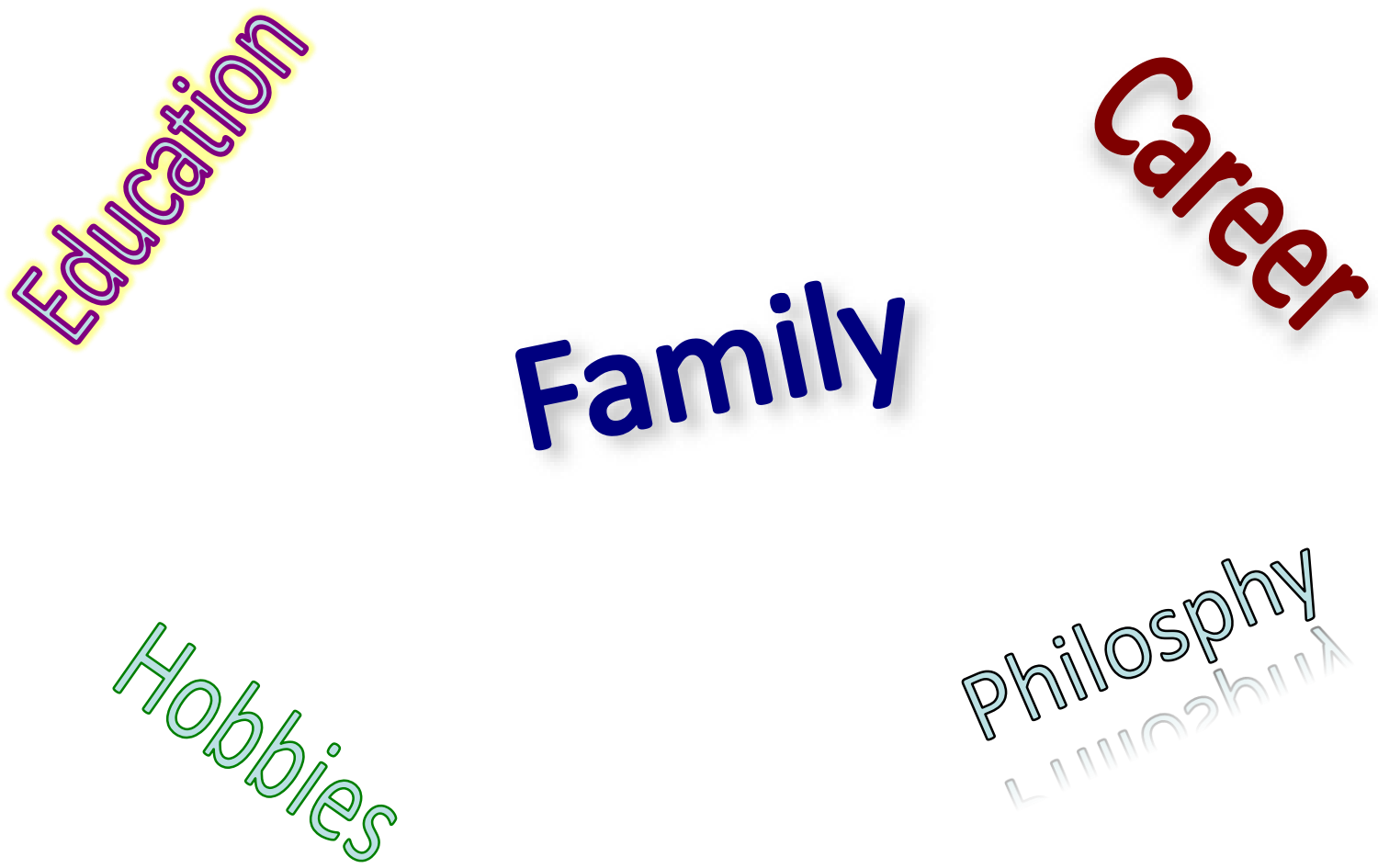
The Circular Economy
And
Pyrolysis Chemistry

Prepared for Seton High School
Mrs. Meese's Classes
2019

by Hugh O'Donnell, Ph.D.

