

POTENTIAL COMMERCIAL USES FOR LIGNIN

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Dispel Urban Myth

**“You can make
anything from lignin
but you can’t make
money”**

Who the Heck is “TechLake”?!

- Michael Lake worked for MeadWestvaco’s chemical division for 34+ years
- Process and product development for lignin, tall oil, and other base chemicals from trees
- After retirement in January 2009, started TechLake first as a consulting company
- Evolved quickly into projects leading to new businesses based on fundamental insights gained through years of developmental work
- Has 26 “associates”

Lignin 2nd Only to Cellulose

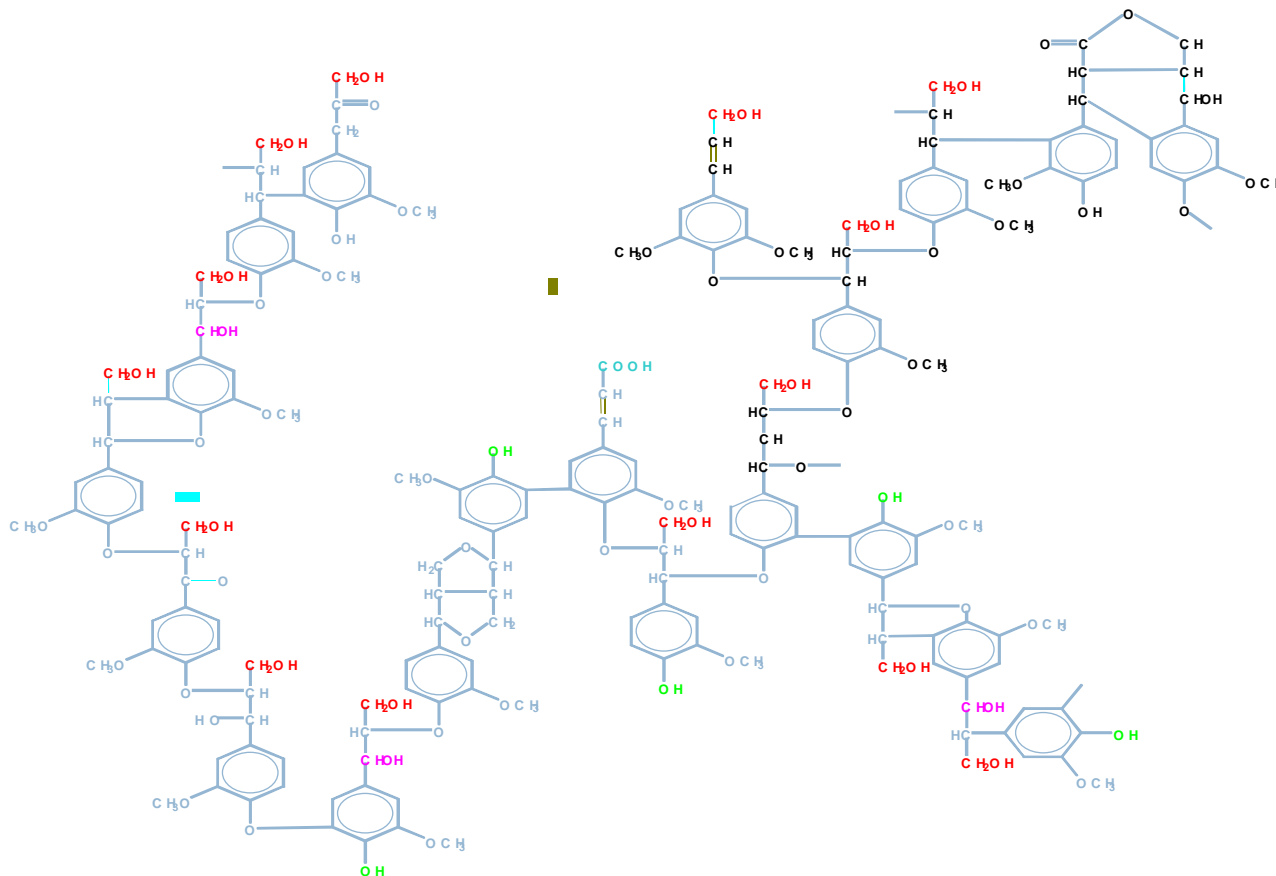
- All living plants have lignin, second most ubiquitous natural polymer behind cellulose
- Lignin is “GOD’S GLUE” that binds cellulose fibers together in living plants
- Papermakers and enzymatic conversions have focused on cellulose; lignin is burned or is an afterthought
- Problem: How to separate and purify lignin?

