WP 8.1. Determination of market potential for selected platform chemicals

Itaconic acid, Succinic acid, 2,5-Furandicarboxylic acid

weastra, s.r.o.

Funded by the 7th Framework Programme of the European Union, FP7 – Knowledge based Bio-Economy, Collaborative Project, Grant agreement number: 289194, KBBE.2011.3.4-02 – Towards a sustainable bio- industry – Biotechnology for renewable chemicals and innovative downstream processes.

www.bioconsept.eu

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ACH	acetone cyanohydrin	MT	metric ton/tons
BBP	benzyl butyl phthalate	MTA	medium quality terephthalic acid
BDO	1,4-butanediol	NMP	N-methyl-2-pyrrolidone
BPA	bisphenol A	PBAT	polybutylene adipate-terephthalate
CAGR	compound annual growth rate	PBS	polybutylene succiniate
CBA	carboxibenzaldehyde	PBSA	polybutylene succinate adipate
CFCs	chlorofluorocarbons	PBST	polybutylene succinate-terephthalate
CO	carbon monoxide	PBT	polybuthylene terephtalate
DBP	dibutyl phthalate	PEF	2,5-furandicarboxylate
DEHP	di-2-ethylhexyl phthalate	PEO	polyethylene oxide
DIDP	diisodecyl phthalate	PET	polyethylene terephthalate
DINP	diisononyl phthalate	PET	polyethylene terephtalate
DMT	dimethyl terephtalate	PHA	polyhydroxyalkanoates
DnOP	di-n-octyl phthal- ate	PIA	purified isophthalic acid
EDTA	ethylene-diamine-tetra-acetic acid	PMMA	polymethyl methacrylate
EG	ethylene glycol	PTA	purified terephthalic acid
EU	European Union	PTMEG	poly-tetramethyl ether-glycol
FDCA	2,5-furandicarboxylic acid	PVA	polyvinyl alcohol
GBL	gamma-butyrolactone	PVC	polyvinyl chloride
GRAS	Generally Regarded As Safe	PX	paraxylene
HCN	hydrogen cyanide	SA	succinic acid
HMF	5-hydroxymethylfurfural	SAP	superabsorbent polymers
MAA	methacrylic acid	SBR	styrene-butadiene rubber
MAN	maleic anhydride	STPP	sodium tripolyphosphate
MEG	mono-ethylene glycol	THF	tetrahydrofuran
MMA	methyl methacrylate	TPA	terephthalic acid
MRC	Mitsubishi Rayon	UPR	unsaturated polyester resins

INTRODUCTION

Report description and background

This market research report including the attached market potential calculation model and presentation is part of the working package 8.1. of the European Union funded R&D project BioConSepT and belongs as such to the consortium of companies, research institutes and industrial partners.

BioConSepT is a 13 million EUR EU-funded project, which aims to produce consumer goods out of biomass, i.e. plant matter, which is not competing with the food chain. Non-edible fats & oils and wood will be the feedstock of the 2nd generation biomass process. Additionally, it aims to be 30% cheaper and 30% more sustainable than the corresponding chemical routes or the biotechnology processes starting from 1stgeneration.

The deliverables of the work package 8.1., where this report also belongs to, should give guidance to the consortium partners in their research and so enable them to be focused on the bio-based chemical intermediates which from the market perspective would have the best potential or those intermediates where relevant end use application could be developed and marketed in an effective and efficient way.

This report comprises the global market for chemical intermediates, which have been selected in a selection process based on interviews with the industrial partners of the consortium (companies in WP6 of the project). The aim of the selection process was to identify those bio-based building blocks, which are considered interesting for development of attractive end use applications. The result of this shortlisting brought up the following chemical intermediates, which have been analyzed and are comprised in this report: succinic acid, itaconic acid and FDCA (2,5-furandicarboxylic acid).

For each of these three intermediates the current market was analyzed, incl. their petrol-based and bio-based substitutes, the potential end use applications have been identified and the market potential was quantified for the most attractive end use applications. The potential B2B consumer needs, requirements and expectations on the end use side as well as on the side of competing products and substitutes allowed to derive further conclusions regarding marketability within several end use applications on a global scale and played a role when determining the chances and limitations of a replacement of the current state of the art chemical routes or other competing routes by routes relying on these bio-based intermediates.

The thorough secondary market research was backed up by primary market research where in depth interviews with potential consumers as well as with producers and other market experts were run or information by email from these players was gathered and provided a valuable inside into the markets readiness and estimations of the potential of the developed products.

Altogether the collected data coming from the secondary and primary sources shaped the market model and the calculations of the market potential within the relevant end use applications for these bio-based intermediates. Towards the end of the project the developed market model was challenged by the most relevant players on the market of these bio-based intermediates, which brought the quality of the data to a better level.

The consortium partner WEASTRA was running this market research and developed this report, market model and presentation.

Generally, the work of WEASTRA can be described as follows:

- Shortlisting of the bio-based chemical building blocks done through interviews with the industrial consortium partners from the work package 6
- Primary and secondary market research with the aim to determine the market potential for selected bio-based intermediates based on an assessment of valuable end-use applications, identification of market trends within these end uses as well as evaluation of the consumer needs, requirements and expectations
- Development of a market model for market potential calculations and challenging the results of the market model with relevant market players
- Delivery of a comprehensive market report including market model and presentation

WEASTRA (www.weastra.com) is a boutique management consultancy based in Slovakia, supporting mid-sized and large enterprises in their business growth in emerging markets or new technologies.

Weastra's services related to R&D consist of market analyses for novel products and technologies, strategic management of R&D outcomes including the development of successful go to market strategies.

The core competencies of weastra's team member range from market research and market modeling, strategy development, project management to the result implementation.

Market research methodology

This market research report is based on a thorough data research and analysis as well as a subsequent detailed market projection and market potential model, which was challenged by relevant market players. The research and analysis work as well as the projections and challenging of results with respective market players were done within the year of 2012.

The secondary and primary market sources list is provided as a part of this report.

The aim of the primary and secondary market research was to determine the market potential for selected bio-based intermediates and their use in end-use applications depending on needs, requirements and expectations of consumers.

All information from secondary market research was compared and challenged by the feedback of players from the primary interviews or email communication with primary sources. The primary sources used for this market research were B2B populations such as experts from related industries and research institutes, current and potential future producers, suppliers and current or potential consumers e.g. relevant end use application producers.

All volumes and values of chemicals and markets used in this market research report are the results of the weastras market model developed for this purpose. This market model was developed within this project to make projections of market development based on many indicators such as price developments, market shares of certain chemicals and their substitutes, production capacities, projected growth of end use application markets, probabilities of replacement of substitutes etc. The model comprises all relevant results from secondary and primary sources. Relevant market players challenged the results of the market model.

Key information taken from secondary sources:

- Technical information and details of the chemicals
- The current global market volumes or market shares of substitutes or chemicals to be replaced
- Past and future market growth of substitutes or chemicals to be replaced
- Publicly available data about key producers, suppliers and consumers
- Related trends and market developments
- Prices of the chemicals, which can be replaced

Key information taken from primary sources:

- New trends in related research and development
- Current and future technical and commercial developments
- Price trends of feedstock, selected chemicals and end-use applications
- Market penetration in potential end-uses from the view of producers and consumers
- Growth trends for chemicals
- Pricing strategies
- Expectations of end use application producers towards new bio-based chemicals (price, properties etc.)
- Estimation of the chances of the new bio-based chemicals to replace a portion of todays existing chemicals (realistic % of substitution projected in time)
- Possible end use applications and their markets
- Today and future production capacities of chemicals, the projected use as per main

applications of these production capacities as expected by the producers

The market model is based of the following key data:

1) Data related to chemicals which can be potentially replaced by selected bio-based chemicals:
   a) *The current market volume and market share by applications* - based mainly on primary and secondary sources.
   b) *Annual growth* - based on primary and secondary sources and was derived by forecasting techniques based on development trends and consumption in end-use applications
   c) *The future market volume and market share by applications* - based on primary and secondary sources and information about annual growth
   d) *Prices* - based mainly on secondary sources compared with the feedback from the primary interviews, the projection of the price developments was challenged in interviews
   e) *Market value* - calculated based on the size of the market and the respective prices

2) Data related to the selected bio-based chemicals analyzed in this report:
   a) *Planned capacities and capacities taking in account the capacity utilization rates* – was determined based mainly on primary sources. Utilization of capacity reflects the utilization curve, ramp up of the newly built capacities.
   b) *% of market to be substituted* - based mainly on primary sources. The percentage of substitution depends on needs, requirements and expectations of consumers and on the overall market demand. Key role play also planned capacities and capacities taking in account the utilization rates
   c) *Prices* - based mainly on primary sources, the projection of the price developments was challenged in interviews
   d) *The current and future market volume* - based mainly on primary sources. The future market volume is based on the market volume of chemicals that can be replaced. Key role in the projected market volume play also planned production capacities and capacities taking in account the utilization rates and % of market to be substituted
   e) *Market value* - calculated based on the calculated and projected market volumes and the gained prices

Major secondary market research sources

1. ICIS, petrochemical market information provider - http://www.icis.com/
2. Espacenet, patent database - http://www.epo.org
3. US Patent and Trademark Office - http://patft.uspto.gov/
4. Eurostat - http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/
5. Chemical patent search - http://www.surechem.org/index.php
6. Chemspider – chemical database
7. Profound - Global Industry Analysts - Itaconic Acid - Full Report - http://www.profound.com
8. "Biocatalysis for Green Chemistry and Chemical Process Development" by Junhua (Alex) Tao, Romas Joseph Kazlauskas, 2011.
9. Chemical & Engineering News magazine - http://cen.acs.org/index.html
10. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy "Environmental assessment for the myriant succinic acid biorefinery (mysab), lake providence, Louisiana "
11. NNFCC - bio-based economy consultancy - http://www.nnfcc.co.uk
12. Online news from Chemical Industry - http://www.chemicals-technology.com
13. Innovative Industry – blogging site focused on the developments in bioplastics, biofuels and commodity chemicals derived from renewable resources http://www.innovativeindustry.net/about
14. Biofuels Digest – online newsletter - http://www.biofuelsdigest.com
15. U.S. Department of Energy. Top Value Added Chemicals from Biomass; Volume 1: Results of Screening for Potential Candidates from Sugars and Synthesis Gas, 2004
16. U.S. Department of Energy. Understanding Biomass as a Source of Sugars and Energy. Biomass Program. http://www.eere.energy.gov/biomass/understanding_biomass.html#biomass (May 28, 2004).
17. Epoxidized Oils and Derivatives (EOD) Category, UNEP Publications, 2006
18. "Market Research Report 2012 - 2,5-Furandicarboxylic acid", Business Analytical Center
19. Chemical directory – suppliers - http://www.chemexper.com/
20. "Feedstock, 2011 Platform Review Report", US Department of energy, Biomass program
21. "Building a Bio-based Economy for Europe in 2020", EuropaBio - www.bio-economy.net
22. "Polymers from Renewable Resources: A Challenge for the Future of Macromolecular Materials", Alessandro Gandini, 2008
23. "Green" Chemicals from Renewable Agricultural Biomass - A Mini Review, Yixiang Xu, Milford A. Hanna* and Loren Isom, Industrial Agricultural Products Center, University of Nebraska, Lincoln, USA, 2008
24. "Sugar platform and beyond, "Concepts for producing advanced biofuels and

bioproducts", Birgitte K. Ahring, Washintgton State University,

25. Biocatalysis for green chemistry and chemical process development, Junhua (Alex) Tao, Romas Kazlauskas, A John Wiley & Sons, Inc., Publication, 2011
26. "Product overview and market projection of emerging bio-based plastics", Li Shen, Juliane Haufe, Martin K. Patel, Final Report, June 2009
27. "Bio-based Chemicals. Value Added products from biorefineries", report by IEA Bioenergy, 2011 - http://www.ieabioenergy.com/
28. "Biofuels second generation", Martin Bajus, FCHFT SUT, Institute of Organic Chemistry, Catalysis and Petrochemistry; Department of Petroleum Technology and Petrochemistry,Slovakia. 2008
29. The Doe Report, http://www.doereport.com/
30. "Platform Chemicals From Biomass", by Arthur J. Ragauskas, Institute of Paper Science and Technology, Georgia Institute of Technology
31. Industrial crop platforms for the production of chemicals and biopolymers. Outputs from the EPOBIO project, April 2007
32. "Literature Review of Physical and Chemical Pretreatment Processes for Lignocellulosic Biomass", P.F.H. Harmsen, W.J.J. Huijgen, L.M. Bermúdez López, R.R.C. Bakker, Wageningen University & Research centre - Food & Biobased Research (WUR-FBR, NL), Energy Research Centre of the Netherlands (ECN, NL), Abengoa Bioenergía Nuevas Tecnologías (ABNT, ES), 2010.
33. "Techno-economic Feasibility of Large-scale Production of Bio-based Polymers in Europe", European Science and Technology Observatory, 2005
34. "Assessment of current activity in the production of platform chemicals from renewable sources and horizon scan to forecast potential future developments in science and technology activity in biocatalysis". A technology assessment for the Industrial Biotechnology Innovation and Growth Team (IB-IGT), Bioscience for Business KTN, 2008
35. "Chemical Routes for the Transformation of Biomass into Chemicals", Avelino Corma, Sara Iborra, and Alexandra Velty Instituto de Tecnologı´a Quı´mica, UPV-CSIC, Universidad Polite´cnica de Valencia, Avenida de los Naranjos, s/n, Valencia, Spain, 2007
36. "The Future of Industrial Biorefineries", World Economic Forum, 2010
37. "Purified Terephthalic Acid – A Global Strategic Business Report", 2011, Global Industry Analysts, Inc.
38. Biosynthesis of Long-Chain Dicarboxylic Acid Monomers From Renewable Resources, by David P., Mobley GE Corporate Research and Development, 1999
39. IHS Global Information Company - http://www.ihs.com
40. Shizuoka University, „Biotechnological production of itaconic acid and its biosynthesis in Aspergillus terreus", by Okabe, Mitsuyasu; Lies, Dwiarti; Kanamasa, Shin; Park, *Enoch Y.*
41. SYNTHESIS OF ITACONIC ACID USING USTILAGO MAYDIS, Ramesh Chandragiri and Prof.R.C.Sastry, Department of Chemical Engineering, National Institute of Technology,India.

42. BIOREFINE.ORG – Resource development project - http://www.biorefine.org
43. M.L.Ribeiro and U. Schuchardt, cooperative effect of cobalt acetyl acetonate and silica in the catalytic cyclization and oxidation of fructose to 2,5-furandicarboxylic acid, Catal. Commun. 2003, 4, 83-86
44. National Institute for Occupational Safety and Health's (NIOSH) Registry of Toxic Effects of Chemical Substances
45. Wisconsin Alumni Research Foundation – http://www.warf.org/
46. "Furandicarboxilic Acid (FDCA), A Versatile Building Block for a Very Interesting Class of Polyesters", E.de Jong, M.A.Dam, L. Sipos, G.-J.M. Gruter:. In ACS Symposium Series; American Chemical Society: Washington, DC, 2012
47. "Global Plasticizer Update; SPI Flexible Vinyl Products Conference July 2012", Cullen S.: www.plasticsindustry.org
48. Natural Resource Base in the Chemical Industry, Groving Markets for Bio-Based Polymers, Lubricants and Surfactants.; www.chemmanager-online.com

Primary market research sources

As primary sources are listed companies who shared information in phone interviews, in email communication or supplied other materials or presentations for this purpose

1. A Meryer Chemical Technology Shanghai Company
2. ALPHA CHEMIKA
3. ANQING HEXING CHEMICAL China
4. Atomax Chemicals Co., Ltd.
5. Avantium Holding B.V.
6. BioAmber Inc.
7. Carbone Scientific
8. Chemsky International
9. Connect Marketing
10. Dalian hengchi chemicals limited
11. Elevance Renewable Sciences, Inc.
12. Evonik Industries AG
13. Finetech Industry Limited
14. Fuso chemical
15. Greenchemicalsblog.com, Doris de Guzman
16. Hangzhou Dayangchem Co
17. Hangzhou Imaginechem Co., Ltd
18. Haohua Industry
19. Hisunny Chemical
20. Hubei Nosk Chemical
21. Innochem
22. InterBioScreen Ltd.
23. Invista
24. Itaconix Corporation
25. Jinan Haohua Industry Co., Ltd
26. Jinan Huaming Biochemistry Co.,Ltd.
27. KaiYi Industry Co
28. KAWASAKI KASEI CHEMICALS LTD Japan
29. KINGS CERAMICS & CHEMICALS CO., LTD.
30. LEIZHOU YUELI ITACONIC ACID CO., LTD.
31. Lucite International
32. Matrix Marketing
33. Molekula
34. Myriant Technologies
35. NANJING HUAJIN BIOLOGICALS CO., LTD.
36. Netherlands Organization for Applied Scientific Research TNO

37. Nippon Shokubai Company Limited
38. Norkem
39. NOVATECH BIOPHARMACEUTICAL CO., LTD.
40. Palvi Power Tech Sales Pvt
41. Pfaltz & Bauer
42. Proviron Industrues NV
43. QINGDAO ABEL TECHNOLOGY CO., LTD.
44. RHODIA OPERATIONS
45. Royal DSM N.V.
46. Satachem Co., Ltd.
47. Shandong Hongye Chemical
48. Shanghai Boyle Chemical
49. Shanghai Hanhong Chemical
50. Shanghai Ruifeng Chemical Co.Ltd.
51. SHIJIAZHUANG YUANCHEM IMP. & EXP. CORP., LTD.
52. Simagchem
53. SINOPEC Luoyang Company
54. SUNILEI TECHNOLOGIA SOLAR, SA
55. Taiyuan Palort Chemical Co., Ltd
56. TAMINCO NV
57. TCI Europe NV
58. Toagosei Company Limited
59. Tokyo Chemical Industry Co., Ltd.
60. Triveni Interchem P. Ltd
61. V & V Pharma Industries
62. VITO NV
63. WUHAN LUOKE FINE CHEMICALS
64. Xiamen Hisunny Chemical Co., Ltd
65. Yick-Vic Chemicals & Pharmaceuticals
66. Zhejiang Guoguang Biochemistry Co., Ltd.
67. Zhejiang Kedao Chemicals Co., Ltd.
68. Zhong Tai Chemical Co

Copyright and Disclaimer

Disclaimer:

WEASTRA (www.weastra.com) is a boutique management consultancy based in Slovakia, supporting mid-sized and large enterprises in their business growth in emerging markets or new technologies.

Weastra's services related to R&D consist of market analyses for novel products and technologies, strategic management of R&D outcomes including the development of successful go to market strategies.

Weastra's market reports and market analysis documents are tailor-made publications for weastra´s clients. Quantitative and qualitative market information in this document is based on secondary research of publicly available information (like published patents, websites of companies, annual reports etc.) as well as on interviews or email responses from market players done in 2012.

The market model projections have been developed solely by WEASTRA s.r.o. and have been challenged by relevant market players in order to correct assumptions deriving from secondary research. WEASTRA s.r.o. takes no responsibility for any incorrect information supplied to us by producers, potential consumers or other market players.

Contact for further information:
E-mail: info@weastra.com

EXECUTIVE SUMMARY

Itaconic acid

Itaconic acid is an important building block in the chemical industry, however it still occupies only a niche market due to the fact that only few end use applications with high volume markets have been identified, but not developed until recently. The today's use of itaconic acid is mainly in the production of lubricant additives, surface active agents, dye intermediates, plastics, synthetic rubber and resins and chemical fibers.

The estimated global itaconic acid market was of 41,400 MT with the value $ 74.5 million in 2011. The largest applications for itaconic acid are SBR latexes, accounting for 44% of the global itaconic acid market in 2011. The other significant applications for succinic acid include, synthetic latex, which account for 8,8% of global market and chelant dispersant agents, which account for approximately 7% of global itaconic acid market in 2011.

The price for itaconic acid oscillates between $ 1,800 / MT - $ 2,000 / MT depending on the supplier, quality and grade of the chemical. The ongoing development of the production process of itaconic acid is expected to significantly reduce its production costs and in result increase the demand for itaconic acid for some applications, where a low price is crucial, eg. for the production of MMA.

The size of the addressable market for itaconic acid depends on applications in which itaconic acid can be used as a substitute. Chemicals, which can be potentially replaced by itaconic acid, include acrylic acid (in the superabsorbent polymers), acetone cyanohydrin (in the production of MMA), maleic anhydride (in the production of UPR) and sodium tripolyphosphate (in the production of phosphate-free detergent builders). Altogether, weastra estimated the total addressable market volume for itaconic acid at approximately 6,163,409 MT with a value of $ 11,1 billion, based on the markets size and price for 2011. The addressable market here means the theoretical market potential for itaconic acid in case of being the winning technology replacing 100% of other chemical in the specific end use application.

The current production capacity for itaconic acid is estimated to approximately 80,000 MT per year, nevertheless the current annual production was 41,400 MT, which is half of the capacity. In the past, the production of itaconic acid was mainly concentrated in 4 countries: USA (Cargill, Pfizer), China, Japan (Iwata Chemicals) and France (Rhodia). Nowadays, all companies in USA, Japan and France have stopped with the production of itaconic acid and almost all production has shifted to China mainly due to the low demand of itaconic acid and the price competition with Chinese production companies. However, in case of higher global demand of itaconic acid, it would be easy to increase the production capacities accordingly. Mainly the producers of citric acid could start producing itaconic acid without any need of investment into new technology.

Weastra sees the biggest market potential for itaconic acid in some big end use application markets such as unsaturated polyester resins and for production of methyl methacrylate. There is 3 market players, specifically Lucite International, DSM and Itaconix, who are focusing on development of end use applications using itaconic acid, out of which the MMA production and maleic anhydride replacement in unsaturated polyester resins being groundbreaking for the itaconic acid potential.

With regard to the potential of itaconic acid in targeted applications and in other possible bio-based routes and intermediates, the projected market for itaconic acid is estimated to approximately 407,790 MT with the value of approximately $ 567.4 million in 2020, in case the MMA production would be feasible. In case the MMA production using itaconic acid will not be economically viable and other routes, the market size of itaconic acid in 2020 will not exceed 197,400 MT with a value of $ 315 million.

The winning application for itaconic acid can potentially be the production of methyl methacrylate. In the case of using itaconic acid for the production of bio-MMA, there are also several competing ways to produce bio-MMA. The key role in this field will play companies such as Evonik and Genomatika, which are also working on the process to produce bio-MMA but without the use of itaconic acid. However, it is not yet clear which bio-based production route of MMA will represent the winning technology. In case itaconic acid price will be going down to levels which make it economically viable to use it for MMA production, in other words, if the price of itaconic acid will be competitive to the price of acetone cyanohydrin, weastra believes it has great chances to be the winning technology for the bio-based MMA production. In such case, weastra estimates that a maximum of 9,25% replacement of acetone cyanohydrin used for MMA production will be realistic until 2020.

In case the price level of itaconic acid will not go down to such levels, this route of bio-based MMA production using itaconic acid will not be successful and the projected market potential for itaconic acid cannot be reached.

Itaconic acid has also potential to replace maleic anhydride in the production for UPR because of its properties and very similar structure to maleic anhydride. Weastra expects that the market of UPR will growth especially in automotive industry, where the UPR components will have a growing tendency replacing the metal parts minimizing the weight of the car. However, there are also other possible substitutes, which can replace maleic anhydride in the production of UPR. Competing chemical in this field could be bio-based fumaric acid, which is currently already under development or in the development pipeline of various players. However, here weastra believes that the time to market will be relevant for determining the winning technology. The estimated potential of replacing maleic anhydride in UPR with itaconic acid is projected up to 5% of the maleic anhydride used in UPR by 2020.

One of the target markets for new applications for itaconic acid could be also the market of superabsorbent polymers (SAP) in which acrylic acid can be replaced. However, there are other possible substitutes, which can replace petrol-based acrylic acid in the production of SAPs. An important chemical competing with itaconic acid in this field will be bio-based acrylic acid, which can be used as a drop in replacement. Therefore, the estimated potential of replacing acrylic acid in SAP with itaconic acid is projected up to max 1% of the acrylic acid used in SAP by 2020. Weastra does not expect itaconic acid to play a big role on this market once the bio-based acrylic acid will be commercially available.

The opportunities for itaconic acid as poly-itaconic acid are also in the replacement of STPP in detergent builders. However, the market of detergent builders might be quite tough to be convinced by the novel properties of this end use product. Therefore weastra expects the potential of replacing STPP in detergent builders with itaconic acid up to max 1.5% of the STPP used in detergent builders by 2020.

The todays existing market of itaconic acid is currently in stagnation due to several factors, including a narrow range of applications and limiting potential. Therefore the existing itaconic acid market, which includes applications such as SBR latex, synthetic latex, chelant dispersant and others, is expected to grow approximately to a volume of 50,329 MT by 2020, at CAGR of 3.6% from 2010 to 2020.

Overall, with regard to the potential of itaconic acid in targeted applications and in other possible bio-based routes and intermediates, weastra estimated the projected market for itaconic acid to approximately 407,790 MT with the value of approximately $ 567.4 million in 2020, in case the MMA production would be feasible. In case the MMA production using itaconic acid will not be economically viable and other routes, the market size of itaconic acid in 2020 will not exceed 197,400 MT with a value of $ 315 million.

Succinic acid

Succinic acid is a platform chemical that has a broad range of applications, from high-value niche applications such as personal care products and food additives, to large volume applications such as plasticizers, polyurethanes, resins and coatings. The possible applications for succinic acid, which are expected to register strong demand growth in the near future, are plasticizers, polyurethanes, bio-plastics, and chemical intermediates.

The estimated global succinic acid market was 40,000 MT in 2011. Over 97% of the succinic acid production was petrol-based; only 3% was bio-based in 2011. The largest applications for succinic acid are resins, coatings and pigments, accounting for 19.3% of the global succinic acid market in 2011. The other significant applications for succinic acid include pharmaceuticals (15.1%), food (12.6%), PBS/PBST (9%) and polyester polyols (6.2%).

According to the weastra market model projection, succinic acid market is expected to reach approximately 599,449 MT in 2020, growing at a CAGR of 33% from 2010 to 2020. The market value in 2011 was estimated at approximately $ 63 million and is expected to reach $ 539 million in 2020.

The addressable market for bio-based succinic acid is relatively high mainly due to the variety of applications in which bio-based succinic acid can be used as a substitute. Chemicals, which can be potentially replaced by bio-based succinic acid, included maleic anhydride in the production of BDO, adipic acid in plasticizers and polyester polyols and phthalic anhydride in plasticizers and alkyd resins.

Altogether, weastra estimated the total addressable market volume for bio-based succinic acid at approximately 6.2 million MT with the estimated value of $ 14.1 billion, based on the markets size and price for 2011. The addressable market here means the theoretical market potential for succinic acid in case of being the winning technology replacing 100% of other chemical in the specific end use application.

Current main producers of petrol-based succinic acid include DSM, Gadiv Petrochemical Industries, Mitsubishi Chemical, Kawasaki Kasel Chemical, Nippon Shokubai, and some several Chinese producers such as Anqing Hexing Chemical, Lixing Chemical and Anhui Sunsing Chemicals, and some producers from India. The main producers of bio-based succinic acid until now are BioAmber, Myriant, Succinity – a joint venture between BASF and Purac, and Reverdia – a joint venture between DSM and Roquette. The current operational production capacity of bio-based succinic acid is estimated to approximately 3,800 MT (2011), but in the near future, a significant increase in production volume of succinic acid is expected by reaching capacities of planned 225,873 MT from 2014, going to approximately 637,452 MT in 2020.

According to primary interviews, players within the succinic acid market see biggest future potential for bio-based succinic acid for the production of BDO, PBS/PBST and polyester polyols. However, using bio-based succinic in those applications would be economically viable only in case when the price of bio-based succinic acid would be competitive with the price of chemicals, which succinic acid is targeting for replacement.

The current price for petrol-based succinic acid oscillates between $ 2,400 / MT - $ 2,600 / MT and for bio-based succinic acid between $ 2,860 / MT - $ 3,000 / MT depending on the supplier, quality and grade of the chemical. From 2013, weastra expects the bio-based succinic acid price to go down as the bio-based succinic acid will start to be commercially available on large scale. However, as the petrol-based routes might be more expensive in future, the bio-based routes do not necessarily need to go down in price to a level much lower than needed, as the expected demand for bio-based succinic acid will be high.

Weastra estimated the projected market for succinic acid to approximately 188,572 MT with the value of approximately $ 167.6 million in 2015 and 599,449 MT with the value of approximately $ 538.8 million in 2020, with regard to the planned capacity, performance in targeting applications and other possible bio-based routes and intermediates. In 2020, the largest projected applications for succinic acid will be BDO, PBS/PBST and polyester polyols.

According to weastra market model, the estimated potential of replacing MAN in BDO with succinic acid is projected up to 11% of the MAN used in BDO by 2020. Overall, taking in account the Davy process and new BioAmber process to produce bio-BDO, estimated potential for bio-BDO produced from bio-based succinic acid is projected up to ca. 9% of overall addressable BDO market by 2020, with consideration of alternative bio-BDO routes on the way.

PBS is currently a very small market, but has a very high potential for bio-based succinic acid and a great market growth ahead. The estimated potential of 100% replacement of the petrol-based succinic acid in PBS/PBST with bio-based succinic acid is projected from 2013 onwards.

One of the emerging markets for bio-based succinic acid is the polyurethanes market. The end use applications producers as well as the end users targeted by bio-based succinic acid on this market are open for a new molecule to be tested and there is a big potential for bio-based succinic acid to replace adipic acid in this field. The relevant building block competing with bio-based succinic here will be bio-adipic acid. Bio-based adipic acid can be used as a drop in replacement, but it will focus more on polyamides market. Other relevant bio-based building block that can be used in the polyurethane market to replace adipic acid or phthalic anhydride will be 2,5-furandicarboxylic acid, which will be commercially available from 2018 on larger scales but here succinic acid has the time to market advantage. The estimated potential of replacing adipic acid in polyester polyols with bio-based succinic acid is projected up to 4.5% of the adipic acid used in polyester polyols by 2020.

Bio-based succinic acid has also potential to replace phthalic anhydride and adipic acid in plasticizers. In the field of plasticizes, bio-based succinic acid will compete with other possible bio-based replacements of the existing routes, which are 2,5-furandicarboxylic acid, isosorbide and bio-based adipic acid. Those chemicals can be highly suitable and might have even better properties than succinic acid in some cases. Potential customers see the main potential for bio-based succinic acid to find his place mainly in short lifespan products as the market of long lifespan products is quite conservative and the pressure for a bio-based product is not strong enough to bear with the risks. However, producers would like to target big portions of the market, not only the foil or food wrapping but also flooring, walls and others. The estimated potential of replacing adipic acid in plasticizers by bio-based succinic acid is projected up to 2.5% of the adipic acid used in plasticizers by 2020. In the case of replacing phthalic anhydride in plasticizes by bio-based succinic acid for, weastra expect limited potential, only 1% replacing of phthalic anhydride with bio- based succinic acid by 2020.

The bio-based succinic acid shows also potential to be used in alkyd resins. Weastra expects that it is realistic to replace 2.5% of alkyd resins produced from phthalic anhydride by 2020.

The existing succinic acid market, which includes applications such as coatings, pigments, solvents and lubricants, de-icer solutions, food, pharmaceutical, cosmetics and others, is expected to reach approximately 92,239 MT by 2020, at CAGR of 13% from 2010 to 2020.

Overall, with regard to the planned capacity, performance in targeting applications and other possible bio-based routes and intermediates, weastra estimated the projected market for succinic acid to approximately 188,572 MT with the value of approximately $ 167.6 million in 2015 and 599,449 MT with the value of approximately $ 538.8 million in 2020.

2,5 – Furandicarboxylic acid

2,5-Furandicarboxylic acid (FDCA) is an oxidized furan derivative, which is a very stable compound. FDCA is a natural di-acid, at first detected in a human body. Despite its chemical stability it undergoes reactions typical for carboxylic acids (halogen substitution, ester and amid formation). Because of its potential as a replacement of several petroleum based platform chemicals, e.g. terephthalic acid, adipic acid and other important di-acids by polymerization, the production of FDCA was in last decades in the focus of the science.

Until today FDCA in an industrial volume was never commercialized, because it was not possible to produce it in an economic way. FDCA nowadays is produced mainly for scientific usage. Currently there are only few companies, which produce and sell FDCA on demand, as there is no economic viability behind its usage.

The current estimated production is between 3.5 and 5 MT a year with a value of approximately $ 10 million. The price is influenced by purity and quantity and is over $ 2,300 / kg.

The addressable market for FDCA is huge mainly due to the variety of applications in which FDCA can be used as a substitute. Chemicals, which can be potentially replaced by FDCA, include terephthalic acid in the production of PET, PBT and polyamides; bisphenol A in polycarbonates; adipic acid in the polyester polyols and plasticizers; phthalic anhydride in the polyester polyols and plasticizers; possible would be also isophthalic acid in the production of PET; but is not in the primary focus. In the field of polyamides market, FDCA does not have big ambitions to be used as a replacement but as platform chemical for completely novel polyamides. FDCA has also strong potential to be used in the production of solvents, especially novel solvents.

Altogether, weastra estimated the total addressable market volume for FDCA at approximately 50.5 million MT with the estimated value of $ 50.5 billion, based on the markets size for 2011 and price for 2016, when the FDCA will be commercialized and the price will be more stable. The addressable market here means the theoretical market potential for FDCA in case of being the winning technology replacing 100% of other chemical in the specific end use application.

The plan to start the first industrial FDCA production is expected to come in 2016 within an industrial plant with a capacity of 30,000 – 50,000 MT, which will be operated by Avantium. The company plans the real commercialization starting from 2018 onwards, on a base of license production with total capacity of 300,000 – 500,000 MT.

Weastra estimated the projected market for FDCA to approximately 498,016 MT with the value of approximately $ 498 million in 2020, with regard to the planned capacity, performance in targeting applications and other possible bio-based routes and intermediates.

However, using FDCA would be economically viable only in case when the price of FDCA would be competitive with the price of chemicals, which FDCA is targeting for replacement. The current price for FDCA is over $ 2,300 / kg and is influenced by purity and quantity. From 2016, weastra expects the FDCA price to go down to approximately $ 1,000 / MT.

FDCA is targeting the existing applications by replacement of existing petrol-based intermediates, but also has a strong potential to become a novel intermediate for brand new applications with novel properties.

According to primary interviews, players within the FDCA field see the biggest future potential for FDCA in two areas, on one hand in polyamides – especially new polyamides with novel properties, and in the main target field of Avantium - as a replacement of terephthalic acid in the production of PET. From FDCA will be produced 2,5-furandicarboxylate (PEF), 100% renewable polyester, which has ambition to replace PET.

PET is currently a huge market, and has a very high potential for FDCA. There is a huge potential to use almost all of FDCA of the commercial scale production in the next few years exactly in this area. The estimated potential of replacing adipic acid in polyester polyols by FDCA is projected by Weastra up to 0.6% of the adipic acid used in plasticizers by 2020.

In the field of polyamides market, FDCA does not have big ambitions to be used as a replacement but as platform chemical for completely novel polyamides. The real potential of FDCA in polyamides till 2020 is strongly determined by the FDCA production capacities development and the price of FDCA. Other bio-based chemical competing with FDCA in the field of polyamides will be the bio-based adipic acid, which can be used as a drop-in replacement and might have good chances of success.

Weastra expects an increase of demand for non-phthalate plasticizers, which should be a potential for the FDCA. Even if FDCA as a platform chemical for plasticizers shows an economical potential, weastra estimates, that in this area in the next decade FDCA will be used just for development and testing of new products in this area. According to weastra market model, the estimated potential of replacing adipic acid in plasticizers by FDCA is projected up to 1% of the adipic acid used in plasticizers by 2020 and the estimated potential of replacing phthalic anhydride in plasticizers by FDCA is projected up to 1% by 2020.

For FDCA, one of the emerging markets is also polyester polyols, used in polyurethanes. The end use applications targeted by bio-based succinic acid and by FDCA on this market are open for a new molecule to be tested and there is a potential for FDCA to replace adipic acid or phthalic anhydride in this field. However, weastra estimates the market of FDCA in polyester polyols until 2020 rather just for development and testing of new products. The bio-based chemical competing with FDCA in this field will be bio-based succinic acid, but also bio-based adipic acid. Bio-based adipic acid can be used as a drop in replacement, but it will focus more on polyamides market. The bio-based succinic acid might have an advantage of time to market and might be more relevant for this end use than FDCA. The estimated potential of replacing adipic acid in polyester polyols by FDCA is projected up to 0.2% of the adipic acid used in polyester polyols by 2020 and the estimated potential of replacing phthalic anhydride in polyester polyols by FDCA is projected up to 4% by 2020.

Interesting market for FDCA are also polycarbonates, in which FDCA can replace the toxic bisphenol A. The estimated potential of replacing bisphenol A in polycarbonates with FDCA is projected up to 0.9% of the bisphenol A used in polycarbonates by 2020.

The market of solvents might not be in the primary focus of current FDCA producer, but there is a strong potential in this area for usage of FDCA. There might be a potential for FDCA in solvents as platform chemical for novel property solvents. Weastra estimates that in this area in the next decade FDCA will be used just for development and testing of new products.

Overall, with regard to the planned capacity, performance in targeting applications and other possible bio-based routes and intermediates, weastra estimated the projected market for FDCA to approximately 498,016 MT with the value of approximately $ 498 million in 2020.

ITACONIC ACID

1. INTRODUCTION

Itaconic acid, also known as methylenesuccinic acid, is a chemical intermediate that was listed in 2004 by the U.S. Department of Energy's biomass program as one of the top 12 Top Value Added Chemicals. It is a five-carbon molecule that is very similar by structure with maleic anhydride.

The first routes of obtaining itaconic acid were by the distillation of citric acid. Since 1960s this chemical intermediate started being produced industrially by fermentation of carbohydrates such as glucose using Aspergillus terreus. Nowadays itaconic acid is obtained mainly through fermentation of sugars with molds.

Itaconic acid is a fully sustainable industrial building block with various applications in different areas.

Among different fungals it is the corn smut also known as Ustilagomaydis which proved to be the best species for the production of itaconic acid, however glucose is the most efficiently utilized substrate. The second most abundant sugar is xylose – a monosaccharide derived from xylan hemicelluloses, which can be found in hardwood and agricultural residues. Xylose is relatively easily recovered by acid or by enzymatic hydrolysis but this process has not been researched properly because during the past years the research was focused more on glucose fermentation. During the recent years some progress has been made in the production of itaconic acid from both pentose and glucose sugars. Nonetheless, such production route of itaconic acid has proved to be uneconomical, because of high substrate cost and/or relatively low yields and it cannot compete with production through fermentation.

Itaconic acid is an important raw material in the chemicals industry. It represents a white crystalline powder that is soluble in water, ethanol and acetone with applications in such products as lubricant additives, surface active agents, dye intermediates, plastics, synthetic rubber and resins and chemical fibers. The current market of itaconic acid is very small and limited to niche applications because of the high cost fermentation process as well as due to the fact that only few end use applications with high volume markets have been identified only recently and not developed yet.