Who is Hugh O'Donnell?



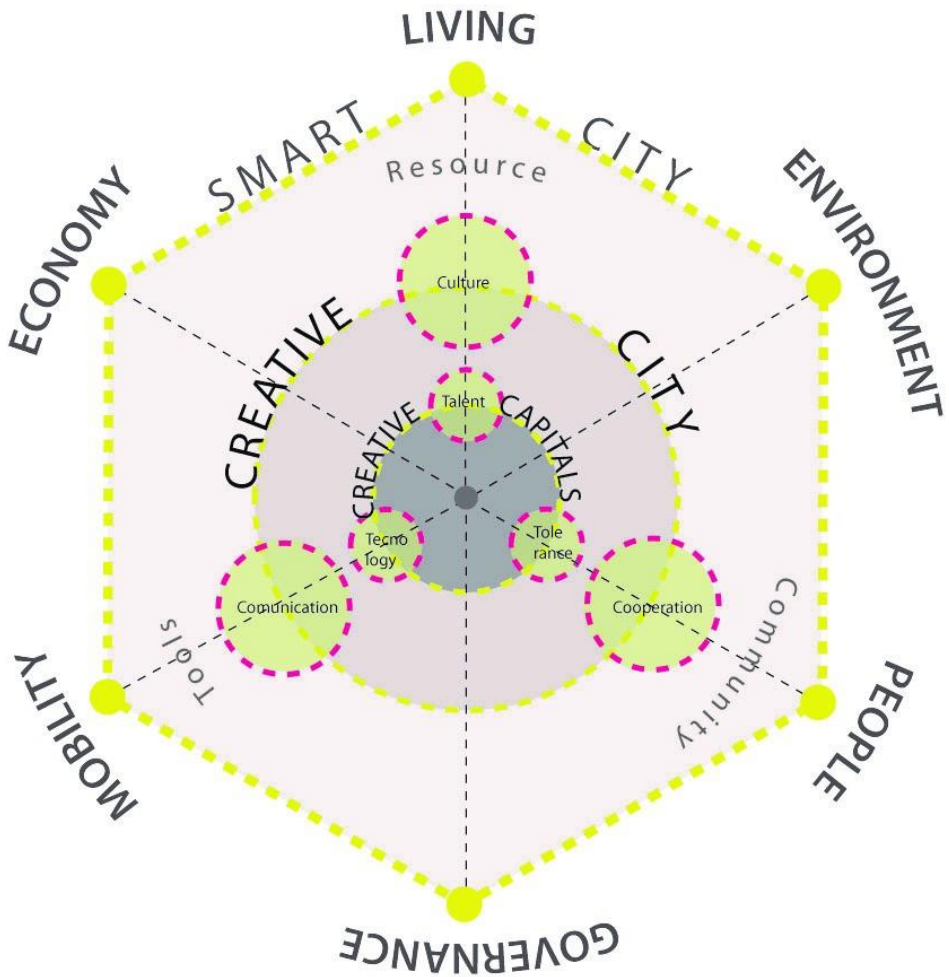
Philosphy Toward Science & Humanity

- ***Know & Learn From The Past***
- ***Create A Better Future***
- ***Everything is Connected***

- ***"When we try to pick out anything by itself we find it hitched to everything else in the Universe"***
  - John Muir, Scottish born American Conservationist
  - Drive for establishing Yosemite National Park
  - Co-founding the Sierra Club

