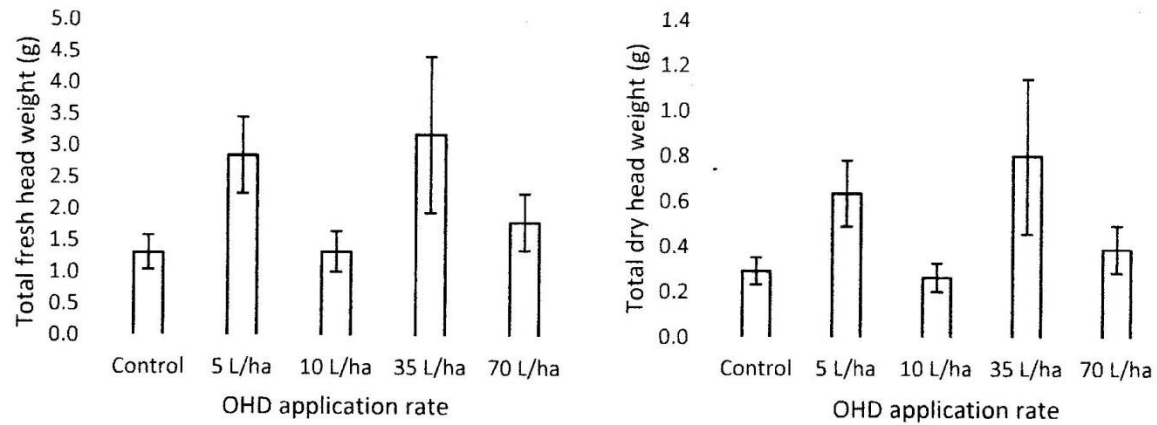
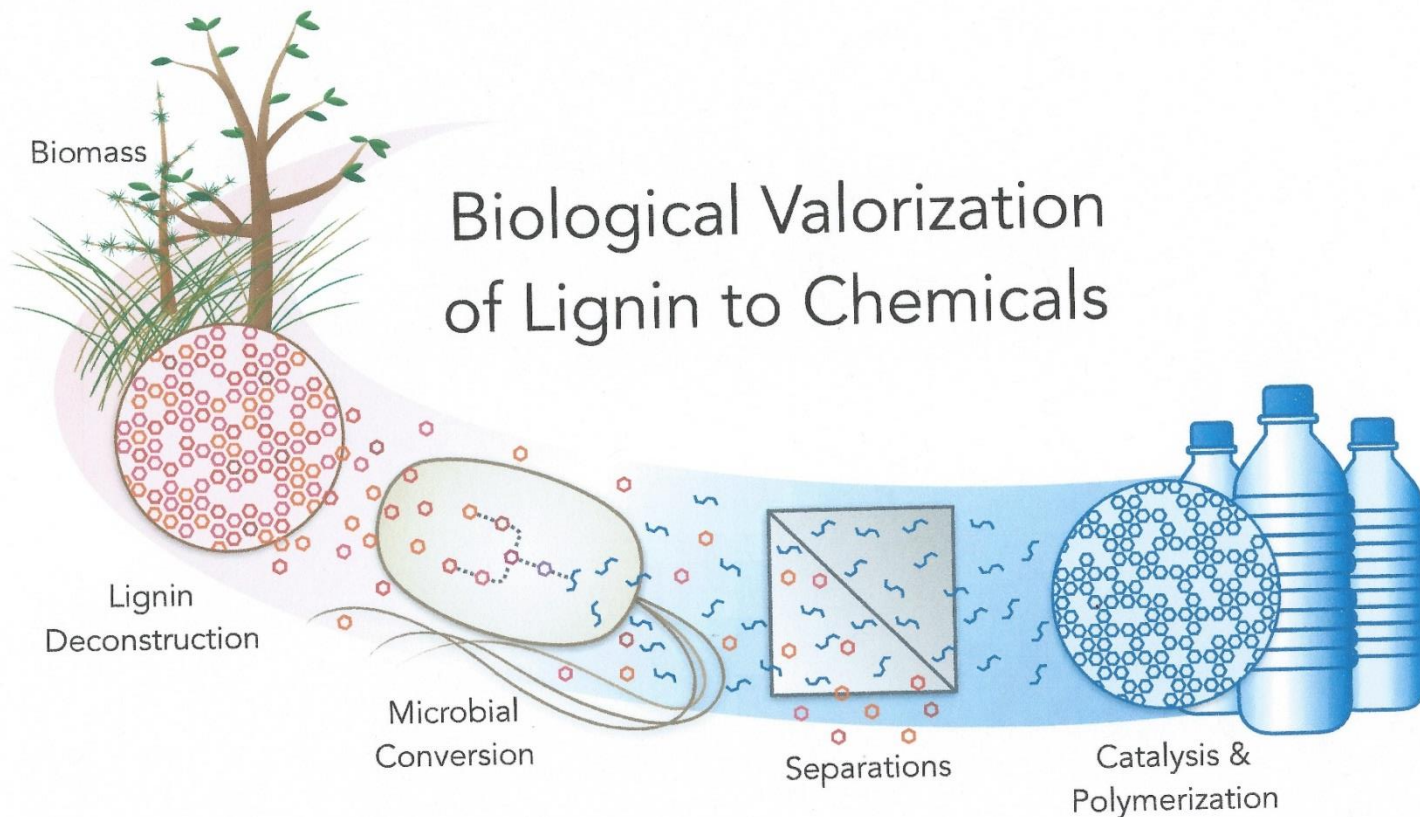


Figure 3.2. Total fresh head weight per plant at harvest, 79 days post-seeding (left). Total dry head weight per plant, 79 days post-seeding (right). Mean values are presented (n=6) and error bars represent \pm standard error.

LIGNIN VALORIZATION

- THE NEXT BIG THING
- Converting lignin [and lignite and black coal] to commercial products



Biological funneling (along with other emerging techniques) may enable a solution to overcome lignin heterogeneity

- Significant opportunity in co-designing *in planta* lignin with biological and catalytic conversion
- Emerging 2G biorefineries offer space for new lignin valorization processes

OUR COLLABORATORS

- 1. Thermaquatica Inc and its CTO Dr Kenneth Anderson-the inventor of the OHD process.
- Professor A Patti, Dr Karen Little of the Green Chemistry Unit, Monash University.
- Dr Cassandra Schefe, consultant agronomist.
- Dr David McManus of BCIA [Brown Coal Innovation Australia], Victoria.