2. VALUE CHAIN

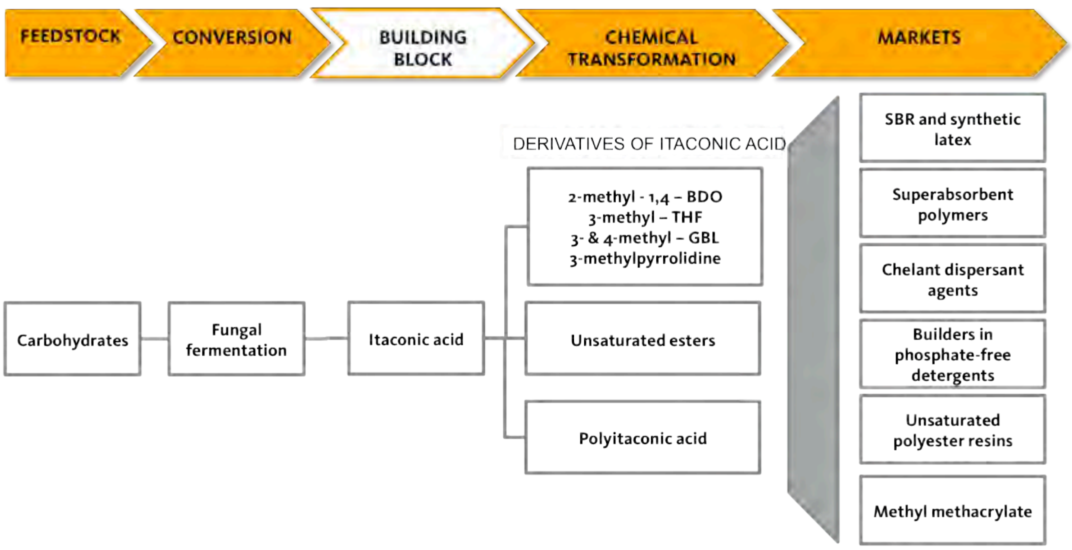
Itaconic acid is a white crystalline unsaturated C5 dicarboxylic acid and it is one of the promising substances within the group of organic acids. It is stable at acidic, neutral and middle basic conditions at moderate temperatures. Due to the two carboxylic groups, rather low monomer contents lead to copolymer with effective acidity and thus better adhesion and increased latex stability.

Itaconic acid was discovered by Baup (1837) as a thermal decomposition product of citric acid. The biosynthesis by fungi from carbohydrates was first reported by Kinoshita (1932), who isolated itaconic acid from the growth medium of an osmophilic fungus, Aspergillus itaconicus[1]. Currently, itaconic acid is mostly produced commercially by Aspergillus terreus (A. terreus) via submerged fungal fermentations[2].

Several producers and research companies are working on the development of new fermentation technologies for a more economical production of itaconic acid. More sophisticated bioprocess control has led to renewed interest in improving itaconic acid production, novel fed-batch strategies and continuous processes using immobilized cells are now being developed and investigated[3].

The value chain of itaconic acid is shown in Figure 1.

Figure 1: VALUE CHAIN OF ITACONIC ACID



[1] Academic Journals - Dowlathabad MuralidharaRao, S. M. D. Jaheer Hussain, V. Pandu Rangadu, K. Subramanyam, G. Sivarama Krishna and A. V. N. Swamy: Fermentative production of itaconic acid by Aspergillus terreus using Jatropha seed cake, May 2007

[2] BMC Biotechnology - An Li, Nina Pfelzer, Robbert Zuijderwijk and Peter Punt: Enhanced itaconic acid production in Aspergillus niger using genetic modification and medium optimization, August 2012; http://www.biomedcentral.com/

[3] Academic Journals - Dowlathabad MuralidharaRao, S. M. D. Jaheer Hussain, V. Pandu Rangadu, K. Subramanyam, G. Sivarama Krishna and A. V. N. Swamy: Fermentative production of itaconic acid by Aspergillus terreus using Jatropha seed cake, May 2007

Itaconic acid is mostly produced by fungal fermentation from carbohydrates, but the fermentation route has a high cost price. There is also another route to produce itaconic acid - via genetically modified plants. Itaconic acid can be produced in starch potato plants where it is accumulated in the storage organs. Also plant-based production systems are developed where methacrylate or methacrylate equivalents such as itaconic acid are produced by genetically engineering existing metabolic pathways in cellulosic ethanol biomass crops such as switch grass[4]. This production route has such challenges as isolation and purification in order to separate the itaconic acid from the plant tissue.

An important derivate of itaconic acid is polyitaconic acid produced by polymerization of itaconic acid. Another important derivate is unsaturated ester, 2-methyl-1,4-BDO, 3-methyl-THF, 3-& 4-methyl-GBL a 3-methylpyrrilidine.

Itaconic acid is useful in a variety of industrial applications. Currently and for the future using, itaconic acid and its derivatives have applications in the lubricant additives, surface active agents, dye intermediates, plastics, synthetic rubber and resins and chemical fibers, SBR and synthetic latex, chelant dispersant agents, superabsorbent polymers, builders in phosphate free detergents and in unsaturated polyester resins. Itaconic acid could be also used for the production of methyl methacrylate (MMA).

[4] Strategic Targets for 2020 – Collaboration Initiative on Biorefineries, H.L. Bos, P.F.H. Harmsen & E. Annevelink Wageningen UR – Food & Biobased Research Version March 2010

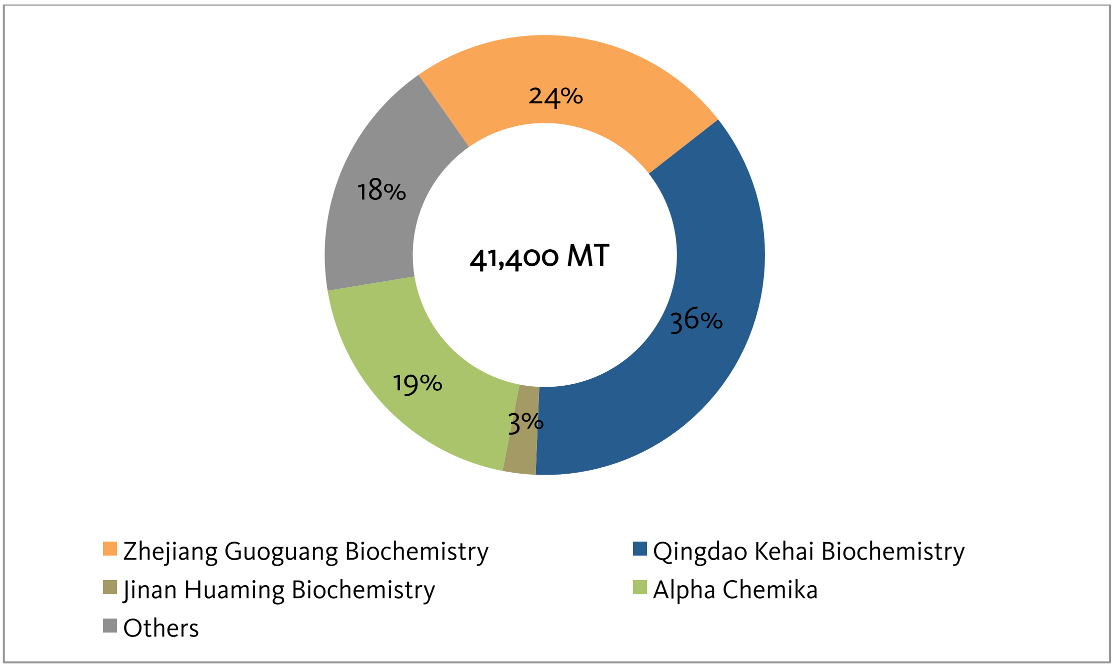
3. GLOBAL MARKET OF ITACONIC ACID

Itaconic acid is an organic compound, a platform chemical that has several potential end uses. Itaconic acid is an important raw material in the chemicals industry, but it still occupies a niche market. The today's use of itaconic acid is in the production of lubricant additives, surface active agents, dye intermediates, plastics, synthetic rubber and resins and chemical fibers.

The price for itaconic acid oscillates between $ 1,800 / MT - $ 2,000 / MT depending on the supplier, quality and grade of the chemical. The current production routes of itaconic acid are for some applications quite costly; the applications are limited to a range of specialized fields, where the current price is acceptable. The purification and fermentation process are still financially demanding and ineffective. The ongoing development of the production process of itaconic acid is expected to significantly reduce its production costs and in result increase the demand for itaconic acid for some applications, where the price is crucial, e.g. for production of MMA.

China is a key player on the market of itaconic acid[5]. The country holds the supply and demand of itaconic acid from the viewpoint of production, manufacture, and worldwide competitiveness.

Figure 2: ITACONIC ACID MARKET SHARE, BY PRODUCERS IN 2011



[5] Shizuoka University- Okabe, Mitsuyasu; Lies, Dwiarti; Kanamasa, Shin; Park, Enoch Y.: „Biotechnological production of itaconic acid and its biosynthesis in Aspergillus terreus“, September 2009

The global itaconic acid market was estimated to 41,400 MT in 2011 and almost the entire production comes from in China. Currently, the main producers of itaconic acid are Qingdao Kehai Biochemistry, which is the current global leader; other main producers include Alpha Chemika, Zhejiang Guoguang Biochemistry and Jinan Huaming Biochemistry. There are also several other small producers, mostly from China.

Itaconic acid market is expected to reach 407,790 MT in 2020, growing at a CAGR of 26.1% from 2010 to 2020. The market value in 2011 was estimated at $ 74.5 million and is expected to reach $ 567.4 million in 2020 at a CAGR of 22.3% from 2010 to 2020[6].

In 2004, the U.S. Department of Energy has identified itaconic acid as one of the five most promising "building blocks". Itaconic acid, as a platform chemical, is used worldwide as monomer or co-monomer in manufacturing plastics, resins[7] because of its specific favorable properties and the unique structure. The plastics and coatings, which are compounded by using 1% to 5% of itaconic and styrene acid have some features, such as light color, easy to paint, easy to separation, water-fast and antisepsis.

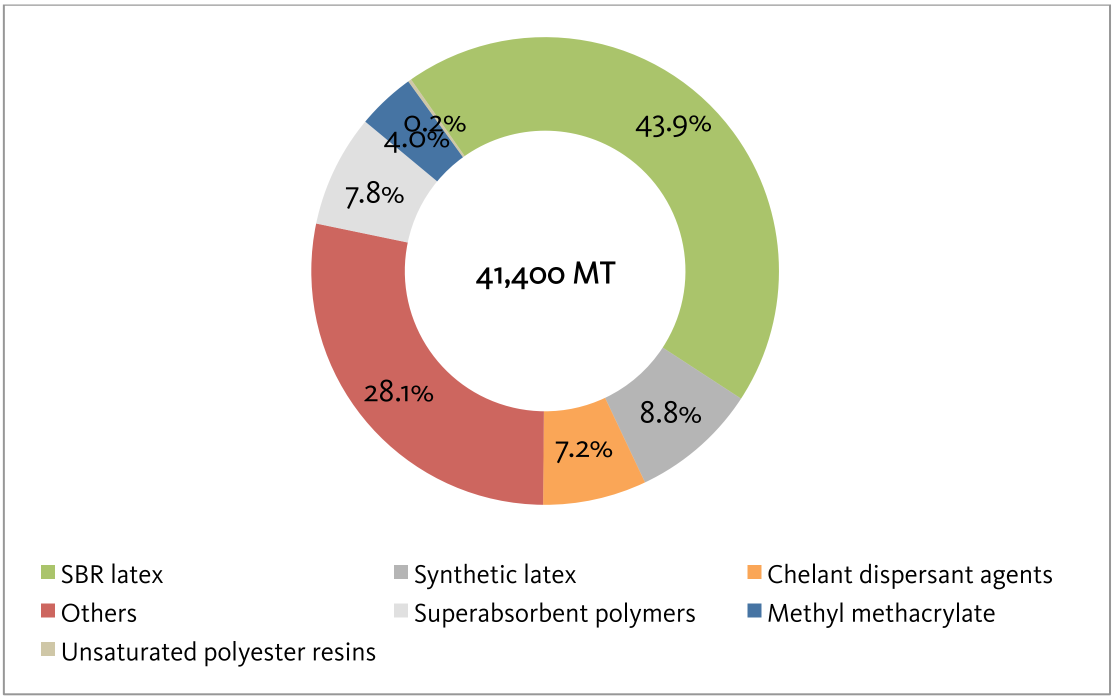
The primary usage of itaconic acid is as a co-monomer in the production of styrene-butadiene rubber and acrylate latexes with applications in the paper and architectural coating industry. Itaconic acid also improves the resistance to abrasion. This building block is used in paints to improve quality and used as fibre carpet sizing agent to make carpet more endurable. Itaconic acid can react with acrylic and methacrylic acid or their esters to prepare resins which can be widely used in emulsion coating, leather coating, coatings for car, refrigerator and other electrical appliances to improve adhesion, color and weather resistance[8]. Some itaconic acid derivatives are used in medicine, cosmetics, lubricants, thickeners, herbicides and wool modifiers.

[6] weastra market model – based on primary and secondary market research

[7] BMC Biotechnology - An Li, Nina Pfelzer, Robbert Zuijderwijk and Peter Punt: Enhanced itaconic acid production in Aspergillus niger using genetic modification and medium optimization, August 2012; http://www.biomedcentral.com/

[8] Norkem Group Chemical Distributor website - http://www.norkem.com/

Figure 3: ITACONIC ACID MARKET SHARE, BY APPLICATIONS IN 2011[9]



Currently, the largest applications for itaconic acid are SBR latexes, accounting for 44% of the global itaconic acid market in 2011. The other significant applications for succinic acid include, synthetic latex, which account for 8.8% of global market and chelant dispersant agents latex, which account for 7.2% of global itaconic acid market in 2011. The biggest market potential for itaconic acid is in new applications, such as unsaturated polyester resins, superabsorbent polymers, phosphate free detergents and for production of methyl methacrylate[10].

[9] weastra market model – based on primary and secondary market research

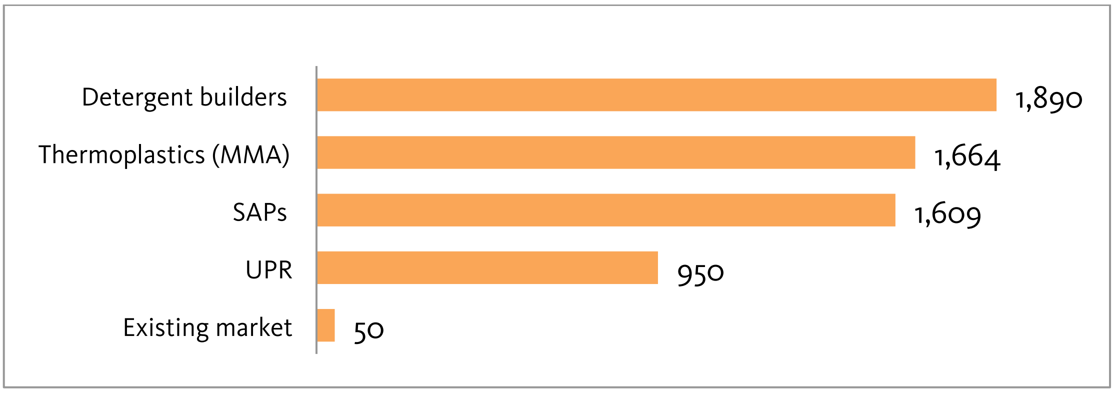
[10] weastra market model – based on primary and secondary market research

4. ADDRESSABLE MARKET OF ITACONIC ACID

The addressable market in this market report means the theoretical market potential for itaconic acid in case of being the winning technology replacing 100% of other chemical specific end use application.

The addressable market for itaconic acid is relatively high mainly due to the variety of applications in which itaconic acid can be used as a substitute. There are currently apart from the existing market, four major new markets that itaconic acid can address as a replacement for petrol-based chemicals.

Figure 4: ADDRESSABLE MARKET VOLUME FOR ITACONIC ACID, based on the markets size for 2011 (in thousands)



Chemicals, which can be potentially replaced by itaconic acid include acrylic acid (in the superabsorbent polymers), acetone cyanohydrin (in the production of MMA), maleic anhydride (in the production of UPR) and sodium tripolyphosphate (in the production of phosphate-free detergent builders).

The total addressable market for itaconic acid is approximately 6,163,409 MT with a value of $ 11.1 billion based on the current markets sizes (2011) [11].

[11] weastra market model – based on primary and secondary market research

Acrylic acid

Acrylic acid is an organic compound, primarily produced from propylene. It is one of the most versatile monomers, used mainly to impart hardness and durability of polymer formulations. There are several ways to produce petrol-based acrylic acid. One of them is through the oxidation or acrylonitrile synthesis of propylene. Other possible ways include production from acetylene, ethylene or acetic acid.

Acrylates and polyacrylic acid are the two main derivatives of acrylic acid. Acrylates, including butyl acrylate, ethyl acrylate, methyl acrylate and 2-ethhexyl acrylate, which are esters of acrylic acid, are used in surface coatings, adhesives, sealants, additives and textiles. Acrylates take approximately 55% of total consumption of acrylic acid. Polyacrylic acid is used in the manufacture of superabsorbent polymers and detergents, which take approximately 35% of the total consumption of acrylic acid. The demand for acrylic acid is stable and strong; the market volume of acrylic acid was approximately 4,600,000 MT with a value of $ 9.4 billion based on the current markets sizes (2011) [12].

Arkema, BASF, Novomer, Dow Chemical, LG Chem, Nippon Shokubai and Mitsubishi Chemical are the major producers of petrol-based acrylic acid.

Several of the major producers are already researching ways for the production of bio-based acrylic acid. As this chemical has a very high and stable demand due to its large variety of applications, its potential would grow even more if it was bio-based. OPX Biotechnologies, Myriant, Genomatica, Metabolix, Novozymes and Cargill are currently working on the development of different ways to produce bio-based acrylic acid.

Cargill and Novozymes are developing the route for the production of bio-based acrylic acid through the 3-hydroxypropionic acid. Metabolix is working on its polyhydroxyalkanoates technology to produce bio-based acrylic acid. OPX Bio together with Dow Chemical are developing a sugar-based process to manufacture bio-acrylic acid at an industrial scale. Arkema is developing catalysts to produce acrylic acid from glycerol. Genomatica wants to produce bio-acrylic acid from bio-fumaric acid by fermentation. One of the leading producers of petrol-based acrylic acid is also focused on finding new routes for the production of green acrylic acid. BASF wants to use their bio-acrylic mainly for the manufacture of superabsorbent polymers[13].

There are opportunities for itaconic acid to replace acrylic acid in the production of superabsorbent polymers (SAP). The total addressable market volume of itaconic acid as a replacement of acrylic acid is approximately 1,609,300 MT with a value of $ 2,89 billion based on the current markets sizes (2011)[14].

[12] weastra market model – based on primary and secondary market research

[13] BASF press release: http://www.basf.com/

[14] weastra market model – based on primary and secondary market research

Acetone cyanohydrin

Acetone cyanohydrin is used as entry material for the production of methyl methacrylate (MMA). Itaconic acid can be a substitute for acetone cyanohydrin in the production of MMA.

The most widely practiced commercial technology for the synthesis of methyl methacrylate (MMA) is the acetone cyanohydrin (ACH) process[15]. Acetone cyanohydrin is converted to a-hydroxyisobutyramide, which is then esterified with methyl formate to produce methyl a-hydroxy isobutyrate and formamide. The methyl a-hydroxy isobutyrate is dehydrated to MMA, which is afterwards dried and purified[16].

Methyl methacrylate is the most important ester of methacrylic acid, with good strength, transparency and with excellent weather resistance. It is also the monomer for polymethyl methacrylate (PMMA) polymers and copolymers[17]. The polymers and copolymers of PMMA are used in the manufacture of a variety of products such as clear plastics (for example Plexiglass), resins, and acrylic sheets. Some of the end products that have utilized these chemicals are advertising signs and displays, skylights, building panels and sidings. MMA also has applications in the field of medicine and dentistry as it is used to make prosthetic devices, surgical bone cements, and be used as a ceramic filler or cement. MMA can also be used in the impregnation of concrete and partially replace styrene in unsaturated polyester resins.

Lucite International - one of the main producers of MMA with a 25% of market share globaly[18], is now developing new, green routes of producing MMA from itaconic acid, which would mean production by fermentation of sugars instead of acetone cyanohydrin.

There are opportunities for itaconic acid to replace acetone cyanohydrin in the production of MMA. The total addressable market volume of itaconic acid as a replacement of acetone cyanohydrin is approximately 1,664,280 MT with a value of $ 3 billion based on the current markets sizes (2011) [19].

Maleic anhydride

Maleic anhydride (MAN), produced by oxidation of benzene or butane, had the market volume of approximately 1,900,000 MT with a value of $ 3 billion in 2011[20]. MAN is mostly used during the

[15] INGENIA ISSUE 45, December 2010 - Acrylics for the future: http://www.ingenia.org.uk/
[16] IHS Chemical - New Methyl Methacrylate Process Via Acetone Cyanohydrin; http://www.ihs.com/
[17] weastra – based on primary and secondary market research
[18] weastra – based on primary and secondary market research
[19] weastra market model – based on primary and secondary market research
[20] ICIS: http://www.icis.com, weastra market model – based on primary and secondary market research

production of unsaturated polyester resins (UPRs), which take approximately 50% of total consumption of MAN[21]. The second largest application of maleic anhydride is 1,4 BDO market and its derivatives, which account for 30% of the total consumption[22]. BDO is mainly used in the manufacturing of engineering plastics and in the application of polyurethane in the leather industry.

Maleic anhydride is a key ingredient required for manufacturing unsaturated polyester resins (UPR). The demand for UPR is constantly growing with the goal to enable the production of lighter, stronger, fiberglass composites for automotive, construction areas, as well as decorative architectural features and a highly varied range of consumer products. These resins offer greater flexibility for innovative designs, improved performance, faster production speeds and higher durability for products, which can serve as replacements to conventional materials.[23] Due to its applications, the demand for unsaturated polyester resins is closely related to the health of the construction industry and overall state of the economy of a country.[24]

As itaconic acid and maleic anhydride have a similar chemical structure and both chemicals have a double bond, there are opportunities for itaconic acid to replace maleic anhydride especially in unsaturated polyester resins (UPR). The total addressable market volume of itaconic acid as a replacement of maleic anhydride was approximately 949,500 MT with a value of $ 1.7 billion based on the current markets sizes (2011) [25].

Sodium tripolyphosphate

Sodium tripolyphosphate (STPP) is an inorganic compound that has applications in different industries, ranging from cleaning products to food preservatives. Also known by alternate names like pentasodium salt or triphosphoric acid, this chemical falls into the classification Generally Regarded As Safe (GRAS), which means that the use of this chemical does not present risk to health. STPP can also find applications in the production of paints and ceramic products.

The key function of STPP is that it allows surfactants, which are molecules that help dissolve surface dirt, to work at their full potential. It also softens hard water for easier foaming and cleaning. For this reason one of its main applications is as an ingredient in detergents and soaps.

Another important application is in food industry where sodium tripolyphosphate is used to preserve foods such as red meats, poultry, and seafood. Pet food and animal feed can also be treated with it, serving the same general purpose as it does in human food. STPP is also used to help preserve the

[21] IHS Chemical – global reports: Maleic Anhydride, November 2011; http://www.ihs.com/
[22] ICIS: http://www.icis.com, weastra market model – based on primary and secondary market research
[23] weastra – based on primary and secondary market research
[24] IHS Chemical – global reports: Maleic Anhydride, November 2011; http://www.ihs.com/
[25] weastra market model – based on primary and secondary market research

quality of drinks.

Although sodium tripolyphosphate is classified as GRAS chemical, in high quantities it can be toxic. The food grade of STPP contains the fewest impurities. There is some public concern about the presence of artificial preservatives such as STPP in food[26], but most current research suggests that it does not appear to cause health issues at the amounts normally ingested.

There are opportunities for itaconic acid to replace STPP in detergent builders. The total addressable market volume of itaconic acid as a replacement of STPP is approximately 1,890,000 MT with a value of $ 3,4 billion based on the current markets sizes (2011) [27].

[26] National Institute for Occupational Safety and Health's (NIOSH) Registry of Toxic Effects of Chemical Substances

[27] weastra market model – based on primary and secondary market research

5. PRODUCTION CAPACITIES OF BIO-BASED ITACONIC ACID

The market of itaconic acid is currently in stagnation due to several factors, including a narrow range of applications and limiting potential. The production capacity for itaconic acid is estimated to approximately 80,000 MT per year, nevertheless the current annual production was 41,400 MT, which is half of the capacity.

In the past, the production of itaconic acid was mainly concentrated in 4 countries: USA, China, Japan and France. Cargill and Pfizer were market leaders, while French Rhodia and Japanese Iwata Chemicals also had strong market positions. Nowadays, all of the above mentioned companies have stopped with the production of itaconic acid. Since Cargill – the last American producer of itaconic acid, has stopped being active in this area, almost all production has shifted to China.

Figure 5: WORLD MAP OF MAIN PRODUCERS OF ITACONIC ACID

Currently there are only 3 companies, which are actively engaged in the production of Itaconic acid in China - Zhejiang Guoguang Biochemistry, Qingdao Kehai Biochemistry and Jinan Huaming Biochemistry. Although these companies are market leaders, they still do not manage to use their capacity at full.

The current global leader in the production of itaconic acid is Qingdao Kehai Biochemistry, with yearly output capacity of 20,000 MT. Except for Chinese producers, the Indian manufacturer Alpha Chemika is also a leader of the market, with a capacity of 8,000 MT per year, based only on contract production. Many Chinese companies still claim that they are producers of itaconic acid, especially through their corporate websites, but in reality most of them closed down their production, due to the low demand of itaconic acid and became only distributors of itaconic acid.

An overview of bio-based itaconic acid production capacities and output is presented in Table 1.

Table 1: ITACONIC ACID PRODUCTION CAPACITY AND OUTPUT IN 2011

Company	Plant location	CAPACITY (MTPA)	OUTPUT (MTPA)
Zhejiang Guoguang Biochemistry	Zhejiang, China	10,000	10,000
Qingdao Kehai Biochemistry	Qingdao, China	20,000	15,000
Jinan Huaming Biochemistry	Jinan, China	15,000	1,000
Alpha Chemika	Mumbai, India	8,000	contract production
Others		27,000	7,400
TOTAL		80,000	41,400

According to our study, the production capacities of itaconic acid are not expected to grow dramatically. In case a raise in production capacities will be needed, a quick ramp-up of added capacity is possible as production of citric acid can be easily switched to itaconic acid.

Nevertheless this might change if Lucite International, which already owns patents on the production of MMA from itaconic acid, will start commercial production of MMA out of itaconic acid.

Lucite International and Mitsubishi Rayon declared that they would like to start with the commercial production of bio-based MMA in 2016. Their goal is to produce 50% of MMA[28], which is approximately 400,000 MT by bio-routes, out of which itaconic acid seems attractive.

[28] Mitsubishi Rayon– press release: http://www.mrc.co.jp/english/

6. PROJECTED MARKET OF ITACONIC ACID BY APPLICATIONS

Most of the interviewed players do not see big future potential for itaconic acid apart from its current market size due to the lack of viable end use applications and therefore a lack on the demand side.

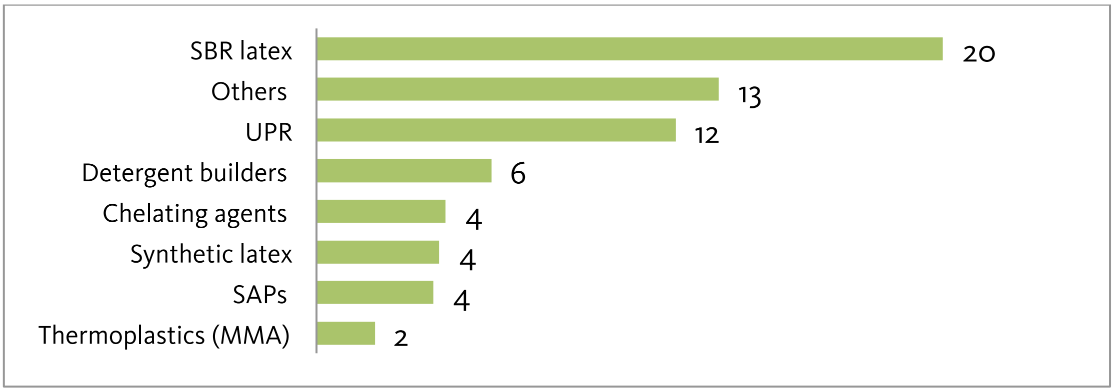
However, there is 3 market players, specifically Lucite International, DSM and Itaconix, who are focusing on itaconic acid, out of which the MMA production and maleic anhydride replacement in unsaturated polyester resins being groundbreaking for the itaconic acid potential.

Itaconix, a producer of polyitaconic acid, is currently one of the main consumers of itaconic acid. Itaconix sees a big potential for itaconic acid in detergent builders and chelants, where they are focusing on developing novel products with novel properties out of polyitaconic acid.

Itaconic acid as a substitute for maleic anhydride in unsaturated polyester resins (UPR) is very interesting end use application mainly for DSM, as they have patented several routes to produce UPR from this intermediate. DSM sees relevant potential for itaconic acid used in UPR, because of its properties and very similar structure to maleic anhydride. Even though itaconic acid not being a direct drop in replacement for maleic anhydride and having the current price of itaconic acid being not competitive to maleic anhydride, the improved properties of the resulting UPR using itaconic acid make this replacement being lucrative and economically viable. The estimated potential of replacing MAN in UPR with itaconic acid is projected up to 5% of the MAN used in UPR by 2020.

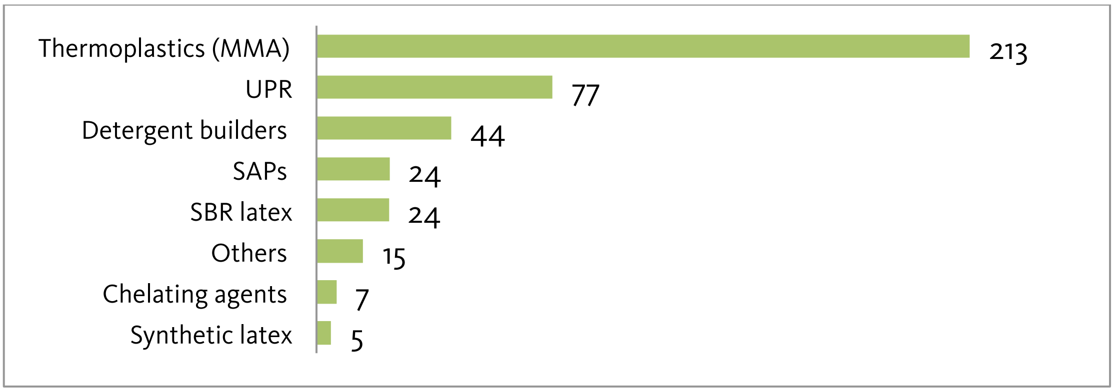
The winning application for itaconic acid can potentially be the production of methyl methacrylate. Lucite International, the subsidiary of Mitsubishi Chemical, owns a patented route to produce bio-based MMA from itaconic acid or other bio-based intermediates. The use of itaconic acid in the production of MMA could be very crucial for the future projection of itaconic acid market. However, using itaconic acid in the production of MMA would be economically viable only in case when the price of itaconic acid would be competitive with the price of acetone cyanohydrin. This means the price of itaconic acid should oscillate in range of $ 1,000 – 1,200 /MT. In case the price level of itaconic acid will not go down to such levels, this route of bio-based MMA production using itaconic acid will not be successful and the projected market potential for itaconic acid can not be reached.

Figure 6: PROJECTED MARKET VOLUME FOR ITACONIC ACID IN 2015 (in thousands)



With regard to potential of itaconic acid in targeted applications and in other possible bio-based routes and intermediates, the projected market for itaconic acid is estimated to approximately 65,073 MT with the value of approximately $ 110.6 million in 2015[29].

Figure 7: PROJECTED MARKET VOLUME FOR ITACONIC ACID IN 2020 (in thousands)



With regard to the potential of itaconic acid in targeted applications and in other possible bio-based routes and intermediates, the projected market for itaconic acid is estimated to approximately 407,790 MT with the value of approximately $ 567.4 million in 2020, in case the MMA production would be feasible[30].

In case the MMA production using itaconic acid will not be economically viable and other routes, the

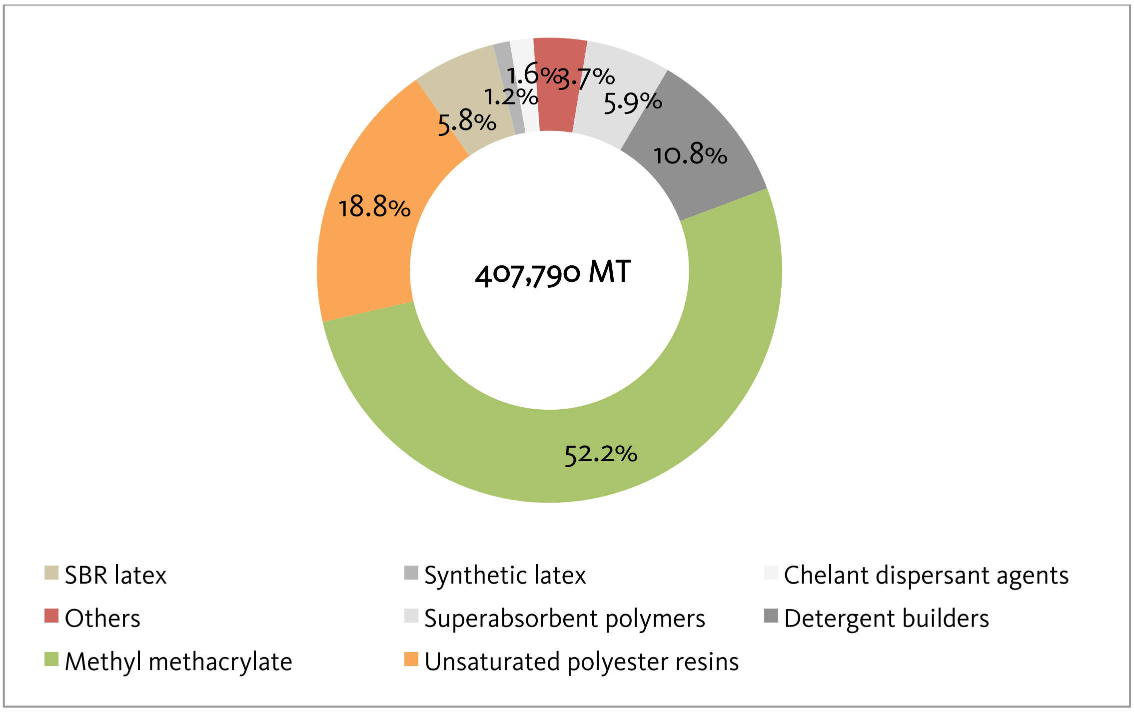
[29] weastra market model – based on primary and secondary market research

[30] weastra market model – based on primary and secondary market research

market size of itaconic acid in 2020 will not exceed 197,400 MT with a value of $ 315 million[31].

Itaconic acid can be successful on both markets – the todays existing market for itaconic acid, where the demand for itaconic acid will according to our research experience a steady increase, as well as on the market for new end use applications where itaconic acid can replace existing petrol-based intermediates.

Figure 8: PROJECTED MARKET SHARE, BY APPLICATIONS IN 2020



The biggest market potential for itaconic acid is in new applications as unsaturated polyester resins, detergents builders and for production of methyl methacrylate. In 2020, the largest projected application for itaconic acid is MMA, accounting for 52.2% of the global itaconic acid market. Unsaturated polyester resins account for 18.8% of global market and detergent builders account for 10.8% of global itaconic acid market in 2020[32].

[31] weastra market model – based on primary and secondary market research

[32] weastra market model – based on primary and secondary market research

New markets for bio-based itaconic acid

Superabsorbent polymers (SAP)

Superabsorbent polymers are primarily used as an absorbent for water and aqueous solutions for diapers, feminine hygiene products and similar applications. Due to their strong performance superabsorbent materials will quickly replace traditional absorbent materials such as cloth, cellulose fiber and others.

SAP's have various properties, which can be applied in several industries. The use of superabsorbent polymers had a very strong impact on the diaper industry as the manufacturers changed the design of diapers in order to take full advantage of the new polymer. SAP's are used not only in the production of diaper, but can also be used in applications such as adult incontinence pads, feminine hygiene products and miscellaneous.

The first superabsorbents were produced from chemically modified starch, cellulose and other polymers like polyvinyl alcohol (PVA), polyethylene oxide (PEO), all of which are hydrophilic and have a high affinity for water[33]. When lightly cross-linked, chemically or physically, these polymers became water-swellable but not water-soluble.

At present, superabsorbent polymers are made from partially neutralized, lightly cross-linked polymerized acrylic acid, which has been proven to give the best performance versus cost ratio.

In 2011, the market volume of SAP made from acrylic acid was approximately 1,609,300 MT. Total global production capacity of SAP's is approximately 2 million MT[34].

Nippon Shokubai, which is a leading producer in SAP's takes 470,000 MT from total global production capacity[35]. Among other leading producers of SAP there is BASF SE, Evonik Degussa, Evonik Stockhausen, Dow Chemical, Hoechst Casella, Chemdal Corporation, LG Chem, Sanyo Chemical Industries, Sumitomo, Sanyo and others.

[33] BASF: Mark Elliott - „Superabsorbent Polymers"; http://chimianet.zefat.ac.il/download/Super-absorbant_polymers.pdf

[34] weastra market model – based on primary and secondary market research

[35] Nippon Shokubai - http://www.shokubai.co.jp/en/

Table 2: SUPERABSORBENTS: ITACONIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	3,080	3,219	3,363	3,515	3,673	3,838
VALUE	5,852	5,793	5,718	5,975	6,244	6,525
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	4,011	4,191	4,380	11,443	23,916	22.7%
VALUE	6,418	6,706	7,008	18,309	38,265	20.7%

The market of superabsorbents was identified as a target market due to the fact that in the production of SAPs, acrylic acid can be replaced by bio-based itaconic acid. Itaconic acid can be used in SAP's through polymerization as polyitaconic acid. Polyitaconic acid, a water soluble polymer, is an attractive replacement to petroleum-based polyacrylic acid, because of similar properties.

One of the biggest players on the market of polyitaconic acid is Itaconix – a USA based company. The company is currently active on the market of SAPs, but according to our primary research, the market on which Itaconix is planning to focus is the usage of polyitaconic acid in new applications, a factor which directly influences the potential of itaconic acid in the production of SAPs. Another factor which influences the usage of itaconic acid in the production of SAP is the development of a more attractive replacement of petrol-based acrylic acid. Several companies such as Myriant, Arkema, Cargill, Genomatica, Nippon Shokubai and Novozymes are already working on the development of a bio-based acrylic acid, which can be used as a drop-in replacement. This is another reason why the potential of itaconic acid in the production of SAP is proving to be questionable. The estimated potential of replacing acrylic acid in SAP with itaconic acid is projected up to 1% of the acrylic acid used in SAP by 2020[36].