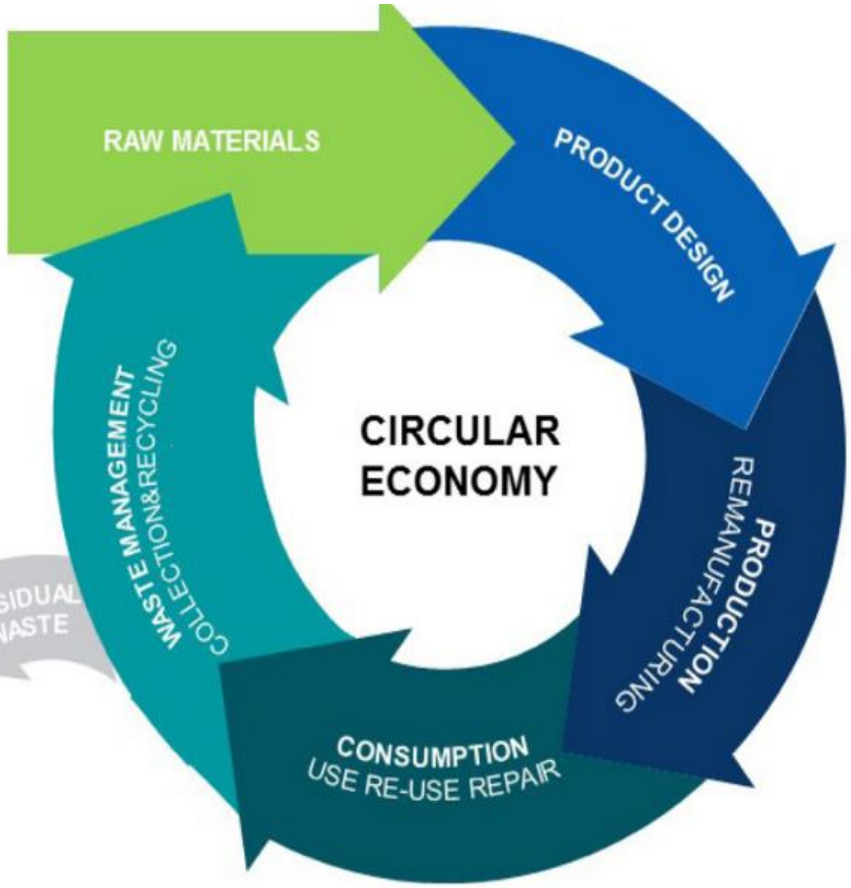
Holistic Science & Design

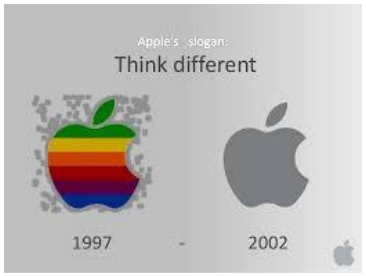
Circular Economy Strategies Require Broad Thinking and Integration



https://www.interaction-design.org/literature/article/holistic-design-design-that-goes-beyond-the-problem

The Circular Economy





Fast Moving Consumer Goods

Paper Plastic Glass or Metal?

How Can Materials Be Recovered?

1. Clean & Reuse
   - Is package over-designed? Hygiene? # Uses?
2. Collect and recycle
   - Plastics degraded during reheating
   - Typically limited to 30% recycled content
3. Conversion into monomers
   - pyrolysis & enzymatic methods
   - new commercial operations
4. Chemical conversion into fuel
   - pyrolysis methods
   - new commercial operations
5. Burn to extract energy
   - incineration

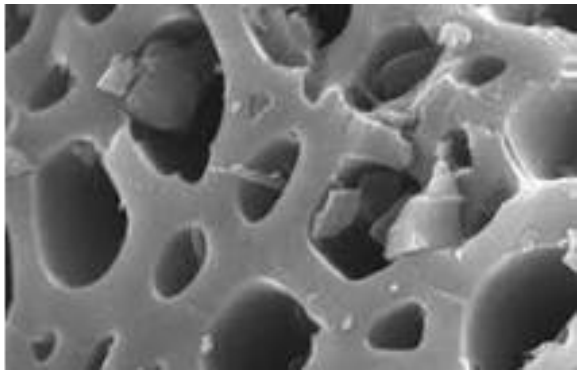
What is Pyrolysis?

- Pyrolysis is the thermal decomposition of materials at elevated temperatures in an inert atmosphere. It involves the change of chemical composition and is irreversible. The word is coined from the Greek-derived elements pyro "fire" and lysis "separating".
  - ***Reacting and separating by fire***

What is a Common Pyrolyzed Material?