Who Cares About Lignin?

- Pulp & Paper Companies
 - displace fossil fuel from lime kiln or boilers
 - increase revenue selling lignin
 - debottleneck recovery furnace
- Enzymatic and Solvent-Extraction Start-Ups
 - “dispose” new lignin byproduct streams
- Power Companies
 - meet state renewable energy thresholds
 - manage potential carbon cap & trade

Chemical Structure of Lignin

“Lignin is a Synthetic Organic Chemist’s Play Box”



Commercial Sources of Lignin

- ❖ Processes “snip” natural lignin into fragments
- ❖ Kraft pulping process (NaOH, NaSH)
 - MWV, LignoBoost, **SLRP**, others
- ❖ Soda pulping process (NaOH only)
- ❖ Sulfite pulping process (sulfites, bi-sulfites)
 - Borregaard, others
- ❖ Solvent pulping (solvent + catalyst)
 - Granit – India (wheat straw)
 - CIMV – France (wheat straw)
 - Lignol Innovations – Canada (wood)
 - Others

Recovering & Purifying Lignin

- Lignin exits biomass processes as a mixture
- Lignin needs to be relatively pure (low ash) for green chemistry – even for fuels
- Most processes use low temp, solid separation
 - sensitive filtrations; batch processes
- **Sequential Liquid-Lignin Recovery & Purification (SLRP)**
 - uses little-known phenomena that lignin “melts”
 - continuous, all liquid; less capital; easier control
 - won DOE Phase II announced 3 Aug 10
 - continuing development at Clemson ChE dept

Lignin Applications depend on Properties of Lignin

□ Positive Traits

- ❖ 2nd most abundant natural polymer (behind cellulose)
- ❖ Numerous chemical functionalities and sites
- ❖ Melt point higher than ambient temperature

□ Negative Traits

- ❖ Brown
- ❖ No two molecules (like snowflakes) are alike
- ❖ Numerous chemical functionalities and sites
- ❖ Solid at ambient temperature

MeadWestvaco Specialty Areas

Three Applications of MWV Focus

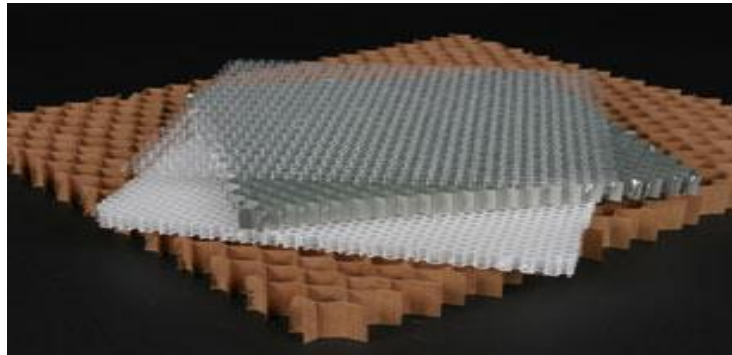
- ❖ Dispersants for polyester dyes
- ❖ Dispersants for agricultural chemicals
- ❖ Emulsifiers (and additives) for asphalt

TechLake cannot consult or develop technology in these areas

Historical “Near Hit” Opportunities

- ❖ MAL co-leader of team of ten formed in 90s
- ❖ Had environment (“green”; oil price) changed?
- ❖ Criteria: 1) near-hits; 2) significant work done
- ❖ Westvaco archives since 20s searched
- ❖ Manufacturing started in late-40s
- ❖ First commercial success in mid-60s
- ❖ Team disbanded in 1999 due to budget cuts
- ❖ TechLake given approval to pursue the opportunities identified by this team

