Reactive Dehydration Technology for Production of Fuels and Chemicals from Biomass

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KSE, Inc. with the University of Massachusetts, Amherst

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Project Objective

- Commercialize a novel reactive distillation technology using the **iCARD** platform (Intensified Catalytic and Reactive Distillation) for compact, inexpensive production of biomass-based chemicals from complex aqueous mixtures.
- Separation/Purification of Biomass Chemicals is Difficult and Costly:
  - Costly separation of complex mixtures of many biomass chemicals typically found in a dilute aqueous stream.
  - Excess water is costly to remove, inhibits biomass conversion, and often drives byproduct reactions.

Conventional Technologies

➢ Distillation

- Highly energy intensive
- Difficult for non-ideal mixtures
- Limitations for heat sensitive materials
- Many costly columns for complex mixtures

➢ Membrane Separation

- High investment, maintenance costs
- Severe limitations on contact material
- No economies of scale

Possible iCARD Commercial Applications

- **Water removal from fuel grade ethanol**
  - 50% reduction in energy requirement
  - Particularly superior for dilute cellulosic ethanol production
  - Extensive experimentation for thermodynamic data
  - Aspen-based process design using thermodynamic data
  - Existing plant retrofit: less than 2 year payout
- **Desalination**
  - Dehydration of directional solvent extractant
- **Water separation during reactions**
  - Water retards reaction, drives byproduct reactions
  - Production of FDCA (furandicarboxylic acid) from hexoses
  - Production of THF from pentoses
  - Simple, intensified process

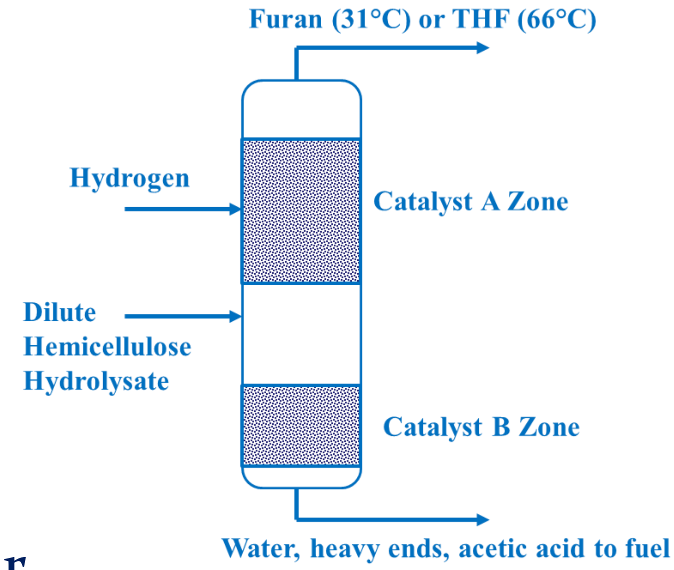
Technical Approach

- Convert water to easily removable chemical using reversible reaction.
- Convert biomass intermediate to easily removable chemical
- Example: THF from Biomass
  - **Now:** Pulp Mill: Hemicellulose containing xylan in ~5% aqueous solution; burned as waste heat
  - **iCARD:** Convert xylan to xylose to furfural to THF
    THF (60°C) or furan (31°C); easily distilled out.
    Heavy column bottoms continue to waste heat boiler
- Low cost THF in compact, highly intensified process

Innovation and Execution

➢ Reactive distillation

- Process intensification
- Reduce reaction and complex separation to a single compact unit
- Low cost THF



➢ Novel structured catalysts

- Combine catalytic functionalities for dehydration, decarbonylation, hydrogenation
- Shape, form suitable for reactive distillation

➢ Industry / University Team

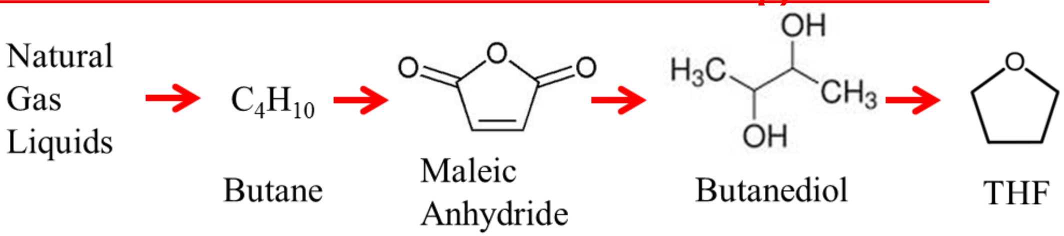
- KSE and University of Massachusetts

Transition and Deployment

WHO CARES?