According to the market model projection, the estimated demand of itaconic acid used in SAPs was 3,080 tons in 2010 and weastra expects that it will reach 23,916 tons by 2020, at CAGR of 22.7% from 2010 to 2020. The overall market value for itaconic acid used in SAP was $ 5.8 million in 2010 and is expected to reach $ 38.2 million in 2020[37].

[36] weastra market model – based on primary and secondary market research

[37] weastra market model – based on primary and secondary market research

Methyl methacrylate

Methyl Methacrylate (MMA) is a key intermediate chemical, due to its ability to undergo polymerization and copolymerization. MMA has one of its main applications in polyacrylates – clear and relatively durable thermoplastics. MMA can be commercially produced by several routes. The global demand for MMA is currently in excess of 3.2 million tons. It is fueled by such new applications as flat panel displays and the overall growth of the Asian region. The Asian market remains of great potential for the MMA and is continuously monitored for new opportunities.

The conventional methyl methacrylate (MMA) can be produced from hydrogen cyanide (HCN) and acetone to give acetone cyanohydrin. After hydrolysis and esterification of the cyanohydrin methyl methacrylate is produced. This process (known as the ACH route) is quite economical and it creates large amounts of ammonium bisulfate by-product. About 1.2 MT of ammonium bisulfate is formed from every ton of MMA produced. Due to the large amounts of bi-product ammonium bisulfate and die to the fact that HCN is highly toxic, a great deal of research started to be aimed at developing a newer cleaner and more cost effective production of MMA[38].

A number of alternative routes have been commercialized over the last two decades and more routes are claimed to be close to commercialization. These new routes focus on such alternatives as new feedstock, such as isobutylene, ethylene, or even methylacetylene and on the development of techniques for recycling the HCN and/or the ammonium bisulfate.

Six process routes to MMA may be distinguished amongst current commercial operating plants:

1. **The ACH Route:** The acetone cyanohydrin route, starting from acetone and hydrogen cyanide (or from purchased acetone cyanohydrin), proceeding with dehydration, hydrolysis and esterification to the production of MMA.

2. **The "i-C4" Route:** Two-stage gas-phase oxidation of isobutylene (or TBA) to methacrylic acid, followed by esterification. This process is applied at commercial scale especially in the Far East.

3. **The BASF Route:** Hydroformylation of ethylene to propionaldehyde, condensation with formaldehyde to methacrolein, followed by oxidation and esterification. The first and only company to commercialize this route is BASF[39].

4. **The Asahi Chemical "Direct Metha" route:** A new process in which isobutylene (or TBA) is first oxidized in the gas phase to methacrolein. The methacrolein is recovered as

[38] Nexant - Prep Program: Methyl Methacrylate http://www.chemsystems.com/

[39] BASF - http://www.basf.com/

liquid, mixed with methanol and then oxidized with air in the liquid phase over a Pd/Pb catalyst with simultaneous esterification to MMA.

5. **The "MGC" or Mitsubishi route[40]:** A recycle version of the ACH route in which ACH is made as usual from acetone and HCN and is then hydrolyzed to alpha-hydroxyisobutyramide, which is reacted with carbon monoxide and methanol under pressure to yield formamide and methyl-alpha-hydroxyisobutyrate. Methyl-alpha-hydroxyisobutyrate is dehydrated to MMA, while the co-product formamide is dehydrated to HCN for recycle. Mitsubishi Gas Chemicals developed this route which is now applied at a commercial plant in Japan.

6. **The Alpha Route[41]:** The Alpha process uses ethylene, carbon monoxide (CO) and methanol as raw materials, instead of the conventional starting materials such as acetone, HCN and isobutylene. And it reduces capital costs for construction by around 40%.

The global consumption of MMA today exceeds 3.2 million metric tons per year, and most of it is from MMA polymers. The other primary product of this industry is crude methacrylic acid (crude MAA), which is produced by a similar technology but often in separate plant units. MAA capacity and production are not generally published. Production of crude MAA (for uses other than MMA) is about 20% of the total production of MMA[42].

Glacial MAA is used directly as a comonomer in various polymers. It is also used to make a variety of small volume specialty methacrylates. Some of the higher methacrylate esters are also made by transesterification of MMA, more particularly in Western Europe and Japan[43].

MMA is used in largest volumes for the production of pure or almost pure homopolymers (PMMA), but there is also a wide variety of copolymer uses. Within the PMMA consumption categories, the largest is for cast and extruded transparent acrylic sheet (PMMA sheet). Acrylic sheet which is used for lighting, signage and other applications has the largest targeted markets in skylights, architectural applications, security glazing, and displays.

Methyl methacrylate is used in the manufacture of resins and plastics. Other principal uses of methyl methacrylate are: cast sheet and other grades (advertising signs and displays, lighting fixtures, glazing and skylights, building panels and sidings, and plumbing and bathroom fixtures), molding/extrusion powder, and coatings (latex paints, lacquer, and enamel resins). It is also used in the impregnation of concrete to make it water-repellent, in medicine and dentistry to make

---

40 Mitsubishi - http://www.mitsubishi.com/mpac/e/monitor/back/1010/images/1010.pdf

41 ICIS - Lucite CEO Ian Lambert outlines ambitious plans to expand MMA using Alpha technology, September 2007; http://www.icis.com

42 Nexant - Prep Program: Methyl Methacrylate http://www.chemsystems.com/

43 Nexant - Prep Program: Methyl Methacrylate http://www.chemsystems.com/

prosthetic devices and as a ceramic filler or cement.

Methyl methacrylate is irritating to the skin, eyes, and mucous membranes in humans. Neurological symptoms have also been reported in humans following acute exposure to methyl methacrylate. Fetal abnormalities have been reported in animals exposed to methyl methacrylate by injection and inhalation.

Mitsubishi Rayon (MRC) and its subsidiary Lucite International announced[44], that they have developed bio-based methyl methacrylate (MMA), a chemical used in coatings, transparent plastics and adhesives. The company currently produces MMA monomers from petrochemical feedstock using two methods: the C4 direct oxidisation process that uses isobutylene as feedstock, and the ACH (acetone cyanohydrin) process that uses acetone and hydrogen cyanide as feedstock. ACH is reportedly an extremely hazardous substance. In 2008 was commercialized their new Alpha route for the production of MMA.

Itaconic acid is also being developed as an alternative way for production of MMA.

Lucite International, a subsidiary of Mitsubishi Rayon is a leader in the production of methyl metacrylates with a market share of 25%[45]. They are working on two approaches for the bio-MMA production. The first is using biomass for feedstock in the existing production processes and the second is using a novel route via fermentation process of biomass. Lucite has already patented the production of MMA through bio-based routes from itaconic acid.

The company has developed a new chemical process to convert itaconic acid to methacrylic acid and is developing microbial fermentations to produce the organic acid precursors. Lucite also is interested to develop a bio-process for direct fermentation of renewable feedstock to produce methacrylic acid. The aim is to develop an improved route to produce itaconic acid by fermentation. Lucite plans to commercialize production and use sustainable feedstock for MMA production by 2016 and intend to achieve at least 50% of MMA production from these sources[46].

But, there are several other routes under development, which are competing in ways to produce MMA from itaconic acid. Evonik is working on two technologies for producing their bio-MMA. One is its AVENEER process, which the company said is a multi-step catalytic process and more economical than conventional sulfo process. The other technology is a metabolic route using sugarcane and bacteria to generate the MMA, which can then be integrated into the AVENEER process[47]. Evonik is starting basic planning for a new MMA production plant using the AVENEER® process at its Mobile site in Alabama, USA and start-up planned for the middle of 2015[48]. Evonik also claims to be working

---

[44] Mitsubishi Rayon press release - http://www.mrc.co.jp/english/

[45] weastra – based on primary and secondary market research

[46] weastra – based on primary and secondary market research

[47] ICIS blog - Mitsubishi develops bio-MMA, November 2011; http://www.icis.com/

[48] Evonik press release - http://corporate.evonik.com/

to improve the performance of the bacteria and adapt it for industrial-scale production. Also Genomatica is working on the process to made bio-based MMA and has patented their route[49].

Table 3: METHYL METHACRYLATE: ITACONIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	1,608	1,664	1,729	1,793	1,857	1,922
VALUE	3,055	2,996	2,938	3,048	3,157	3,267
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	36,888	76,452	118,695	164,209	212,698	63.0%
VALUE	44,265	91,743	142,433	197,051	255,238	55.7%

MMA is an important chemical and can represent one of largest markets for itaconic acid. However, it is not yet clear which bio-based production route of MMA will win the battle, so in case itaconic acid price will be going down to levels which make it economically viable to use it for MMA production at all, weastra estimates that a maximum of 9,25% replacement of acetone cyanohydrin used for MMA production will be realistic until 2020. Therefore, the estimated demand of itaconic acid used in MMA was 1,608.0 tons in 2010 and is expected to reach 212,698.0 tons by 2020, at CAGR of 63% from 2010 to 2020. The overall market value for itaconic acid used in MMA was $ 3 million in 2010 and is expected to reach $ 255.2 million in 2020[50]. The estimated potential of replacing acetone cyanohydrine in MMA with itaconic acid is projected up to 9.25% of the aceton cyanohydrine used in MMA by 2020[51].

Unsaturated polyester resins

Unsaturated polyester resins (UPR) are produced by the polycondensation of saturated and unsaturated dicarboxylic acids with glycols[52]. Unsaturated polyester resins form highly durable structures and coatings when they are cross-linked with a vinylic reactive monomer, most commonly styrene. The properties of unsaturated polyester resins depend on the types of acids and glycols used and their relative proportions.

[49] Evonik: weastra primary market research and interviews

[50] weastra market model – based on primary and secondary market research

[51] weastra market model – based on primary and secondary market research

[52] IHS Chemical –Polyester Resins, Unsaturated, April 2012; http://www.ihs.com/

On their own, cross-linked unsaturated polyester and vinyl ester resins have limited structural integrity, but when combined with such chemicals as fiberglass or mineral fillers they enhance their mechanical strength. When combined with fiberglass resigns transform into fiberglass-reinforced plastic (FRP), which is consumed primarily in the construction, marine and land transportation industries. Non-reinforced cross-linked unsaturated polyester resin is used to make cultured marble and solid surface countertops, gel coats, automotive repair putty and filler, bowling balls, buttons and other products.

UPR are the most widely used resin type for composites, comprising in excess of 70% [53]of all thermoset resins. They are used in the production of fibre reinforced plastics or non-reinforced filled products[54]. Due to the easy processing of UPR, it can be applied in a large variety of manufacturing processes. UPR's are well known in marine and automotive industries[55], as well as in the production of wind turbine blades.

The largest global UPR producers include DSM, Ashland, AOC Resins, Reichhold and Cook Composites and Polymers.

Maleic Anhydride is the primary entry chemical in the production of Unsaturated Polyester Resins. Considering the fact that Itaconic acid has a similar structure as maleic anhydride, it can also be used for the production of UPR. Itaconic acid in this case cannot be used as a drop-in replacement but it can serve as a good substitute.

Among the companies, which are the most active in the area of production of UPR is DSM, which is currently focused on the task of using itaconic acid in the most effective way for the production of UPR. The company is already planning to start with the commercialization of their itaconic-based UPR. DSM is developing a route for 100% bio-based polyester composites and in May 2012 it published its patent for the production of bio-based polyester composites from itaconic acid[56].

The UPR market is expected to grow in future by 5.5%[57]. The main growth is expected to be in the automotive industry, where the UPR components will replace the metal parts. Due to the qualities of UPR, they do not only have a low carbon footprint but also long durability and low weight. It is the low weight added value, which will have key importance in the automotive industry. Due to the lightweight components, the cars will achieve a lower weight, which will have a strong positive impact on fuel consumption, the price of which is constantly growing.

Nevertheless, there are also other substitutes, which can replace maleic anhydride in the production

---

[53] Research and Markets - Worldwide Unsaturated Polyester Resin Competitive Analysis and Leadership Study, brochure 2007; http://www.researchandmarkets.com/

[54] DSM: weastra primary market research and interviews

[55] The Plastics Portal - http://www.plasticseurope.org/what-is-plastic/types-of-plastics/unsaturated-polyester-resins.aspx

[56] DSM: weastra primary market research and interviews

[57] weastra – based on primary and secondary market research

of UPR, such as bio-based fumaric acid. Currently Myriant is working on the development of such a substitute. The market entry for bio-based fumaric acid will probably much easier and faster as it can be used as a drop-in replacement for maleic anhydride[58]. The estimated potential of replacing maleic anhydride in UPR with itaconic acid is projected up to 5% of the maleic anhydride used in UPR by 2020[59].

Table 4: UNSATURATED POLYESTER RESINS: ITACONIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	0	95	601	1,585	11,149	11,763
VALUE	0	171	1,022	2,695	18,954	19,996
	2016	2017	2018	2019	2020	CAGR 2014 - 2020
VOLUME	24,819	26,184	41,437	58,287	76,867	38%
VALUE	39,711	41,895	66,298	93,260	122,986	36,6%

According to the market model projection, the estimated demand of itaconic acid used in UPR was approximately 90 tons in 2011 and weastra expects that it will reach 76,867 tons by 2020, at CAGR of 38% from 2014 to 2020. The overall market value for itaconic acid used in UPR was $ 171,000 in 2011 and is expected to reach $ 122.9 million in 2020[60].

Detergent builders

Detergent builders play a central role in the washing process. Their function is largely to support the surfactant action and to eliminate water hardness. Modern detergent builders must fulfill a number of criteria[61], such as:

- Not be toxic for humans
- Be biodegradable

[58] Myriant: weastra primary market research and interviews
[59] weastra market model – based on primary and secondary market research
[60] weastra market model – based on primary and secondary market research
[61] ECAMA - http://www.ecama.org/level_2/applic/Alternative_builder_for_phosphate_free_detergents.pdf

- Counteract the effects of water hardness
- Facilitate dissolving of surfactants
- Stabilize the detergent mixture during storage
- Prevent the deposition of insoluble salts on fabrics and heating elements of washing machines

Builders are added to a cleaning compound to upgrade and protect the cleaning efficiency of the surfactants. The main function of builders are softening, buffering, and emulsifying. They provide a desirable level of alkalinity (increase pH), which aids in cleaning. Builders help emulsify oily and greasy soil by breaking it up into tiny globules.

The most widely used builder in regions without limitation by law on phosphorus is STPP (sodium tripolyphosphate). STPP combine with hardness minerals to form a soluble complex, which is removed with the wash water. They also sequester dissolved iron and manganese, which can interfere with detergency.

Unfortunately, it was found that STPP in detergents produces a significant increase of the phosphorus load in surface water and a significant risk for eutrophication. Due to this fact, the number of regions and countries, which have limited or even banned the use of phosphates as builders in detergents, has increased.

Sodium carbonate (soda ash) is used as a builder but can only soften water through precipitation. Precipitated calcium and magnesium particles can build up on surfaces, especially clothing, and therefore sodium carbonate is not used in laundry detergents.

Sodium silicate serves as a builder in some detergents when used in high concentrations. When used in lower concentrations, it inhibits corrosion and adds crispness to detergent granules.

Measures to reduce the use of STPP based detergents in the EU included the introduction of laws or voluntary agreements to change to Zeolite as the builder for household laundry detergents. As a result STPP consumption has decreased substantially.

Zeolites[62], which are catalysts by definition, replaced harmful phosphate builders, making the chemical process more efficient, thus saving energy and indirectly reducing pollution. Moreover, with zeolites, processes can be carried out in fewer steps, minimizing unnecessary waste and by-products. As solid acids, zeolites reduced the need for corrosive liquid acids, and as redox catalysts and sorbents, they can remove atmospheric pollutants, such as engine exhaust gases and ozone-depleting CFCs.

Zeolites are also used to separate harmful organics from water, and in removing heavy metal ions, including those produced by nuclear fission, from water.

---

[62] British Zeolite Association - http://www.bza.org/zeolites.html

STPPs have already been virtually sidelined in the laundry detergent markets in both North America and Europe, due to such reasons as predominance of liquid detergents, minimal hardness of water supplies and as a step to prevent eutrophication. The estimated potential of replacing STPP in detergent builders with itaconic acid is projected up to 1.5% of the STPP used in detergent builders by 2020[63].

Table 5: DETERGENT BUILDERS: ITACONIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	0	0	0	0	5,470	5,743
VALUE	0	0	0	0	9,298	9,764
	2016	2017	2018	2019	2020	CAGR 2014 - 2020
VOLUME	12,061	17,729	18,616	27,924	43,980	41.5%
VALUE	19,297	28,367	29,786	44,678	70,368	40.1%

Their retreat from consumer detergents should provide the greatest windfall to well-established alternatives such as zeolites, sodium carbonate and citric acid[64], as well as co-builders such as polycarboxylates and polyphosphonates.

According to the market model projection, the estimated demand of itaconic acid used in detergent builders will be 5,470 tons in 2014 and weastra expects that it will reach 43,980 tons by 2020, at CAGR of 41,5% from 2014 to 2020. The overall market value for itaconic acid used in chelating agents will be $ 9.3 million in 2014 and is expected to reach $ 70.3 million in 2020[65].

Existing markets for bio-based itaconic acid

SBR latex

SBR latexes have a styrene-based content and are primarily used in the manufacturing of foams for mattresses, pillows and carpet foam backings, as well as in the production of flooring adhesives,

[63] weastra market model – based on primary and secondary market research

[64] ICIS - Detergents shift to greener builders, January 2009; http://www.icis.com/

[65] weastra market model – based on primary and secondary market research

asphalt modification and tire cord treatments[66]. Latex foam mattresses and pillows are becoming more and more interesting in both Europe and North America, as consumers believe that latex is a supreme material for sleeping, being more healthy and quieter than the polyurethane equivalents.

Nevertheless, the largest growth market for SBR latex is forecasted for the area of asphalt modification as latex has the ability to improve the overall performance of asphalts, by improving ductility, which leads to low-temperature flexibility and crack resistance. It also increases elasticity, decreases bleeding, improves the adhesion and cohesion of asphalt and decreases thermal and oxidative aging effects.

Itaconic acid can participate in the production of SBR latex, through copolymerization with styrene and butadiene. Itaconic acid is used in this process in order to improve the quality of the final product – SBR latex.

Based on our research we do not expect that the usage of itaconic acid in SBR latex will significantly change. A more significant change would happen if a novel product with novel properties enters the market.

Table 6: SBR LATEX: ITACONIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	17,656	18,180	18,726	19,288	19,866	20,462
VALUE	33,546	32,726	31,834	32,789	33,773	34,786
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	21,076	21,708	22,366	23,030	23,721	3.0%
VALUE	33,722	34,733	35,775	36,849	37,954	1.2%

According to the market model projection, the estimated demand of itaconic acid used in SRB latex was 17,656 tons in 2010 and weastra expects that it will reach 23,721 tons by 2020, at CAGR of 3% from 2010 to 2020. The overall market value for itaconic acid used in SRB latex was $ 33.5 million in 2010 and is expected to reach $ 37.9 million in 2020[67].

[66] IHS Chemical -Styrene-Butadiene Latexes, December 2011; http://www.ihs.com/
[67] weastra market model – based on primary and secondary market research

Chelating agents

Chelating agents capture traces of iron, copper, manganese, calcium and other metals that occur naturally in many materials. Chelants, or chelating agents, are widely used in agriculture, pulp and paper manufacturing, food processing, in the manufacture of cleaners and detergents, textiles and in water treatment. Dow Chemical Company is one of four major producers of aminopolycarboxylic chelants in the U.S. and Europe.

Ethylene-diamine-tetra-acetic acid (EDTA) is a chelating agent produced as a series of salts[68]. The various salts of EDTA have different appearances, as clear to amber liquids, sometimes with a slight amine odor. They can be used as chelating agents over a broad pH range in aqueous systems. Salts which are produced as dry powders and crystals are water soluble, but insoluble in acid and organic liquids.

Chelating agents are used as components or process chemicals in a wide range of applications, but there are five uses which account for about 80%[69] of the worldwide consumption. These applications are the following: pulp and paper, cleaning, chemical processing, agriculture and water treatment. Specific application of EDTA include such as areas as metalworking, oil field applications, personal care, polymerization, photography, pulp and paper, textiles, cleaning products, water treatment, agriculture, food and pharmaceutical products.

Itaconic acid can be used in chelating agents through polymerization as polyitaconic acid.

One of the biggest players on the market of polyitaconic acid, USA based Itaconix, is currently active on the market of chelating agents. Itaconix is focusing on the market of chelating agents and is already offering its own branded products. Due to this reason we see a potential for itaconic acid initially on the American market of chelating agents.

[68] DOW Chemical Company - http://www.dow.com/

[69] DOW Chemical Company - http://www.dow.com/

Table 7: CHELATING AGENTS: ITACONIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	2,825	2,966	3,115	3,426	3,769	4,145
VALUE	5,367	5,339	5,295	5,824	6,407	7,047
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	4,560	5,016	5,518	6,069	6,676	9.0%
VALUE	7,296	8,026	8,828	9,711	10,682	7.1%

According to the market model projection, the estimated demand of itaconic acid used in chelating agents was 2,825 tons in 2010 and weastra expects that it will reach 6,676 tons by 2020, at CAGR of 9% from 2010 to 2020. The overall market value for itaconic acid used in chelating agents was $ 5.3 million in 2010 and is expected to reach $ 10.6 million in 2020[70].

[70] weastra market model – based on primary and secondary market research

7. Top players in the field of itaconic acid production, research and end use applications

DSM NETHERLANDS

Het Overloon 1
6411 TE Heerlen
The Netherlands
Tel: +31-045-578-8111
Fax: +31-045-571-9753
Website: www.dsm.com

Company overview

DSM is a Dutch company, founded in 1902 as a coal mining company. Today DSM N.V. is a leading global science-based company focused on the production of nutritional ingredients, industrial chemicals and pharmaceutical ingredients. The company is present in more than 50 countries worldwide and employs over 22.000 people. It is strong oriented on innovations, promoting the goal “to brighten the lives of people today and generations to come”.

Financials

DSM’s net sales for 2011 were € 9,048 million, from which 21% were generated by polymer intermediates and 32% were generated by performance materials. The company has over 150 locations worldwide and more than 10 production facilities located in Europe, China and North America.

Product and service portfolio

DSM’s activities are grouped in several business entities: Nutrition, Pharma, Performance Materials, Polymer Intermediates and Emerging business Areas focused on bio-based products, biomedical materials and advanced surfaces. In cooperation with Roquette Frères S.A. the company has developed technology and started the production of bio-based succinic acid. Target markets for its bio-based products include plasticizers, polyurethanes, personal care products, resins, coatings and other.

Company strategy

The company’s strategy is to grow through innovation, meeting the changing needs of the population, to focus on high growth economies through constant development, sustainable products and strategic partnerships.

DSM is most active in the area of production of UPR. The company is currently focused on the task of using itaconic acid in the most effective way for the production of UPR. The company is already planning to start with the commercialization of their itaconic-based UPR. DSM is developing a route for 100% bio-based polyester composites and in May 2012 it published its patent for the production of bio-based polyester composites from itaconic acid.

The company is also involved in development and production of bio-based succinic acid and formed a joint venture with Roquette Frères S.A. for the manufacturing and commercialization of Biosuccinium™ - a sustainable succinic acid. Their manufacturing facility is planned to achieve a capacity of 10.000MT by 2015.

ITACONIX CORPORATION

2 Marin Way
Stratham NH 03885, USA
Tel.: 603 775 4400
Fax: 603 617 4581
Email: info@itaconix.com
Web: www.itaconix.com

Company overview

Itaconix Corporation is one of the world leaders in polymers made of itaconic acid. It was founded in 2008 by Dr. Yvon Durant, former associate research professor in material sciences at the University of New Hampshire, and John Shaw, president of Kensington Research Inc. The company develops, produces and sells new polymers made of itaconic acid using its patented polymer technologies. The company's first commercial product line, Itaconix® DSP™, are water-soluble polymers used in detergents and cleaners based on its chelation and dispersion properties. The company is expanding its product capabilities around its extensive range of linear, cross-linked and emulsion polymer technologies.

Financials

In 2009, Itaconix received a $2 million grant from the U.S. Department of Agriculture to research and develop the use of wood biomass as the feedstock for fermenting itaconic acid. In 2012 Itaconix has received $1.15 million in equity funding, according to US federal documents.

Product and service portfolio

Itaconix offers polyitaconic acid products for use in detergents, water treatments, and other applications. Itaconix® DSP™ polymers are sold to consumer and industrial detergent formulators as effective builders to replace phosphates, EDTA, citric acid and petroleum-based chemicals due to their outstanding binding capacity, ready biodegradability, and favorable production from renewable resource.

Company strategy

Itaconix sees a big potential for polyitaconic acid as effective builders in detergents and cleaners, but is also focusing on developing new products based on novel properties possible from polymers of itaconic acid.

Developments and partnerships

In 2009, Itaconix received a $2 million grant from the USDA to research and develop the use of wood biomass as a feedstock for fermenting itaconic acid.

The company worked with the University of Maine and the University of Massachusetts at Lowell to establish its ability to ferment itaconic acid from a variety of carbohydrate sources.

In 2011, the company received an SBIR research grant from NSF for the enzymatic production of itaconic acid.

In 2012, the company received an SBIR research grant from NSF to produce novel latex polymers.

In 2012, Lux Research named Itaconix Corporation as one of the top ten emerging technologies companies of 2012.

The company is working with partners in specific industries to develop novel applications of polyitaconic acids.[71]

[71] Corporate website: www.itaconix.com and feedback from the management of Itaconix Corporation

LUCITE INTERNATIONAL GROUP LTD.

Head office:
Cumberland House
15-17 Cumberland Place
Southampton
SO15 2BG
Hampshire
United Kingdom
Tel: +44 (0) 870 240 4620
Fax: +44 (0) 870 240 4626
Email: contactus@lucite.com
Web: www.lucite.com

Company overview

Lucite International was created from the acrylic businesses of ICI and DuPont. Lucite International is since 2009 a subsidiary of Mitsubishi Rayon Co., Ltd. The company is the global leader in the design, development and manufacture of acrylic-based products. Since being acquired by Mitsubishi Rayon, Lucite has further strengthened its position as the world's largest supplier of MMA, the essential building block for all acrylics. Lucite International has one of the most diverse asset portfolios of any major acrylics producer with 22 plants at 14 manufacturing sites worldwide. Lucite employs over 1800 people.

Financials

The revenues of Lucite reach around US$1.7billion.

Product and service portfolio

Lucite is a global leader in methacrylate monomers with around 1000kte of nameplate capacity a 25% global market share in this field. The Company is the single largest manufacturer of MMA for the global merchant market and is the only supplier demonstrating total commitment to this market.

Lucite International has a strong range of consumer and trade product brands including Lucite®, Perspex® from Lucite®, Lucite® TufCoat®, Elvacite® and Colacryl®

The Lucite and Perspex brands in particular are associated with contemporary design and innovation in a multitude of applications; bathrooms to architectural interiors, corporate identity projects to directional signage for the world's newest transportation systems.

Company strategy

The company understands the growing importance of bio-based chemicals and of environmental protection, therefore is working to define the most appropriate options to move the business to a much lower carbon footprint with using renewable feedstocks and on developing a new routes to produce bio-MMA[72].

Lucite International and Mitsubishi Rayon declared that they would like to start with the commercial production of bio-based MMA in 2016. Their goal is to produce 50% of MMA[73], which is approximately 400,000 MT by bio-routes, out of which itaconic acid seems attractive.

The company is focusing on selection of renewable feedstocks and conversion to soluble carbohydrate, production of a number of different chemical intermediates by fermentation, conversion of these to methacrylates, directs production of methacrylates by fermentation[74].

Developments and partnerships

Lucite international claims to have established long-term cooperation with Shanghai SECCO Petrochemical Company Limited for using their HCN as one major raw material. Lucite has also partnership with Vopak Shanghai Limited for providing the logistic services[75].

---

[72] Corporate website: www.luciteinternational.com

[73] Mitsubishi Rayon– press release: http://www.mrc.co.jp/english/

[74] Corporate website: www.luciteinternational.com

[75] Corporate website: www.luciteinternational.com

Qingdao Kehai Biochemistry Co., Ltd

subsidiary of Shadong Qingdao Langyatai Group Co., Ltd.

South shanghai RD,
Coastal Industry Park
Jiaonan City,Qingdao China.
Tel: + 86 532 8615 0824
Fax: + 86 532 8615 1260
Website: www.sodium-gluconate.com

Company overview

Qingdao Kehai Biochemistry Co., Ltd, a subsidiary company of Qingdao Langyatai Group Co., Ltd – a Chinese company, established in 1958, ranking as one of the top 500 best efficiency industrial enterprises. The company is primarily engaged in the production of white spirit, juice and biochemical products. Qingdao Kehai Biochemistry is one of the large-size enterprises in China, with one of the biggest itaconic acid output and fast profit growth. The company is also the largest R&D base of itaconic acid based products in the world.

Financials

Shadong Qingdao Langyatai Group has 2000 employees, covers an area of 450.000 sq. meters and has 13 subsidiaries, including Qingdao Kehai Biochemistry Co., Ltd.

Product and service portfolio

The main products of Qingdao Kehai Biochemistry are itaconic acid and derivatives of itaconic acid, sodium gluconate-based products, Ruimin eco-fertilizer and others. The company possesses the annual output capacity of 20.000 MT itaconic acid, 50.000 MT of sodium gluconate, 2.000 MT of delta-gluconolactone, 2.000 MT of gluconic acid, 1000 MT of Isomaltulose, 2000 MT of Carbamide Liquor and 2000 MT of calcium gluconate.

Company strategy

The Shadong Qingdao Langyatai Group is adjusting to the needs of the market and seeks long-term healthy development. The group has vast experience in the biological fermentation field, which allows it to develop the biochemical industry and its range of products, including the main products itaconic acid and sodium gluconate.

Zhejiang Guoguang Biochemistry Co.,Ltd.

subsidiary of Zhejiang Guoguang S&T Group

Plot A-30
High-Tech Park Quzhou City
Zhejiang 324004, China
Tel: +86 570 3881 875
Fax: +86 570 3881 765
Website: www.ggbiochem.com

Company overview

Zhejiang Guoguang Biochemistry Co.,Ltd. was founded in 1994 in Zhejiang as a biological fermentation production company. Zhejiang Guoguang Biochemistry owns an R & D Center which is focused on the development of new products. The company is certified by ISO9001 quality management system / HACCP FOOD SAFETY MANAGEMENT SYSTEM / FAMI-QS and exports to Asia, Europe, North America, South America and other regions of the world. The company also cooperates with universities, research institutes on technology and product development.

Financials

Based on our primary research, Zhejiang Guoguang Biochemistry Co.,Ltd. can produce up to 10000MT of Itaconic acid per year and 12.000MT of Feed Grade L-Threonine. At present, export represents 75% of the company's production.

Product and service portfolio

Currently Zhejiang Guoguang Biochemistry Co. produces Itaconic acid, L-Threonine, Itaconic anhydride and Sodium Gluconate. The applications of the company's Itaconic acid are eletroporetical coating, paints, deodorants, resins, ubricants, binders, cosmetics and other areas.

Company strategy

Zhejiang Guoguang Biochemistry Co. is focused on product and technology development. The company cooperates on a local and national level with universities and research institutions in order to provide products of superior quality to its customers.

ALPHA CHEMIKA

Mohid Heights Unit no 5, 4th Floor, Lokhandwala RTO Road, off Four Bunglows, opp Versova Tel Exchange Andheri (W),
Mumbai - 400 053, India
Tel: +91 22 65218147, Fax: +91 22 26317055
Website: www.alphalabchem.com

Company overview

Alpha Chemika is an Indian company that is a widely recognized as a manufacturer and supplier of scientific precision quality products and of a complete range of laboratory chemicals, laboratory glass wares, laboratory equipment, micro biological media and analytical instruments. Alpha Chemika represents several global companies for their entire range of solvents and acts as their exclusive distributor in India. Also the company helps its customers to source products from India by identifying, evaluating potential vendors, their capabilities and the quality of their products. Alpha Chemika has been globally renowned in the field of Laboratory Chemicals Laboratory Glassware VT & Laboratory Equipments. As the company is mainly focused on Indina, it is facilitating the entire process of market identification and product selling in order to make it easier for foreign companies to target India as a potential market for their product line.

Financials

Alpha Chemical has declared a total turnover of about $120 million (€92 million). It exports to about 40 countries around the world and has 250 employees. The production plant along with the warehouse facilities occupies a total area of 34.000 sq. feet (10.363 sq. meters) with a capacity of 120 tons, with possible expansion to 360 tons.

Product and service portfolio

Alpha Chemika is one of the leading scientific manufacturers in India. The company's product portfolio includes: laboratory chemicals, laboratory glasswares, scientific equipments, micro biological media, analytical Instruments, microscope and soil cement. Alpha Chemika can produce up to 8000MT of Itaconic acid, based on contract manufacturing.

Company strategy

Alpha Chemika strives to provide high quality products and superior services to the pharmaceutical, chemical and biotechnology sectors. It is a leading company in India which has numerous foreign partnerships and which promotes the Indian market as a potential market for both demand and supply of chemicals and technology. The guiding principles of the organization are "Innovation, Collaboration, Expand & Grow without Compromising on Quality & Ethics". Alpha Chemika aims to be ethical, transparent and understands the important role of research and development in a company's growth.

JINAN HUAMING BIOCHEMISTRY CO.,LTD.

Middleod Xihuan Road,
Mingshui, Zhangqiucity,
Jinan, Shandong,
250200 China
Tel: + 86 531 832 57610
Fax: +86 531 832 57420
Website: www.jnhuaming.com

Company overview

Jinan Huaming Biochemistry Co.,Ltd. is a Chinese company, subsidiary of Jinan Huaming Heat&Power which was founded in 2002 in Qingdao. The entire group of companies consists of six subsidiaries: LangGou Heat&Power plant, Jinan Huaming Biochemistry Co.,Ltd, Jinan Huaming coalmining Co.,Ltd,GuanZhuang coalmining Co.,Ltd, Jinan Fengwen Plastic&Rubber Co.,Ltd and Jinan Huaming gas Co.,Ltd. is engaged in the production of chemical industry including itaconic acid, sodium gluconate, L- lactic acid and L- calcium lactate. It has established a long-term cooperation with a well-known academy of science institute in Shandong, Shanghai and obtained the ISO9001 Quality System Certification and ISO14001 Environment System Certification.

Financials

Jinan Huaming Biochemistry Co.,Ltd. declares to have the following capacities: 15000 MT per year of itaconic acid, 20000MT per year of sodium gluconate and 5000MT per year of L- calcium lactate. Other sources of the primary research have questioned the current production capacities of this market player, indicating that the company's current capacity of producing itaconic acid might be around 1000MT per year.

Product and service portfolio

Jinan Humaing Biochemistry mainly produces itaconic acid, sodium gluconate, L- lactic acid and L- calcium lactate.

Company strategy

The company understands the growing importance of bio-based chemicals and of environmental protection. It would like to purse further development of partnerships with domestic and foreign customers based on good products and best service.

Developments and partnerships

Jinan Humaing Biochemistry claims to have established long-term cooperation with Dow Chemical, BASF of Germany and Fuso of Japan and other companies. This information could not be confirmed by primary research.

QINGDAO ABEL TECHNOLOGY CO., LTD.

Rm 702,East Towe Tianhe International ,NO.196 ,
Changjiang Road
Qingdao Development Zone,Qingdao
266555, China
Tel: +86-532-8699 0832/ 8699 8083
Fax: +86-532-86997693
Website: www.abelcn.com

Company overview

Qingdao Abel Technology Co.,Ltd is one of the biggest and professional chemicals manufacturers in China. The company focuses on several product areas, having top production lines with advanced tecnhologies. Along with their own R&D team, Qingdao Abel Technology Co.,Ltd strives to achieve lower production costs and develop new products and Technologies. The company has ISO9001-2000, HACCP , HALAL certification.

Financials

The company's production capacities are 100.000 MT of Sodium Gluconate ,150.000 MT of Ammonium Bicarbonate, 50.000 MT of L(+)-lactic acid and its calcium salt , 5.000 MT of alkylpolyglycosides.

Product and service portfolio

Qingdao Abel Technology Co.,Ltd produces food additives, construction chemicals, surfactant material, fine chemicals, water treatment chemicals and feed additives. The company specializes in manufacturing and commercializing biochemical products. The company claims to produce Itaconic acid with an annual capacity of 10000MT but our primary research has shown that Qingdao Abel Technology was not producing itaconic acid in 2011, it was rather involved in trade.

Company strategy

Qingdao Abel Technology Co.,Ltd has its own R&D team to engage in the activity of researching and developing new products. Among the recently developed products the company offers nonionic surfactant, biodegradable, L-lactic acid and amber acid which can be used for the production of PLA and PBS and which are biodegradable.

Developments and partnerships

December 2011	Qingdao Abel Technology Co.,Ltd opened a new sodium gluconate factory, which will have an yearly output of 100.000 MT.

RONAS CHEMICALS IND. CO., LTD.

Rome International Plaza, Room 09A,
19th Floor, NO.210, West Yulong Street, Qingyang District,
Chengdu City, Sichuan Province,
610015, China
Tel: +86-28-8608-2869
Fax: +86-28-8608-2869
Website: www.ronasgroup.com

Company overview

Ronas was founded in 1980, in China, as a manufacturer and exporter of persulfate salts. The company went through major developments and expansions into new product areas in 2000, 2003 and 2005. Nowadays, Ronas Chemicals is a reliable manufacturer and supplier of chemicals in China.

Financials

The company has 2 production factories, in China and Taiwan.

Product and service portfolio

Ronas Chemicals Ind. Co. Ltd., is producing food additives, pharmaceuticals, intermediates, vitamins, chemicals, aminoacid derivats and feed additives. The company's products include Ammonium Persulfate (APS), Itaconic acid, Ammonium Thiocyanate (ATC), Calcium Hypochlorite, Ethyl Cellulose (EC), Hydroxyethyl Cellulose (HEC), Hydroxypropyl Methyl Cellulose (HPMC), Methyl Cellulose (MC), Potassium Permanganate (PPM), Potassium Persulfate (KPS), Potassium Thiocyanate (KTC), Sodium Carboxymethyl Cellulose (CMC), Sodium Dichloroisocyanurate (SDIC), Sodium Hydrosulfite, Sodium Persulfate (SPS), Sodium Thiocyanate (STC), and Trichloroisocyanuric Acid (TCCA). According to our primary research Ronas Chemicals Ind. Co. was not producing Itaconic acid in 2011.

Company strategy

Ronas Chemicals Ind. Co. Ltd., is aiming to expand its business operations in all major fields such as chemicals, pharmaceuticals medical products, electronics and telecommunication. The company has its own research and development facility, which works on the development of new technologies and products. Ronas is striving for products of the highest quality and worldwide cooperation.

SHANDONG KAISON BIOCHEMICAL CO., LTD.