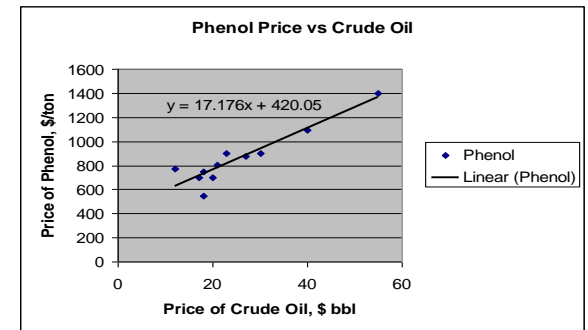
Lignin in Phenolic Resins



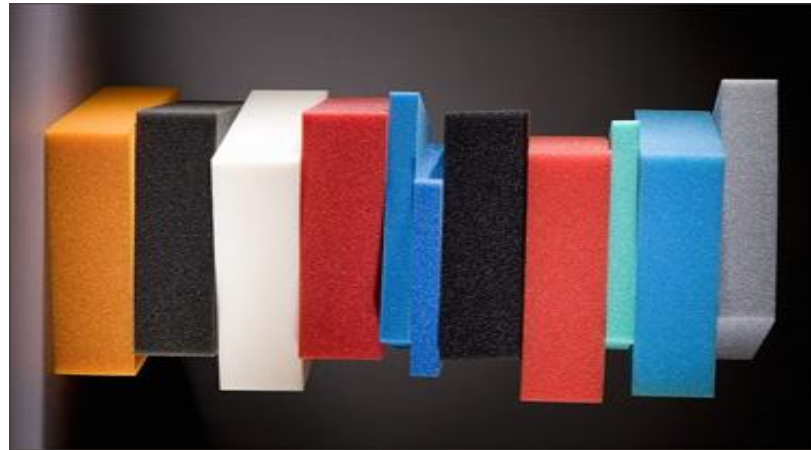
- ❖ Canadian government used lignin from kraft mills
- ❖ Substitute for phenol in composites during WWII
- ❖ Continued manufacture and sales through the 0s
- ❖ Stopped when phenol prices dropped
- ❖ Application targets for Westvaco were composites and foundry resins

Phenol Price Critical

- ❖ Phenol is a commodity; tracks oil price
- ❖ Purchase decision (lignin vs phenol) dominated by phenol price
- ❖ With oil @ \$80/bbl; phenol price = \$1800/ton
- ❖ Lignin @ **\$1500/ton** provides 20% savings
- ❖ Two billion #/yr phenol used in North America for phenol-formaldehyde resins



Lignin in Polyurethane Foams



- ❖ Must have low salt and constant water content
- ❖ Limited applications have been tested
- ❖ Lignin increases modulus of PU foam
- ❖ Lignin price could exceed \$2000/ton
- ❖ World-wide volume of PU exceeds 12 billion #/yr