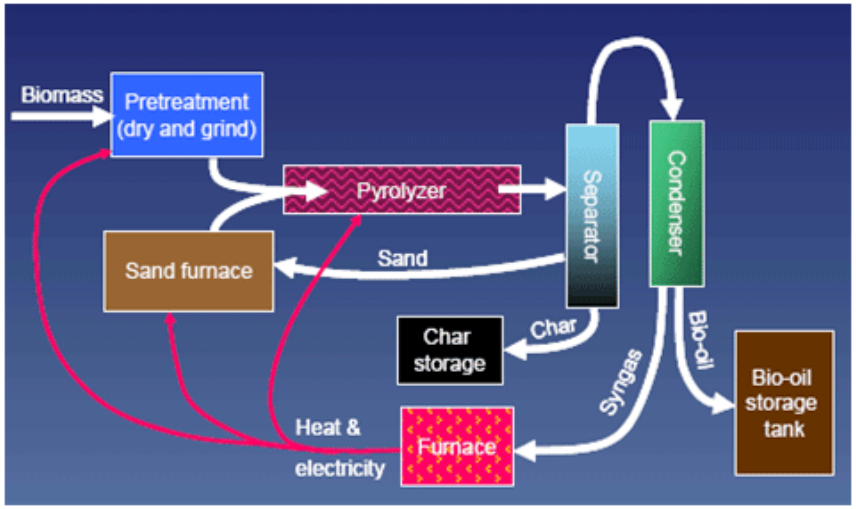
- Wood → Charcoal

Chemical properties of **charcoal**. **Charcoal** is mostly pure carbon, made by cooking wood with low oxygen. The process can take days and burns off volatile compounds such as water, methane, hydrogen, and tar, and leaves about 25% of black lumps and powder of the original weight.



Why Pyrolytically Treat Materials?

- Create Fuel
  - Solid fuel; liquid fuel; and gaseous fuel
- Return Materials Back to Starting Materials
  - Waste Plastic to Starting Monomers or Feedstocks



Primative Technology:

Making Charcoal via Pyrolysis Oven

17 Million Views!

Learn from The Past

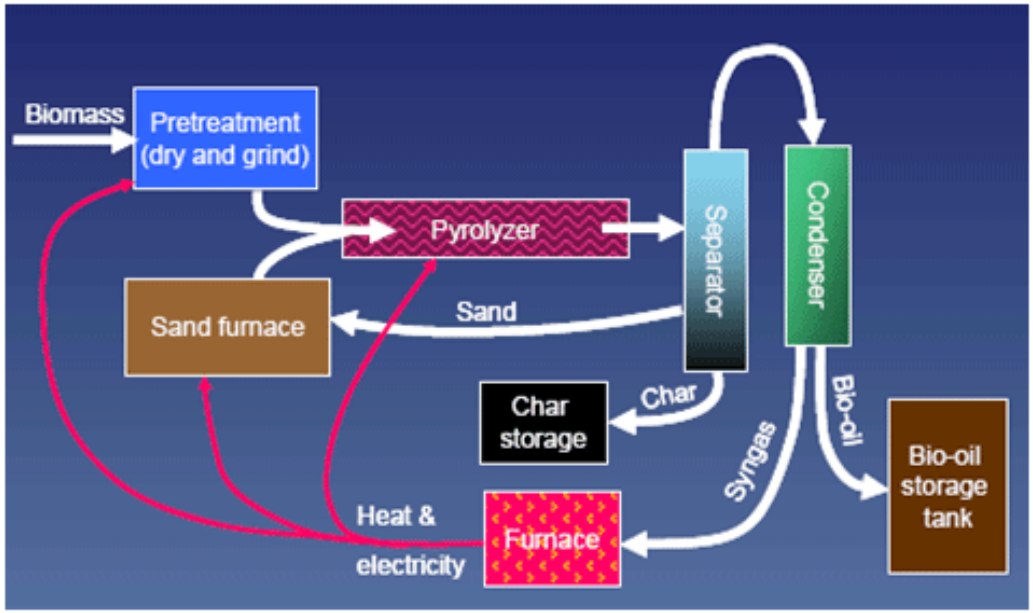
Ready for a rainy day

We are still doing this in my place (Sorsogon, Philippines) during summer season. We are using the coconut shell and dry woods. We usually burn them in a pit and we will store them for rainy season. Primitive way of living is normal for us who are living in mountains.

https://www.youtube.com/watch?v=GzLvqCTvOQY&t=257s

Does Primative Process Fit Modern Day Process?