No. 52 Yanhe Road
Wulian county
Shandong province
P.C: 262300, China
Tel: +86-633-6157777
Fax: +86-633-6157776
Website: www.itaconicacid.com

Company overview

Shandong Kaison Biochemical Co.,Ltd. is a Chinese company, located in Rizhao city, close to major ports and expressways. The company is involved in the production and trade of several chemicals. Shandong Kaison Biochemical Co.,Ltd. posseses ISO9001, ISO14001 and OHSAS18001 certificates、as well as FDA certificates,Halal certificates and Kosher certificates.

Financials

Shandong Kaison Biochemical Co.,Ltd. is one of the biggest manufacturers and suppliers of Glucono-Delta-Lactone and Sodium Gluconate in China, with an annual production of 6000MT of Glucono-Delta-Lactone and 45.000MT of Sodium Gluconate. The company exports its products to US, EU, Southeast Asia and The Middle East.

Product and service portfolio

Shandong Kaison Biochemical Co.,Ltd. specializes in the production of Gluconic Acid Solution, Glucono-Delta-Lactone and Sodium Gluconate using biofermentation equipment and technologies. According to our primary research, the company was producing itaconic acid earlier, but has stopped the production of Itaconic acid in 2006.

Company strategy

The company's strategy is to seek continuous innovation and development and to produce high quality products.

FUSO CHEMICAL

Company overview

Fuso Chemical was established in 1957 in Japan as a company focused on the research and production of chlorine compounds. Fuso Group is also formed from Fuso Teiyaku (Qingdao) Co., Ltd., Teikoku Seiyaku Co., LTD., Teikoku Pharmacare Co,.Ltd. who specialize in the pharmaceutical area. Fuso Chemical has a Life Science department and an Electronic Materials and Functional chemicals department. The company has distribution and production activities spread worldwide.

Financials

In 2012, the company's net sales achieved a level of JPY 28,247 million (€ 0,3 million). Fuso Chemical has factories in China, Japan, Thailand and US.

Product and service portfolio

FUSO is currently the only manufacturer in Japan of malic acid and a top manufacturer of citric acid. The company also produces lactic acid, gluconic acid, ascorbic acid, amino acid and their derivates, itaconic acid and succinic acid. It also offers electronic materials such as alkyl silicate and functional chemicals such as benzoic acid derivates and esterification products. Both itaconic and succinic acid are synthetic. Our primary research has not confirmed that FUSO is a producer of Itaconic acid as of 2011, however once the demand would be there, it will be easy for FUSO to re-start the production of itaconic acid again.

Company strategy

Fuso Chemical strives to manufacture „gold medal products", products which are No.1 on the market.

The company is aware of the latest situation of biomass-based Succinic Acid and it is already making a preliminary survey of the market. Another goal is not only to develop from the technological point of view, but also to develop the company's worldwide presence.

Developments and partnerships

2011	A new FUSO factory is constructed in Thailand.
2008	Began the partnership with X-one Co., Ltd. - cosmetics and health food retailer. FUSO (THAILAND) CO., LTD. and KAIYO CHEMICAL CO.,LTD. are established.
2007	The Electronic Materials manufacturing equipment of the Kyoto Second Factory is constructed.
2003	FUSO CHEMICAL QINGDAO CO.,LTD. is established. The domestic chemical business and the total shares of "PMP Fermentation Products, Inc." (a FUSO subsidiary) in the United States are purchased from Astellas Pharma Inc.

HIGH HOPE INT'L GROUP JIANGSU NATIVE PRODUCE IMP & EXP CORP. LTD.

High Hope Mansion,
91 Bai Xia Road,Nanjing
210001 China
Tel: +86 258 4691 641
Fax: +86 258 4692 773

NANJING HUAJIN BIOLOGICALS CO., LTD. – subsidiary of High Hope Int'l Group
62 Tianyuan Road,
Jiangning, Nanjing,
China

Company overview

Nanjing Huajin Biologicals Co., Ltd. is a subsidiary of High Hope Int'l Group, which was formed in 1973 and quickly became one of the leading export import companies in the Jiangsu Province. The company owns advanced technology and production equipment, holds skilled technicians with experience in fermenting and synthesizing chemicals. It also cooperates with many research institutes and scientific experts.

Financials

Nanjing Huajin Biologicals Co., claims to produce 2,000 MT of CONFOR brand itaconic acid annually. Other sources of the primary research could not confirm this information as of the year 2011.

Product and service portfolio

High Hope Int'l Group is focused on a number of industries such as textiles, machinery, chemicals, shoes, mineral resources and others. Nanjing Huajin Biologicals Co. is one of 22 subsidiaries and is focused on the production of Itaconic acid through fermentation.

Company strategy

Due to a very convenient location, the company has good connections to transportation by sea, land or air. It is working on maintaining good relations with trade partners throughout the worlds and on closing new partnerships. Nanjing Huajin Biologicals' principal is "putting the quality, service and faith first".

ZHEJIANG KEDAO CHEMICALS CO., LTD. - SUBORDINATE TO ZHEJIANG GUOGUANG S&T GROUP

Area A-30, High- and New-tech Industrial Park,
Quzhou, Zhejiang,
324000, China.
Tel: + 86 570 3881 875
Fax: +86 570 3881 765

Company overview

Zhejiang Kedao Chemicals Co., Ltd. is one of eight subsidiaries of Zhejiang Guoguang S&T Group. The group focuses on electrical and mechanical electronic industry, beer, biochemical and medical instruments industry. Zhejiang Kedao Chemicals Co., Ltd manufacturers mainly bio-chemicals and *fine chemicals.*

Financials

Zhejiang Guoguang S&T Group has 2500 employees, out of which 400 represent technical personnel. The Group has a total asset of more than 1.5 billion yuan (€ 0,18 billion), the annual turnover of over 1.6 billion yuan (€ 0,2 billion).

Product and service portfolio

The company's main products are L-Threonine, Formaldehyde, Paraformaldehyde and Dimethoxymethane. Other sources of our primary research have shown that Zhejiang Guoguang S&T Group was not producing Itaconic acid in 2011.

Company strategy

Zhejiang Kedao Chemicals Co., Ltd. is functioning according to the principle "Developing the company through high quality". Within its production technologies the company applies 3 strategies: low energy consumption, low release of pollutants and low cost. Zhejiang Kedao Chemicals strives to offer high quality products to customers all over the world.

TAIYUAN PALORT CHEMICAL CO.

Taiyuan,Shanxin, China
Tel: +86 0351 2363 767
Fax: +86 0351 2363767
Website: www.palort.com

Company overview

The company Taiyuan Palort Chemical Co., Ltd. was founded in 2000 and it is specializing on manufacturing, research and exporting of chemical raw materials. It is situated on a business area of 150.000 sq. meters, with 6 production lines. Taiyuan Palort Chemical exports to Europe, Asia and Middle East.

Financials

The company has 400 employees, 12 engineers, 26 technicians and its own modern technologies.

Product and service portfolio

Taiyuan Palort Chemical Co. claim to produce bio based itaconic acid, bio based succinic acid, phthalic acid, PTA, acrylic acid and adipic acid. The company also produces alcohols, rubbers, polyethylene, salts and other products. Our other primary research sources have shown that Palort was not producing itaconic acid in 2011.

Company strategy

Taiyuan Palort Chemical Co. has a market-oriented strategy, focusing on high quality products. Technological innovation and development play key roles in the strategy of the company. Taiyuan Palort Chemical is growing through partnerships on both domestic as well as foreign markets.

CHENGDU JINKAI BIOLOGY ENGINEERING CO., LTD., CHINA

No.98 Middle Section Yangliu East Road,
Wenjiang District,Chengdu City,China.
Tel: +86 28 8276 1370
Fax: +86-28-82766910
Website: www.cdjkchem.com

Company overview

Chengdu Jinkai Biology Engineering Co., Ltd. is a Chinese technology enterprise which was built as a result of cooperation of several technology institutes including Sichuan Provincial Research Design Institute for Food Fermenting Industry. The company is located in state-level development zone - Chengdu Cross-Strait Technology Industry Development Park. Chengdu Jinkai Biology Engineering mainly performs R&D, production and sales of organic acids and bio-products. It has 3 production lines and 280 employees. The products have both local as well as foreign clients from United States, Japan, South Korea, the European Union, Africa, South America and other countries and regions.

Financials

The company possesses more than 5000 million yuan (€614 million) of total investment, and covers an area of more than 10.000 sq. meters.

Product and service portfolio

Currently, Chengdu Jinkai Biology Engineering has three production lines and claims to have an annual output of 50 tons of kojic acid, 200 tons and ε-Polylysine and 50 tons of itaconic acid. Our other primary research sources indicated that in fact Chengdu Jinkai Biology Engineering does not have its own production of itaconic acid currently and was acting in 2011 as a trader only.

Company strategy

Chengdu Jinkai Biology Engineering adheres to business philosophy of "people-oriented, technology flourishing enterprise, cooperation and more benefits, long-term development", and strives to achieve business goal of "product-based, financing to be listed and becoming stronger and bigger". The company welcomes new partners both from China as well as from abroad.

TOKYO CHEMICAL INDUSTRY CO., LTD

Head office: 4-10-2 Nihonbashi-honcho, Chuo-ku,
Tokyo 103-0023
Tel : +81 3 5640 8851
Fax : +81 3 5640 8865
Website: www.tcichemicals.com

Company overview

TCI is a worldwide catalog house which was founded in 1894 as Kakuko Asakawa Shoten, a wholesaler of pharmaceuticals in Tokyo. In 2006, after several corporate changes and developments the company was renamed into Tokyo Chemical Industry Co., Ltd. Today , the company's head office is based in Japan with subsidiaries in America, Europe, China and India. TCI is a global supplier of organic laboratory chemicals with an offer of 22.000 quality reagents and its own offices overseas in the USA, Europe and China.

Financials

TCI has offices and production plants both in Japan, as well as overseas. The company's offices and research laboratories in Japan employ more than 300 people.

Product and service portfolio

Tokyo Chemical Industry Co., Ltd. Is focused on the manufacture of fine chemicals such as pharmaceutical and cosmetic raw materials, and electroluminescence compounds, the building blocks for liquid crystals. The company's wide range of products is divided into the following categories: Laboratory Chemicals (among which also biochemicals), Fine & Specialty Chemicals (among which also itaconic acid and FDCA), Custom Synthesis products and Chromatography Columns.

Company strategy

TCI constantly seeks ways to improve its technology and skills in order to „open the door to a bright future". The manufacturer's aim is to provide a growing and valuable range of research products and to reach ever higher levels of quality, and customer service.

LOBA CHEMIE

Jehangir Villa, 107, Wode House Road, Colaba,
Mumbai 400 005. India
Tel: +91 22 6663 6663
Fax: +91 22 6663 6699
Website: www.lobachemie.com

Company overview

Founded in 1973 as a fine chemical manufacturer, Loba Chemie is a company located in India and currently positioned as a customer-focused global supplier of high quality chemicals, laboratory supplies and equipment. Loba Chemie has implemented and follows the ISO Guidelines since 2002. The company as a production plant at Tarapur, India with a Quality Assurance Laboratory equipped with technologically advanced equipment for testing and maintaining the consistency and quality of all its products. Loba Chemie has over 250 Agents / Stockist / Distributors of its products in India and is represented in over 100 countries around the globe.

Financials

Loba Chemie has a production plant in Tarapur, India which occupies a total area of 150000 sq. feet (45720 sq.meters) and is constructed on an area of over 6.5 acres of land. The plant is in complete compliance with HAZMAT guidelines for storing and handling of chemicals and operates as per Good Manufacturing Practices (cGMP) Standards.

Product and service portfolio

Loba Chemie offers the following products: laboratory chemicals, high purity solvents, ready to use volumetric solutions, standard solutions for as, concentrated volumetric solutions, rapid tests, tlc phases, products for filtration and extraction, flammable cabinets, corrosive cabinets, toxic cabinets and multirisk, pesticide range, customized production of scientific Instruments. The company has recently introduced a new line of products called Loba Life which includes laboratory glassware, liquid handling products, analytical instruments, lab Essentials. Loba Chemie also offers itaconic acid and succinic acid but the information about whether the company is a trader of these chemicals or manufacturer could not been confirmed.

Company strategy

Loba Chemie is developing its activities by creating new, quality products, offering good service according to customers' needs, on schedule deliveries for competitive prices. The company has a broad network of partners which plans to further expand.

SUCCINIC ACID

1. INTRODUCTION

Succinic acid is a chemical intermediate that was listed in 2004 by the U.S. Department of Energy's biomass program as one of the top 12 Top Value Added Chemicals. The chemical structure of this four-carbon molecule is similar to the structure of maleic anhydride. Because the two chemicals are so similar, succinic acid can potentially serve as an attractive replacement for maleic anhydride and a platform chemical for the synthesis of a multitude of compounds.

The current commercial production of succinic acid is conducted through petrochemical routes by catalytic hydrogenation of maleic acid or anhydride. Numerous companies and research institutes are currently working on the development of innovative, bio-based production routes. Bio-based succinic acid can be produced by the fermentation of glucose using natural producers or engineered organisms, for example, Anaerobiospirillum succiniproducens and Escherichia coli or other microorganisms such as Coryne-type bacteria. The feedstock used for the production of bio-based succinic acid can be wheat, maize, glucose, lignocellulosic derived sugar, or sorghum grain processed to starch. The appearance of succinic acid is colorless to white, crystal or powder and it is soluble in water.

Bio-based succinic acid is identical in structure to petrol-based succinic acid and can be directly substituted into a broad range of chemical production processes, making every day consumer applications greener and more eco-friendly. Bio-based succinic acid also can be used as a building block for the production of new applications such as polyurethanes, resins, polybutylene succinate (PBS) and plasticizers, as well as a precursor for other chemicals such as 1,4 butanediol (BDO).

The current market of succinic acid is very small and limited to niche applications because the petrochemical process is inefficient and costly. The fermentative production process of succinic acid is will be in a future more cost-effective than petrol-based process. The cost of bio-based succinic acid is expected to be lower than petrol-based succinic acid, with an equal or even higher purity.

2. VALUE CHAIN

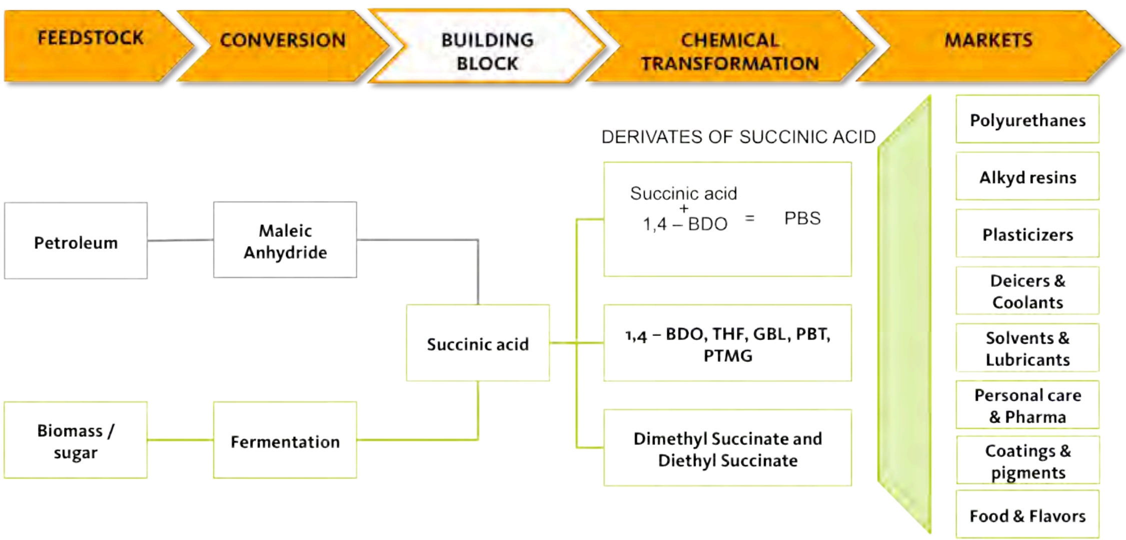
Until now, the commercial production of succinic acid was possible by using only petrol-based raw materials. The possibilities of using succinic acid are various, but also limited. The reason for this is the cost related to its production, which is dependent on the rising oil prices. It is expected that the production of bio-based succinic acid should change this situation because of the significant reduction of production costs.

The production of bio-based succinic acid from renewable materials has been researched for several years and innovative production routes are still being discovered and optimized. However, at present, the fermentative production of succinic acid from biomass forms only a small share of the total production of succinic acid worldwide.

Succinic acid is conventionally produced from butane. To produce succinic acid, butane is first oxidized to produce maleic anhydride (MAN) releasing roughly half the raw material mass as CO_2, after which MAN is reduced to succinic acid through hydrolysis. Succinic acid can now be produced via fermentation of sustainable, bio-based feedstock using natural producers or engineered organisms, for example Anaerobiospirillum succiniproducens and Escherichia coli, delivering better environmental performance[76].

The value chain of succinic acid is shown in Figure 9.

Figure 9: VALUE CHAIN OF SUCCINIC ACID[77]



[76] Hyohak Song, Sang Yup Lee: Production of succinic acid by bacterial fermentation; http://cursoshistorico.iteso.mx/moodle/pluginfile.php/673841/mod_resource/content/0/Produccion_de_succinato_por_bacterias.pdf

[77] weastra - based on primary and secondary market research

Succinic acid is produced in existing chemical processes from maleic anhydride, which serves as its main intermediate in the production process. Nowadays, several leading market players started producing succinic acid as a final product ready for commercialization. Examples of chemicals produced in high volumes, which can use bio-based succinic acid as an intermediate include BDO, gamma-butyrolactone (GBL), and tetrahydrofuran (THF) and also PBS/PBST[78].

An important derivate of succinic acid is the biodegradable polybutylene succinate (PBS), a key polymer used in the production of bio-plastics. PBS is produced by combining succinic acid and 1,4 BDO[79].

Succinic acid is useful in a variety of industrial applications. Currently, succinic acid is mostly used within the food and beverage industry. Industrially used succinic acid and its derivatives find industrial application in the pharmaceutical field, as precursors to pharmaceutical ingredients such as additives, solvents, and polymers.

[78] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/

[79] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/

3. GLOBAL MARKET OF SUCCINIC ACID

Succinic acid is a platform chemical that has a broad range of applications, from high-value niche applications such as personal care products and food additives, to large volume applications such as plasticizers, polyurethanes, resins and coatings. The possible applications for succinic acid, which are expected to register strong demand growth in the near future, are plasticizers, polyurethanes, bio-plastics, and chemical intermediates. Currently there is only a small number of companies which sell succinic acid as a merchant product.

The current price for petrol-based succinic acid oscillates between $ 2,400 / MT - $ 2,600 / MT and for bio-based succinic acid between $ 2,860 / MT - $ 3,000 / MT depending on the supplier, quality and grade of the chemical.

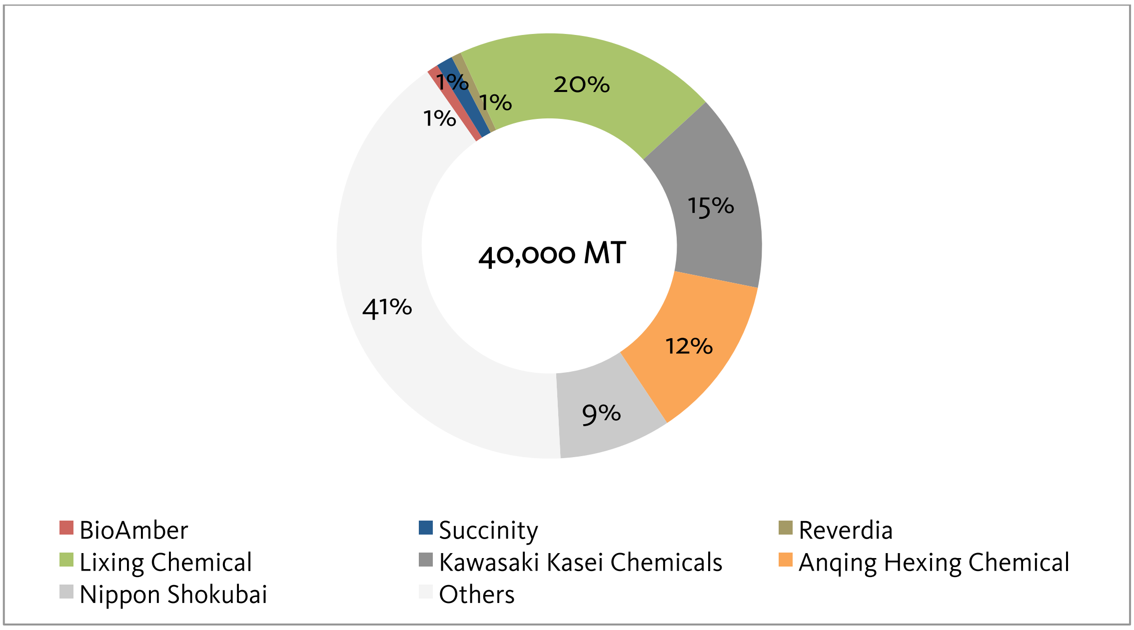
Succinic acid is categorized into 3 grades[80]: pharmaceutical grade, food grade and industrial grade. Each grade has different characteristics, such as purity, melting range, appearance, etc. All of these characteristics influence the quality, variety of applications and the price of the chemical. Due to the fact that the current production routes of succinic acid are costly, the applications are limited to a narrow range of specialized fields.

The ongoing development of the production process of succinic acid is expected to significantly reduce its production costs and in result increase the demand for succinic acid. The high cost of producing succinic acid from petroleum-based feedstock limited its use to a narrow range of applications such as pharmaceuticals and food ingredients.

As a result, the global succinic acid market was estimated to 40,000 MT in 2011 and over 97% of the succinic acid production was petrol-based[81]. Currently, the main producers of succinic acid are DSM, Gadiv Petrochemical Industries, Mitsubishi Chemical, Kawasaki Kasel Chemical, Nippon Shokubai, along with several Chinese producers such as Anqing Hexing Chemical, Lixing Chemical and Anhui Sunsing Chemicals, and some producers from India. The main producers of bio-based succinic acid in 2011 were BioAmber (350 MT), Succinity (500 MT) and Reverdia (300 MT)[82].

[80] weastra - based on primary and secondary market research
[81] weastra - based on primary and secondary market research
[82] weastra - based on primary and secondary market research

Figure 10: SUCCINIC ACID MARKET SHARE, BY PRODUCERS IN 2011[83]



Succinic acid market is expected to reach approximately 699,449 MT in 2020, growing at a CAGR of 32.9% from 2010 to 2020. The market value in 2011 was estimated at $ 63.2 million and is expected to reach $ 538.8 million in 2020 at a CAGR of 26% from 2010 to 2020[84].

Succinic acid as a platform chemical can be used in a broad range of markets, from high-value niche applications such as personal care products and food additives, to large volume applications such as plasticizers, polyurethanes, resins and coatings. In 2004, the U.S. Department of Energy has identified succinic acid as one of the five most promising "building block" chemicals that can be produced commercially from biomass rather than fossil fuels[85].

Currently, the largest applications for succinic acid are resins, coatings and pigments, accounting for 19.3% of the global succinic acid market in 2011. The other significant applications for succinic acid include pharmaceuticals (15.1%), food (12.6%), PBS /PBST (9%) and polyester polyols (6.2%)[86].

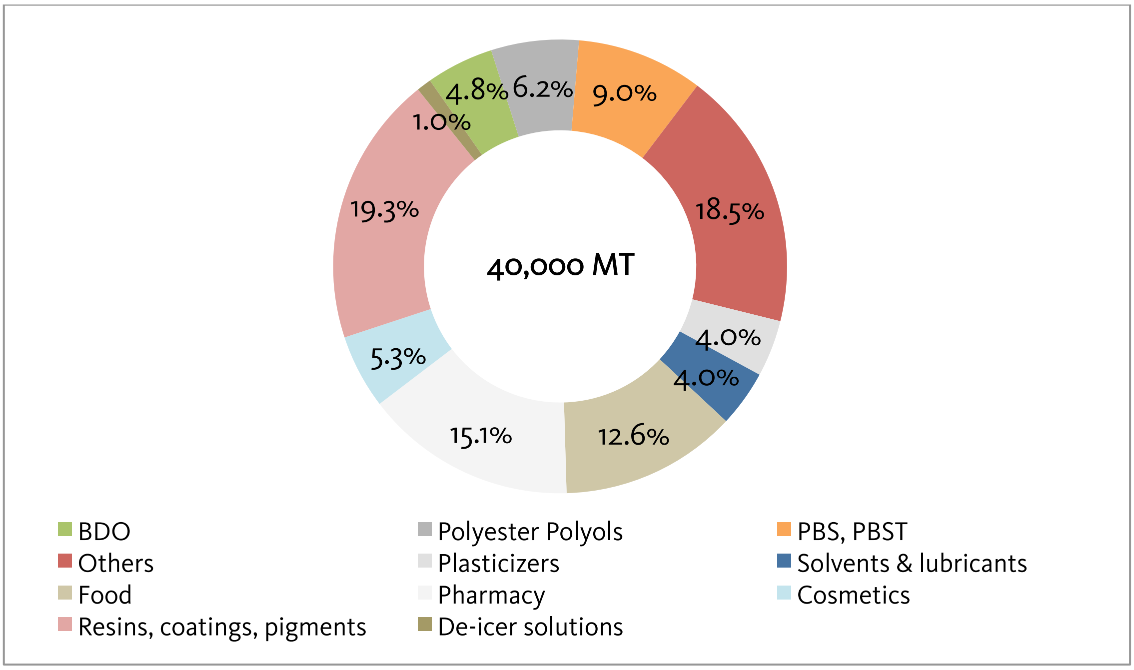
PBS polymers as a new application are biodegradable, and can be used to replace conventional plastics in applications such as flexible packaging, agricultural films and compostable bags. PBS polymers market is currently very small, but it is expected to grow significantly over time as demand

[83] weastra - based on primary and secondary market research
[84] weastra market model - based on primary and secondary market research
[85] U.S. Department of Energy. Top Value Added Chemicals from Biomass; Volume 1: Results of Screening for Potential Candidates from Sugars and Synthesis Gas, 2004
[86] weastra - based on primary and secondary market research

for biodegradable plastics increases[87].

The biggest market potential for succinic acid is in such applications as BDO, PBS and polyurethanes, which are expected to increase by 2020, while the share of resins, coatings and pigments is expected to decline[88].

Figure 11: SUCCINIC ACID MARKET SHARE, BY APPLICATIONS IN 2011[89]



[87] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/

[88] weastra market model - based on primary and secondary market research

[89] weastra market model - based on primary and secondary market research

Table 8: APPLICATIONS OF SUCCINIC ACID[90],[91]

SUCCINIC ACID

INDUSTRIAL

- PBS, PBST
- BDO (as replacement of MAN)
- Plasticizers for polymers (as replacement of adipic acid and phthalic anhydride)
- Polyester polyols for polyurethanes (as replacement of adipic acid)
- Alkyd resins (as replacement of phthalic anhydride)
- Coatings, Solvents & lubricants
- De-icers
- Engineering plastics
- As an intermediate in the manufacture of Dyes, perfumes, lacquers, photographic chemicals

PHARMACEUTICAL

- In the preparation of active calcium succinate, which acts as anti-carcinogenic agent
- As deodorant for removal of fish odour
- Starting material for Active Pharmaceutical Ingredients
- Medicines of sedative, antispasmer, antiplegm, antiphogistic, contraception and cancer curing
- In the preparation of Vitamin A
- Antidote for toxic substance

FOOD

- As a flavouring agent in food and beverages
- For dry gelatine desserts, cake flavourings
- As bread softening agents
- As sodium succinate as flavour enhancer
- In the preservation of chicken against Salmonella
- In the synthesis of modified starch
- Dog food preservative
- As Micro encapsulation of flavouring oils
- For protein gelatination

OTHERS

- Chemical metal plating
- Anodizing aluminum
- Adhesive and powder coating
- Corrosion inhibitor
- the electroplating bath
- Depilatory component
- Acidic ingredient in toothpaste and denture cleaner
- Soil chelating agent
- Crop dust antistat
- Cut flower preservative
- Component of barley seed antismut treatment
- Root simulator for grapes
- Plant growth regulator and accelerator

[90] weastra - based on primary and secondary market research

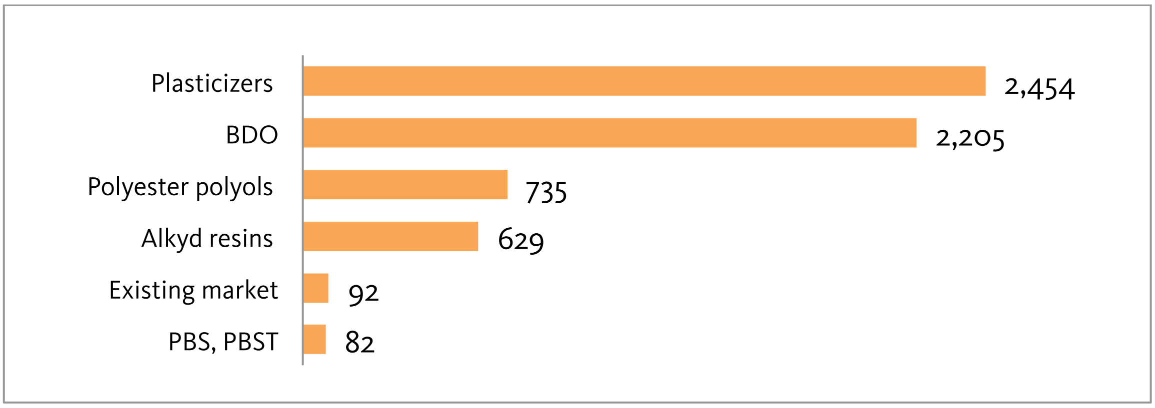
[91] http://www.thirumalaichemicals.com/images/sacapplications.pdf

4. ADDRESSABLE MARKET OF BIO-BASED SUCCINIC ACID

The addressable market in this market report means the theoretical market potential for succinic acid in case of being the winning technology replacing 100% of other chemical specific end use application.

The addressable market for bio-based succinic acid is relatively high mainly due to the variety of applications in which bio-based succinic acid can be used as a substitute. There are currently three major markets that bio-based succinic acid will attack as a drop-in replacement for petrol-based chemicals.

Figure 12: ADDRESSABLE MARKET VOLUME FOR SUCCINIC ACID based on the markets size for 2011 (in thousands) [92]



Chemicals, which can be potentially replaced by bio-based succinic acid, included maleic anhydride (in the production of BDO), adipic acid (in plasticizers and polyester polyols), phthalic anhydride (in plasticizers and alkyd resins).

Altogether, the total addressable market volume for bio-based succinic acid is approximately 6.2 million MT with the estimated value of $ 14.1 billion in 2011. When divided by its separate markets, the market for bio-based succinic acid as a replacement in plasticizers is approximately 2,454,000 MT, in BDO is 2,205,000 MT, in PBS/PBST is 82,000 MT, in polyester polyols used in polyurethanes it is 735,000 MT, and in alkyd resins 629,000 MT. We have to also count with the existing succinic acid market, which is estimated to grow to 92,000 MT until 2020.

[92] weastra market model - based on primary and secondary market research

Maleic anhydride

Maleic anhydride, produced by oxidation of benzene or butane, has the market volume approximately 1,900,000 MT with a value of $ 3 billion in 2011[93]. MAN is mostly used during the production of unsaturated polyester resins (UPRs), which take approximately 50% of total consumption of MAN. The second largest application of maleic anhydride is 1,4 BDO market and its derivatives, which account for 30% of the total consumption.

Succinic acid is produced in existing chemical processes that use maleic anhydride (MAN) as an input. Due to the fact that succinic acid has a similar chemical structure as maleic anhydride it could serve as an attractive replacement for maleic anhydride. A major market for bio-based succinic acid, used as a drop-in replacement of MAN will be the production of BDO and its derivatives such as gamma-butyrolactone (GBL), tetrahydrofuran (THF) and polybutylene terephtalate (PBT).

BDO is produced through several processes: Reppe process (42% of global capacity), the Davy process (28%), the Propylene Oxide process (20%) and the Mitsubishi process (7%)[94].

BDO is mainly used in the manufacturing of engineering plastics and in the application of polyurethane in the leather industry. In certain applications, it can be also used in manufacture of hot melt adhesive. Approximately half of the BDO consumption is used for production of THF, which is used in various industrial applications such as a solvent in pharmaceuticals. THF is also the starting material for the production of poly-tetramethyl ether-glycol (PTMEG) used mainly in elastic fibers, e.g. Spandex®. The second largest market for BDO is the production of gamma-butyrolactone (GBL), which accounts for 25% of total consumption. GBL is used in industrial cleaning products and in the production of Methylpyrrolidone (NMP) and 2-pyrrolidone. PBT takes 20% of total consumption of BDO and is used in electrical and automotive components[95].

The largest global BDO producers include BASF, Invista, ISP now owned by Ashland, Dairen Chemical, LyondellBasell, and China National BlueStar[96].

If produced by the Davy process, which is the target market of Myriant Corporation, the addressable market volume of bio-based succinic acid used as a replacement of MAN in the production of BDO is approximately 494,000 MT. The value of this potential market was$ 1.13 billion in 2011[97].

BioAmber is developing new routes to produce BDO through succinic acid. In this case, the overall BDO market, which is 1,470,000 MT, becomes a potential market for bio-based succinic acid with a

[93] weastra market model - based on primary and secondary market research

[94] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/

[95] ICIS: Chemical profile: 1,4-Butanediol, March 2008; http://www.icis.com/

[96] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/

[97] weastra market model - based on primary and secondary market research

total size of 2,205,000 MT and a market value of $ 5 billion in 2011[98].

Adipic acid

Adipic acid is a raw material used in the production of the plasticizers, polyester polyols and nylon 6,6 and other polymer applications. The main markets in which adipid acid is commonly used are automotive, footwear and construction markets. Adipic acid is also used in everyday products such as carpets, coatings, furniture, bedding and automobile parts. As a feedstock for the production of adipic acid, benzene and cyclohexane can be used.

Adipic acid has the total market volume of approximately 2,940,000 MT with the value of $ 6.45 billion in 2011[99]. Nylon 6,6 is the largest market of adipic acid, which accounts for 60% of total consumption. Nylon 6,6 is primarily used in the production of carpets and rugs. The second largest market with a 25% share of total consumption of adipic acid consists of polyester polyols, which are used in polyurethanes[100].

Producers of bio-based succinic acid are not focusing on nylon 6,6 market because of better performance of adipic acid in this area. There are opportunities for bio-based succinic acid to replace adipic acid in applications such as in polyurethanes and plasticizers[101].

Invista, BASF AG, Ascend Performance Materials, Asahi Kasei Corporation, Sumitomo Chemical Co,, Rhodia, SK Capital Partners, Shandong Haili Chemical Co., are the major producers of petrol-based adipic acid[102]. There are also several companies, which are currently working on the development of bio-based adipic acid. In the next few years, DSM and Myriant plan to enter the market with their bio-based adipic acid. Companies, which are also looking into producing adipic acid from renewable feedstock, include Verdezyne, BioAmber, Rennovia and Genomatica[103].

Once the green adipic acid will start being produced and sold at large scale, the chances for succinic acid will be more limited - these intermediates might coexist. Bio-based adipic acid can be used as a drop in replacement, but it will probably focus more on polyamides market[104].

The total addressable market volume of bio-based succinic acid as a replacement of adipic acid is approximately 882,000 MT with a value of $ 2 billion in 2011. This addressable market accounts with

[98] weastra market model - based on primary and secondary market research

[99] weastra market model - based on primary and secondary market research

[100] ICIS: Green Chemicals: DSM adds adipic acid to bio-based chemicals portfolio, October 2011; http://www.icis.com/

[101] weastra – based on primary and secondary market research

[102] weastra – based on primary and secondary market research

[103] ICIS: Green Chemicals: DSM adds adipic acid to bio-based chemicals portfolio, October 2011; http://www.icis.com/

[104] weastra – based on primary and secondary market research

735,000 MT for polyester polyols and 147,000 MT for plasticizers[105].

Phthalic anhydride

Phthalic anhydride, generally manufactured from o-xylene, is a major chemical intermediate used as a raw material to produce plasticizers, coatings and polymer resins.

Total market volume of phthalic anhydride was approximately 4,194,000 MT with the value of $ 5.67 billion[106]. Plasticizers form the largest market of phthalic anhydride, which accounts for 55% of total consumption. Plasticizers are primarily used in the production of plastics, especially polyvinyl chloride (PVC) and are added to improve the properties of plastics. Unsaturated polyester resins form the second largest market with 20% of total phthalic anhydride consumption while alkyd resins account with 15% of total phthalic anhydride consumption. The minority market with 5% of total phthalic anhydride consumption are polyester polyols.

Since 1999, the EU has restricted the use of some phthalates (phthalate esters) in the production of children's toys. In 2008, the U.S. government fully restricted the usage of three phthalates and temporary restricted the usage of another three phthalates to compose not more than 0.1% of any children's product for ages 12 and under. In 2005, the EU restricted the use of six phthalates in children's products, and in 2011 Canada restricted the use of six phthalates to a quantity below 1,000 milligrams per kilogram in the composition children's toys and childcare products[107].

BASF, ExxonMobile, UPC Group, Nan Ya, Thirumalai Chemicals Ltd., Nanjing Huafeier Chemical Co., and Aekyung Petrochemical are the major producers of phthalic anhydride[108].

Due to the increasing ban on phthalates, the demand from manufacturers who are looking for phthalate free chemicals also grew. There are opportunities for bio-based succinic acid to replace phthalic anhydride in plasticizers, because succinic acid esters and phthalates have similar performance characteristics.

The addressable market for bio-base succinic acid as a replacement of phthalic anhydride in plasticizers is estimated to 2,307,000 MT and in alkyd resins it is 629,000 MT. The total potential market volume of bio-based succinic acid as a replacement of phthalic anhydride is approximately 2,936,000 MT with the value of $ 6.7 billion in 2011[109].

