

U.S. Department of Energy Energy Efficiency and Renewable Energy Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable



## Top Value Added Chemicals from Biomass Volume I—Results of Screening for Potential Candidates from Sugars and Synthesis Gas

Produced by the Staff at Pacific Northwest National Laboratory (PNNL) National Renewable Energy Laboratory (NREL) Office of Biomass Program (EERE) For the Office of the Biomass Program T. Werpy and G. Petersen, Editors

> Exhibit 2005 E.I. du Pont de Nemours & Co. and Acher-Daniels-Midland Co. v. Furanix Technologies BV

Find authenticated court documents without watermarks at <u>docketalarm.com</u>.





## Top Value Added Chemicals From Biomass

Volume I: Results of Screening for Potential Candidates from Sugars and Synthesis Gas

> Produced by Staff at the Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL)

T. Werpy and G. Petersen, Principal Investigators

Contributing authors: A. Aden and J. Bozell (NREL); J. Holladay and J. White (PNNL); and Amy Manheim (DOE-HQ)

Other Contributions (research, models, databases, editing): D. Elliot, L. Lasure, S. Jones and M. Gerber (PNNL); K. Ibsen, L. Lumberg and S. Kelley (NREL)

August 2004



**Acknowledgement**: The authors gratefully acknowledge the support and assistance from NREL staff members S. Bower, E. Jarvis, M. Ruth, and A. Singh and review by Paul Stone and Mehmet Gencer, independent consultants from the chemical industry as well as specific input and reviews on portions of the report by T. Eggeman of Neoterics International and Brian Davison of Oak Ridge National Laboratory.

#### NOTICE

This report was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or any agency thereof.

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from:

U.S. Department of Energy Office of Scientific and Technical Information P.O. Box 62 Oak Ridge, TN 37831-0062 phone: 865.576.8401 fax: 865.576.5728 email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from: U.S. Department of Commerce National Technical Information Service 5285 Port Royal Road Springfield, VA 22161 phone: 800.553.6847 fax: 703.605.6900 email: <u>orders@ntis.fedworld.gov</u> online ordering: <u>http://www.ntis.gov/ordering.htm</u>



DOCK

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

## **Table of Contents**

Ex	ecutive	Summary	1		
1	Ba	ckground	3		
2	Ob	jective	4		
3	Ov	erall Approach	5		
4	Ini	tial Screening to the Top 30	6		
5	Se	lected Sugar-derived Chemicals	13		
6	Sy	ngas Results – Top Products	17		
7	Pa	Pathways and Challenges18			
8	Мс	oving Forward	20		
9	То	p 12 Candidate Summary Bios	21		
9	To 9.1	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic)	21		
9	To 9.1 9.2	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA)	21 22 		
9	To 9.1 9.2 9.3	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA)	21 22 26 29		
9	To 9.1 9.2 9.3 9.4	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA) Aspartic acid	21 22 26 29 31		
9	To 9.1 9.2 9.3 9.4 9.5	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA) Aspartic acid Glucaric acid	21 22 		
9	To 9.1 9.2 9.3 9.4 9.5 9.6	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA) Aspartic acid Glucaric acid Glutamic acid	21 		
9	To 9.1 9.2 9.3 9.4 9.5 9.6 9.7	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA) Aspartic acid Glucaric acid Itaconic acid			
9	To 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA) Aspartic acid Glucaric acid Glutamic acid Itaconic acid Levulinic acid			
9	To 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA) Aspartic acid Glucaric acid Glutamic acid Itaconic acid Levulinic acid 3-Hydroxybutyrolactone			
9	To 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 9.10	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA) Aspartic acid Glucaric acid Glutamic acid Levulinic acid 3-Hydroxybutyrolactone Glycerol			
9	To 9.1 9.2 9.3 9.4 9.5 9.6 9.7 9.8 9.9 9.10 9.11	p 12 Candidate Summary Bios Four Carbon 1,4-Diacids (Succinic, Fumaric, and Malic) 2,5-Furan dicarboxylic acid (FDCA) 3-Hydroxy propionic acid (3-HPA) Aspartic acid Glucaric acid Glutamic acid Itaconic acid Levulinic acid 3-Hydroxybutyrolactone Glycerol Sorbitol (Alcohol Sugar of Glucose)			