1. Dry wood
2. Furnace
3. Collect effluent of syngas & bio-oil
4. Reuse heat
5. Charcoal



Is Paper Better Than Plastic?

Pros & Cons

- Benefit
  - Cellulose biodegrades and can be repulped into paper
  - Forest is conservatively managed
- Challenges
  - Paper making is an intensive process:
    - water; caustics and acids; bleach; energy; effluent
  - There is significant waste
    - 25% is waste product
    - Lignin is the main component that is waste. What to do with it?
  - Recycling
    - ~60% recycling but fibers are shortened each time they are recycled
    - Fiber length correlate to paper substrate strength

Waste Wood Product

Lignin Pyrolysis

Wood = Cellulose + Hemicellulose + Lignin

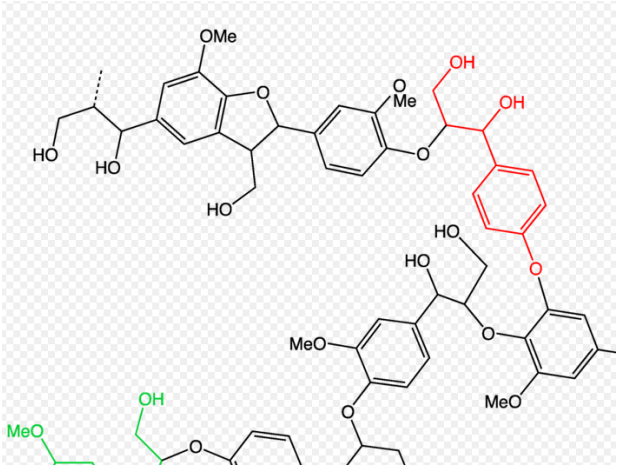
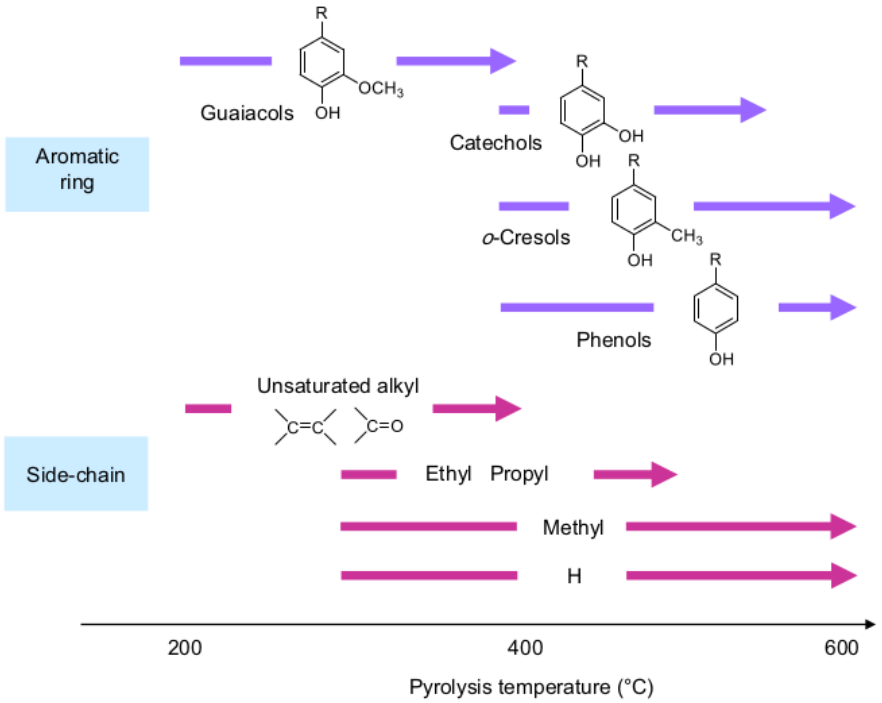


Fig. 2 Effect of pyrolysis temperature on aromatic substitution pattern and side-chain structure of the products from G-type lignin



Lignin
- 20 - 30% wood
- Primarily waste product from wood
- What to do with lignin?