---

[105] weastra market model - based on primary and secondary market research

[106] weastra market model - based on primary and secondary market research

[107] weastra - based on primary and secondary market research

[108] weastra – based on primary and secondary market research

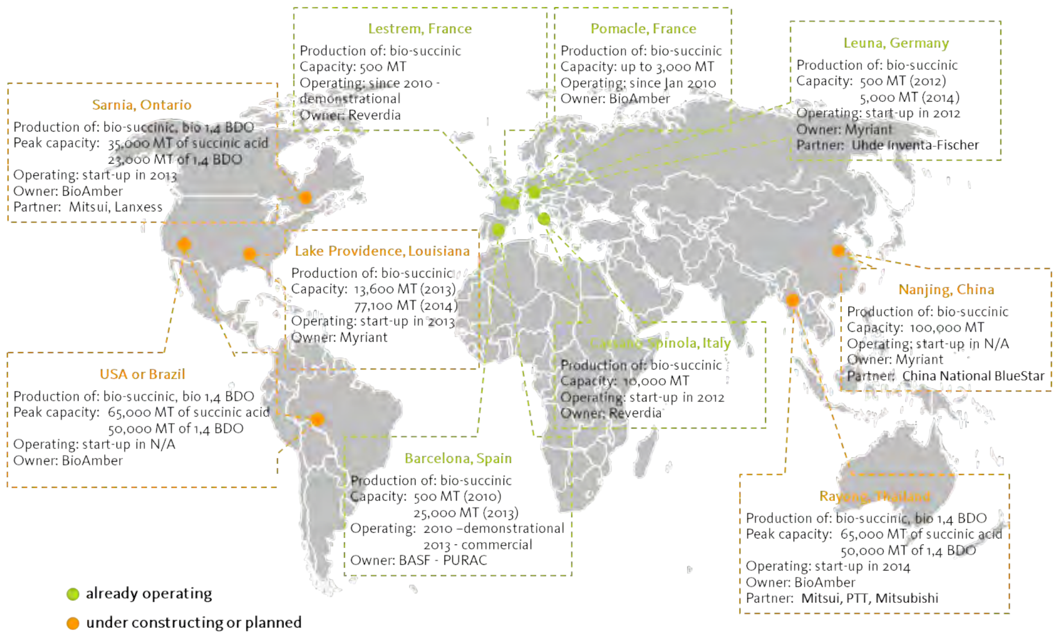
[109] weastra market model - based on primary and secondary market research

5. GROWING CAPACITIES OF BIO-BASED SUCCINIC ACID

Numerous companies and research institutes are currently developing bio-based production routes. In the near future a significant increase in production volume of bio-based succinic acid is expected. The current operational production capacity of bio-based succinic acid is estimated to approximately 3,800 MT (2011), and it is generated by three companies, which already started operations in their bio-based succinic acid pilot plants. These include BioAmber, Reverdia and Succinity, the joint venture between BASF and Purac. Other bio-based succinic acid manufacturers plan the start of bio-succinic acid production, including Myriant Corporation, which is expecting to be one of leaders on bio-based succinic acid market.

The production capacities for succinic acid are expected to have a dramatic increase as new production plants are planned to be built, reaching capacities of planned 225.873 MTPA from 2014, going to approximately 637.452 MTPA in 2020[110].

Figure 13: WORLD MAP OF PRODUCTION OF BIO-BASED SUCCINIC ACID[111]



BioAmber operates the world's first large-scale bio-based succinic acid production facility. The capacity of this plant is 3,000 MT. The plant is located in Pomacle, France and has been producing bio-succinic acid since 2010, using a 350,000 liter fermenter. BioAmber will expand their production

[110] weastra market model - based on primary and secondary market research

[111] weastra - based on primary and secondary market research

to a global scale in 2013. This plant will continue to be used mainly for research and development activities.

BioAmber formed a joint venture with Mitsui (Japan). The joint venture plans to build another plant in Sarnia, Ontario with a capacity of approximately 17,000 MT of bio-based succinic acid. The plant will have a 700,000 liter fermenter and, is expected to start operations in 2013. BioAmber plans to expand this plant and generate a total annual capacity of approximately 34,000 MT of bio-based succinic acid and 23,000 MT of bio-based 1,4 BDO. BioAmber said, "the Ontario based plant will offer economies of scale and benefit from lower feedstock and utility costs than France, leading to a significant reduction in the price of BioAmber's bio-succinic acid"[112].

The joint venture with Mitsui also has the goal of building an additional plant in Rayong, Thailand with an expected annual capacity of 65,000 MT of bio-based succinic acid and 50,000 MT of bio-based 1,4 BDO. The plant in Thailand is expected to be completed and start production in 2015[113].

One more bio-succinic acid production facility is planned by Mitsui and BioAmber to be located either in the United States or Brazil, with a target annual capacity of 65,000 MT of bio-succinic acid and 50,000 MT of bio-based 1,4 BDO, or some other reasonably equivalent combined production capacity of bio-succinic acid and bio-based 1,4 BDO. The start-up date for this plant is currently not available[114].

Reverdia, the Netherlands-based joint venture between Dutch chemical company DSM and France-based starch derivatives producer Roquette, is expected to start its first commercial bio-succinic acid plant in Cassano Spinola, Italy, in the end of 2012. The plant will have an annual capacity of 10,000 MT of bio-based succinic acid. Reverdia already has a pilot plant located in Lestrem,France , built in 2008 with a capacity of 500 MT annually[115].

German chemical company BASF has partnered with Dutch company Purac, to form a joint venture called Succinity, for the production of bio-based succinic acid. The partnership already operates a plant located in Barcelona, Spain currently producing only demonstrational quantities with a capacity of 500 MT. The companies are currently expanding this plant to increase the total annual capacity to 25,000 MT and start commercial production in 2013, the latest. A world-scale plant with annual capacity of 50,000 MT is one of the long term goals of BASF and Purac, although no timeline and location has yet been announced for this project[116].

Myriant Corporation plans to complete the construction of their plant located in Lake Providence, Louisiana and begin commercial operations during the first quarter of 2013. The Louisiana plant will

---

[112] weastra - based on primary and secondary market research
[113] weastra - based on primary and secondary market research
[114] weastra - based on primary and secondary market research
[115] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/
[116] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/

have an initial capacity of 13,600 MT in the first quarter of 2013, which will expand to 77,110 MT annually by early 2014[117].

Myriant has signed a partnership with China National BlueStar, one of the leading BDO producers in Asia, to build a plant located in Nanjing, China, near to BlueStar's BDO plant. This production facility would have a capacity to produce approximately 100,000 MT annually, of which 84,000 MT would be dedicated for use in BlueStar's BDO plant[118].

Myriant has also entered a partnership with Uhde to build a plant for the production of bio-based succinic acid located in Leuna, Germany. The plant would be owned and operated by Uhde and would have an annual capacity of around 5,000 MT. In its first year of operation the plant is expected to produce 500 MT of bio-based succinic acid[119].

An overview of all planned bio-based succinic acid production capacities is presented in *Table 9.* Capacities of BDO, wich BioAmber declares for their BDO plants, are recalculated to the succinic acid. According to BioAmber, weight loss during the conversion of bio-based succinic acid to bio-based BDO is approximately 24%; therefore weastra recalculated all of BioAmber's BDO capacities to capacities for succinic acid, which are used in the Table 2 and also in weastra market model.

[117] Myriant: weastra primary market research and interviews
[118] Myriant: weastra primary market research and interviews
[119] Myriant: weastra primary market research and interviews

Table 9: BIO-BASED SUCCINIC ACID PRODUCTION CAPACITY[120]

Company	Plant location	Production of	Capacity of succinic acid (MTPA)							Operational date
			2011	2012	2013	2014	2015	2016	2017 <	
Succinity (BASF-Purac)	Barcelona, Spain	SA	500	500	25,000	25,000	25,000	25,000	25,000	2013
	N/A	SA	-	-	-	-	-	-	50,000	N/A
BioAmber	Pomacle, France	SA	3,000	3,000	3,000	3,000	3,000	3,000	3,000	2010
	Sarnia, Ontario	SA	-	-	17,000	35,000	35,000	35,000	35,000	2013
		BDO	-	-	-	30,263	30,263	30,263	30,263	2014
	Rayong, Thailand	BDO	-	-	-	-	65,789	65,789	65,789	2014
		SA	-	-	-	-	65,000	65,000	65,000	2014
	USA or Brazil	BDO	-	-	-	-	-	-	65,789	N/A
		SA	-	-	-	-	-	-	65,000	N/A
Myriant	Lake Providence, Louisiana	SA	-	-	13,600	77,110	77,110	77,110	77,110	2013
	Leuna, Germany	SA	-	500	5,000	5,000	5,000	5,000	5,000	2012 (Q4)
	Nanjing, China	SA	-	-	-	-	-		100,000	N/A
Reverdia	Lestrem, France	SA	300	500	500	500	500	500	500	2010-pilot plant
	Cassano Spinola, Italy	SA	-	10,000	10,000	10,000	10,000	10,000	10,000	2012 (Q4)
	TOTAL		3,800	14,500	74,100	185,873	316,662	316,662	597,452	

[120] weastra - based on primary and secondary market research

Table 10: SUCCINIC ACID PRODUCTION CAPACITY - TAKING IN ACCOUNT THE PROJECTED CAPACITY UTILIZATION [121]

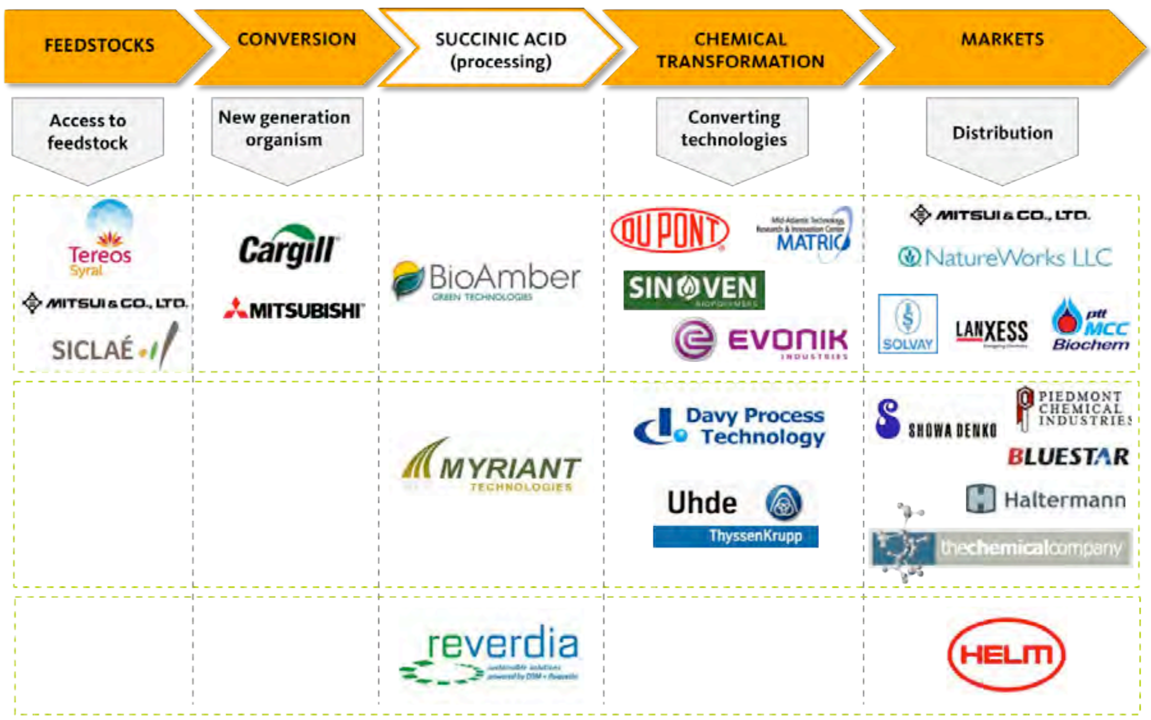
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CAPACITIES	43,800	54,500	114,100	225,873	356,663	356,663	506,663	506,663	637,452	637,452
utilization of capacity	*41,250*	*50,200*	*83,150*	*132,937*	*192,147*	*261,688*	*438,663*	*463,663*	*529,057*	*594,452*
petrol-based succinic	**40,000**	**40,000**	**40,000**	**40,000**	**40,000**	**40,000**	**40,000**	**40,000**	**40,000**	**40,000**
ulitization rates	100%	100%	80%	50%	0%	0%	0%	0%	0%	0%
utilization of capacity	*40,000*	*40,000*	*32,000*	*20,000*	*0*	*0*	*0*	*0*	*0*	*0*
bio-based succinic	**3,800**	**14,500**	**74,100**	**185,873**	**316,663**	**316,663**	**466,663**	**466,663**	**597,452**	**597,452**
ulitization rates	33%	70%	69%	61%	61%	83%	94%	99%	89%	99%
utilization of capacity	*1,250*	*10,200*	*51,150*	*112,937*	*192,147*	*261,688*	*438,663*	*463,663*	*529,057*	*594,452*
BASF Barcelona, Spain	500	500	25,000	25,000	25,000	25,000	25,000	25,000	25,000	25,000
utilization rates	100%	100%	50%	75%	100%	100%	100%	100%	100%	100%
utilization of capacity	*500*	*500*	*12,500*	*18,750*	*25,000*	*25,000*	*25,000*	*25,000*	*25,000*	*25,000*
BASF N/A							50,000	50,000	50,000	50,000
utilization rates							100%	100%	100%	100%
utilization of capacity							*50,000*	*50,000*	*50,000*	*50,000*
BioAmber Pomacle, France	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
utilization rates	15%	40%	60%	0%	0%	0%	0%	0%	0%	0%
utilization of capacity	*450*	*1,200*	*1,800*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
BioAmber Sarnia, Ontario, Canada - succinic acid plant			17,000	35,000	35,000	35,000	35,000	35,000	35,000	35,000
utilization rates			75%	75%	75%	100%	100%	100%	100%	100%
utilization of capacity			*12,750*	*26,250*	*26,250*	*35,000*	*35,000*	*35,000*	*35,000*	*35,000*
BioAmber Sarnia, Ontario, Canada - for production BDO				30,263	30,263	30,263	30,263	30,263	30,263	30,263
utilization rates				50%	75%	100%	100%	100%	100%	100%
utilization of capacity				*15,132*	*22,697*	*30,263*	*30,263*	*30,263*	*30,263*	*30,263*
BioAmber Rayong, Thailand - succinic acid plant					65,000	65,000	65,000	65,000	65,000	65,000
utilization rates					50%	75%	100%	100%	100%	100%
utilization of capacity					*32,500*	*48,750*	*65,000*	*65,000*	*65,000*	*65,000*
BioAmber Rayong, Thailand - for production of BDO					65,789	65,789	65,789	65,789	65,789	65,789
utilization rates					50%	75%	100%	100%	100%	100%
utilization of capacity					*32,895*	*49,342*	*65,789*	*65,789*	*65,789*	*65,789*
BioAmber USA or Brazil - succinic acid plant									65,000	65,000
utilization rates									50%	100%
utilization of capacity									*32,500*	*65,000*
BioAmber USA or Brazil - for production of BDO									65,789	65,789
utilization rates									50%	100%
utilization of capacity									*32,895*	*65,789*
Myriant Lake Providence, Louisiana			13,600	77,110	77,110	77,110	77,110	77,110	77,110	77,110
utilization rates			100%	50%	50%	75%	100%	100%	100%	100%
utilization of capacity			*13,600*	*38,555*	*38,555*	*57,833*	*77,110*	*77,110*	*77,110*	*77,110*
Myriant Leuna, Germany		500	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
utilization rates		100%	50%	75%	75%	100%	100%	100%	100%	100%
utilization of capacity		*500*	*2,500*	*3,750*	*3,750*	*5,000*	*5,000*	*5,000*	*5,000*	*5,000*
Myriant Nanjing, China - succinic acid							15,000	15,000	15,000	15,000
utilization rates							75%	100%	100%	100%
utilization of capacity							*11,250*	*15,000*	*15,000*	*15,000*
Myriant Nanjing, China - for production of BDO							85,000	85,000	85,000	85,000
utilization rates							75%	100%	100%	100%
utilization of capacity							*63,750*	*85,000*	*85,000*	*85,000*
Reverdia Lestrem, France	300	500	500	500	500	500	500	500	500	500
utilization rates	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
utilization of capacity	*300*	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*	*500*
Reverdia Cassano Spinola, Italy		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
utilization rates		75%	75%	100%	100%	100%	100%	100%	100%	100%
utilization of capacity		*7,500*	*7,500*	*10,000*	*10,000*	*10,000*	*10,000*	*10,000*	*10,000*	*10,000*

[121] weastra market model - based on primary and secondary market research

6. MARKET MECHANISM

Important step for a successful entry into the market of bio-succinic acid is creating strategic partnerships with other leading companies in the global chemical industry, especially in the field of addressable market for succinic acid. These partnerships will help to reduce production costs. Three leading companies, BioAmber, Myriant Corporation and Reverdia, have already signed several partnerships to help them to leverage existing know-how, infrastructure and reduce production costs. The companies with which they have partnered include feedstock partnerships, fermentation, downstream processing, chemical transformation and commercial partnerships. The example of market mechanism of these companies is shown in Figure 14.

Figure 14: MARKET MECHANISM[122]



Succinity GmbH, the joint venture between BASF and Purac did not disclose any information about agreements so far.

Currently, Reverdia, the joint venture between DSM and Roquette, has signed publicly only one agreement with the chemical distributor Helm to distribute and develop the market for the company's bio-based succinic acid[123].

[122] weastra - based on primary and secondary market research

[123] Reverdia press release; http://www.reverdia.com/

In November 2011, BioAmber entered into a joint venture agreement with Mitsui to finance and build a manufacturing facility in Sarnia, Ontario. The joint venture agreement also establishes the parties' intent to build and operate two additional facilities, one located in Thailand and the other located in either the United States or Brazil. In connection with the joint venture, Mitsui has agreed to provide know-how regarding shipping and logistics, warehousing, credit checks, freight insurance, and trade finance globally. Such an agreement will facilitate sales in Asia and support the implementation of internal control systems for BioAmber[124].

BioAmber has been chosen by Mitsubishi Chemical Corporation and PTT-MCC Biochem Ltd. to exclusively supply bio-succinic acid for their new 20,000 MT polybutylene succinate (PBS) plant located in Thailand, which is expected to start operations in 2014. Under the terms of agreement, PTT MCC will offer its succinic acid technology to the BioAmber's bio- succinic acid production platform to create low cost bio-succinic acid, which will in turn reduce the production cost for polybutylene succinate. The memorandum of understanding also memorializes Mitsubishi's and PTT-MCC's intent to supply BioAmber with bio-based PBS for their future needs and intent to develop bio-succinic acid production technology[125].

BioAmber also entered into a joint development agreement with Lanxess, a global leader in phthalate-free plasticizers, to develop bio-succinic acid-based plasticizers that are both renewable and phthalate-free. BioAmber and Sinoven Biopolymers Inc. have signed a supply agreement for bio-based succinic acid. Under the terms of the agreement, BioAmber will be Sinoven's exclusive supplier of bio-based succinic acid, enabling Sinoven to produce renewable modified PBS[126].

BioAmber's partnership with Cargill covered the development of a new generation microorganism to produce bio-based succinic acid used by Cargill's technology. BioAmber has licensed a technology from DuPont to convert its bio-based succinic acid to bio-BDO and also entered a partnership with Evonic – a long-term cooperation for the development and manufacturing of catalysts for making BDO, THF and GBL from bio-based succinic acid[127].

In September 2012 BioAmber signed an agreement to supply its renewable succinic acid to Inolex for a range of succinate emollients, which can be used in skin care, hair care, color and antiperspirant products[128].

Myriant Technology has also signed several partnerships. The Memorandum of understanding between Myriant and Davy contemplates that if Davy successfully completes engineering and testing of their bio-based succinic acid, the company would guarantee to its licensees that Myriants' bio-based succinic acid will work in replacement of MAN in its BDO production process. This approach

[124] weastra - based on primary and secondary market research
[125] weastra - based on primary and secondary market research
[126] weastra - based on primary and secondary market research
[127] weastra - based on primary and secondary market research
[128] weastra - based on primary and secondary market research

takes advantage of the existing installed asset base that uses the Davy process for BDO production and would enable Davy process licensees to use Myriant's bio-based succinic acid in their production process without significant additional capital expenditures[129].

An agreement with Japan based Sojitz Corporation covered the creation of a sales and marketing partnership to distribute bio-based succinic acid in Japan, China, South Korea and Taiwan[130].

Showa Denko has partnered with Myriant for the supply of bio-based succinic acid for their PBS[131].

Myriant also entered into supply agreements with Haltermann Ltd., a leading supplier of a wide range of chemicals, The Chcemical Company (TCC), a leading manufacturer and distributor of specialty and commodity chemicals and Piedmont Chemical Industries I, LLC. to supply companies with 100% of their requirements for bio-based succinic acid[132].

With China National BlueStar Myriant has signed an agreement for the exclusive supply of bio-based succinic acid. The Chinese company is a BDO licensee of Davy Technology. A joint venture with Thailand-based PTT Chemical covered the deployment of Myriant's technology in Southeast Asia[133].

---

[129] Myriant: weastra primary market research and interviews
[130] Myriant: weastra primary market research and interviews
[131] Myriant: weastra primary market research and interviews
[132] Myriant: weastra primary market research and interviews
[133] Myriant: weastra primary market research and interviews

7. PROJECTED MARKET OF BIO-BASED SUCCINIC ACID BY APPLICATIONS

Most of the interviewed players see biggest future potential for bio-based succinic acid for the production of BDO, PBS/PBST and polyester polyols, which could become a “low hanging fruit”. However, using bio-based succinic in those applications would be economically viable only in case when the price of bio-based succinic acid would be competitive with the price of chemicals, which succinic acid is targeting for replacement[134].

The current price for petrol-based succinic acid oscillates between $ 2,400 / MT - $ 2,600 / MT and for bio-based succinic acid between $ 2,860 / MT - $ 3,000 / MT depending on the supplier, quality and grade of the chemical.

From 2013, weastra expects the bio-based succinic acid price to go down to $ 2,300 – 2,400/MT. The main producers of succinic acid expect, that the price development of bio-based succinic acid, once all of the capacities will be on the market might be going down. However, as the petrol-based routes will be more expensive, the bio-based routes do not necessarily need to go down in price[135].

Myriant is targeting the price of its succinic acid to be competitive with the price of Maleic anhydride. Already by the current 1st generation process they can reach this price, but after the integration with DAVY (2nd generation), it will be even more attractive[136].

BioAmber believes, that they can produce bio-succinic acid that is cost-competitive or even lower in price than petrol-based succinic acid. In future, they believe that the cost of BioAmber's bio-based succinic acid will be 40% below that of petroleum-based succinic acid[137].

With regard to the planned capacity, performance in targeting applications and other possible bio-based routes and intermediates, the projected market for succinic acid is estimated to approximately 188,572 MT with the value of approximately $ 167.6 million in 2015 and 599,449 MT with the value of approximately $ 538.8 million in 2020[138].

[134] weastra - based on primary and secondary market research

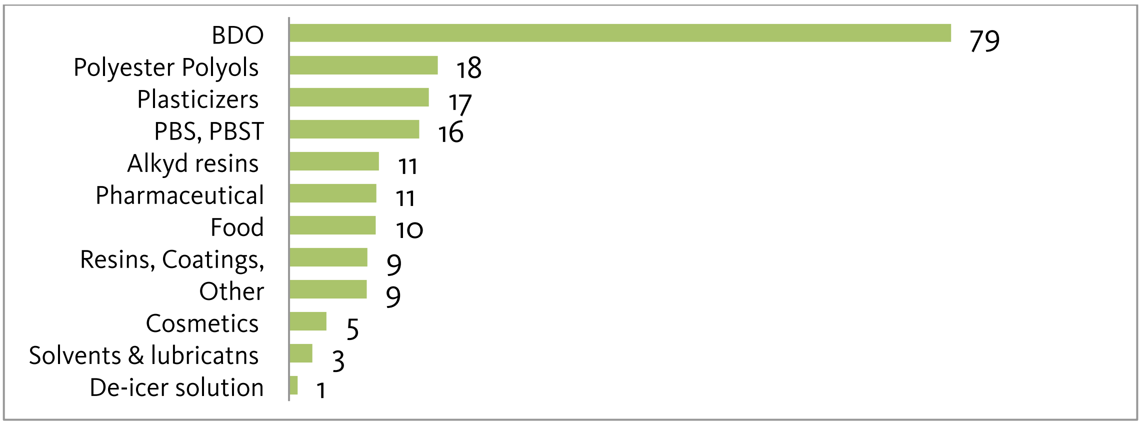
[135] weastra - based on primary and secondary market research

[136] Myriant: weastra primary market research and interviews

[137] BioAmber: weastra primary market research and interviews

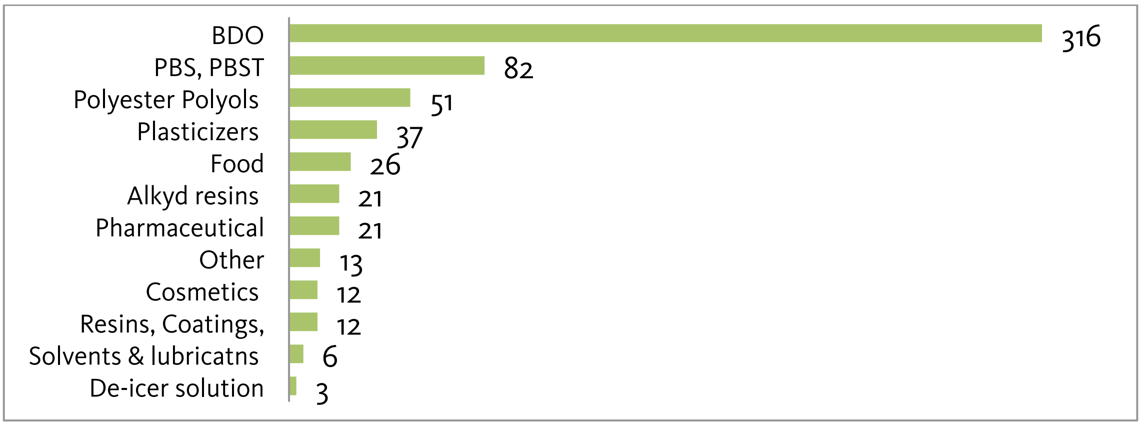
[138] weastra market model - based on primary and secondary market research

Figure 15: PROJECTED MARKET VOLUME FOR SUCCINIC ACID IN 2015 (in thousands) [139]



When divided by its separate markets, the market for bio-based succinic acid as a replacement in BDO will be 79,395 MT, in PBS/PBST will be 15,600 MT, plasticizers will be 16,807 MT, in polyester polyols used in polyurethanes it will be 17,868 MT, and in alkyd resins 10,828 MT. Projected volume of existing succinic acid market is estimated to 48,074 MT.

Figure 16: PROJECTED MARKET VOLUME FOR SUCCINIC ACID IN 2020 (in thousands) [140]



When divided by its separate markets, the market for bio-based succinic acid as a replacement in BDO will be 315,730 MT, in PBS/PBST will be 81,600 MT, plasticizers will be 37,136 MT, in polyester polyols used in polyurethanes it will be 51,310 MT, and in alkyd resins 21,433 MT. Projected volume of

[139] weastra market model - based on primary and secondary market research

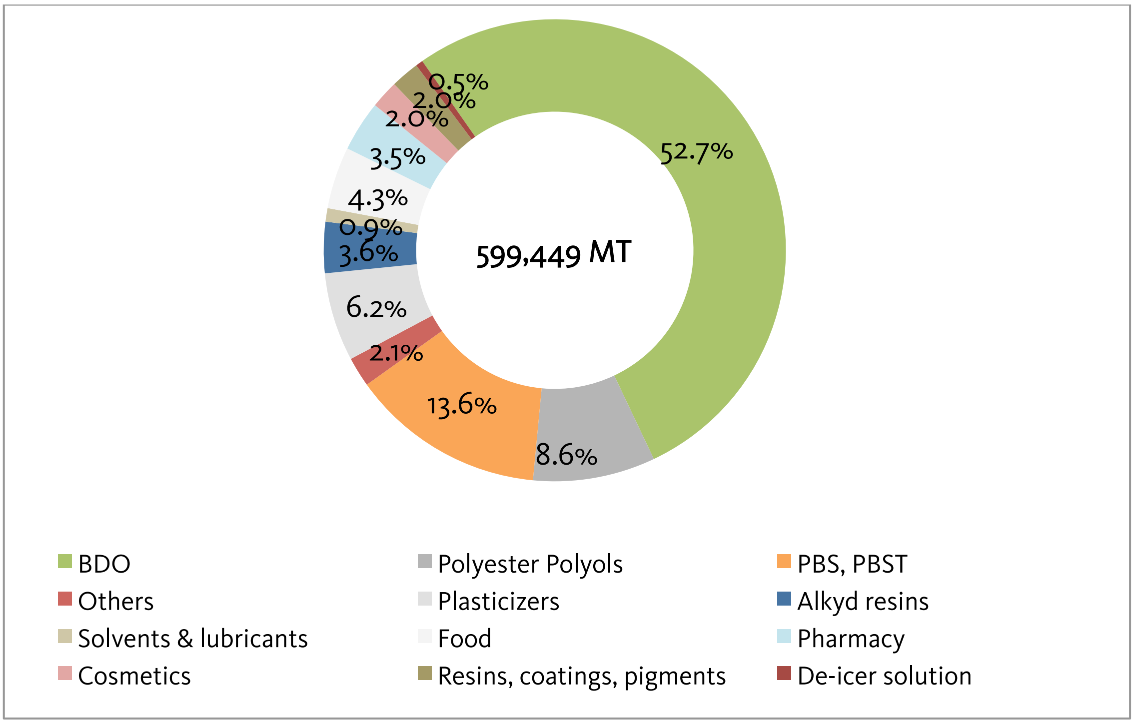
[140] weastra market model - based on primary and secondary market research

existing succinic acid market is estimated to 92,239 MT[141].

From the view of possible end use applications, bio-based succinic acid is playing a role on two main markets. One of them is the new market with the applications in which bio-based succinic acid can replace other existing petrol-based intermediates. The second market is the currently existing market of succinic acid, where bio-based succinic acid will replace petrol-based succinic acid.

The biggest market potential for succinic acid is in the production of BDO and PBS/PBST. In 2020, the largest projected applications for succinic acid is BDO, accounting for 52.7% of the global succinic acid market. PBS/PBST account for 13.6% of global market and polyester polyols account for 8.6% of global succinic acid market in 2020[142].

Figure 17: PROJECTED SUCCINIC ACID MARKET SHARE, BY APPLICATIONS IN 2020[143]



[141] weastra market model – based on primary and secondary market research

[142] weastra market model – based on primary and secondary market research

[143] weastra market model - based on primary and secondary market research

New market for bio-based succinic acid

1,4-butanediol and derivatives

1,4-butanediol (BDO) is a chemical intermediate, which is used in resins, fibers, coatings and other downstream chemical products. The current global 1,4-BDO output was estimated to approximately 1,5 mio MT in 2011. Half of global BDO is used as an intermediate in the production of THF, which is an intermediate in the production of elastic fibers, e.g. Spandex® and Lycra®. THF is also used in the production of performance polymers, resins, solvents and printing inks for plastics. THF is further used in the production of polytetramethylene ether glycol (PTMEG) [144].

The rest of the global production of 1,4-BDO is used as a raw material for engineering polymers of polybutylene terephtalate (PBT), polyurethanes and other applications[145].

The largest global producers of petrol-based 1,4-BDO include BASF, Dairen Chemical, LyondellBasell, ISP, Invista and China National BlueStar Corporation[146].

BDO producers use approximately two-thirds of global 1,4-BDO output. 1,4-BDO can be produced through different processes. Here are the four main production processes: the Reppe process (42% of global capacity), the Davy process (28%), the Propylene Oxide process (20%) and the Mitsubishi process (7%). These processes are petrol-based, but currently a number of companies are engaged in the development of routes to produce bio-BDO[147].

One of the production routes of bio-BDO is through the usage of succinic acid as an intermediate. From the perspective of succinic acid, there is a big potential to use bio-succinic acid in the production of bio-BDO. Bio-based succinic acid is an attractive solution, as a drop in replacement for MAN, which participates in the production of BDO through the Davy process. The Davy has licensed more than half a million tons of annual production capacity of BDO, THF and GBL. Myriant Corporation and Davy signed a Memorandum of Understanding covering the use of succinic acid as a bio-derived feedstock for the production of BDO, THF and GBL. For this Davy process to produce bio-based BDO from bio-based succinic acid, weastra calculated in market model with the ratio, that 1.2 MT of bio-based succinic acid is needed to replace 1 MT of maleic anhydride[148].

BioAmber has licensed DuPont's hydrogenation catalyst technology to make bio-based 1,4 BDO and THF from bio-succinic acid. According to BioAmber, weight loss during their conversion of bio-based

---

[144] Nexant: Is Bio-Butanediol Here to Stay?, prospectus – July 2012; http://www.chemsystems.com/
[145] Nexant: Is Bio-Butanediol Here to Stay?, prospectus – July 2012; http://www.chemsystems.com/
[146] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/
[147] ICIS: Chemical industry awaits for bio-succinic acid potential, January 2012; http://www.icis.com/
[148] Myriant: weastra primary market research and interviews

succinic acid to bio-based BDO is approximately 24%[149].

There are also other ways to make bio-BDO, without using succinic acid as an intermediate. Novamont and Genomatica, created a joint venture, for their first industrial plant for the production of BDO from renewable feedstock[150].

Metabolix announced that it will form a joint development deal for its polyhydroxyalkanoates (PHA)-based C4 chemicals with Korea-based industrial biotechnology company CJ CheilJedang[151].

Table 11: 1,4-BDO & DERIVATES: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	1,013	1,924	2,645	12,244	37,172	79,395
VALUE	2,431	5,005	7,348	28,015	63,786	129,430
	2016	2017	2018	2019	2020	CAGR 2014 - 2020
VOLUME	110,454	212,661	227,987	271,436	315,730	43%
VALUE	180,062	346,680	371,664	442,496	514,704	42%

1,4-BDO market is the most relevant and interesting market for bio-based succinic acid. The estimated potential of replacing MAN in BDO with succinic acid is projected up to 11% of the MAN used in BDO by 2020.

Overall, taking in account the Davy process and new BioAmber process to produce bio-BDO, estimated potential for bio-BDO produced from bio-based succinic acid is projected up to ca. 9% of overall addressable BDO market by 2020, with consideration of alternative bio-BDO routes on the way (Genomatica, Metabolix) with different quality and price levels, but all will co-exist on the market[152].

According to the market model projection, the estimated demand of succinic acid used in BDO and its derivatives was 1,013 tons in 2010 and weastra expects that it will reach 315,730 tons by 2020, at CAGR of 43% from 2014 to 2020. The overall market value for succinic acid used in BDO and its

[149] weastra - based on primary and secondary market research

[150] Genomatica press release: http://www.genomatica.com/

[151] ICIS blog : Is bio-based BDO for real?, September 2011; http://www.icis.com/blogs/green-chemicals/

[152] weastra market model – based on primary and secondary market research

derivatives was $ 2.4 million in 2010 and is expected to reach $ 514.7 million in 2020[153].

Polybutylene succinate (PBS)

The polybutylene succinate (PBS) is biodegradable synthetic aliphatic polyester with similar properties as PET and is one of the newest biopolymers. PBS is currently produced by combining petroleum-based succinic acid and 1,4-BDO, both of which are usually derived from maleic anhydride[154]. The market for this biopolymer is currently still very small, limited by capacity and price, but it is expected to grow as demand for biodegradable plastics increases. The current PBS market was estimated to approximately 6,000 MT in 2011[155].

Mitsubishi Chemical, Showa Denko, Samsung Fine Chemical, and several Chinese firms such as Kingfa Science & Technology, Zhejiang Hangzhou Xinfu Pharmaceutical Co. Ltd., Hanqing Hexing Chemical Co. Ltd., and China New Materials are current producers of PBS[156].

At present, several strategic partnerships exist for exclusive supply of bio-based succinic acid from succinic acid producers to PBS producers.

PBS has excellent mechanical properties and can be applied to a range of end applications via conventional melt processing techniques. It is a key component used in the production of bio-plastic products that include biodegradable mulch films and compostable bag applications. PBS can be used in packaging (food), non-woven, fiber or textile, consumer goods, electrics and electronics, automotive interior and others. In addition, coffee or tea cups, bowls, plates, plastic utensils, agricultural mulch films and diapers are also made with using PBS[157].

PBS can be generally blended with other compounds, such as thermoplastic starch and adipate copolymers (to form PBSA) to make its use more economical. Interesting area for development is also the replacement of adipate part in PBAT with succinate part, to make PBST.

[153] weastra market model – based on primary and secondary market research
[154] Li Shen, Juliane Haufe, Martin K. Patel: Product overview and market projection of emerging bio-based plastics, PRO-BIP 2009, Final Report, June 2009
[155] weastra market model – based on primary and secondary market research
[156] ICIS blog: Uhde expands into PBS processing, May 2012; http://www.icis.com/blogs/green-chemicals/
[157] Reverdia website: http://www.reverdia.com/

Table 12: PBS/PBST: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	3,600	3,600	3,600	3,600	15,600	15,600
VALUE	8,640	8,670	9,554	8,237	26,770	25,431
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	39,600	63,600	63,600	81,600	81,600	37%
VALUE	64,556	103,681	103,681	133,024	133,024	31%

PBS is an important application for bio-based succinic acid. Currently PBS is very small market but has a huge growth potential predicted in packaging applications. PBS is a fantastic market not only for bio-based succinic, but also for bio-based BDO.

According to the market model projection, the estimated demand of succinic acid used in PBS was at 3,600.0 tons in 2010 and is expected to reach approximately 81,600.0 tons by 2020, at CAGR of 37% from 2010 to 2020, if will be completely bio-based and bio-degradable. The overall market value of succinic acid used in PBS was $ 8.6 million in 2010 and is expected to reach $ 133 million in 2020. The estimated potential of 100% replacing petrol-based succinic acid in PBS/PBST with bio-based succinic acid is projected from 2013 onwards[158].

Polyester polyols

The polyurethanes market is currently emerging as a one of the major applications of succinic acid beside BDO and PBS. Polyurethanes are manufactured from isocyanates and polyols. Polyester polyols are one of two types of polyols used in polyurethanes and they are typically made from di-acids and glycols. The two main types of polyols used in polyurethane industry include polyethers and polyesters. Currently very small portion of polyols are derived from succinic acid.

At present, the process of polyurethanes production includes adipic acid, which is used in polyester polyols and is dominating this market. Bio-based succinic acid can be used to replace adipic acid in this market and is currently the only renewable alternative to adipic acid for the production of polyurethanes. Suppliers of polyester polyols are actively looking for bio-based, cost-effective substitutes for adipic acid to improve the environmental profile and reduce the cost of their

[158] weastra market model – based on primary and secondary market research

products[159].

Reverdia, a joint venture between DSM and Roquette, is specializing in the field of polyurethanes, especially focusing on its main product - Biosuccinium™. The company uses yeast technology to convert bio-based feedstock into succinic acid[160].

Polyurethanes are used in soles for footwear, molded foams for automotive applications like car seats and arm rests, and non-foam applications such as coatings, adhesives and sealants.

Table 13: POLYESTER POLYOLS: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	1,750	2,499	3,859	8,103	12,763	17,868
VALUE	5,075	7,147	11,036	18,541	21,901	29,128
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	23,452	44,324	46,540	48,867	51,310	40%
VALUE	38,231	72,256	75,870	79,663	83,646	32%

Polyurethanes market, made from polyester polyols, is one of the emerging markets for bio-based succinic acid. The end use applications targeted by bio-based succinic acid on this market are so called “forgiving chemistry”, which means that they are open for a new molecule to be tested and there is a big potential for bio-based succinic acid to replace adipic acid in this field. However, the opportunity should be exploited quickly. Once the green adipic acid will start being produced and sold at large scale, the chances for succinic acid will be more limited - these intermediates might coexist. Bio-based adipic acid can be used as a drop in replacement, but it will focus more on polyamides market[161]. The estimated potential of replacing adipic acid in polyester polyols with bio-based succinic acid is projected up to 4.5% of the adipic acid used in polyester polyols by 2020[162].

