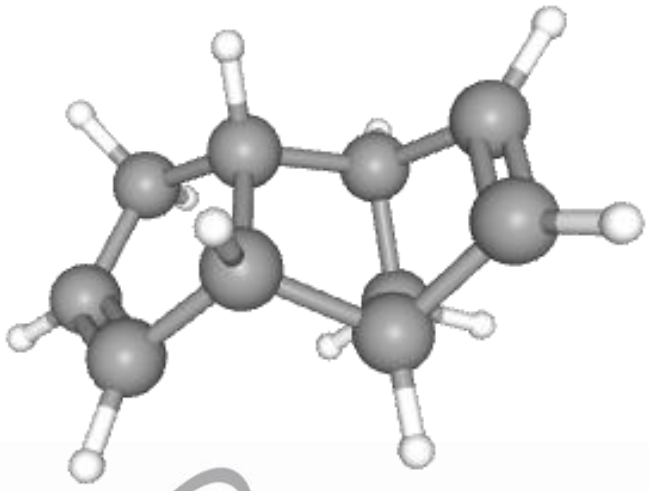
Sustainable Dicyclopentadiene



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William L. Kubic, Jr.

Andrew D. Sutton,
Cameron M. Moore,
Troy A. Semelsberger, and
Xiaokum (Claire) Yang

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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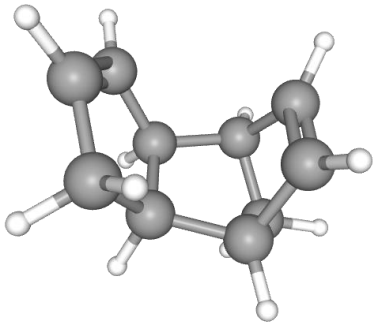
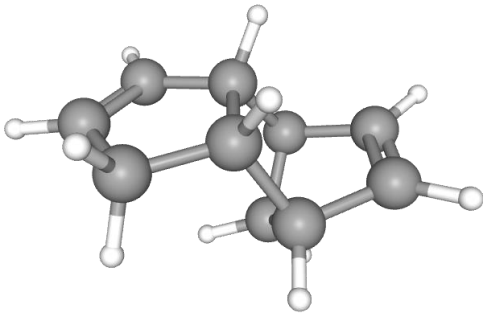
Dicyclopentadiene (DCPD)

- **Current Source**
  - **Produced from pyrolysis gasoline, a byproduct of ethylene production**
  - Current US demand about 160,000 tonne per year
  - **Current prices are between $1800 and $2500 per tonne depending on the purity**
- **Current uses**
  - **Polymers**
  - Flame retardants
  - **High energy density fuel**
  - Specialty products