Chemical Disassociation Energies

What will break first and what will form?

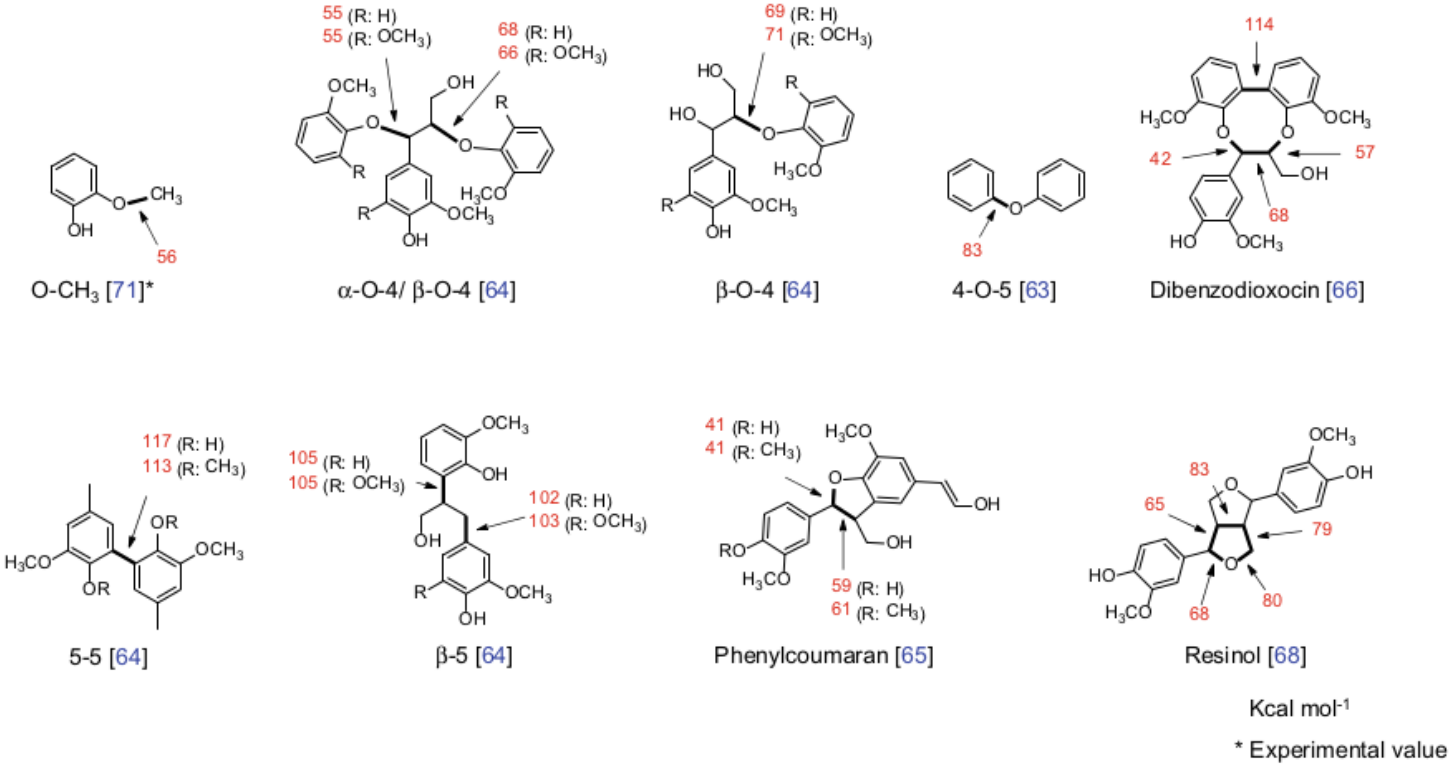


Fig. 3 Bond dissociation energies of various C–O and C–C bonds in lignin model compounds as evaluated by theoretical calculations

Plastic to Fuel

Grocery Bags Are Fuel

- High density polyethylene, HDPE, was pyrolyzed in a self-designed stainless steel laboratory reactor to produce useful fuel products. HDPE waste was completely pyrolyzed at 330–490 C for 2-3 hours to obtain solid residue, liquid fuel oil, and flammable gaseous hydrocarbon products. Comparison of the fuel properties to the petrodiesel fuel standards ASTM D 975 and EN 590 revealed that the synthetic product was within all specifications.