According to the market model projection, the estimated demand of succinic acid used in polyurethanes was 1,750.0 tons in 2010 and is expected to reach approximately 51,310.0 tons by 2020, at CAGR of 40% from 2010 to 2020. The overall market value for succinic acid used in polyurethanes was $ 5 million in 2010 and is expected to reach $ 83.6 million in 2020.

159 weastra – based on primary and secondary market research

160 Reverdia website: http://www.reverdia.com/

161 weastra – based on primary and secondary market research

162 weastra market model – based on primary and secondary market research

Plasticizers

Plasticizers are organic esters that are primarily used to make flexible polyvinyl chloride (PVC), which is widely used because of its low cost, durability and versatility. Bio-based succinic acid esters can be used as replacements for some of the major phthalate-based plasticizers, which account for a significant majority of the worldwide demand. World plasticizers consumption was estimated at 6.4 million MT in 2011. From all plasticizers production, 85% are phthalate plasticizers and only 15% are non-phthalate plasticizers, such as adipates, polymerics and others[163].

By adding phthalates into the production of PVC, the manufacturers reach a plastic, which is more flexible and durable. Six of the commonly used phthalates in consumer products are di-(2-ethylhexyl) phthalate (DEHP), diisononyl phthalate (DINP), dibutyl phthalate (DBP), diisodecyl phthalate (DIDP), di-n-octyl phthal- ate (DnOP), and benzyl butyl phthalate (BBP). European Union permanently banned the use of DEHP, DPB, BBO, DINP, DIDP and DNOP in all children's articles, which can be put on purpose or by mistake in the mouth[164].

A number of substances have been identified as alternative non-phthalate plasticizers. These alternatives include citrates, sebacates, adipates, and phosphates. They are being substituted in products that traditionally use phthalates, such as toys, childcare articles and medical devices. Replacing phthalate plasticizers is not an easy task. Aspects like economics (price and availability), performance (process ability, long term compatibility and others) has to be taken into consideration. There are several companies, which are engaged in the production of phthalate-free plasticizers mainly from citric acid, levulinic acid, soybean or castor oil. The demand for non-phthalate plasticizers will increase significantly around the globe[165].

Table 14: PLASTICIZERS: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	1,337	1,615	1,671	3,597	7,667	16,807
VALUE	3,878	4,618	4,779	8,231	13,157	27,399
	2016	2017	2018	2019	2020	CAGR 2013 - 2020
VOLUME	20,376	24,772	28,647	32,765	37,136	39,6%
VALUE	33,217	40,383	46,701	53,413	60,540	33%

[163] BASF SPI Plasticizer Market Update Phthalates CHAP, July 2011

[164] The Lowell Center for Sustainable Production at the University of Massachusetts Lowell: Phthalates and Their Alternatives: Health and Environmental Concerns, January 2011

[165] Eastman: Global Plasticizer Update; SPI Flexible Vinyl Products Conference, July 2012

The plasticizers market is one of biggest addressable markets for bio-based succinic acid. Bio-based succinic acid has a potential to replace phthalic anhydride and adipic acid in plasticizers. Another possible competitive replacements are 2,5-furandicarboxylic acid, isosorbide and bio-adipic acid, which can be suitable and even have better properties in some cases[166].

Potential customers see the main potential for bio-based succinic acid to find his place in short lifespan products. However, producers would like to target big portions of the market, not only the foil or food wrapping but also flooring, walls and others[167].

In the case of replacing adipic acid in plasticizers by bio-based succinic acid, weastra believes that there are applications where succinic acid has great chances. Bio-based adipic acid will mostly target polyamides (Nylon 6.6), and all of the other applications of todays petrol-based adipic acid are open to be targeted by bio-based succinic. However, the price of bio-based succinic will be important. When comparing to polyester polyols, replacing adipic acid in plasticizers by bio-based succinic acid is of secondary focus[168]. The estimated potential of replacing adipic acid in plasticizers by bio-based succinic acid is projected up to 2.5% of the adipic acid used in plasticizers by 2020[169].

In the case of replacing phthalic anhydride in plasticizes by bio-based succinic acid, weastra expect limited potential[170]. Because of the huge plasticizers market made from phthalic anhydride, the estimated potential of replacing phthalic anhydride in plasticizers by bio-based succinic acid is projected up to 1% by 2020[171].

According to the market model projection, the estimated demand of succinic acid used in plasticizers was at 1,337 tons in 2010 and is expected to reach approximately 37,136 tons by 2020, at CAGR of 39.6% from 2013 to 2020. The overall market value for succinic acid used in plasticizers was $ 3.8 million in 2010 and is expected to reach $ 60.5 million in 2020[172].

Alkyd resins

Bio-succinic acid can be used to replace phthalic anhydride in alkyd resins. Bio-succinic acid offers environmental advantages and cost-effectiveness as well as very similar performance to petrol-based raw materials.

---

[166] weastra – based on primary and secondary market research
[167] weastra – based on primary and secondary market research
[168] weastra – based on primary and secondary market research
[169] weastra market model – based on primary and secondary market research
[170] weastra – based on primary and secondary market research
[171] weastra market model – based on primary and secondary market research
[172] weastra market model – based on primary and secondary market research

Table 15: ALKYD RESINS: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 - 2020

	2010	2011	2012	2013	2014	2015
VOLUME	0	0	0	3,369	6,974	10,828
VALUE	0	0	0	7,709	11,968	17,651
	2016	2017	2018	2019	2020	CAGR 2013 - 2020
VOLUME	11,207	15,465	16,006	16,567	21,433	30%
VALUE	18,269	25,211	26,094	27,007	34,940	24%

The potential for bio-based succinic acid used in alkyd resins seems to be somewhere between polyester polyols and plasticizers. Alkyd resins is a interesting market and weastra expects that it is realistic to replace 2.5% of alkyd resins produced from phthalic anhydride by 2020[173].

According to the market model projection, the succinic acid as a substitute for phthalic anhydride in alkyd resins has been not used in 2010, but is expected to reach approximately 21,433 tons by 2020, at CAGR of 30% from 2013 to 2020. The overall market value for succinic acid used in alkyd is expected to reach $ 34.9 million in 2020[174].

Existing market for bio-based succinic acid

De-icer solutions

Chlorides are the most commonly used de-icer for roadways. Potassium salts are typical non-chloride de-icers used for roadways as well as airport runways and other surfaces. Succinate based de-icing solutions are significantly less corrosive than potassium acetate and potassium formate and sodium chloride brine.

De-icer solutions made from bio-based succinic acid are competing with de-icers made from formic acid. However, de-icing from formic acid have lower cost, but de-icer solutions, which contain succinic acid proved to have better properties especially in area of corrosion[175].

[173] weastra – based on primary and secondary market research

[174] weastra market model – based on primary and secondary market research

[175] weastra - based on primary and secondary market research

Table 16: DE-ICER SOLUTIONS: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 - 2020

	2010	2011	2012	2013	2014	2015
VOLUME	350	420	504	605	762	960
VALUE	840	1,008	1,441	1,384	1,308	1,565
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	1,210	1,524	1,921	2,420	3,049	24%
VALUE	1,972	2,485	3,131	3,945	4,971	19%

According to the market model projection, the estimated demand of succinic acid used in de-icers was at 350 tons in 2010 and is expected to reach approximately 3,049 tons by 2020, at CAGR of 24% from 2010 to 2020. The overall market value for succinic acid used in de-icers was $ 840,000 in 2010 and is expected to reach $ 4.9 million in 2020[176].

Solvents and lubricants

Solvents and lubricants are used in many industrial applications. Bio-based succinic acid used in lubricants is an environmentally friendly solution as base oils and additives in industrial lubricants. Bio-based succinic acid improves flow ability in cold temperatures and offers better prevention of oxidation and corrosion.

In solvents, bio-based succinic acid has a potential on side of ethanol resin based solvents, not methanol resin based, especially because of not good properties of succinic acid, and expensive production. Succinic acid used in solvents dies do not need to have very high purity as for example the succinic acid used in BDO and polyesters. Solvents are not in the primary focus of current succinic acid players[177].

[176] weastra market model – based on primary and secondary market research

[177] weastra – based on primary and secondary market research

Table 17: SOLVENTS & LUBRICANTS: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	1,400	1,610	1,852	2,129	2,449	2,816
VALUE	3,360	3,864	4,532	5,094	4,609	4,590
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	3,238	3,724	4,283	4,925	5,664	15%
VALUE	5,279	6,071	6,982	8,029	9,233	11%

According to the market model projection, the estimated demand for succinic acid used in solvents and lubricant was 1,400 tons in 2010 and is expected to reach approximately 5,664 tons by 2020, at CAGR of 15% from 2010 to 2020. The overall market value of succinic acid used in solvents and lubricant was $ 3.3 million in 2010 and is expected to reach $ 9.2 million in 2020[178].

Pharmaceuticals

Succinic acid has many uses in pharmaceutical industry. It can be used as starting material for active pharmaceutical ingredients including N-methyl pyrrolidinone, 2-pyrrolidinone, as an additive in formulation and as an insulinotropic agent, in the preparation of Vitamin A. The compound can also be used as a cross linker in drug control release polymers[179].

Table 18: PHARMACEUTICALS: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	5,250	6,038	6,943	7,985	9,182	10,560
VALUE	15,750	17,811	20,482	18,844	19,503	19,937
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	12,144	13,965	16,060	18,469	21,239	15%
VALUE	22,927	26,366	30,321	34,869	40,100	10%

178 weastra market model – based on primary and secondary market research

179 http://www.in-pharmatechnologist.com/Ingredients/Bio-succinic-acid-to-go-commercial

According to the market model projection, the estimated demand of succinic acid used in pharmaceutical industry was 5,250 tons in 2010 and is expected to reach approximately 21,239 tons by 2020, at CAGR of 15% from 2010 to 2020. The overall market value of succinic acid used in pharmaceutical industry was $ 15.7 million in 2010 and is expected to reach $ 40.1 million in 2020[180].

Cosmetics

Succinic acid is also used in cosmetics and personal care products. There is a potential for bio-based succinic acid and its derivatives, which can be used as emollients and surfactants. Emollients are used in lotions, liquid soaps and cleansers to improve and moisturize skin, while surfactants are used in soaps, body washes and shampoos to allow easier spreading[181].

Table 19: COSMETICS: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	1,750	2,118	2,562	3,100	3,751	4,539
VALUE	4,550	5,506	6,795	7,851	8,444	8,570
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	5,492	6,646	8,041	9,730	11,773	21%
VALUE	10,369	12,547	15,182	18,370	22,228	17%

According to the market model projection, the estimated demand of succinic acid used in cosmetics was 1,750 tons in 2010 and is expected to reach approximately 11,773 tons by 2020, at CAGR of 21% from 2010 to 2020. The overall market value of succinic acid used in cosmetics was $ 4.5 million in 2010 and is expected to reach $ 22.2 million in 2020[182].

[180] weastra market model – based on primary and secondary market research

[181] weastra - based on primary and secondary market research

[182] weastra market model – based on primary and secondary market research

Food

Succinic acid is currently widely used in food and baking industry. This platform chemical can be used as a flavoring agent, as a pH regulator for food ingredients and as an acidulant, to increase the tartness or acidity of food. Succinic acid can be used also as bread softening agent, for preparing cake flavorings and for dry gelatin desserts[183].

Table 20: FOOD: SUCCINIC ACID MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	4,200	5,040	6,048	7,258	8,709	10,451
VALUE	10,500	12,600	15,422	17,449	19,169	19,397
	2016	2017	2018	2019	2020	CAGR 2010 - 2020
VOLUME	12,541	15,049	18,059	21,671	26,005	20%
VALUE	23,276	27,932	33,518	40,222	48,266	16%

According to the market model projection, the estimated demand of succinic acid used in food was 4,200 tons in 2010 and is expected to reach approximately 26,005 tons by 2020 at CAGR of 20% from 2010 to 2020. The overall market value of succinic acid used in food was $ 10.5 million in 2010 and is expected to reach $ 48.2 million in 2020[184].

[183] weastra - based on primary and secondary market research

[184] weastra market model – based on primary and secondary market research

8. Top players in the field of succinic acid production, research and end use applications

BIOAMBER

Main office:
3850 Annapolis Lane North, Suite 180
Plymouth, Minnesota, USA 55447
Telephone: +1 (763) 253-4480
Website: www.bio-amber.com

Company overview

BioAmber Inc. was established in 2008, in Minnesota. The company is focused on technology innovation and production of green and sustainable chemicals. Since 2008 BioAmber has established an industrial scale facility and developed strategic partnerships in R&D and distribution with several major companies such as DuPont (U.S.), Mitsui & Co. Ltd(Japan), Mitsubishi Chemical Corporation(Japan), Solvay SA(Belgium) and others. BioAmber has one of the largest facilities for the production of bio-based succinic acid which was opened in France, in 2010. The facility is owned by ARD and is a subject of an agreement for exclusive use until June 2013, with an option to extend the term. The development of the organism used by BioAmber was originally funded by the DOE in 1990's., then developed, scaled up and optimized by BioAmber at the facility in France. In partnership with Mitsui & Co. the company is planning to build a global-scale manufacturing facility in Sarnia, Ontario and two additional facilities in Thailand and either the United States or Brazil. The facilities will be producing mainly bio-succinic acid and BDO. BioAmber Inc. distributes its products directly to customers, but also appoints distributors for some regions of the world (e.g. Asia-Pacific).

Financials

BioAmber Inc. reported revenue of $0.97 million in the financial year 2010. During twelve months ended in December 31,2011 the company incurred net losses of $30.9 million. These loses are expected to continue as BioAmber further develops technologies, proprietary processes, builds its operating infrastructure and provides customers with products for testing and verification for their end uses.

The current production capacity for bio-succinic acid is 3000 MT, with plans to expand to 164.000 MT by 2015. The company produced so far 331 MT of bio-succinicum acid at the facility in Pomacle and sold approximately 65.5 MT in samples to 14 customers.

BioAmber has entered into supply agreements for the sale of over 139.000MT of bio-succinic acid and its derivatives over the next five years, including the exclusive supply agreement with Mitsubishi Chemical. The manufacturer believes that bio-succinic acid, 1,4-BDO, THF and PBS, which are all its target products, represent a $10 billion market opportunity.

BioAmber has 28 full time employees and 46 full-time equivalents through various collaboration agreements.

Product and service portfolio

The company's products are bio-based chemicals: bio-succinic acid produced from renewable feedstock; 1,4 butanediol (BDO) and THF made from succinic acid using DuPont's hydrogenation catalyst technology, plasticizers, polymers and C6 building block chemicals. BioAmber already started with the development of bio-adipic acid and also plans to produce bio-based caprolactam and bio-based hexamethylene diamine (HMDA) from renewable feedstock.

Under the conditions that oil price per barrel is $35 and corn price per bushel is $6.50, BioAmber estimates that bio-succinic acid will be produced at cost-competitive price with petrol based succinic. The company believes that their solutions enable them to address multiple large chemical markets that are currently served by petrochemicals, incl. plasticizers, polyurethanes, resins and coatings, lubricants and other. Currently, the manufacturer sells its product directly to customers or indirectly through Mitsui, which is BioAmber's exclusive distributor in the Asia-Pacific region. Further supply and cooperation agreements are planned and developed.

Company strategy

BioAmbers main goal is to replace petroleum based chemicals by bio-based alternatives. The company plans to achieve that by quickly expanding it's manufacturing facilities, constantly lowering the production costs, developing next-generation succinic-derived products and expanding its platform of chemicals to new bio-based building blocks. BioAmber implements an active partnership strategy by forming partnerships and signing agreements with top players of this industry such as Cargill (U.S.) for its microorganism technology, Lanxess for the development of renewable succinic-based plasticizers product line and Mitsui (Japan) for the development of bio-succinic acid plant in Canada and Thailand.

Mitsui was also selected as an exclusive distribution partner in Asia region. BioAmber also has a non-binding letter of intent with Tereos SyralS.A. – a leading European feedstock producer for an additional two facilities to be located in Europe and Brazil.

A part of the strategy is to target and expand on the market of 1,4BDO, for which BioAmber licensed DuPont's technology.

Developments and partnerships

Date	Description
July 2012	Evonik Industries' Catalysts Business Line and BioAmber Inc.formed a long term cooperation for the development and manufacturing of catalysts for making BDO (1,4- butanediol), THF (tetrahydrofuran) and GBL (gamma – butyrolactone) from bio-based succinic acid.
February 2012	The bio-plastics market leader NatureWorks and BioAmber have announced the creation of AmberWorks, a joint venture to bring new performance bio-based polymer compositions to market.
November 2011	BioAmber Inc. with Mitsui & Co. formed a partnership focused on the construction and operation of bio-succinic acid production plant in Sarnia, Ontario, Canada. The first stage of the plant should be by 2013 with an annual production capacity of 17,000 MT . Both companies are aiming for construction of two additional production facilities that will raise their overall succinic acid production capacity, including Sarnia plant, to 164,000 tons and 1,4-butanediol capacity to 123,000 tons.
October 2011	BioAmber formed a partnership with Lanxess for the development of succinic acid based plasticizers where succinic acid is renewable and phthalate-free. Both the companies plan to develop renewable succinic-based plasticizers product line which can exceed the phthalates performance at competitive prices.
September 2011	BioAmber will construct bio-succinic acid unit in Thailand to provide bio-based succinic acid to PTT MCC Biochem Company Limited for the production of polybutylene succinate together with 1,4-butanediol (BDO). Both the plants are scheduled to be operational by 2014. BioAmber's succinic acid facility will have capacity of 65,000 metric tons and has plans to produce 50,000 metric tons of bio-based 1,4-butanediol at the plant.
April 2011	BioAmber and its distribution partner Mitsui & Co. (Japan) formed an agreement with Mitsubishi Chemical Corporation for the supply of bio-based succinic acid to Mitsubishi Chemical. The companies are also carrying out feasibility studies for the construction of a succinic acid plant near the Mitsubishi's proposed PBS production plant in Thailand. The expected cost of the facility is $200 million.
January 2011	BioAmber Inc. and Cargill formed a partnership for the use of Cargill technology in the development of a new microorganism to produce bio-succinic acid. This agreement should help BioAmber to increase its production capacity with minimum investment and lower its cost of production of bio-succinic acid.

November 2010	DNP Green Technology bought remaining 50% stake in the BioAmber, a joint venture between DNP Green Technology and Agro Industries Recherche et Developpement, from ARD.
July 2010	BioAmber, a joint venture between U.S-based DNP Green Technology and France-based ARD, entered into licensing agreement with DuPont Applied BioSciences for the bio-based derivatives of succinic acid. As per the agreement, BioAmber will license certain DuPont's technology whereas DuPont will have right to first refusal to secure off-take from future commercial plants. This transaction helped BioAmber to reduce its time to market by utilizing DuPont's technology to transfer bio-succinic acid into value-added derivative products.
April 2010	BioAmber Inc. chose Mitsui & Co. Ltd as its exclusive distributor for the supply of bio-succinic acid in the Asian market. This agreement will allow BioAmber to penetrate into the Asian bio-succinic acid market much faster bue to Mitsui's strong presence in Asian market.
March 2010	DNP Green Technology signed partnership contract with GreenField Ethanol for the construction of bio-based succinic acid refinery, worth $50 million, for the production of bio-renewable deicer.The technology for producing succinic acid will be licensed from BioAmber Inc.
January 2010	BioAmber Inc. started operations in its first bio-based succinic acid plant in Pomacle, France. The plant has annual capability of producing 2,000 metric tons bio-succinic acid and is made from wheat derived glucose.
November 2009	BioAmber Inc. signed a supply contract with Sinoven Biopolymer Inc. for the supply of bio-succinic acid for the manufacturing of renewable modified polybutylene succinate plastic.
May 2009	BioAmber Inc. signed partnership deal with National Research Council of Canada Biotechnology Research Institute for the development of next generation technology to produce bio-based succinic acid for broad range of industrial applications.

MYRIANT

1 Pine Hill Drive
Batterymarch Park II
Suite 301
Quincy
MA 02169
U.S.
Tel: +1-617-6575-200
Fax: +1-617-6575-210
Website: www.myriant.com

Company overview

Myriant Corporation was founded in 2004 in Quincy, Massachussetts, USA. The main focus of the company is low-cost production of biochemicals that substitute for traditional petroleum-based industrial chemicals from a range of renewable and easily available feedstock. The company has developed a broad pipeline of bio-based chemicals based on its technology which combines proprietary microorganisms and a fermentation process designed to produce high-performing, affordable biochemicals.

Myriant is currently building a 13.700MT succinic acid plant in Lake Providence, Louisiana and has contracts committing customers to buy 100% of each customer's annual succinic acid requirement from Myriant. The plant should begin operations during the first quarter of 2013.

Financials

In 2010 Myriant reported overall revenue of €11,01 million. The company was awarded $50 (€38.6) million by US Department of Energy and $25(€19.3) million by US Departnemt of Agriculture B&I program to help build a succinic plant in USA. Over past year and a half, Myriant has produced 24 metric tons of bio-succinic acid at the pilot plant, as support of the testing programs for current and potential customers. The production capacity of the commercial Louisiana plant should be around 77.000MT by the end of first quarter of 2014.

Myriant's team consists of 68 employees, including 37 scientists and researchers.

Product and service portfolio.

Myriant offers broad portfolio of bio-chemicals including succinic acid, acrylic acid, lactic acid, muconic acid, and fumaric acid to be used in different end markets including biodegradable plastics, chemical intermediates and solvents, food, cosmetics and personal care, inks and pigments, metalworking, and photography. Myriant's biocatalysts are feedstock flexible and can consume sugars from sugarcane, cellulostic sugars from waste biomass and glycerol. After completing start-up and operational trials, the company plans to transition to low cost sugars such as 95 Dextrose.

Myriant's main customers are the following companies:

Company	Agreement conditions
Johann Haltetmann Ltd.	Supply agreement from June 2010 to supply it with 100% of its requirements for succinic acid, no to exceed approx. 9070MT annually. Five year term.
Piedmont Chemical Industries I, LLC	Supply agreement from January 2011 to supply it with 100% of its requirements for succinic acid, with a target volume of approx. 2300MT annually. Five year term.
The Chemical Company	Supply agreement from May 2010 to supply it with 100% of its requirements for succinic acid with a target volume of approx. 2300MT annually. Five year term.
Showa Denko Europe GmbH	Non-binding Heads of Agreement since February 2010 outlining that Showa Denko would purchase Myriant's biosuccinic acid in replacement of petroleum-based succinic acid for use in the production of PBS.
Wilson Industrial Sales Company, Inc	Supply agreement since June 2011 to supply it with 100% of the liquid ammonium sulfate produced at the Louisiana Plant.

Company strategy

Myriant is aiming to accelerate and enlarge its presence on the global market of succinic acid. This growth strategy is pursued through expansion of its production capacities and agreements with major companies.

After unveiling its new procedure for producing bio-based succinic acid from non-food, renewable, and cellulosic feedstock the company is able to form production bases for its succinic acid products. Myriant signed an agreement with Uhde GmbH for engineering and construction of bio-based succinic acid facility at Port of Lake Providence, U.S. It also entered into agreements with Davy Process Technology for the integration of its succinic acid process with the Davy butanediol process for the production of bio-based butanediol, and with PTT Chemical for the commercialization of its bio-succinic acid technology in South East Asia. The company chose Sojitz Corporation (Japan) as its exclusive distributor of bio-succinic acid in Japan, China, South Korea, and Taiwan.

Developments and partnerships

January 2012	Myriant Corporation signed a supply agreement with Showa Denko for the worldwide supply of its bio-succinic acid to the Showa Denko. The bio-based succinic acid will be used for the production of eco-friendly polybutylene succinate.
November 2011	Myriant Corporation chose Sojitz Corporation as a distributor in charge of sales, marketing, and distribution of bio-based succinic acid in Japan, China, South Korea, and Taiwan. The main applications of Myriant's bio based succinic will be in plasticizers, polymers, urethanes, and solvents.
October 2011	Myriant has unveiled a new technology for the production of bio-based chemicals such as succinic acid, both L (+) and D (-) lactic acid, from 2nd generation cellulosic feedstock. This new procedure will enable the company to form production bases for the bio chemicals and supply them for numerous applications.
May 2011	Myriant signs a memorandum of understanding with China National Bluestar Group to develop a proposal for a jointly-owned 99700MT biosuccinic acid plant in Nanjing,China, where the biosuccinic requirements of Bluestar would be fully supplied by Myriant.
May 2011	Myriant signs exclusive alliance agreements with ThyssenKtupp's subsidiary Uhde GmbH, a chemical plant engineering company and its US subsidiary, to integrate their fermentation technology with Uhde's separation technology in the plant design and to provide process and performance guarantees for the future plants on mutually agreeable terms to facilitate access to project finance.
February 2011	Myriant Corporation signed a Memorandum of Understanding to enter into a definitive joint venture development agreement with Johnson Matthey PLC's subsidiary Davy Process Technology for the application of succinic acid as a bio-derived feedstock for the production of butanediol, tetrahydrofuran, and gamma-butyrolactone. The agreement focuses on two main key-points: non-exclusive testing and approval of Myriant's product succinic acid as a feedstock to the Davy process and an exclusive joint development contract for the combination of Myriant bio-succinic acid technology with the Davy butanediol

	technology.
January 2011	PTT Chemical Group made a $60(€46.5) million equity investment in Myriant Corporation Inc. to proceed with the development of bio-based chemicals technology. The investment will also be used for building a large scale bio-succinic production plant in Louisiana, U.S. The investment also carries an agreement to create a joint venture between both the companies to exploit Myriant's technology in Southeast Asia.
December 2010	Myriant Lake Providence Inc., a subsidiary of Myriant Corporation will invest $80 (€62) million into the construction of the largest bio-based succinic acid facility in Louisiana, U.S. The plant should start its operations in 2012 and produce 30 million pounds of succinic acid annually by using sorghum and carbon dioxide. The company received funding of $50 (€38.7) million from the Department of Energy, U.S. and $10 (€7.8) million from Lake Providence Port Commission and the LouisianaDepartment of Transportation.

SUCCINITY (BASF SA – PURAC)

Succinity GmbH is a joint venture between BASF and Purac, a subsidiary of CSM. The company will be operational in 2013. The establishment of Succinity GmbH is subject to filing with the relevant competition authorities. The company headquarters will be in Düsseldorf, Germany.

BASF SA

Main office:
Carl-Bosch-Strasse 38
Ludwigshafen 67056
Germany
Tel: +49-621-600
Fax: +49-62-1604-2525
Website: www.basf.com

Company overview

BASF, founded in 1865 in Germany is the world leading chemical company. The company has 370 production sites located worldwide, 111.000 employees and customers in almost every country in the world. The company manages six main segments which are: Chemicals, Plastics, Performance Products, Functional Solutions, Agricultural Solutions and Oil & Gas. Petrochemicals, inorganics and intermediates are included in BASF's chemical segment.

Financials

In 2011, BASF posted sales of € 73.5 billion from which around 15% are generated by sales of chemicals.

Product and service portfolio

BASF is active in several industries such as aerospace, packaging, agriculture, construction, automotive and others. Chemicals represent one out of the company's six divisions. The company's product portfolio includes succinic acid and its derivatives – BDO, THF, PBS and others.

Company strategy

BASF is planning to address the global challenges by innovations in chemistry and focus on bio-based chemicals. The company strives to develop sustainable production process and development of chemicals based on renewable resources. It also constantly optimizes and diversifies its portfolio of products and services through partnerships and agreements. BASF signed cooperation agreement with the Purac (The Netherlands) for the development 25.000 MT of bio-based succinic acid plant in Spain with plans to expand production capacities to 50.000 MT.

Developments and partnerships

August 2012	BASF, Cargill and Novozymes have signed an agreement to develop technologies to produce acrylic acid from renewable raw materials.
August 2011	BASF SE is planning a joint venture agreement with the CSM, a subsidiary of Purac, to build facilities for the production of bio-based succinic acid. The new production unit will have a capacity of 25,000 tons and will be located at the Purac plant near Barcelona, Spain. The plant is scheduled to be operational by 2013. The companies further intend to build a plant with the capacity of 50,000 tons anticipating growing demand for bio-succinic acid.
September 2009	BASF SE signed co-operation agreement with CSM N.V. for the development and production of bio-based succinic acid. Both the company conducted the study on the development of the industrial fermentation and down-stream processing of bio-based succinic acid and will begin manufacturing of bio-succinic acid at commercial scale in the second quarter of 2010.
January 2009	BASF announced the closure of its 1, 4-butanediol (BDO) and tetrahydrofuran (THF) manufacturing plant in Ulsan, Korea.

PURAC

Arkelsedijk 46
Gorcum 4206 AC
The Netherlands
Tel: +31-18-369-5695
Fax: +31-18-369-5602
Website: www.purac.com

Company overview

Purac was founded in 1931 in the Netherlands as a subsidiary of CSM N.V - a global player in bakery supplies and food ingredients. The company's initial activities were focused on the industrial use of natural lactic acid in dyes for leather and wool. Today Purac is a leading company in natural food preservation, lactic acid based bio-plastics and bio-based chemicals with branches all over the world. The company employs more than 1000 people with production plants in USA, Spain, Brazil, the Netherlands and Thailand.

Financials

In 2011 Purac reported net sales in the amount of € 400 million.

Product and service portfolio

Purac is active in the following markets: food ingredients, bioplastics, bio-based materials, home and personal care, medical and pharma, animal health. In cooperation with BASF the company is constructing a bio-based succinic acid plant in Spain, with a planned capacity of 25.000 MT. The new plant is scheduled to be operational by 2013.

Company strategy

Purac is using white biotechnology for the production of our products during the last 80 years. This makes the company one of the most experienced companies in the production of ingredients and chemicals through fermentation of carbohydrates. Purac's strategy is focused on driving growth through innovation, sustainability and new product development. The company formed a joint venture with BASF (Germany) for the construction of bio-based succinic acid plant in Spain, as it expects the demand for succinic acid will grow strongly in the following years.

Developments and partnerships

November 2011	Purac unveiled new office in Mumbai, India in order to expand its operations in large and growing Indian market. The new office enables the company to better understand local markets and will facilitate in serving bio-based chemicals and bio-plastics markets.
August 2011	BASF SE and CSM (Purac subsidiary) are planning a joint venture agreement to build facilities for the production of bio-based succinic acid. The new production unit will have a capacity of 25,000 tons and will be located at the Purac plant near Barcelona, Spain. The plant is scheduled to be operational by 2013. The companies further intend to build a plant with the capacity of 50,000 tons anticipating growing demand for bio-succinic acid.
September 2009	CSM N.V. signed a co-operation agreement with BASF for the development and production of bio-based succinic acid. Both the company conducted the study on the development of the industrial fermentation and down-stream processing of bio-based succinic acid and will begin manufacturing of bio-succinic acid at commercial scale in the second quarter of 2010.

REVERDIA (DSM – ROQUETTE)

Urmonderbaan 20H
6167 RD Geleen
the Netherlands
Tel: +31 15 279 2503
Fax: +31 15 279 2223
Website: www.reverdia.com

Company overview

Reverdia was formed in June 2010 by the joint venture of Royal DSM N.V., the global Life Sciences and Materials Sciences company and Roquette Frères, the global starch and starch-derivatives company. Reverdia focuses on the production, commercialization and market development of a sustainable succinic acid - Biosuccinium™. Since 2008 the joint venture has been working on the development of the most suitable fermentative technology to produce bio-based succinic acid and in 2011 Reverdia has announced the construction of a commercial-scale with a capacity of 10 kilotons per year, located in Cassano Spinola in Italy.

Financials

Royal DSM N.V. is a global science-based company with 22,000 employees and annual net sales of around € 9 billion. Roquette, a French family group with an international dimension, processes plant-based raw materials, employs 6600 employees and generates more than € 2.5 billion in sales. By 2015 Reverdia is planning to produce 10.000 MT of bio-succinic acid.

Product and service portfolio

Reverdia fully focuses on the production of Biosuccinium™ - a sustainable succinic acid. The product was tested and validated and is of the highest quality and purity which is essential for applications where color and other criteria are important.

Company strategy

Reverdia is aiming to become the global leader in the production, commercialization and market development of Biosuccinium™ by combining the knowledge and experience of DSM and Roquette.

DSM NETHERLANDS

Het Overloon 1
6411 TE Heerlen
The Netherlands
Tel: +31-045-578-8111
Fax: +31-045-571-9753
Website: www.dsm.com

Company overview

DSM is a Dutch company, founded in 1902 as a coal mining company. Today DSM N.V. is a leading global science-based company focused on the production of nutritional ingredients, industrial chemicals and pharmaceutical ingredients. The company is present in more than 50 countries worldwide and employs over 22.000 people. It is strong oriented on innovations, promoting the goal "to brighten the lives of people today and generations to come".

Financials

DSM's net sales for 2011 were € 9,048 million, from which 21% were generated by polymer intermediates and 32% were generated by performance materials. The company has over 150 locations worldwide and more than 10 production facilities located in Europe, China and North America.

Product and service portfolio

DSM's activities are grouped in several business entities: Nutrition, Pharma, Performance Materials, Polymer Intermediates and Emerging business Areas focused on bio-based products, biomedical materials and advanced surfaces. In cooperation with Roquette Frères S.A. the company has developed technology and started the production of bio-based succinic acid. Target markets for its bio-based products include plasticizers, polyurethanes, personal care products, resigns, coatings and other.

Company strategy

The company's strategy is to grow through innovation, meeting the changing needs of the population, to focus on high growth economies through constant development, sustainable products and strategic partnerships. The company formed a joint venture with Roquette Frères S.A. for the manufacturing and commercialization of Biosuccinium™ - a sustainable succinic acid. Their manufacturing facility is planned to achieve a capacity of 10.000MT by 2015.

DSM is also active in the area of production of UPR. The company is currently focused on the task of using itaconic acid in the most effective way for the production of UPR. The company is already planning to start with the commercialization of their itaconic-based UPR. DSM is developing a route for 100% bio-based polyester composites and in May 2012 it published its patent for the production of bio-based polyester composites from itaconic acid.

Developments and partnerships

January 2012	POET and DSM sign a joint venture on advanced biofuels with the goal to commercially demonstrate and license cellulosic bio-ethanol.
May 2011	DSM N.V. and Roquette Frères S.A. announced the plan to construct a commercial scale facility together for manufacturing of bio-based succinic acid. The new plant will be situated at Roquette's site in Cassano Spinola, Italy and will have annual production capacity around 10.000 MT by 2015. It will start operations in 2012.
March 2011	DSM completes the acquisition of Martek Biosciences which will ensure a leading position in poly-unsaturated fatty acids and Infant Formula market and improve company's performance.
June 2010	DSM N.V. signed a joint venture with Roquette Frères S.A. for the manufacturing, commercialization, and market development of bio-based succinic acid. Both the companies will have equal stakes in the new company called Reverdia, headquartered in The Netherlands. Reverdia is planning to produce fermentation based succinic acid and will concentrate on applications such as 1,4-butanediol, polyurethane resins, and polybutylene succinate for use in paints and coatings, automotive, and textiles.

ROQUETTE FRERES S.A.

1 Rue De La Haute Loge
Lestrem
Pas de Calais 62136
France
Tel: +33-032-1633-600
Fax: +33-032-1633-850
Website: www.roquette.com

Company overview

Roquette Frères S.A. was founded in 1933 in Lestrem, France as a starch and starch derivates production company. Today the company is one of the top-ranked processors of starch in the world, a world leader in polyols and a European leader in the production of maltodextrins. Roquette Frères has 5 production plants in France, altogether 17 production units in Europe and the company markets its products in over 120 countries. In 2011 Roquette Frères had 6600 employees.

Financials

The company reported overall revenue of € 2.3 billion, offering more than 700 products divided into several business sectors. In 2010 the company devoted € 50 million to R&D. 10% of company's sales are generated by chemicals and bio-industry.

Product and service portfolio

Roquette offers to its customers more than 700 products derived from starch, divided into the following sectors: human nutrition, paper/corrugated cardboard, animal feed, pharmaceuticals/cosmetics, and chemicals/bio-industry. The company started the production of bio-based succinic acid within the joint venture with DSM N.V (Reverdia) which will concentrate on such applications as 1,4-butanediol, polyurethane resins and polybutylene succinate.

Company strategy

Roquette concentrates on starch and its by-products applying expertise and innovation in order to develop new, cost effective and sustainable products in order to meet the market's needs. The company formed a joint venture (Reverdia) with the Dutch DSM for the production of bio-based succinic acid. Reverdia is building a production plant in Italy, with the capacity of 10.000MT by 2015.

Developments and partnerships

March 2012	Reverdia-joint venture is launched and formally approved by the relevant regulatory authorities. The new facility located in Italy is scheduled to be operational by the end of Q3 2012.
May 2011	Roquette Frères S.A. and DSM N.V. plan together to construct a commercial scale facility for the manufacturing of bio-based succinic acid. The new plant will be situated at Roquette's site in Cassano Spinola, Italy and will have annual production capacity around 10 kilotons.
June 2010	DSM N.V. signed a joint venture with Roquette Frères S.A. for the manufacturing, commercialization, and market development of bio-based succinic acid. Both the companies will have equal stakes in the new company called Reverdia, headquartered in The Netherlands. Reverdia is planning to produce fermentation based succinic acid and will concentrate on applications such as 1,4-butanediol, polyurethane resins, and polybutylene succinate for use in paints and coatings, automotive, and textiles

MITSUI & CO. LTD

2-1 Ohtemachi 1-chome
Chiyoda-ku
Tokyo 100-0004
Japan
Tel: 81-033-2851-111
Fax: 81-033-2859-819
Website: www.mitsui.com

Company overview

Mitsui & Co was founded in 1876 in Tokyo, Japan and currently the group is one of the largest corporate conglomerates in Japan. The company operates in several business segments such as product sales, worldwide logistics, financing, as well as development of international infrastructure in such fields as iron and steel products, metal resources, construction machinery, food resources, marine and aerospace and chemicals. Mitsui & Co has 153 offices in 67 countries and a total number of employees of 44.805. The company markets its products in several countries all over the world including the US, Canada, Brazil, Japan, China, Russia and others.

Financials

Mitsui & Co. Ltd has reported a gross profit of Yen 878.3 billion (€8.8 billion) for the financial year ended in March 2012, with an increase of 2.2% since 2011.

The segment of Chemicals reported a gross profit of Yen 65.2 billion (€0.65 billion) for the financial year ended in March 2012.

Product and service portfolio

Mitsui & Co. is focused on several business segments, offering services and products in the fields of chemicals, consumer services, metal resources, energy, food resources, iron and steel products and others. The company has a basic chemicals unit and a performance chemicals unit.

It collaborates with BioAmber for the construction of a bio-succinic acid plant. The plant will be located at Sarnia, Ontario, Canada and will have a production capacity of 17.000MT. The plant should start the operations in 2013 and be also used for the manufacture of BDO.

Company strategy

The company's aim is to "become a global business enabler that can meet the needs of customers throughout the world." This is planned to be achieved by development of technologies, products and services including becoming a key player in the growing renewable chemicals market. The partnership with BioAmber for the construction of a bio-succinic plant and for distribution of bio-succinic in Asian region is one of the steps made in that direction.