Lignin for PU for Automobiles



Must meet three criteria for Tier 1 customers

- ❖ Must be consistent
- ❖ Must have no-to-low odor
- ❖ Must be easy to use

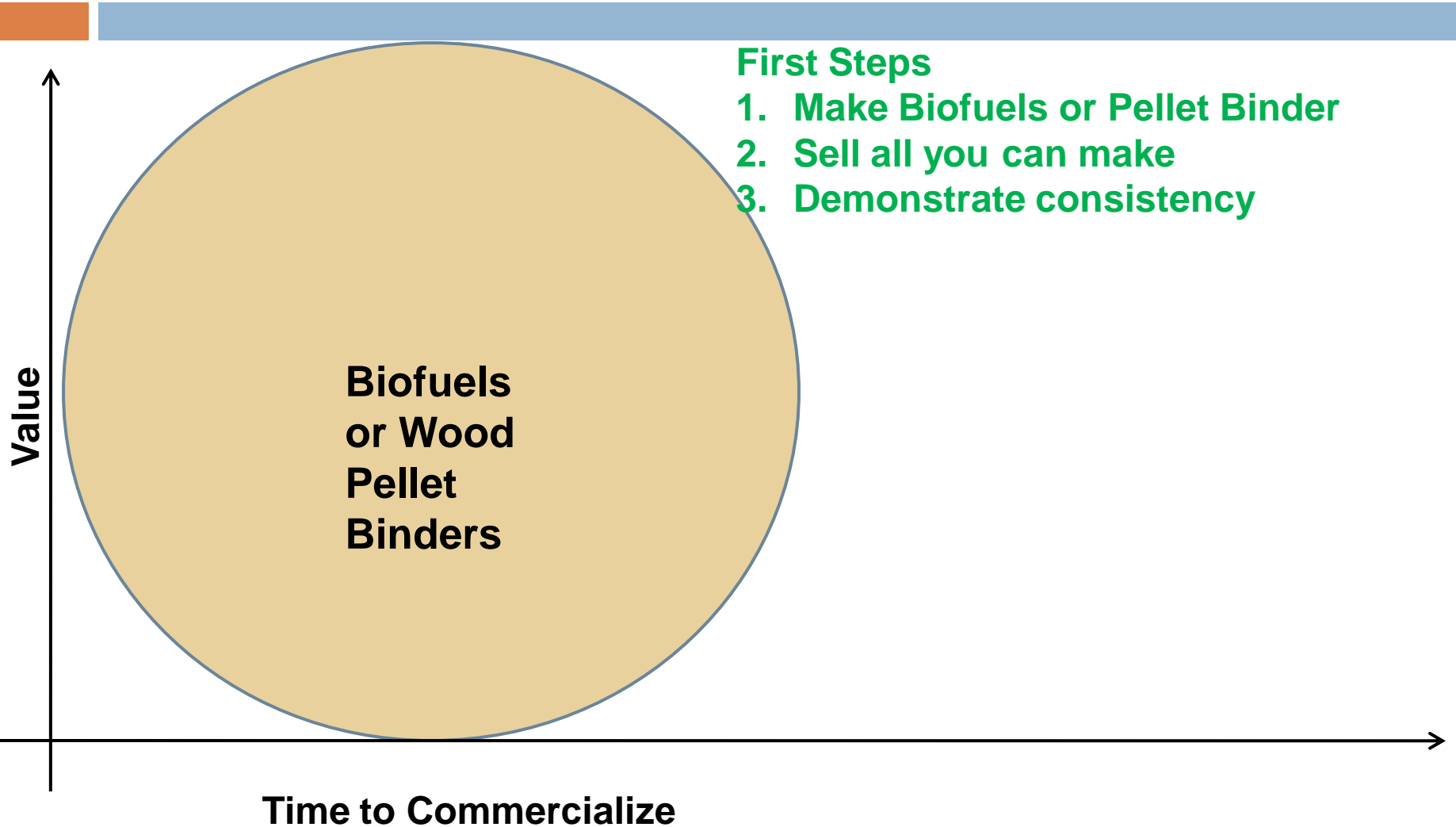
Lignin for Carbon Fibers

- ❖ Original work at ORNL – feasible with MWVs hardwood lignin
- ❖ Fred Baker (former MWV) leading team at ORNL
- ❖ Technical benchmark – solvent-extracted lignin
- ❖ Criteria:
 1. volatiles <5% at 250C
 2. ash <0.1%
 3. particulates < 1 micron & < 500 ppm in melt
 4. target lignin cost = 50 cents/lb