Pyrolosis is Diffuse

VADXX
PLASTIC TO ECOFUEL

Argonne National Laboratory (ANL), part of the U.S. Department of Energy, released the following findings on May 16, 2017. Follow the link below to see what

Reductions of up to 14 percent in greenhouse gas emissions, up to 58 percent in water consumption, and up to 96 percent in traditional energy use when compared to ULSD from conventional crude oil.
https://www.americanchemistry.com/Media/PressReleasesTranscripts/ACC-news-releases/Plastics-to-Fuel-Technology-Helps-Reduce-GHG-Emissions.html

The MidWest is growing eco-businesses

1 & 2 **Vadxx Energy, Polyflow**: Akron is the starting point for the two plastics-to-fuel companies

"cluster" of companies put together by NorTech, a Cleveland nonprofit focused on developing the region's high-tech economy.

3 U.S. Energy Logistics, Toledo, Ohio

https://www.cleveland.com/business/index.ssf/2011/08/northeast_ohios_quasar_energy.html

Shell

Catalysts for Renewable Fuels

The CRI Renewables group shares the goal of serving a global customer base with high performance, cost-effective catalysts and process technologies specific to the renewable fuels arena.

CRI Catalyst Company is part of CRI/Criterion Inc., the global catalyst technology company of the Shell Group.
https://www.cricatalyst.com/cricatalyst/catalysts/renewables.html

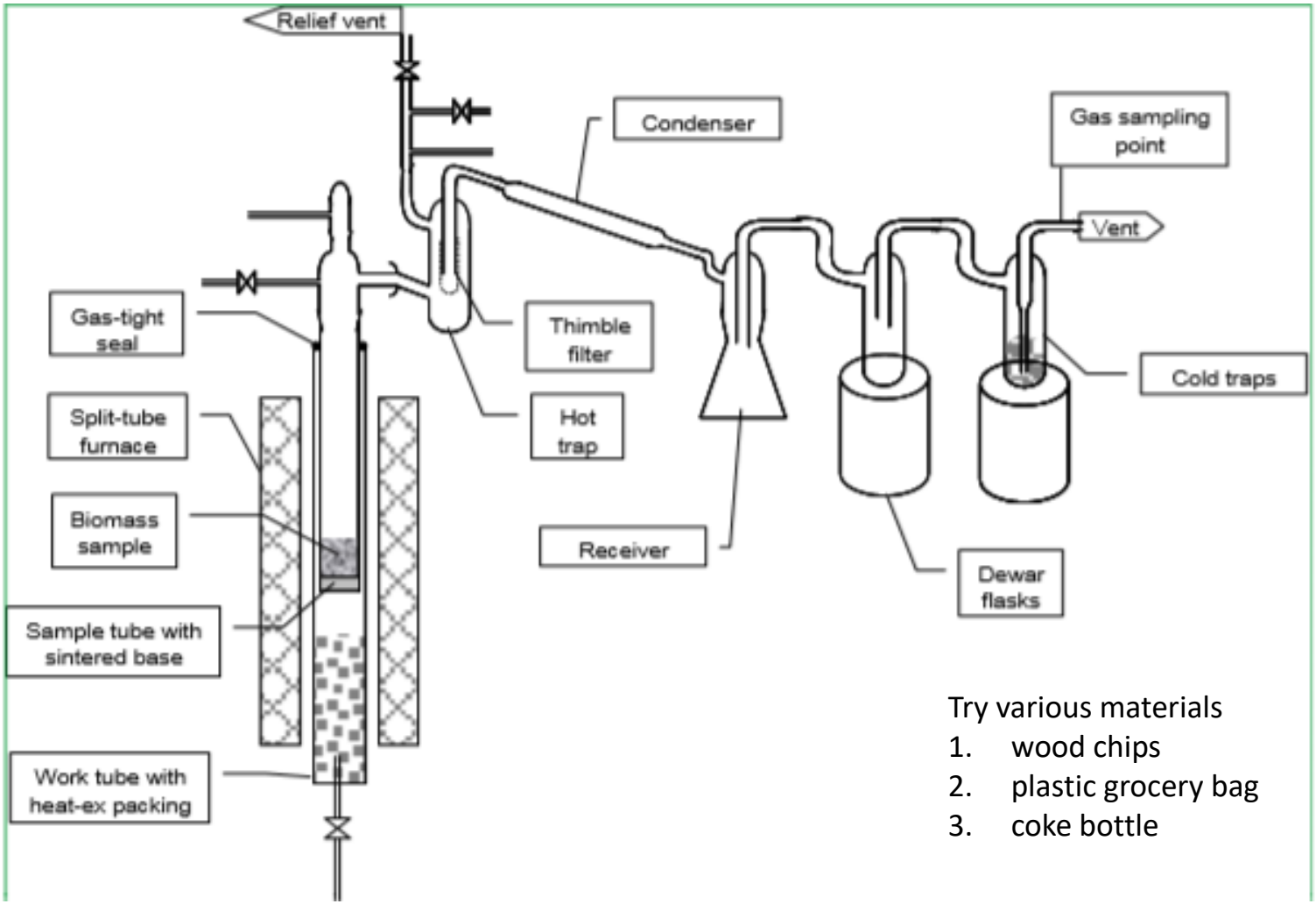
The IH^2 (Integrated Hydropyrolysis and Hydroconversion) technology is a continuous catalytic thermochemical process estimated to provide a cost-effective route, from a broad spectrum of organic wastes to fungible liquid hydrocarbon transportation fuels.