The company secured sustainable feedstock supply in Brazil, Thailand and other countries in line with its strategy for the renewable chemicals.

Developments and partnerships

November 2011	BioAmber Inc. with Mitsui & Co. formed a partnership focused on the construction and operation of bio-succinic acid production plant in Sarnia, Ontario, Canada. The first stage of the plant should be by 2013 with an annual production capacity of 17,000 MT . Both companies are aiming for construction of two additional production facilities that will raise their overall succinic acid production capacity, including Sarnia plant, to 164,000 tons and 1,4-butanediol capacity to 123,000 tons. .
April 2010	BioAmber Inc. chose Mitsui & Co. Ltd as its exclusive distributor for the supply of bio-succinic acid in the Asian market. This agreement will allow BioAmber to penetrate into the Asian bio-succinic acid market much faster bue to Mitsui's

	strong presence in Asian market.

GADIV PETROCHEMICAL INDUSTRIES ISRAEL

Hahistadrut Blvd.
Haifa 31000
Israel
Tel: 97-24-8788-020
Fax: 97-24-8788-018
Website: www.gadiv.com

Company overview

Founded in 1974, Haifa (Israel) based Gadiv Petrochemical Industries Ltd. operates as a subsidiary of Oil Refineries Limited and as a sister company of Carmel Olefins Ltd. and is one of the major petrochemical companies in Israel. It is one of the leading petrochemical companies in Israel. The company is engaged in the production and marketing of petrochemical products and industrial chemicals to several industries including chemical, plastics, food, and pharmaceutical. Gadiv Petrochemical Industries Ltd. markets its products in over 20 countries across Europe, North America, and the Far East.

Recently, the company has completed a organization change with the intention of building a basis for the future developments in the petrochemical industry. For this purpose a petrochemical sector has been established, of which Gadiv is part of.

Financials

Gadiv manufactures and markets over 500.000MT of 15 different products which enabled the company to penetrate new markets all over the world. All of Gadiv's feedstock is supplied by Oil Refineries Ltd. (Bazan), the neighboring parent company and sister company Carmel Olefins Ltd., thus facilitating optimization of the production system.

Product and service portfolio

Gadiv's product range can be divided into 3 categories: aromatic hydrocarbons, aliphatic solvents and intermediates. Gadiv is a producer of petrol based succinic acid, phthalic anhydride and fumaric acid.

All of Gadiv's intermediates are produced with full standard certification and GMP, FCC and Kosher authorization.

Company strategy

Gadiv's marketing strategy is based on long term relationships with its existing customers as well as building good business relations with potential new customers. The company aims at expanding its presence on the global succinic acid market by offering new products and services according to the changing needs of the customers.

Developments and partnerships

The company is now in the process of preparing its units for the receipt of natural gas and thus be able to meet the tougher demands of the environment protection agencies.

MITSUBISHI CHEMICAL JAPAN

1-1 Marunouchi 1-chome, Chiyoda-ku,
Tokyo 100-8251, Japan
Tel: +81 3 6748 7300
Fax: +81 3 3286 1210
Website: www.m-kagaku.co.jp

Company overview

Mitsubishi Chemical Corporation was established in 1950. In October 2005 Mitsubishi Chemical Corporation merged with Mitsubishi Pharma Corporation to form Mitsubishi Chemical Holdings Corporation, headquartered in Tokyo, Japan. The company started its operations by primarily focusing on the production and marketing of industrial materials, performance and healthcare products. Nowadays Mitsubishi Chemical Corporation produces a broad range of chemicals with application in different industries such as automobiles, aicrafts, food, agriculture, healthcare and others. The company has several plants and R&D offices in Japan and subsidiaries in US, Europe and Asia-Pacific.

Financials

The company reported net sales for 2011 in the amount of Yen 2,080,902 with an increase of 9% as compared to 2010. It has 7 production plants in Japan and 27,689 employees.

Product and service portfolio

The main segments of production on which Mitsubishi Corporation is focused are the following: Electronics Segment, Performance Chemicals Segment, Health Care Segment, Petrochemicals Segment, Carbon Segment and Polymers Segment.

The company is constructing a PBS plant in Thailand and conducting feasibility studies for the development of succinic acid production facility to be positioned next to the plant for PBS. PBS is one of the potential and applocations market for bio-based succinic acid.

Company strategy

Mitsubishi aims to cread "Good Chemistry for Tomorrow" [185]by redirectinf its focus on the bio-based chemicals business. During the last couple of years the company has formed several partnerships in order to broaden its possibilities in the production and commercialization of green chemicals. It formed a joined venture with PTT PLC(Thailand) for the development of a PBS plant in Thailand and partnered with BioAmber for the supply of bio-based succinic acid. Mitsubishi Corporation also penned a Memorandum of understanding with Genomatica (US) for the production of bio-based 1,4butadeniol at commercial scale in Middle East region.

Developments and partnerships

September 2011	BioAmber and its distribution partner Mitsui & Co. (Japan) formed an agreement with Mitsubishi Chemical Corporation for the supply of bio-based succinic acid to Mitsubishi Chemical. The companies are also carrying out feasibility studies for the construction of a succinic acid plant near the Mitsubishi's proposed PBS production plant in Thailand. The expected cost of the facility is $200 million.

[185] Corporate website, Group Vision - http://www.m-kagaku.co.jp

May 2011	Mitsubishi Chemicals signed partnership agreement with Genomatica Inc. for the production of bio-based 1,4-butanediol at commercial scale and further intends to produce other bio-based chemicals such as butadiene, propylene, and purified terephthalic acid. The company is planning to build bio-based 1,4-butanediol manufacturing plant with annual capacity of 40,000-50,000 MT in Middle East region or in Asia and is expected to come on stream by 2015. The output of this plant will be used for the production of its GS Pla biodegradable plastic.
September 2009	Mitsubishi Chemical Corporation signed a Memorandum of understanding with PTT Public Company Limited for conducting joint study for business development of bio-polybutylene succinate, a bio-degradable polymer, derived from biomass resources in Thailand. Mitsubishi is planning to produce its GS Pla, a biodegradable polymer from bio-based succinic acid.

NIPPON SHOKUBAI CO. LTD

Kogin Bldg., 4-1-1 Koraibashi
Chuo-ku
Osaka 541-0043
Japan
Tel: 81-066-2239-111
Fax: 81-066-2013-716
Website: www.shokubai.co.jp

Company overview

Nippon Shokubai was founded in 1941 in Tokyo, Japan and currently it is the leading[186] supplier of superabsorbent polymers in the world. It is also actively engaged in the production of acrylic acid. In general, the company is focused on producing and marketing a broad range of chemicals, focusing on three main business segments: basic chemicals, functional chemicals, environment and catalysts.

[186] Corporate website - http://www.shokubai.co.jp

Nippon Shokubai has production centers and offices in USA, Asia and Europe, most of its R&D being concentrated in Japan.

Financials

Nippon Shokubai reported a revenue of Yen 288,345 million for the financial year 2011 with an increase of 11,08 % as compared to 2010. As of March 2012 the company has 3779 employees.

The company is a global leader in the production of superabsorbent polymers with a total annual capacity of 470.000 MT.

Product and service portfolio

Nippon Shokubai's business divisions are the following: Ethylene Oxide, Acrylic Business Division, Fine and performance chemicals, E & I materials, Catalysts and Green Energy business division.

The company produces petrol-based succinic acid for food applications such as sake, synthetic Liquor, soy sauce, soft drinks, and confectionery.

Company strategy

The company's strategy by 2015 is to strengthen its position and business competitiveness and on the market, as well as develop new technologies and products for a greener future. It will also focus on expanding its possibilities within the market of bio-based succinic acid through a strong sales network and new-patented technologies. Nippon Shokubai Co. Ltd has developed a technology platform that combines industrial biotechnology, an innovative purification process, and chemical catalysis to convert renewable feed stocks into chemicals for use in a wide variety of products, including plastics, food additives, and personal care products.

ANQING HEXING CHEMICAL CO. LTD

Industry Park, Economy and Technology Area
Anqing, Anhui 246005
China
Tel: +86 556 5345 315
Fax: +86 556 5345 507
Website: www.hexinggroup.com

Company overview

Anqing hexing chemical CO.,LTD, was established in 1998 and represents one of the main producers and exporters of succinic acid and disodium succinate in Anhui Province and an important enterprise of organic pigments in China. The company mainly operates in China and exports its products to several countries in Europe, America and Asia.

Financials

The last reported financial numbers are from 2008 when Anqing hexing chemical had sales of $3.1 million (CNY20.15 million). Currently it has a production capacity of 8000 MT of succinic acid, representing 10% of the total succinic acid production for 2011.

Product and service portfolio

The company's product portfolio includes petrol-based succinic acid, disodium succinate, polybutylene succinate, triphenylphosphine succinic anhydride, succinimide, dimethyl succinate, diethyl succinate, dibutyl succinate, calcium succinate, succinate and other medical intermediates.

Company strategy

Anqing hexing chemical is focused on strengthening its position of the Chinese as well as foreign markets through expanded production capacities, innovative products and lower production costs. The succinic acid market as well as succinic acid derivates will remain the company's main target market. In May 2009, the company has enhanced its polybutylene succinate capacity to 10,000 tons catering to the growing need of bio-based plastic products.

Developments and partnerships

May 2009	Anqing Hexing Chemical Co. Ltd. started a new production line for the manufacturing of polybutylene succinate (PBS) in Anhui Province, China. The new production unit has annual capacity of 10,000 MT of PBS. The company is intending to enhance its PBS capacity to 60,000 tons per year within few years.

KAWASAKI KASEI CHEMICALS LTD

17F Kawasaki-ku
Kawasaki-Shi 210-0007
Japan
Tel: +88 44 246 7100
Fax: +88 44 246 7462
Website: www.kk-chem.co.jp

Company overview

Kawasaki Kasei Chemicals was founded on May 20, 1948 under the corporate name of Chuo Kasei Chemicals Ltd. At that time the company was focused on the refining and processing of tar. Nowadays Kawasaki Kasei Chemicals produces a large variety of chemical products, including succinic acid. All plants and research laboratories of the company are located in Japan.

Financials

In 2011 Kawasaki Kasei Chemicals reported a revenue of $183.4 million. Kawasaki Kasei Chemicals produced 13% on the world production of petrol-based succinic acid in 2013.

Product and service portfolio

The company's product portfolio includes organic acid products, its derivatives and quinine products. Among them there is succinic acid, phthalic anhydride, fumaric acid, plasticizers and polyester polyols.

Company strategy

Kawasaki Kasei Chemicals is constantly striving to strengthen its position on the global market by offering innovative products at competitive costs. The company intends to expand its activity on the market of organic chemicals and its derivatives, including the market of succinic acid, plasticizers and polyester-polyol.

LIXING CHEMICAL

10#, Zhongwanglu,
Jixi County Eco-industrial Park,
Anhui, China
Tel: +86 563 816 5518
Fax: +86 563 816 7310
Website: www.lixingchem.com

Company overview

Lixing Chemical was established in 1992 and currently represents a specialized in the production of fine chemical products. The company lays on an area over 20.000 sqm, on which research, production and sales are located. Lixing Chemical is cooperating with several universities in China in order to be innovative and offer the market new products and lower costs. The company's products are exported to Europe, the United States, Japan and South Korea and Southeast Asia, and many other countries. Lixing Chemical is a well-known company in the Anhui area of China for offering quality products which correspond to international standards and have the necessary certification.

Financials

In 2011, Lixing Chemical reported annual sales in 192 million Yuan RMB, and direct exports in $7.5 million. It employs 250 employees and its production of succinic acid represents 17% of the total global output for 2011.

Product and service portfolio

Lixing Chemical has a product portfolio that is divided into the following series: ether solvent series, chlorobenzene series, organosilicon and biochemical series. The company's existing equipment production capacity is 10000 tons/year.

Company strategy

Lixing Chemical is striving to maintain its position on the Chinese market as a well known player who offers qualitative and innovative products. It cooperates with universities and has its own research institute. Also, Lixing Chemical is aware of the strong position of the foreign market, which is why the company is open to growth and expansion through cooperation and partnerships.

2,5 – FURANDICARBOXYLIC ACID

1. INTRODUCTION

2,5-Furandicarboxylic acid (FDCA) is an oxidized furan derivative, which is a very stable compound. FDCA is a natural di-acid, at first detected in human body[187]. Despite its chemical stability it undergoes reactions typical for carboxylic acids (halogen substitution, ester and amid formation). Because of its potential as a replacement of several petroleum based platform chemicals, e.g. terephthalic acid, adipic acid and other important di-acids by polymerization, the production of FDCA was in last decades in the focus of the science.

Until today FDCA was never commercialized in an industrial volume, because it was not possible to produce it in an economic way. The main problem of economics of FDCA production, despite of more than thousand studies written since 1895 in this field, is the instability of the intermediate needed for the production of FDCA - 5-hydroxymethylfurfural (HMF). The synthesis of 2,5-Furandicarboxylic acid is much easier than the synthesis of HMF, where the main problems are the need of expensive catalysts, need of high pressure, decomposition of HMF to levulinic and formic acid, separation of DMSO and toxicity of byproducts if DMSO if used as a solvent.

FDCA nowadays is produced mainly for scientific usage with the price of over $ 2,300 / kg. In last few years there were some promising results in economically feasible production of FDCA, based on new reactive separation technologies and novel catalysts based on Nanoflow technology with the lead of Avantium, Spin-off from Royal Dutch Shell.

The main focus of usage of FDCA as a potential platform chemical for renewable chemicals is in renewable plastics. The direct substitution of FDCA for terephthalic acid in polymer synthesis has been known since the 1970´s[188]. The replacement of terephthalic acid in polyesters (e.g. polyethylene terephthalate – PET) leads to a promising novel property bio based product, with a huge market potential.

If the production of FDCA will be economically viable (at around $ 1000 / MT), the demand for bio-based FDCA is projected to experience a massive growth. A lot of currently used petrol based chemicals as well as the most of currently developed bio-based routes and bio-based intermediates (e.g. succinic acid, levulinic acid) could be replaced by FDCA. The chemical properties of FDCA lead to end products with better characteristics which are manufactured by technically easier production processes with lower quantities of by-products. FDCA could become the most interesting platform chemical for next few decades, however there are still questions regarding its economics of the production and the price of FDCA, and also regarding the availability of necessary bio mass (C6 sugars) to cover the enormous potential demand of FDCA.

[187] Witten, T.A.; Levine, S.P.; King J.O.; Markey S.P. Clin. Chem. 1973, 19, 586-689

[188] A. Gandini, Adv. Polym. Sci. 1977, 25, 47 - 96

2. VALUE CHAIN

Biomass based hexoses (glucose, fructose, manose) can be used as a feedstock for the production of FDCA. The most convenient process in terms of chemical yield by preparation of 5-Hydroxymethylfurfural – the intermediate for FDCA is the acid catalyzed dehydratation of fructose. Although fructose has been the main feedstock to prepare HMF in optimal yield, glucose is a more abundant and inexpensive monosaccharide; therefore it seems to be more efficient in mass production as fructose.

Methods for the synthesis of FDCA can be divided into three groups[189]:

- Methods based on the dehydration of hexose derivatives
- Methods based on the oxidation of 2,5 – disubstituted furans
- Methods based on catalytic conversions of various furan derivatives

The synthesis of FDCA directly from fructose would be the most interesting route to obtain FDCA. This route was even reported – by the catalytic one-pot cyclization and oxidation of fructose over bifunctional acid redox catalysts, namely cobalt acetylacetonate, encapsulated in sol-gel silica[190].

Current industrial usage of FDCA is limited by the economic inefficiency of its production. But according to the chemical structure of FDCA, there is a huge potential for replacing petrol-based acids in polymer applications, such as terephthalic acid, isophthalic acid, adipic acid, bisphenol A or phthalic anhydride. The field of industrial potential of FDCA in polyesters, polyamides, resins, plasticizers, polyurethanes and solvents as a bio-based product is enormous.

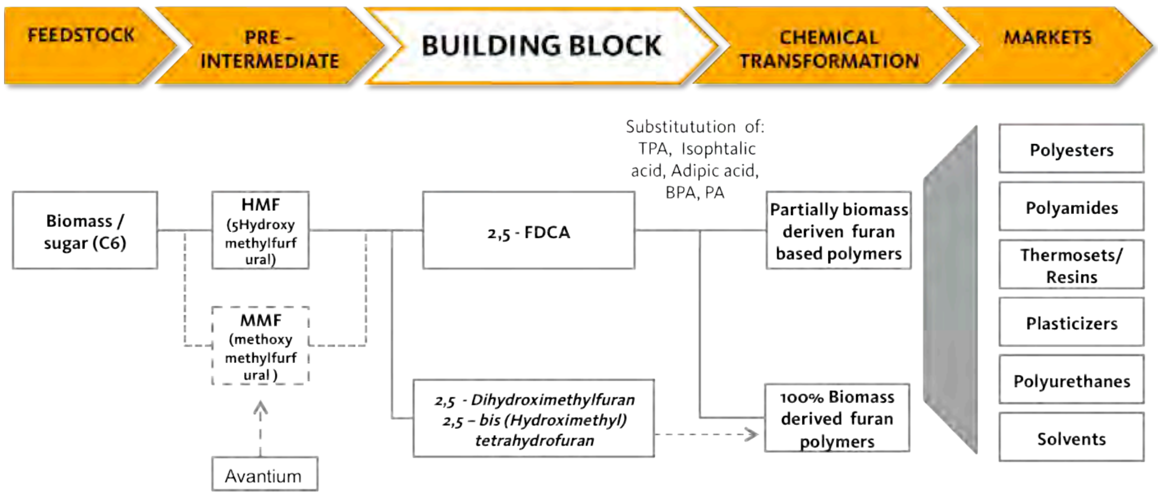
With substitution of alcohol components in production of polymers with derivatives of HMF 100% biomass derived furan polymers can be produced.

The value chain of 2,5-Furandicarboxylic acid is shown in Figure 18.

[189] Lewkowski, J.: Arkivoc 2001, 17-54

[190] M.L.Ribeiro and U. Schuchardt, cooperative effect of cobalt acetyl acetonate and silica in the catalytic cyclization and oxidation of fructose to 2,5-furandicarboxylic acid, Catal. Commun. 2003, 4, 83-86

Figure 18: VALUE CHAIN OF 2,5-FURANDICARBOXYLIC ACID



Currently FDCA is used in very small amounts for scientific tests. It is valuable as an intermediate for pharmaceuticals, agrochemicals, insecticides, antibacterial agents, fragrances and so forth. FDCA has applications in pharmacology as a base for anaestheticum and antibacterial pharmacology. A diluted solution of FDCA in tetrahydrofuran is utilized for preparing artificial veins for transplantation. FDCA as most of polycarboxylic acids can be an ingredient of fire foams. Such foams help to extinguish fires in a short time caused by polar and non-polar solvents.

3. GLOBAL MARKET OF FDCA

Currently there are only a few of companies, which produce and sell FDCA on demand, as there is no economic viability behind its usage.

The current estimated production is between 3.5 and 5 MT a year with a value of approximately $ 10 million. The price is influenced by purity and quantity and is over $ 2.300 / kg[191].

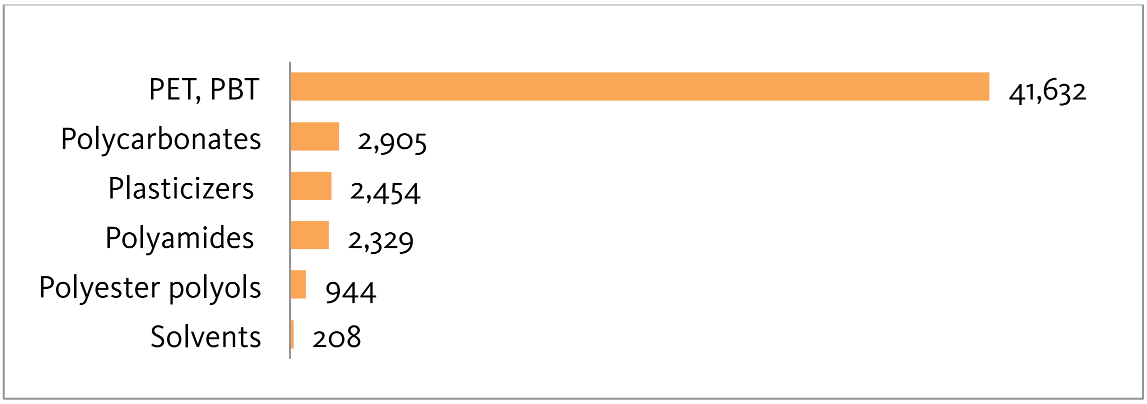
The main current producers of FDCA are Synbias, V & V Pharma Industries, Carbone Scientific Tokyo Chemical Industry and Chemsky. There are also a few other companies, which are able to produce FDCA, but none of them is focusing on this product, the real production is always tailor made - on request.

4. ADDRESSABLE MARKET OF FDCA

The addressable market in this market report means the theoretical market potential for FDCA in case of being the winning technology replacing 100% of other chemical specific end use application.

According to the chemical structure of FDCA, the addressable market for this platform chemical is huge, mainly due to the variety of applications in which FDCA can be used as a substitute.

Figure 19: ADDRESSABLE MARKET VOLUME FOR FDCA, based on the markets size for 2011 (IN THOUSANDS TONS)



[191] weastra – based on primary and secondary market research

There are currently five major new markets that FDCA can address as a replacement for petrol-based chemicals, such as terephthalic acid (in the production of PET, PBT and polyamides), bisphenol A (in polycarbonates), adipic acid (in the polyester polyols and plasticizers), phthalic anhydride (in the polyester polyols and plasticizers), possible is also isophthalic acid (in the production of PET) but is not in the primary focus. In the field of polyamides market, FDCA do not have big ambitions to be used as a replacement but as platform chemical for completely novel polyamides.

The market of solvents is not in the primary focus of current FDCA producers, but there is a strong potential in this area for usage of FDCA. There might be a huge potential for FDCA in solvents as platform chemical for novel property solvents.

The total addressable market for FDCA is approximately 50.5 million MT based on the current markets size (2011) [192].

For the purposes of the weastra market model, weastra counted with a replacement ratio of 1:1 in relevant applications for the respective building blocks.

Terephthalic acid

Terephthalic acid (TPA), one of three isomeric phthalic acids is one of the most important precursors in the plastic sector. The main market, where TPA is used is the polyester production - mainly polyethylene terephthalate (PET), textiles, packaging, furnishing, consumer goods, coatings, resins.

The two most common grades of TPA commercially used are Purified Terephthalic Acid (PTA) – with content of 99,9% of TPA and less than 400 ppm 4 Carboxibenzaldehyde (4-CBA) and Medium quality terephthalic acid (MTA) with content of TPA 99,90% but with up to 400 ppm of 4-CBA. The use of MTA is changing the color of the end product, which is not acceptable in the industry.

Nearly all PTA is consumed in the production of PET bottle resins, polyester fibers and polyester films. Only a small part of terephthalic acid production is used in semiaromatic and aromatic polyamides. Dimethyl terephthalate (DMT) is used more often in the production of Polybuthylene terephthalate (PBT) engineering resins, however the manufacture of PBT with DMT is more expensive than with TPA. The main cause of using DMT instead of TPA is the design and technological equipment of existing plants and lack of ability to new technological investments. New PBT plants are built on TPA as feedstock. The global consumption of PTA is over 50 million tons/year. Almost half of TPA production is consumed by the Chinese market. For Asia as such, this number counts over 75%[193] of total consumption. However, more than half of TPA production is also based in Asia (China, Republic of Korea, and Taiwan). The growth of production capacities in last years, and

[192] weastra market model – based on primary and secondary market research

[193] weastra – based on primary and secondary market research

also the planned investments to TPA production are mainly in two regions – Asia-Pacific and Middle East. Nowadays China is an importer of TPA and is planning in the next few years a huge domestic Terephthalic acid industry expansion. ICIS expects Chinese capacities of PTA to approximately 39 mil tons in 2015[194].

More than 90% of TPA produced in the world is used to polymer for polyester fibers and PET solid-state resin for packaging applications, mainly bottles. As PTA counts 70% of PET resin content[195], where the rest (30%) is mono-ethylene glycol (MEG) which is currently produced in a bio based way, there is a push on replacement of petrol based PTA with a bio platform to get a 100% pure bio PET resin. The current production of PTA is based on the oxidation of para-xylene and purification of the crude intermediate terephthalic acid. There are several activities on the market in field replacement of the petrol based PTA production by a bio way, forced mainly by main food and beverage producers – Coca Cola, Pepsico, Danone (as PET is the mostly used bottle packaging for beverages).

There are several bio-based terephthalic acid production routes on stream:

1. ***Bio TPA through isobutanol:*** sugar – isobutanol – bio PX – bio TPA
   The companies, which are active in this area are: GEVO (with Toray), Global Bioenergies, Butalco, Butamax (DuPont). As isobutanol is also used in bio fuel industry, there might be a focus rather on this area in the future, depending on the market potential of bio fuels.The GEVO – Toray consortium has a lab scale for bio PET production - Toray used terephthalic acid synthesized from Gevo's biobased para-xylene and commercially available renewable mono ethylene glycol (MEG) as raw materials. In June 2011[196] the consortium successfully produced PET samples and achieved PET polymerization by applying the new technology. Gevo signed a cooperation contract in this field also with Coca Cola.

2. ***Bio TPA through mucoic acid:*** sugar – mucoic acid – bio PX – bio TPA
   The companies, which are active in this area are: Drath (Amyris), Genomatica.

3. ***Bio TPA through xylenes:*** biomass – BTX – bio PX – bio TPA
   The companies, which are active in this area are: Anello tech, Virent.
   The route of TPA production based on xylens seems to be an economically effective and competitive way to petrochemical TPA production. Virent declares the production of xylene based TPA under the brand BioFormPX in their pilot scale capacities in Madison. Virent is working now on the commercialization of the product through PET supply chain companies, e.g. Coca Cola.

4. ***Bio TPA through Terpens:*** biomass – limonene – bio PX – bio TPA

[194] ICIS - PTA expansions threaten margins, May 2012; www.icis.com
[195] weastra – based on primary and secondary market research
[196] TORAY - www.toray.com

The companies, which are active in this area are: Sabic

5. ***FDCA to replace TPA:*** biomass – HMF (resp.MMF) - FDCA
The companies, which are active in this area are: Avantium
The drop in replacement of TPA by FDCA seems to be more valuable than the other bio TPA ways, because the end product of PET polymerization (polyethylene-furanoate -PEF)has additional novel properties. Avantium signed a cooperation contract in this field with Coca Cola and Danone.

6. ***Bio TPA through other routes:***
There are also other players working on bio TPA, however up until today it is not clear what bio routes they are focusing on. These players are Chemtex (M&G) and UOP (Honeywell)

Because of the chemical structure of FDCA, which allows an easy drop in replacement for terephthalic acid, and also for its significant market potential, TPA is the main target platform chemical for FDCA producers. TPA is a real low hanging fruit. However, even if the mass production of FDCA does start very soon, to replace just a small part of TPA will take at long time period, because of the market volume and need of investments to production – the facing curve has to be projected with focus on longer term. Therefore the rest of platform chemicals, which will be described in this chapter, have a rather small possibility to be replaced in a short time by FDCA, despite the compatibility of their chemical structure to FDCA.

There are opportunities for FDCA to replace terephthalic acid mainly in the production of PET and PBT. The total addressable market volume of FDCA as a replacement of terephthalic acid is approximately 43 million MT with a value of $ 43 billion based on the current markets sizes (2011). This addressable market theoretically accounts with 40.7 million MT for PET, 885,000 MT for PBT and 1.3 million MT for polyamides[197].

Isophthalic acid

Purified isophthalic acid (PIA) is mainly used as an intermediate in the production of unsaturated polyester resins, alkyd resins (surface coatings), and inks, reinforced plastics and packaging applications. The fastest growing application is its usage as a comonomer by the PET bottle resin production. The main role of PIA in polymers is the upgrading of some attributes of the end product, such as hardness, corrosion and stain resistance, hydrolytic and thermal stability and low resin color.

PIA is produced by catalytic oxidation of metaxylene in acetic acid. The current market volume of isophthalic acid weastra estimates at around 600,000 MT. Actually, there is global overcapacity for isophthalic acid. The main consumer of PIA is China, with a market share of approx. 25%, US and

[197] weastra market model - based on primary and secondary market research

Europe, both around 20%. Despite of relatively low market volume of PIA comparing to TPA, and low market price driven by overcapacity, there is a limited space for drop in replacement of PIA by FDCA.

Adipic acid

Adipic acid is a key raw material mainly in plastics and polyamide industries. The main end uses are the industries, which are producing products from nylon (6.6), but also polyester resins, fibers, polyurethane, plasticizers and lubricants.

Adipic acid has the total market volume of approximately 2,940,000 MT with the value of $ 6.45 billion in 2011. Nylon 6,6 is the largest market for adipic acid, which accounts for 60% of total consumption.[198] Nylon 6,6 is primarily used in the production of carpets and rugs. The second largest market with a 25% share of total consumption of adipic acid consists of polyester polyols, which are used in polyurethanes.

The opportunities to replace adipic acid by FDCA are in a theoretical way, as the chemical structure of FDCA allows to use it e.g. in the polyamide production. In the reality, if bio-based adipic acid will come to economically effective production, the potential for a replacement of adipic acid by FDCA is rather small. There are opportunities for FDCA to replace adipic acid in applications such as in polyurethanes and plasticizers, which are even higher, than to replace it with succinic acid, as properties of FDCA are better. However within this research weastra did not find companies, which are working on a drop in replacement of adipic acid by FDCA, players are rather working on development of FDCA based novel product (polyamides, polyurethanes) with novel properties.

The major producers of petrol-based adipic acid are: Invista, BASF AG, Ascend Performance Materials, Asahi Kasei Corporation, Sumitomo Chemical Co, Rhodia, SK Capital Partners, Shandong Haili Chemical Co.

There are also several companies, which are currently working on the development of bio-based adipic acid. In the next few years, DSM plans to enter the market with their bio-based adipic acid. Also Myriant is having bio-based adipic acid in its pipeline. Companies, which are also looking into producing adipic acid from renewable feedstock, include Verdezyne, BioAmber, Rennovia and Genomatica [199].

However, the total addressable market volume of FDCA as a replacement of adipic acid is approximately 882,000 MT with a value of $ 882 million based on the current markets sizes (2011). This addressable market accounts with 735,000 MT for polyester polyols and 147,000 MT for

[198] ICIS - DSM adds adipic acid to bio-based chemicals portfolio; October 2011; www.icis.com

[199] ICIS - DSM adds adipic acid to bio-based chemicals portfolio; October 2011; www.icis.com

plasticizers[200].

Bisphenol A

Bisphenol A (BPA) is an organic chemical compound, which functions as the building block for polymers. More than 99% of BPA is converted into polycarbonate plastic. Only a very small amount of all BPA produced is used as an essential antioxidant in soft PVC plastics.

The global market volume of BPA on 4.15 million MT[201]. The main consumers of BPA are Europe and US, all with a market share of over 25%, however the fastest growing demand is in Asia, mainly China - with market share of 20%. The main portion of BPA and polycarbonate resin investments has taken place in Asia. Polycarbonate plastic is the main use of BPA, accounting for approx. 70% of total BPA demand.

BPA is produced from phenol and acetone. BPA can leach into food and drinks from the protective epoxy resin coatings of canned foods or beverages and from such consumer products as polycarbonate tableware, plastic food storage containers and reusable hard plastic bottles.

BPA belongs to a group of hormone disruptors, which are able to disrupt the chemical messenger system in the human body. BPA is also linked to children obesity and as a risk factor to brain tumor. Therefore in the last years there are legal measurements leading to eliminate BPA in plastics for children, and also a push on elimination of BPA as such. The acetone compound can already be produced through a bio route (ABE process or Hock process). There are also other replacements for BPA, e.g. isosorbid.

The total addressable market volume of FDCA as a replacement of BPA used for production of polycarbonates is approximately 2.9 million MT with a value of $ 2.9 billion based on the current markets sizes (2011)[202].

Phthalic anhydride

Phthalic anhydride, generally manufactured from o-xylene, is a major chemical intermediate used as a raw material to produce plasticizers, coatings and polymer resins.

weastra estimates the total market volume of phthalic anhydride to be approximately of 4.2 million MT with the value of approximately $ 5.6 billion. Plasticizers form the largest market of phthalic

[200] weastra market model - based on primary and secondary market research

[201] weastra - based on primary and secondary market research

[202] weastra market model - based on primary and secondary market research

anhydride, which could account more than the half of total consumption. Plasticizers are primarily used in the production of plastics, especially polyvinyl chloride (PVC) and are added to improve the properties of plastics. Unsaturated polyester resins represent the second largest market with ca 1/5 of total phthalic anhydride consumption. Weastra counts 15% of total phthalic anhydride consumption on alkyd resins. The consumption of phthalic anhydride for production of polyester polyols is not more than 5% of total phthalic anhydride market[203].

Since 1999 the EU has restricted the use of some phthalates (phthalate esters) in the production of children's toys. In 2008, the U.S. government fully restricted the usage of three phthalates and temporary restricted the usage of another three phthalates to compose not more than 0.1% of any children's product for ages 12 and under. In 2005, the EU restricted the use of six phthalates in children's products, and in 2011 Canada restricted the use of six phthalates to a quantity below 1,000 milligrams per kilogram in the composition children's toys and childcare products.

Due to the increasing ban on phthalates, the demand from manufacturers who are looking for phthalate free chemicals also grew. FDCA could replace phthalic anhydride also in polyester polyols, however this market is not in the primary interest of current FDCA market players.

The total addressable market volume of FDCA as a replacement of phthalic anhydride is approximately 2.5 million MT with a value of $ 2.5 billion based on the current markets sizes (2011). This addressable market accounts with 209,000 MT for polyester polyols and 2.3 million MT for plasticizers[204].

[203] weastra market model – based on primary and secondary market research

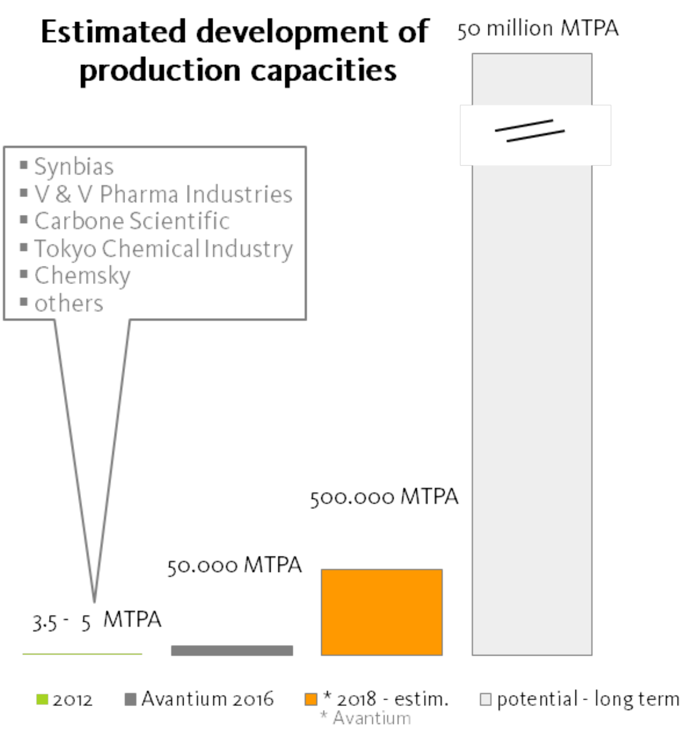
[204] weastra market model - based on primary and secondary market research

5. POTENTIAL CAPACITIES OF FDCA

Based on new reactive separation technologies and novel catalysts Avantium declared the effective and economically feasible way of production of FDCA with a price of around $ 1000 / MT since 2016. The company is nowadays operating a pilot plant in Geelen (Netherlads) with a total capacity of 40 MT. There is a plan to start the first industrial FDCA production in 2016 within an industrial plant with a capacity of 30,000 – 50,000 MT, which will be operated by Avantium. The company plans the real commercialization starting from 2018 onwards, on a base of license production with total capacity of 300,000 – 500,000 MT [205].

There can also be other potential producers, as several patents in the area of HMF, resp. MMF and FDCA synthesis were done in last few years. E.g. the Wisconsine Alumni Research Foundation has developed a method for selective dehydration of carbohydrates (preferably fructose) to produce furan derivatives (mainly HMF) with high yields in a separation friendly solvent[206]. Despite of this and other patents available in this area, no other than Avantium published agreements on commercialization were done yet.

Figure 20: DEVELOPMENT OF FDCA PRODUCTION CAPACITIES[207]

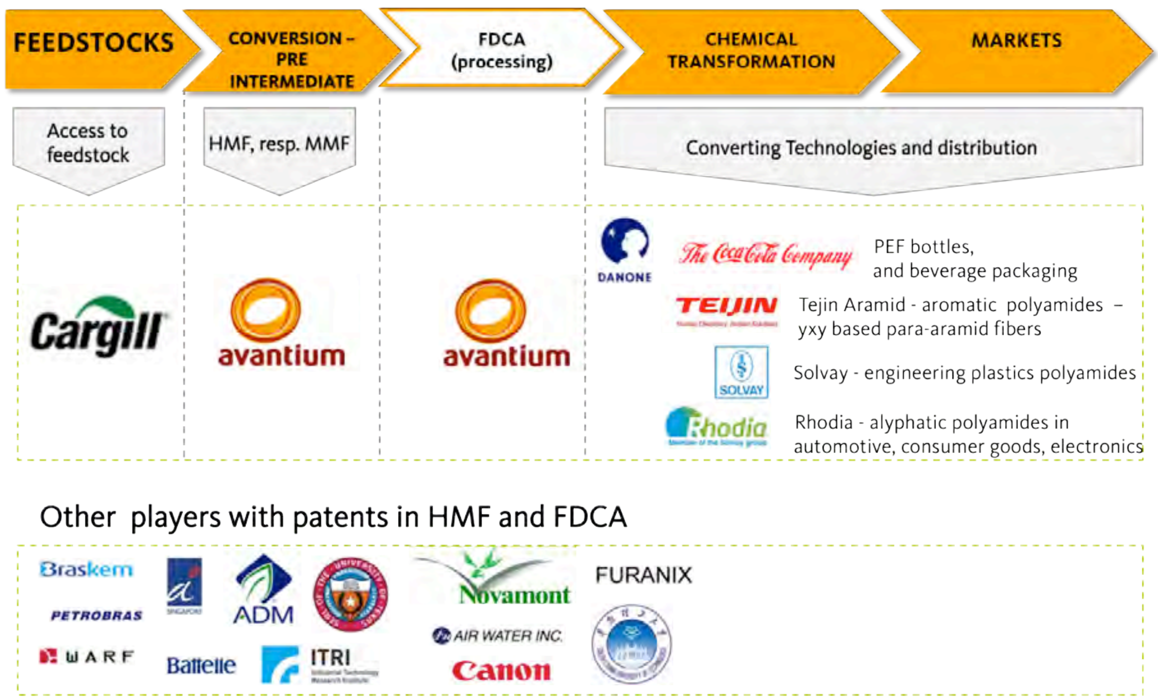


[205] Avantium: weastra primary market research and interviews
[206] Wisconsin Alumni Research Foundation - http://www.warf.org/
[207] weastra – based on primary and secondary market research

6. MARKET MECHANISM

Accessibility of feedstock as well as flexibility of feedstock used will play a big role in future. The mass production of FDCA has to be served by huge feedstock input – non food (second, third generation). The most important players becoming those on the beginning of value chain, they can become a gatekeeper for the whole chain. It seems that establishment of strategic consortiums and partnerships leading through the whole value chain are necessary.