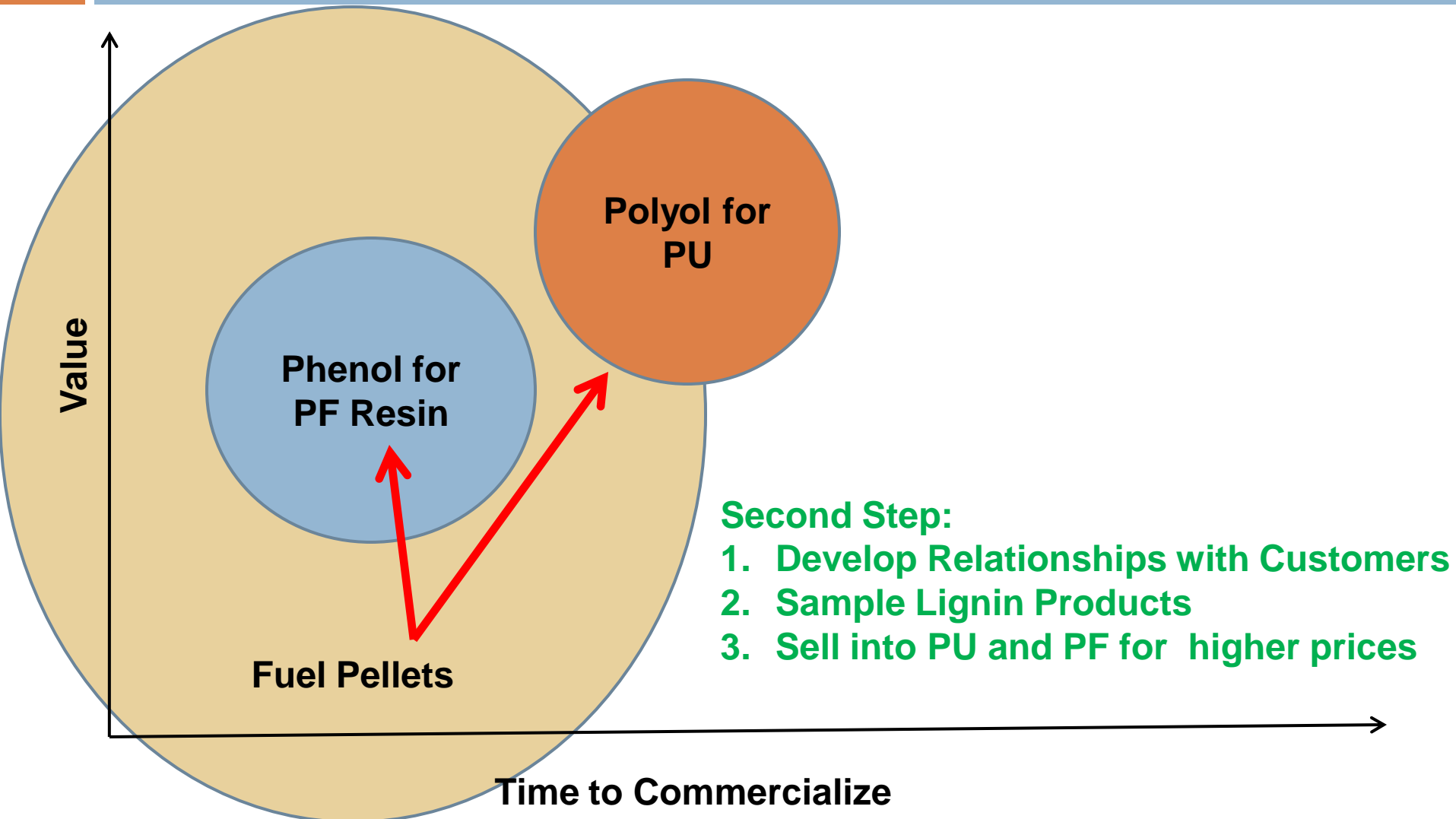
Binders for Wood Pellets

- Lignin energy density: 50% higher than wood
- Lignin as binder reduces dust
- Lignin as binder improves water resistance
- Development work ongoing at University of Maine; test lignin for \$1000
- NA export to Europe > 3 million ton/yr
- Lignin at 10-20%
- Price > \$150/ton