U.S. Producers of THF and Spandex (PTMEG)

Conventional Manufacturing of THF



Complex, Energy Intensive, Costly Process
Manufacturing Cost: $1.45/Pound

KSE iCARD Manufacturing of THF

Process Intensification, Simplification
Manufacturing Cost: $0.70/Pound

PTMEG Spandex

Transition and Deployment

The Customer Cares

U.S. Pulp & Paper Industry

- $200 Billion annual sales
- 6% of U.S. manufacturing GDP
- Employment over 1 million
- Over 170 mills closed last 20 years

U.S. Kraft Pulp Mills

- Produce Xylan-rich hydrolysate
- Currently disposed for waste heat
- **iCARD** will utilize hydrolysate for THF
- Pulp mill profitability enhancement

Impact: Transformational Technology

➢ Energy Savings

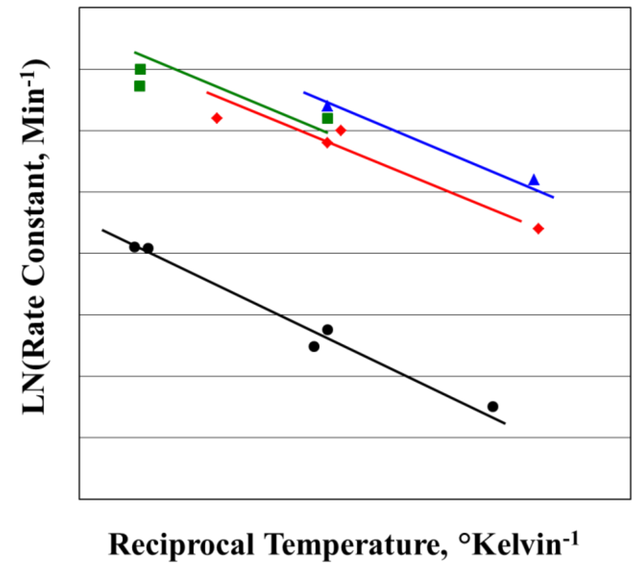
Cumulative Energy Demand (CED), MJ/kg Conventional THF Manufacturing	270
Cumulative Energy Demand (CED), MJ/kg KSE iCARD THF Manufacturing	75
Energy Savings for iCARD THF Manufacturing, MJ/kg	195
Annual U.S. THF Production, Million Pounds	320
Potential Annual U.S. Energy Savings, Trillion BTU's	62

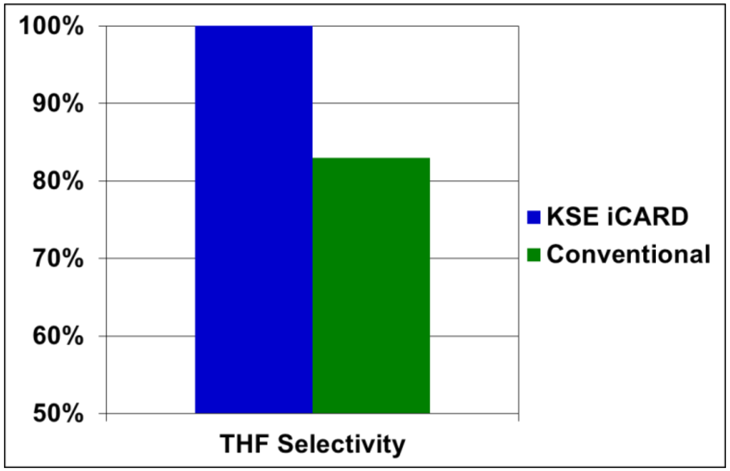
➢ Manufacturing cost savings

Conventional THF Manufacturing Cost, $/Pound THF	$1.45
KSE iCARD Manufacturing Cost, $/Pound THF	$0.70
KSE iCARD Savings, $/Pound THF	$0.75
Total Manufacturing Cost Savings for Single 32 Million PPY Plant	$24 Million/Yr

Results and Accomplishments

- Completed Phase I laboratory technical and economic demonstration from furfural
  - Novel catalyst compositions: activity order of magnitude greater than conventional catalysts
  - THF selectivity 100%
- Completed Aspen-based process design





Project Management & Budget

- Key Milestone Schedule
  - Complete patent filings — 6 months
  - Selection of commercial partner — 12 Months
  - Prototype for xylan hydrolysate conversion to THF — 18 Months
  - Start up of toll processing unit — 24 Months
  - Completion of commercial process design — 24 Months
  - Startup of commercial unit — 36 Months

Total Project Budget	
DOE Investment	$2,000,000
Cost Share	$1,500,000
Project Total	$3,500,000

Project Contacts

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