endo-DCPD

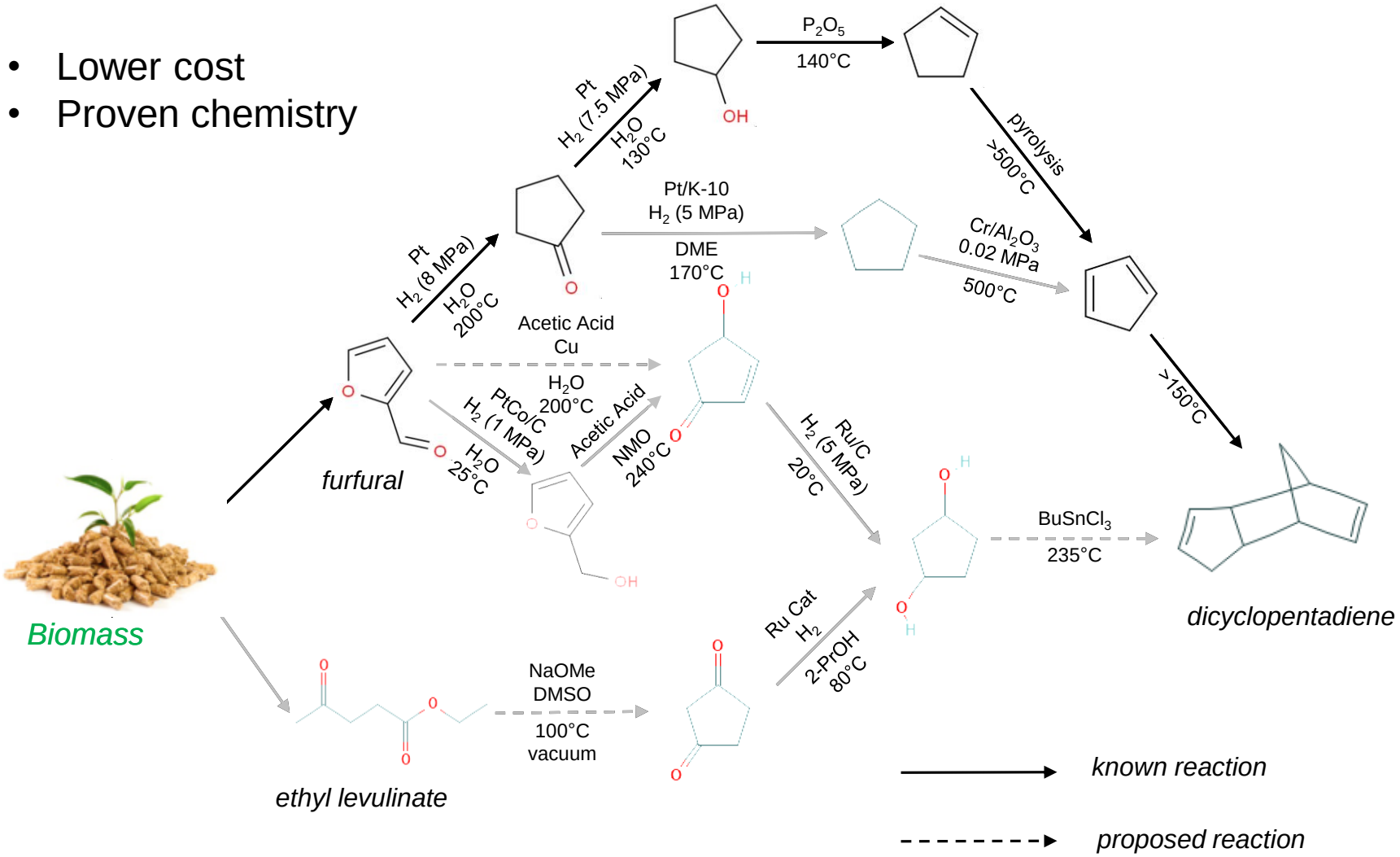


exo-DCPD

- **Motivation for Bio-DCPD**
  - The ongoing shift from naphtha cracking to ethane cracking for ethylene is reducing supply of pyrolysis gasoline
  - Potentially a renewable source of structural polymers (polyDCPD)
  - **Renewable source of high energy density fuels for the military**

Pathways to Bio Dicyclopentadiene

- Lower cost
- Proven chemistry



Need an Economical Source of Furfural

- **Corn bran and fiber identified as potential source of furfural**
  - High hemicellulose content relative to alternatives
  - Requires no additional harvesting
  - Byproducts of corn ethanol
  - Can be incorporated into an integrated biorefinery
- **Potential supply of corn bran and fiber sufficient to meet furfural and DCPD demand**
  - World furfural demand projected to reach 590,000 tonne/year in 2020
  - US DCPD demand is about 160,000 tonne/year

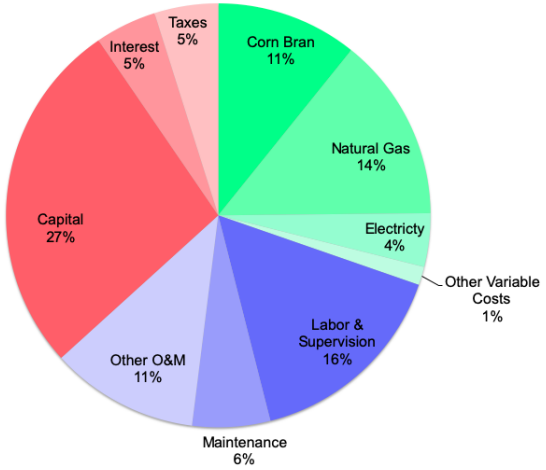
Rough Estimate of Availability, Costs, and Yields

Feedstock	Availability (million tonne/yr)	Hemicellulose Yield (million tonne/yr)	Cost of Hemicellulose ($/tonne)	Furfural Yield (tonne/yr)	DCPD Yield (tonne/yr)
Corn Stover	81	16	$375	6,800,000	3,600,000
Corn Cobs	37	14	$260	5,900,000	3,100,000
Corn Bran	10	4	$125	1,800,000	970,000
Corn Fiber	4	1.6	$140	640,000	350,000

Project Summary

- **Experimental**
  - Verify reaction chemistry
  - Demonstrate reactions in continuous flow reactor
  - Optimize catalysts and reaction conditions
- **Process Engineering**
  - Develop process flow diagrams for furfural and DCPD
  - Perform techno-economic analysis (TEA) for the process
- **Progress**
  - Demonstrated synthesis of DCPD from furfural
  - Heterogeneous and gas phase reactions being tested in flow reactor
  - Preliminary TEA completed
    - Transfer price for furfural is $865/tonne
    - Minimum selling price for high-purity DCPD is $2140/tonne

Furfural Production Cost



DCPD Production Cost