Neste's Oil Products business.
Neste is the world's leading producer of renewable diesel.

"Our target is to also be a leader in low-carbon refining and support a circular economy by developing innovative solutions based on waste plastic.

In April 2011, **Plastic2Oil®** and Smurfit-Stone Container Corporation entered into a referral agreement arrangement and the Company made its first fuel sale. In June 2011, Plastic2Oil® entered into a fuel supply agreement with Coco Paving, Inc. On July 29, 2011, Plastic2Oil® entered into a 10-year referral and revenue sharing agreement with RockTenn to convert mill by-product waste into fuel using the P2O technology.

Pyrolysis Experiment For You



Try various materials

1. wood chips
2. plastic grocery bag
3. coke bottle

The Future is Yours

- Questions?

- Question for You –
  - *What else can you do with the fuel?*

Backup Slides

Lignin to Bio-Fuels

- Phenols were the main component of PKS bio-oil from pyrolysis at 500 °C, and the phenol content of PKS bio-oil (13.49%) was higher than in WS bio-oil (1.62%) and PS bio-oil (0.55%).

- The temperature dependence of the pyrolysis products of two types of lignin (Alcell lignin and Asian lignin) was investigated using pyrolysis−gas chromatography−mass spectrometry (PyGC−MS). About 50 compounds were identified and quantified for each type of lignin over a temperature range of 400−800 °C. The maximum yield of phenolic compounds was obtained at 600 °C for both lignins, which was 17.2% for Alcell lignin and 15.5% for Asian lignin.

- Pyrolysis of corn stover lignin was investigated by using a micro-pyrolyzer coupled with a GC-MS/FID (FID=flame ionization detector). The system has pyrolysis-vapor residence times of 15-20 ms, thus providing a regime of minimal secondary reactions. The primary pyrolysis product distribution obtained from lignin is reported. Over 84 % mass balance and almost complete closure on carbon balance is achieved.

6 Steps to Effective Problem Solving

1. Identify the issues
2. Understand everyone's interests
3. List the possible solutions
4. Evaluate the options: data driven
5. Select an option or options
6. Monitor, Measure, Evaluate, Update

https://www.mediate.com/articles/thicks.cfm