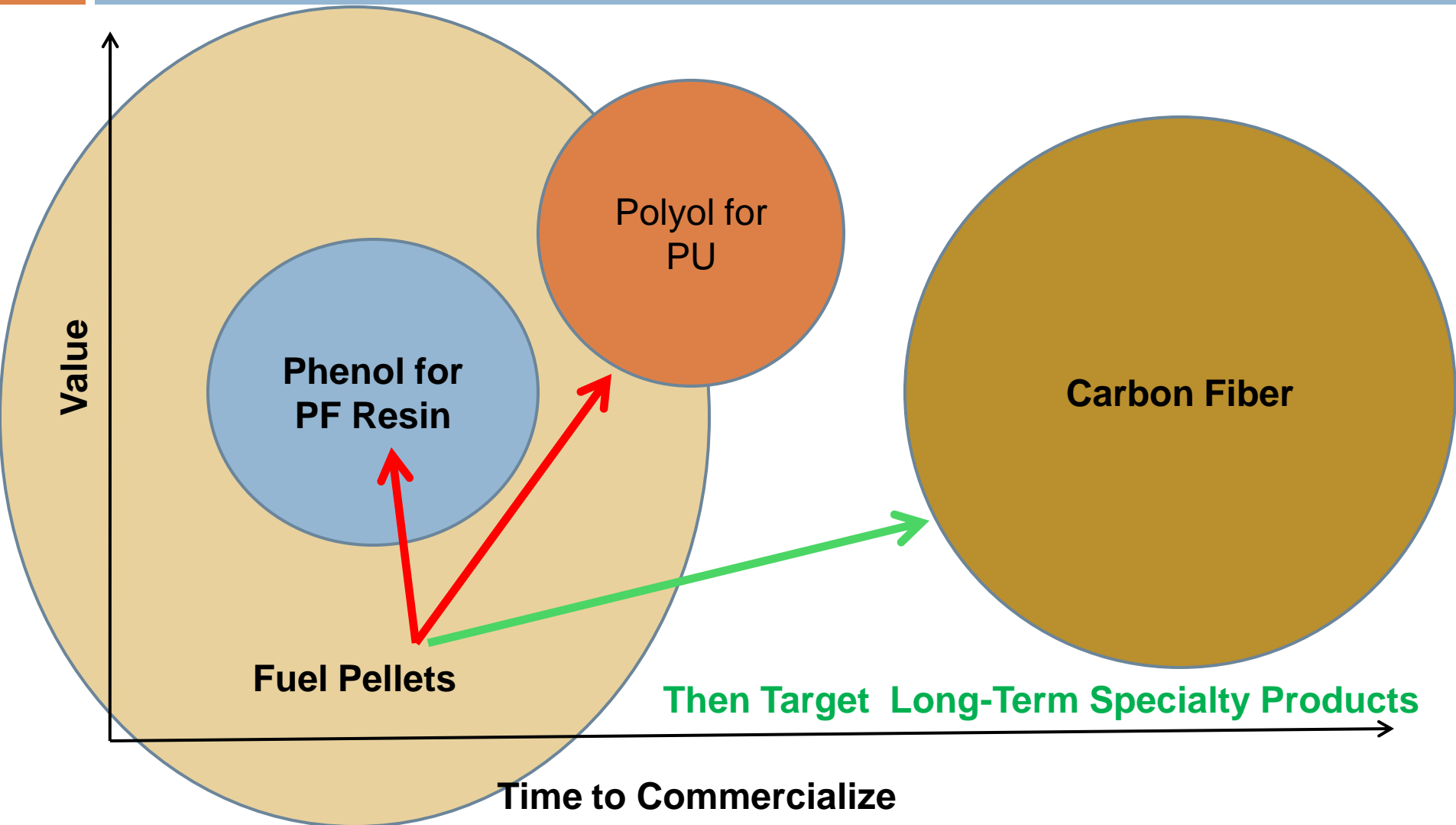
Value vs Time Diagram



Value vs Time Diagram



Value vs Time Diagram



Make Money From Lignin

	Revenue/yr lignin as fuel	Revenue/yr lignin as green chemicals
Ethanol	\$60MM	\$60MM
Lignin as binder for fuel pellets	\$7.5MM	--
Lignin for green chemicals	--	\$75MM

1. Ethanol production = 30 million gal/yr from switchgrass;
2. Switchgrass cellulose = 29%; lignin = 18%
3. Conversion of cellulose -> ethanol and recovery of lignin = 100%
4. Ethanol value: \$2/gallon; fuel pellet value = **\$150/ton**
5. Green chemical value = **\$1500/ton** (phenolic resins, polyurethanes, carbon-fiber composites)

Moral of Story

Lignin is a valuable resource;
paraphrasing a popular slogan of
ethanol companies:

~~Drink~~ **Use** the Best
Burn the Rest!



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Thank You!!

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