Figure 21: MARKET MECHANISM



Avantium currently publicly discloses these partnerships in production and commercialization of FDCA. One of the main global players in field of feedstock is becoming Cargill directly or through its daughter NatureWorks. Avantium has teamed with Cargill Inc., for access to starch-based sources such as syrups. NatureWorks is also conducting in-house testing of a selection of Avantium's polymers for a range of applications, such as personal electronics, automotive, fibers and other engineering plastics applications. Avantium identified through novel chemocatalytic approaches via high-throughput screening experimentation catalysts. Based on it, they formulated a stable HMF ether derivative under acidic conditions through its proprietary catalyst. The patented catalytic chemical process converts carbohydrates into furanic compounds. Avantium's catalytic process has several benefits such as cost efficiency, processing time and environmentally friendly production over the biological production. The technology can also be equipped into the existing refineries and chemical plants. The company plans to license the technology for commercialization on an industrial scale.

The Coca-Cola Company has partnered with Avantium to develop bio-based PEF bottles for its products (Coca-cola has this kind of cooperation also with other companies developing a bio based replacement of purified terephthalic acid as the main compound of PET – Gevo, Virent) [208].

Danone Research and Avantium have entered into a Joint Development Agreement for the development of PEF bottles for Danone, which is the second largest player on a worldwide scale in bottled water business[209].

Avantium partnered with Teijin Aramid for the development of the novel materials in the category of aromatic polyamides – furan based para aramid fibers[210].

In June 2011, Solvay and Avantium partnered to jointly develop a next generation of green high-performance polyamides for engineering plastics. Solvay and Avantium target a next generation of polyamides with new properties that can serve a range of applications. Subsequently, Solvay Specialty Polymers will test these polyamides for engineering applications in areas such as automotive and electronic materials. Solvay and Avantium have entered into a multi-year, exclusive collaboration towards commercialization of the new polyamides.

Rhodia, member of the Solvay Group, and Avantium announced that they have entered into a partnership to jointly develop a range of new bio-based polyamides targeting a variety of applications. Rhodia will test these new polyamides for fibers and engineering applications in various areas such as consumer goods, automotive and electronic materials[211].

[208] weastra – based on primary and secondary market research
[209] weastra – based on primary and secondary market research
[210] weastra – based on primary and secondary market research
[211] weastra – based on primary and secondary market research

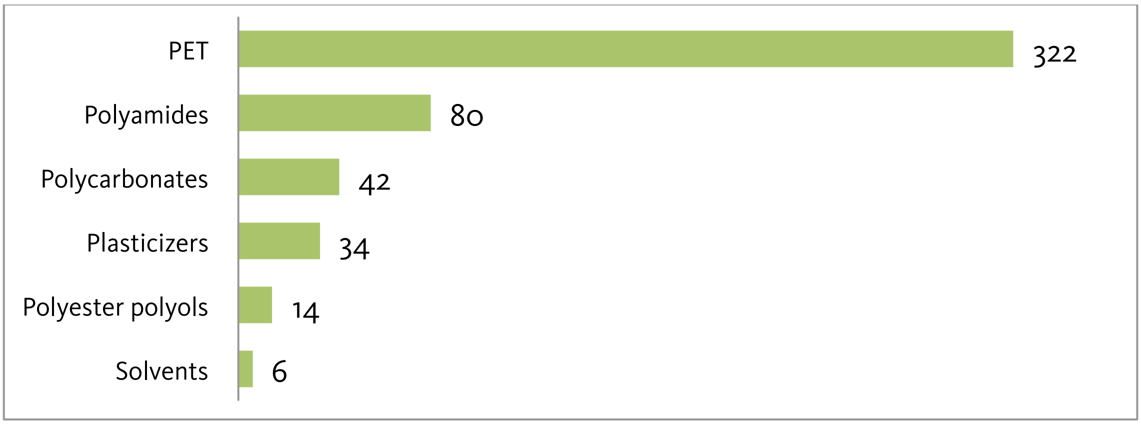
7. PROJECTED MARKET OF FDCA BY APPLICATIONS

Most of the interviewed players see biggest future potential for 2,5 – Furandicarboxylic acid (FDCA) in the replacing the purified terephthalic acid (PTA) in PET and in brand new applications with novel properties, especially new polyamides. However, using FDCA acid in those applications would be economically viable only in case when the price of FDCA acid would be competitive with the price of chemicals, which it is targeting for replacement[212].

The current price for FDCA is over $ 2,300 / kg and is influenced by purity and quantity. From 2016, weastra expects the FDCA price to go down to approximately $ 1,000 / MT.

With regard to the realization of planned development and investments, planned capacity and performance in targeting applications and other possible bio-based routes and intermediates, the projected market for FDCA is estimated to approximately 498,0016 MT with the value of approximately $ 498 million in 2020[213].

Figure 22: PROJECTED MARKET VOLUME FOR 2,5 – FURANDICARBOXYLIC ACID IN 2020 (IN THOUSANDS TONS)[214]



When divided by its separate markets, the market for FDCA will be split as follows: in PET it will be 322,459 MT, in polyamides it will be 80,000 MT, in polycarbonates it will be 42,314 MT, in plasticizers it will be 33,714 MT, in polyester polyols it will be 13,711 MT, and in solvents 5,816 MT[215].

[212] weastra - based on primary and secondary market research

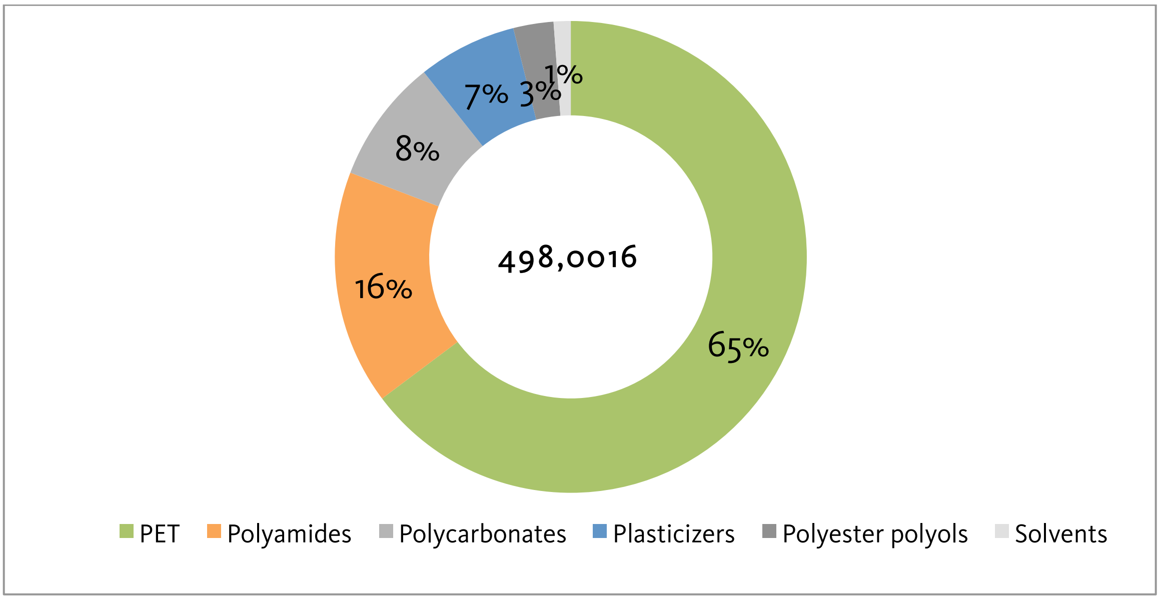
[213] weastra market model - based on primary and secondary market research

[214] weastra market model - based on primary and secondary market research

[215] weastra market model – based on primary and secondary market research

From the view of possible end use applications, FDCA is playing a role in two different ways. On one hand, FDCA is targeting the existing applications by replacement of existing petrol-based intermediates. On the other hand, FDCA has a strong potential to become a novel intermediate for brand new applications with novel properties, creating completely new markets.

Figure 23: PROJECTED FDCA MARKET SHARE, BY APPLICATIONS IN 2020



The biggest market potential for FDCA will be in applications as PET and polyamides – especially new polyamides with novel properties. In 2020, the largest projected application for FDCA will be PET, accounting for 65% of the global FDCA market. Polyamides will account for 16% of global market, polycarbonates will account for 8% and plasticizers for 7% of global FDCA market in 2020[216].

PET

Commercial production of PET is on the market since 1950´s. PET is one of the most commonly used polymer product, which is produced by polycondensation of terephthalic acid or its dimethyl ester with ethylene glycol (EG). As PET is used mainly in the food and beverage packaging, there is a push towards its bio route based production. The EG part of PET is already commercially produced through a bio-based way, based on bioethanol, replacing 30% of the petrol intermediates in the final PET. In 2010 the Coca Cola company launched the plant bottle, a PET bottle with bio-based EG and oil-based PTA. With replacement of terephthalic acid by FDCA and by using of renewable EG, a 100% renewable polyester, such as 2,5-furandicarboxylate (PEF) can be produced. The production of PEF is

[216] weastra market model – based on primary and secondary market research

known and patented since 1946[217]. Since the publication of this patent a lot developments in this field were published (e.g. Osaka university, Moore, Canon Kabushiki Kaisha, Mitsubishi, Gandini, others).

Comparing the properties of the newly synthesized PEF relative to PET the following characteristics are observed: The glass transition temperature (Tg) of PEF is higher while the melting temperature (Tm) is lower and PEF has a higher Heat deflection temperature (HDT) than PET. PEF has higher tensile strength but hardly any elongation to break. This elongation is much lower than with PET. The rate of Quiescent Crystallization is lower than with PET, interestingly preform crystallization is not observed in the required heating window. Drawing & strain hardening/SIC of PEF is similar with PET. PEF does have a higher density than PET both at low and high crystallinity, while haze and hydrolysis rates are similar. One of the most important characteristics of polyester bottles is their barrier property. The oriented PEF bottles have barrier properties for both H_2O and CO_2 more than 2 times better while the barrier properties for O_2 is even more than 6 times better[218]. With novel properties, the PEF has a strong potential to completely replace the PET in beverage bottle industry.

Avantium operates a pilot plant at the Chemelot site (Geleen, the Netherlands) for production and processing of furanics. Part of this pilot plant is focusing on polyester, and will be used to produce a wide range of furan-based polyesters with an aim to optimize catalysts compositions as well as additives formulations on a small scale. As the commercialization of PEF in case of successful development is secured by business contracts with the most relevant market players (Coca Cola, Danone), there is a huge potential to use almost all of FDCA commercial scale production in the next few years exactly in this area.

Table 21: PET: FDCA MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	0	3	6	20	20	21
VALUE	0	7,497	14,637	45,228	46,584	47,982
	2016	2017	2018	2019	2020	
VOLUME	35,813	44,264	253,291	292,196	322,459	
VALUE	35,813	44,264	253,291	292,196	322,459	

Purified terephthalic acid (PTA) is currently produced at 45 - 55 million MT per year with a current

[217] Drewitt, J.G.N.; Lincoln, J. Br. Patent 621971, filed November 12, 1946.

[218] E.de Jong, M.A.Dam, L. Sipos, G.-J.M. Gruter: Furandicarboxilic Acid (FDCA), A Versatile Building Block for a Very Interesting Class of Polyesters. In ACS Symposium Series; American Chemical Society: Washington, DC, 2012

price of around $ 1100 – 1200 / MT, of which the high majority in the PET production is used.

Avantium declares, that at >300k MTPA scale the price of FDCA will be < $ 1000 per ton, and therefore competitive with PTA produced at the same scale. By this price and the need of investments to develop and implement new production technologies, the market of FDCA replacing the PTA in PET is expected to reach approximately 322,459 MT by 2020. The overall market value for FDCA used in PET is expected to reach $ 322.5 million in 2020 [219]. The estimated potential of replacing terephthalic acid in PET with FDCA is projected up to 0.6% of the terephthalic acid used in PET by 2020[220].

PBT

PBT is also prepared via the same route as PET, but using a different diol – 1,4-butanediol (BDO), or the trans esterification of dimethyl ester of terephthalic acid with BDO. The market of PTA in production of PBT is currently in a minor focus, regarding to the current market volume (only 1/50 of the PET market) development of the product and of its commercialization and incomparable lower market potential towards PET. The diol part of PBT (BDO) is currently being produced already the bio-based way (see chapter: Succinic acid, of this study) and for the future the fully 100% bio PBT could become an interesting bio-polymer product. However, PBT is mainly used in the automotive and electrical/electronic sectors, where the push on the bio based production is not as significant as e.g. by food and beverage packaging. For the next period of time, despite of the potential, until 2020 weastra does not expect the usage of FDCA in the production of PBT.

Polyamides

Polyamides are semi-crystalline polymers with very good mechanical properties excellent sliding and wear characteristics. Polyamides are divided into 3 groups – aliphatic PA, polyphthalamides and aramides. The main commercially used PA is the aliphatic nylon (6 or 66). Type 6,6 Nylon 101 is the most common commercial grade of nylon, and Nylon 6 is the most common commercial grade of molded nylon.

The main intermediate in the PA production is the adipic acid. As there are several companies working on commercialization of bio-based adipic acid, there is space for this bio platform chemical to be successful in field of PA production – as a drop in replacement of adipic acid by bio-based adipic acid could aim a bio polyamide with the same properties as a petrol based, by a comparable price using the same production technologies.

[219] weastra market model – based on primary and secondary market research
[220] weastra market model – based on primary and secondary market research

Weastra expects the potential of FDCA in polyamides to be rather in the development of novel property bio products[221].

As Avantiun signed several contracts in field of development and commercialization of these polyamides (Tejin, Solvay, Rhodia), the premises for the development are prepared. Also other companies are currently working on the bio-based polyamide development (BASF, DSM, Verdezyne, DuPont, Arkema and others), based on several bio-based routes, e.g. castor oil, azealic acid, 9-octadecenioic acid, etc.

Table 22: POLYAMIDES: FDCA MARKET VOLUME (TONS) & MARKET VALUE ($ THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	0	1	3	5	8	10
VALUE	0	2,300	6,900	11,500	18,400	23,000
	2016	2017	2018	2019	2020	
VOLUME	500	1,000	30,000	50,000	80,000	
VALUE	500	1,000	30,000	50,000	80,000	

The main competitive advantage of bio-based polyamides will be in their novel properties towards existing, or bio- adipic acid based PA´s. By the price of FDCA at around $ 1000/MT and the need of investments to develop and implement new production technologies – as for the FDCA production, as well for the FDCA based PA production, weastra expects the potential of FDCA in this area in 2020 at around 80,000 MT with the value of $ 80 million[222].

The real potential of FDCA in polyamides until 2020 is strongly determined by the FDCA production capacities development and the price of FDCA.

Polyester polyols

Plans for the production of polyurethanes based on FDCA is currently not published by any of relevant market players, however the structure of FDCA allows the potential development of novel bio based polyurethanes. Polyurethanes are high performance synthetic polymers – extremely

[221] weastra – based on primary and secondary market research

[222] weastra market model – based on primary and secondary market research

versatile plastics, which are used in soles for footwear, molded foams for automotive applications like car seats and arm rests, and in non-foam applications such as coatings, adhesives and sealants. Polyurethane market is an emerging market for bio platform chemicals. Nowadays they are used in production of PUR several renewable resources, e.g. soybean oil, castor oil, sunflower oil, etc. Polyurethanes have recurring urethane groups in the main chain. They are produced by reacting of polyols with isocyanate. Isocyanate is so far derived from petrochemical feedstock.

Polyester polyols are one of two types of polyols used in polyurethanes and they are typically made from di-acids and glycols. The two main types of polyols used in polyurethane industry include polyethers and polyesters.

In this area there is a potential for FDCA in replacement of phthalic anhydride and also adipic acid. As the investments into production technologies, processes and methods, which could replace phthalic anhydride seems to be significant, the current market players are not declaring a high willingness to change.

When speaking about the replacement of adipic acid by FDCA, as mentioned before, bio-adipic acid is a strong competition in this field. Bio-based adipic acid might change the focus of producers of polyurethanes if thinking of bio-based production, as bio-based adipic acid could be a drop in replacement, without any needs of technical investments or innovations.

There is a variety of bio based – sugar fermentation chemicals, which can be used by production of polyester polyols such as azealic acid, dimer acid, glutaric acid. Currently a very small portion of polyols is derived from succinic acid (see chapter succinic acid).

Table 23: POLYESTER POLYOLS: FDCA MARKET VOLUME (TONS) & MARKET VALUE ($THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	0	0	0	0	0	0
VALUE	0	0	0	0	0	0
	2016	2017	2018	2019	2020	
VOLUME	0	516	3,185	9,369	13,711	
VALUE	0	516	3,185	9,369	13,711	

Weastra expects the main potential for FDCA based polyols in novel products with novel properties, however getting new products to the consumer is more difficult and time consuming, than just replacing the existing petrol based platform chemicals with a bio-based one, by the same properties of end products. Therefore weastra estimates the market of FDCA in polyester polyols until 2020 rather just for development and testing of new products, with a market volume for FDCA not higher than 14,000 MT in 2020[223].

The estimated potential of replacing adipic acid in polyester polyols by FDCA is projected up to 0.2% of the adipic acid used in polyester polyols by 2020[224] and the estimated potential of replacing phthalic anhydride in polyester polyols by FDCA is projected up to 4% by 2020[225].

Plasticizers

Plasticizers are organic esters. FDCA esters can be used as replacements for some of the major phthalate-based plasticizers, which account for more than 85% of total all plasticizers production worldwide. World plasticizers consumption was estimated at 6.4 million MT in 2011[226].

Phthalic anhydride and its derivatives are hot candidates for the replacement by bio-based chemicals, as negative impacts of phthalates on the human body and on the environment are leading to legislation tightening in this area in even more countries worldwide. A number of substances have been identified as alternative non-phthalate plasticizers. These alternatives include citrates, sebacates, adipates, and phosphates.

There are several companies, which are engaged in the production of phthalate-free plasticizers mainly from citric acid, levulinic acid, soybean or castor oil. One of the target markets of the bio-based succinic acid producers is the market of plasticizers. However, according to primary research, FDCA has better properties in this field than succinic acid (e.g. solubility).

[223] weastra market model – based on primary and secondary market research

[224] weastra market model – based on primary and secondary market research

[225] weastra market model – based on primary and secondary market research

[226] Cullen S.: Global Plasticizer Update; SPI Flexible Vinyl Products Conference July 2012. http://ww.plasticsindustry.org

Table 24: PLASTICIZERS: FDCA MARKET VOLUME (TONS) & MARKET VALUE ($THOUSAND), 2010 – 2020

	2010	2011	2012	2013	2014	2015
VOLUME	0	0	10	10	10	11
VALUE	0	0	21,962	22,731	23,527	24,350
	2016	2017	2018	2019	2020	
VOLUME	11	1,418	6,283	13,235	33,716	
VALUE	11	1,418	6,283	13,235	33,716	

Weastra expects an increase of demand for non-phthalate plasticizers, which should be a potential for the FDCA. But as mentioned previously, there are easier drop in replacement possibilities (e.g. in PET production), which for FDCA producers is a low hanging fruit market with the main focus in next few years. Even if FDCA as a platform chemical for plasticizers shows an economical potential, weastra estimates, that in this area in the next decade FDCA will be used just for development and testing of new products, which would lead to a market volume for FDCA in this applications not higher than 34,000 MT with the value of $ 33.7 million in 2020[227]. For now, no relevant market player declares mass production of FDCA based plasticizers and also no publicly known contracts were disclosed on the market.

The estimated potential of replacing adipic acid in plasticizers by FDCA is projected up to 1% of the adipic acid used in plasticizers by 2020[228] and the estimated potential of replacing phthalic anhydride in plasticizers by FDCA is projected up to 1% by 2020[229].

Polycarbonates

Polycarbonates belong to group of thermoplastic polymers. Polycarbonates of bisphenol A are clear plastics used to make shatterproof windows, lightweight eyeglass lenses. It is made from bisphenol A (BPA) and phosgene.

The use of polycarbonates for the purpose of food storage is controversial. There are several studies demonstrating the impact of bisphenol A on the hormonal system of human body. BPA is present in

[227] weastra market model – based on primary and secondary market research
[228] weastra market model – based on primary and secondary market research
[229] weastra market model – based on primary and secondary market research

many of the products we all use every day. The European Food Safety Authority is permanently mapping the impact of BPA on human body and as a first step prohibited the production of BPA-containing baby bottles from March 2011 and bans import and sale in the EU from June 2011. The same trends in legislation are in USA and Canada, and they are expected to become worldwide trends in a short period of time.

The potential replacement of BPA in polycarbonates (and also in epoxy resins) by a bio-based intermediate is therefore a challenge for chemical companies. There are bio based alternative bio routes for BPA replacement (e.g. isosorbid produced from cornstarch, but other sugar-containing materials can also function as raw material), however the current consumption of BPA in polycarbonates and epoxy resins weastra still estimates on ca. 3.8 million MT[230].

Table 25: POLYCARBONATES: FDCA MARKET VOLUME (TONS) & MARKET VALUE

	2010	2011	2012	2013	2014	2015
VOLUME	0	0	0	0	0	0
VALUE	0	0	0	0	0	0
	2016	2017	2018	2019	2020	
VOLUME	0	1,974	4,184	31,048	42,314	
VALUE	0	1,974	4,184	31,048	42,314	

FDCA as base for replacement of BPA is currently developed only in a theoretical way. Weastra expects that economically viable way of FDCA production could very quickly increase the interest of polycarbonate producers for this platform chemical. For now no relevant market player declares the interest of FDCA based polycarbonates and also no publicly known contracts were disclosed on the market between potential FDCA producers and other chemical companies in this area.

Despite the big potential, weastra estimates that in the next decade FDCA will be used just for development and testing of new products in this area. According to weastra market model, the market volume for FDCA in this application will not be higher than 43,000 MT in 2020[231]. The estimated potential of replacing bisphenol A in polycarbonates with FDCA is projected up to 0.9% of the bisphenol A used in polycarbonates by 2020[232].

[230] weastra market model – based on primary and secondary market research

[231] weastra market model – based on primary and secondary market research

[232] weastra market model – based on primary and secondary market research

Solvents

Despite the fact, that solvents are not in the primary focus of current FDCA producers, there is a strong potential in this area for usage of FDCA. Solvents are used in many industrial applications and the total market of solvents counts to approximately 20 million MT[233].

As classical petrol based solvents are generally highly dangerous for human health and for the environment, several bio based materials were developed and used in last few years, e.g. fatty acid methyl esters, methyl soyate, ethyl lactate, D-limonene, etc. These bio-based solvents have been in fact successful only on niche markets. The potential for these solvents is much higher, what documents the scientific and development activities of big multinational chemical companies in this area.

The new trends are leading to novel solvents, as e.g. ionic liquids, where more than 1,000 patents were done in the last decade. However also behind the production of ionic liquids are still a lot of questions regarding the economic viability, the toxicity or their recycling (where other organic solvents are necessary).

Another way towards green solvents leads through replacement of conventional organic solvents by biogenic solvents. Conversion of furfural to tetrahydrofouran (THF) is one of the possibilities. There is also the potential for FDCA in the area of solvents. THF is mainly used in the process of production of polytetramethylene ether glycol (PTMEG), a major raw material in the manufacturing of spandex fibers. The growth of PTMEG market leads to increase of demand for THF.

The main challenge in the bio-based production of THF is the price, as the production costs of bio THF are not yet economically competitive. There are also other bio based solvent possibilities, as e.g. N-methylpyrrolidone (NMP).

[233] Natural Resource Base in the Chemical Industry, Groving Markets for Bio-Based Polymers, Lubricants and Surfactants.; http://www.chemmanager-online.com

Table 26: SOLVENTS: FDCA MARKET VOLUME (TONS) & MARKET VALUE

	2010	2011	2012	2013	2014	2015
VOLUME	0	0	0	0	0	0
VALUE	0	0	0	0	0	0
	2016	2017	2018	2019	2020	
VOLUME	0	0	1,349	2,801	5,816	
VALUE	0	0	1,349	2,801	5,816	

There might be a potential for FDCA in solvents also as a base for novel property solvents. As for now, no relevant market player declares the production of FDCA based solvents and also no publicly known contracts were signed on the market between potential FDCA producers and solvent producers. Weastra estimates that in this area in the next decade FDCA will be used just for development and testing of new products. According to weastra market model, the market volume for FDCA in this application will not be higher than 6,000 MT in 2020[234].

[234] weastra market model – based on primary and secondary market research

8. TOP PLAYERS – in field of FDCA production and research

AVANTIUM

Zekeringstraat 29
1014 BV Amsterdam
The Netherlands
Tel.: +31 (0)20 586 8080
Fax: +31 (0)20 586 8085
Email: info@Avantium.com
Website: www.avantium.com

Company overview

Avantium is a privately held Research & Technology company in Amsterdam. A consortium of venture capital funds that has the goal of transforming the world of R&D and developing new generation bio-based plastics and chemicals supports it. Avantium provides high-throughput equipment and services for chemical and pharmaceutical clients. Specifically, the biochemical producer uses a parallel catalyst-testing platform called Nanoflow for its catalyst development work. The company inherited the basis of the technology from oil conglomerate Royal Dutch Shell, from which Avantium was formed. It subsequently advanced the technology and developed several proprietary features to enable the testing of heterogeneous catalysts under industrial conditions. The use of its Nanoflow technology allows the company to run many experiments within its 64 fixed-bed lab-scale reactors as effectively and economically as petrochemical platforms. By the catalytic way of production of methoxymethyl furfural (MMF) as a stable alternative to HMF and its oxidation to 2,5 FDCA they declare an economically feasible way of FDCA production. For now they using 1st generation sugars and starch crops. Avantium calls its furanic chemistry platform "YXY."

Financials

The company is backed by an international group of venture capital firms, including Sofinnova Partners, Capricorn Cleantech and Aescap. Currently it employs 120 people and operates one pilot production plant which was a €30 million investment.

Product and service portfolio

The group is a global leader in the catalytic conversion of fossil- and bio-based feedstock and a leading provider of catalyst development services & systems.

The use of HTS in its technology platform has been essential to Avantium's goals of creating a bio-based alternative to petroleum-derived polyethylene terephthalate (PET) by using bio-based ethylene glycol, and replacing purified terephthalic acid (PTA) with its platform chemical 2,5-furandicarboxylic acid (FDCA). The YXY technology can be also applied in making advanced biofuels.

Company strategy

Avantium aims to help world leading companies to make their products and packaging more renewable. The group is planning to achieve that by actively seeking partnerships and collaborations with forward-thinking in order to accelerate the process of transferring to renewable materials. Avantium believes that its two production technologies along with the rapid growth of the group through partnerships and acquisition will be able to meet the constantly rising demand of the market for renewable solutions. Currently they operate an Yxy pilot plant in Chemelot (NL) – 40 t/y (2011). Avantium plans an industrial plant 30,000 – 50,000 t/y (2016), which will be fully owned and provided by Avantium. As the industrial plant works well the main strategy of Avantium is to run on license base commercial plants with overall capacity 300,000 – 500,000 t/y (2018).

Developments and partnerships

Avantium teamed with NatureWorks (Cargill subsidiary) to help commercialize its furanics and to access to starch-based sources such as syrups. In 2011 Avantium acquired Jeff Kolstad – who commercialized PLA in NatureWorks. Avantium also signed Cooperation agreements in end uses – agreements on testing, and commercialization of

- Polyesters:
  - Coca Cola: plant bottle production – polyethylene2,5 furandicarboxylate (PEF) bottles to replace PET,
  - Danone: production of PEF instead of PET
- Polyamides:
  - Tejin Aramid: production of aromatic polyamides (aramides) – yxy based para-aramid fibers
  - Solvay: production of engineering plastics polyamides
  - Rhodia: production of polyamides in automotive, consumer goods and electronics

THE WISCONSIN ALUMI RESEARCH FOUNDATION (WARF)

Wisconsin Alumni Research Foundation (WARF)
614 Walnut Street, 13th floor
Madison, WI 53726
Telephone: 608.263.2500
Fax: 608.263.1064
Email: info@warf.org
Website: www.warf.org

Company overview

Since its founding in 1925 as the patenting and licensing organization for the University of Wisconsin-Madison, WARF has been working with business and industry to transform university research into products that benefit society. WARF intellectual property managers and licensing staff members are leaders in the field of university-based technology transfer. They are familiar with the intricacies of patenting, have worked with researchers in relevant disciplines, understand industries and markets, and have negotiated innovative licensing strategies to meet the individual needs of business clients.

Warf manages more than 800 pending and 1,300 issued U.S. patents on UW-Madison technologies, as well as more than 2,000 international equivalents. It offers more than 1,000 technologies for licensing and maintains more than 380 active commercial license agreements. WARF has completed more than 30 percent of its license agreements with Wisconsin companies and holds equity in 37 UW-Madison spin-off companies.

UW-Madison faculty researchers have developed a method for the selective dehydration of carbohydrates (preferably fructose) to produce furan derivatives (preferably HMF). This new process provides a cost-effective way for making these valuable chemical intermediates, which could replace key petroleum-based building blocks used in production of plastics, fine chemicals, diesel fuel and fuel additives. The method is more commercially viable than those previously developed because it yields a higher concentration of HMF and produces HMF in a separation-friendly solvent which does not require difficult extraction processes. The dehydration process employs a two-phase reactor system in which a reactive aqueous phase containing fructose and a chemically modified acid catalyst is contacted with an organic extracting phase modified with a C1-C12 alcohol (preferably 2-butanol). Currently, the researchers are producing furfural from corn stover.

Developments and partnerships

The Wisconsin Alumni Research Foundation (WARF) is seeking commercial partners interested in developing a cost-effective and high-yield procedure to synthesize furan derivatives (e.g., 5-hydroxymethylfurural (HMF), furfural, dimethylfuran, etc.) for use as monomers, diesel fuel precursors and fuel additives.

9. CURRENT FDCA PRODUCERS (offering FDCA produced by an orthodox and expensive method, on kg scale)

SYNBIAS LTD.

Synbias Ltd.
Legal address: Chlupina str. 9/2, Donetsk 83017 Ukraine
Office address: Rosa Luxemburg str. 70, Donetsk 83114 Ukraine
Mail address: P.O.Box 6153 Donetsk 83114 Ukraine
Tel/Fax: +38 062 3322 533/4
Website: www.synbias.com

Company overview

Synbias Ltd is a producer of fine chemicals that was founded in 1993 in Donetsk, Ukraine. The main activities of the company are research, manufacturing and trading. Most of its trading partners are within Ukraine and ex-Soviet countries. The company has 52 employees, including highly qualified chemists and ex-researchers of academic institutes. The research and manufacturing facilities of the company have all necessary equipment for the manufacturing on analytical reagents and for custom organic synthesis (the main direction are aromatics and N-heterocycles). The company's analytical laboratory is certified by Ukrainian Committee for Standardization and Metrology.

Financials

Synbias declared preceding year sales in the amount of $ 1 500 000 (€ 1,152,101). It is situated on an area of 2150 sq. meters which is rented but for next year the company is planning to build its own laboratory and storage facilities. Lasr year Synbias produced 1000kg of FDCA and its esters.

Product and service portfolio

Synbias offers over 450 types of fine chemicals, among which is also 2,5-Furandicarboxylic acid which is usually produced based on contract manufacturing.

FDCA is produced from carbohydrate with a stable quality of 99%+. Synbias can produce 3-5MT of these products yearly now and the capacities can increase up to 10-20MT depending on the demand.

Company strategy

The company is planning further growth within itself as well as within its capacities.

V & V PHARMA INDUSTRIES

„Sanskruti Prasad“, 73
Ram maruti road
Thane (west) 400 602
Maharashtra, India.
Tel : +91 22 2536 6492
Fax: +91 22 2543 4546
Website: www.vandvpharma.com

Company overview

V & V Pharma Industries was established in 2002 in Maharashtra, India. The company is active in the area of pharmaceutical ingredients (API‘s), pharmaceutical intermediates and specialty chemicals. The company has two multipurpose production plants, both located in India, close to Mumbai.

V & V Pharma Industries is engaged in the development of emerging technologies in collaboration with many Institutes & industrial centers of excellence.

Financials

The company can produce 1000kg of 2,5 – Dicarboxylic acid per year, through synthesis. It is located on a site with the total size of 12000 sq.meters with 4 Glass assemblies (50 – 100 liters), 4 S. S Reactors (50 - 300 litres), 5 ltr Autoclave (Working pressure 100 kg / sqcm) and downstream equipment for isolation of products.

Product and service portfolio

V and V Pharma industries produces the following chemicals: APIs intermediates, Carboxylic/ Dicarboxylic acid derivatives, Cycloalkane Derivatives, Furan Derivatives, Imidazole Derivatives, Indane Derivatives, Indole derivatives, Isoquinoline Derivatives, Isoxazole Derivatives, Morpholine/Phenanthroline Derivatives, Octane derivatives, Benzene Derivatives, Pyrazole Derivatives, Pyridine Derivatives, Quinoline Derivatives, Triazole-Benzotriazole derivatives, Laboratory reagents.

Company strategy

V and V Pharma industries worked extensively and developed innovative technologies in the area of APIs intermediates Technology. The company has an innovative team of chemists who are ready to provide high quality products and excellent service. Further development of production and technologies is one of the main goals of V and V Pharma industries.

CHEMSKY INTERNATIONAL

No.868 Sanlin Road,
Room 207 Pudong New Area,
Shanghai 201201,China
Tel：+86 21 5013 5380
Fax：+86 21 5013 5380
Website: www.shchemsky.com

Company overview

Chemsky (shanghai) International Co.,Ltd was founded in 2010 in Shanghai, China. The company focuses on R&D and production of new active pharmaceutical ingredients, pharmaceutical intermediates and other specialty chemicals. The main activities of the company include R&D, custom production, scale-up, worldwide distribution, relative technical support and quality assurance.

Chemsky (shanghai) International serves clients from North America, Japan and Europe. With extended stock space and innovative technical equipment, the company developed to one of the leading catalog houses for R&D chemicals in Asia.

Financials

Chemsky (shanghai) International Co.,Ltd produces 1000kg of 2,5 – Furandicarboxylic acid per year. The company's professional laboratory of Product Technology Center (PTC) occupies an area of 3000 sq. meters , including Organic Research Lab、Organic Synthesis Lab、 Analysis Lab、Kilogram-scale Workshop.

Product and service portfolio

Chemsky (shanghai) International Co.,Ltd offers a catalog of more than 20,000 regular products and synthesis from gram to kilogram tailored clients' specific needs. The products are divided in 3 categories: API, Raw chemicals and Intermediates/Fine Chemicals. The company's Product

Technology center is in close cooperation with key laboratories of famous Chinese universities.

Company strategy

Chemsky (shanghai) International Co.,Ltd is constantly working on improving its production technologies and widening its offer of products. Innovative technology, experienced workers with degrees and cooperation with university laboratories are key factors for the success of Chemsky. The company already has foreign partners and is open to international cooperation.

ASTATECH

Keystone Business Park
2525 Pearl Buck Road
Bristol PA, 19007, USA
Tel: + 1 215 785 3197
Fax: + 1 215 785 2656
Website: www.astatechinc.com

Company overview

AstaTech is an American company that was founded in 1996 in Philadelphia, Pennsylvania by former scientists working with leading pharmaceutical companies. In 2000 the company has established its first R&D center AstaTech (Chengdu) Pharmaceutical Co., Ltd. in China. In 2004 AstaTech established its next R&D center in Canada. AstaTech has more than 100 chemists, offers a wide range of products and services and has partnerships on both local and international level with more than 1000 companies.

Financials

Currently, the company has its headquarters in Bristol, PA, one R&D center site and one manufacture plant in Sichuan, China occupying a total area of over 100.000 sq. meters.

Product and service portfolio

AstaTech offers over 10000 advanced intermediates and drug-like building blocks, 75% of which are available in stock and 10% products can be scaled up to kg / MT scales.

Among other services the company offers custom synthesis, bulk manufacturing, flexible sourcing solutions and analytical services. AstaTech is a producer of 2,5 – Furandicarboxylic acid. Catalog products are divided into the following categories: Amines, Alcohols, Carboxylic acids, Aldehydes & Ketones, Halides, Nitriles, Boronic Acids, Heterocyclic Compounds.

Company strategy

AstaTech focuses on an extensive portfolio of catalog products, cost-effective drug discovery and development, and manufacturing solutions to meet the clients 'needs.

ALFA AESAR – (part of Johnson Matthey group)

26 Parkridge Rd
Ward Hill, MA 01835, USA
Tel: +1 978 521 6300
Fax: +1 978 521 6350
Website: www.alfa.com

Company overview

Part of the Johnson Matthey group of companies, Alfa Aesar is a leading manufacturer and supplier of research chemicals, metals and materials in a wide span of applications. For more than 45 years, scientists have relied on Alfa Aesar to supply high purity raw materials for a variety of research and development applications. Today we offer over 30,000 products in stock, in sizes from gram-scale catalog items to semi-bulk and bulk production quantities. With custom manufacturing capabilities to supply many more specialized items, we are a one-stop source for research chemicals, metals and materials. The company's product line consists of a comprehensive range of inorganic, organic and organometallic compounds; pure metals and elements; precious metal compounds and catalysts; fuel cell products; nanomaterials; rare earths; analytical products; and select laboratory equipment. Backed by the global manufacturing network of Johnson Matthey and other key partnerships, Alfa Aesar offers customers the highest quality and purity in fine chemical products. The company is accustomed to supplying R&D laboratories in the pharmaceutical industry and the electronics industry, as well as academic institutions and many others. Alfa Aesar is a trusted, service-oriented company. Product quality is of paramount importance, but production expertise is just the beginning. Factors such as product availability, packaging and delivery are just as crucial to meeting and exceeding your expectations.

Financials

Alfa Aesar offers synthesis capabilities from various locations globally. One of the company's primary lab- and kilo-scale organic synthesis units is located in Heysham in northwest England. The high purity materials are made in Royston, England. And the newest plant in Yantai, China includes a pilot plant with eight reactors ranging from 100L to 2000L capacity.

Product and service portfolio

Own brands: Premion, Puratronic, REacton, Ultra Dry line of materials, Specpure, Spectroflux

Company strategy

Alfa Aesar, a Johnson Matthey company, is a global business focused on its core skills in fine chemicals, precious metals and materials. It is the company's strategy to grow its business through investment in people, technology, and processes concerned with protecting the environment and through the responsible management of the very valuable materials with which they work.