10 Catalog of Potential Chemicals and Materials from Riomass

**DOCKET A L A R M** Find authenticated court documents without watermarks at <u>docketalarm.com</u>.

Bibli	iography	66
I	References Used to Develop Catalog for Potential Biobased Products	66
I	References for Assigning Chemical and Biochemical Pathways	66

## Tables

Table 1	Biorefinery Strategic Fit Criteria	6
Table 2	Top Candidates from the First Screen	8
	The Tep Sugar derived Building Blocks	. IZ
Table 4	Sugar Transformation to 2 UDA	10
	Sugar Transformation 21D to 1.2 DDQ via actalytic debudregenetion	. 14
	Reductive Transformation – SHP to 1,5 PDO via catalytic dehydrogenation	. 14
	Deliyurative Transformation – 5-FFA to activite activite deliyuration	. 14
	Pathways to Building Block From Sugara [Four Carbon 1.4 Disside	. 19
Table 9	Patriways to building block From Sugars [Four Garbon 1,4 Diacids (Succinic Eumaric and Malic]	22
Table 10	Eamily 1: Peductions [Primary Transformation Pathway(s) to Derivatives Four	. 22
	Carbon 1 4-Diacids (Succinic Fumaric and Malic)]	22
Table 11	Earnily 2: Reductive Aminations [Primary Transformation Pathway(s) to	. 22
	Derivatives - Four Carbon 1 4-Diacids (Succinic Fumaric and Malic)	22
Table 12	Eamily 3: Direct Polymerization [Primary Transformation Pathway(s) to	. 22
	Derivatives - Four Carbon 1 4-Diacids (Succinic Fumaric and Malic)	23
Table 13	Pathways to Building Block From Sugars [25-Euran dicarboxylic Acid (EDCA)]	20
Table 14	Family 1: Reduction [Primary Transformation Pathway(s) to Derivatives:	20
	2 5-Euran dicarboxylic Acid (EDCA)]	26
Table 15	Family 2 <sup>•</sup> Direct Polymerization [Primary Transformation Pathway(s) to	. 20
	Derivatives: 2.5-Furan dicarboxylic Acid (FDCA)]	. 27
Table 16	Pathways to Building Block from Sugars (3-HPA)	. 29
Table 17	Family 1: Reductions [Primary Transformation Pathway(s) to	-
	Derivatives (3-HPA).	. 29
Table 18	Family 2: Dehydration [Primary Transformation Pathway(s) to	
	Derivatives (3-HPA).	. 29
Table 19	Pathways to Building Block - Aspartic Acid	. 31
Table 20	Family 1: Reductions [Primary Tansformation Pathway(s) to Derivatives –	
	Aspartic Acid	. 32
Table 21	Family 2: Dehydration - [Primary Tansformation Pathway(s) to Derivatives –	
	Aspartic Acid]	. 32
Table 22	Family 3: Direct Polymerization [Primary Tansformation Pathway(s) to	
	Derivatives – Aspartic Acid	. 32
Table 23	Pathway to Building Block From Sugars [Glucaric Acid]	. 36
Table 24	Family 1 - Dehydration [Primary Transformation Pathway(s) to Derivatives –	
	Glucaric Acid]	. 36
Table 25	Amination and Direct Polymeriation [Primary Transformation Pathway(s) to	
	Derivatives – Glucaric Acid]	. 36

**DOCKET A L A R M** Find authenticated court documents without watermarks at <u>docketalarm.com</u>.

# DOCKET



# Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

### **Real-Time Litigation Alerts**



Keep your litigation team up-to-date with **real-time** alerts and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

#### **Advanced Docket Research**



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

## **Analytics At Your Fingertips**



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

#### API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

#### LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

#### **FINANCIAL INSTITUTIONS**

Litigation and bankruptcy checks for companies and debtors.

#### **E-DISCOVERY AND LEGAL VENDORS**

Sync your system to PACER to automate legal marketing.

