EXECUTIVE SUMMARY

Bio-based Intermediate Chemicals 2019 Update

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Lux Research

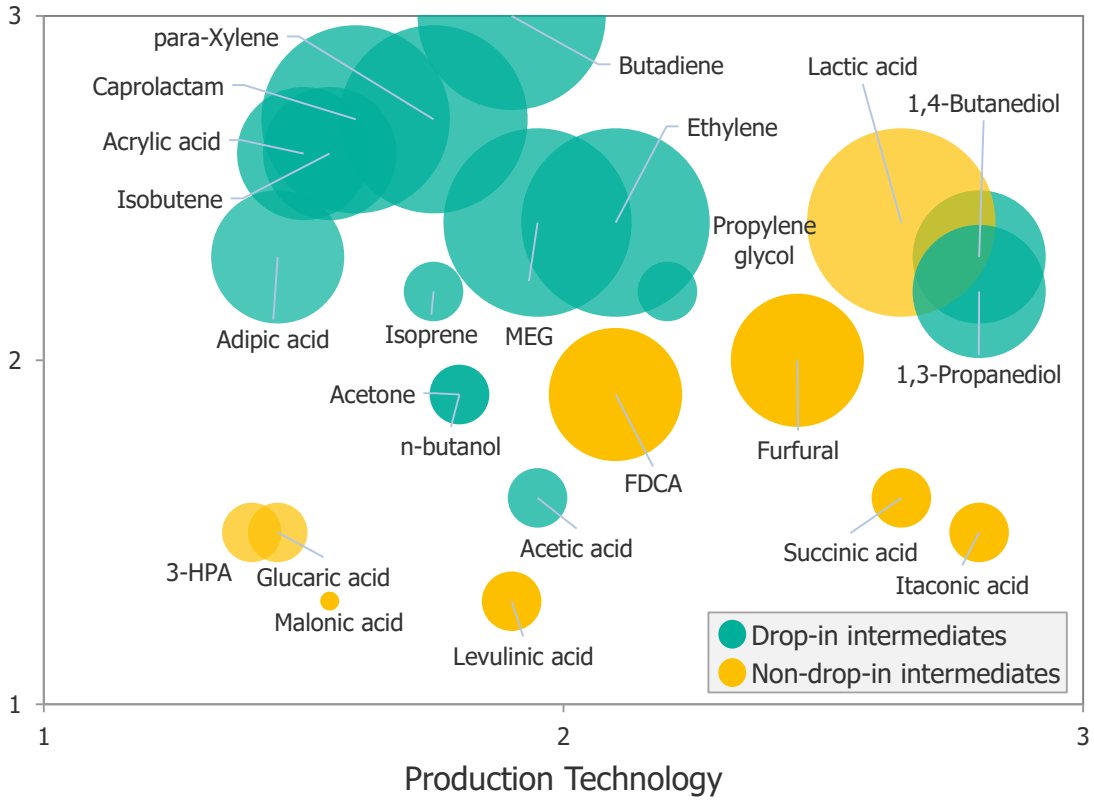
Executive Summary

Bio-based intermediate chemicals have long promised large markets and high margins but have confounded developers and chemical companies alike. **Given the higher costs of production for the majority of drop-in intermediates, those being targeted in the short term must have niche markets where labeling products as being "bio-based" is an asset.** Targeting niche markets in the short term allows time for production technologies to be further optimized and more favorable market conditions to arise to penetrate larger markets in the mid-to-long term.

Non-drop-in intermediates could capture sizable market value if pursued correctly but are inherently a greater risk. This risk is due to the significant amount of downstream market development required in addition to effective scale-up. While performance is important and can help offset higher costs of production, it is important to target applications where reformulation/redesign is already being encouraged.

24 Bio-based Intermediate Chemicals

Market Potential



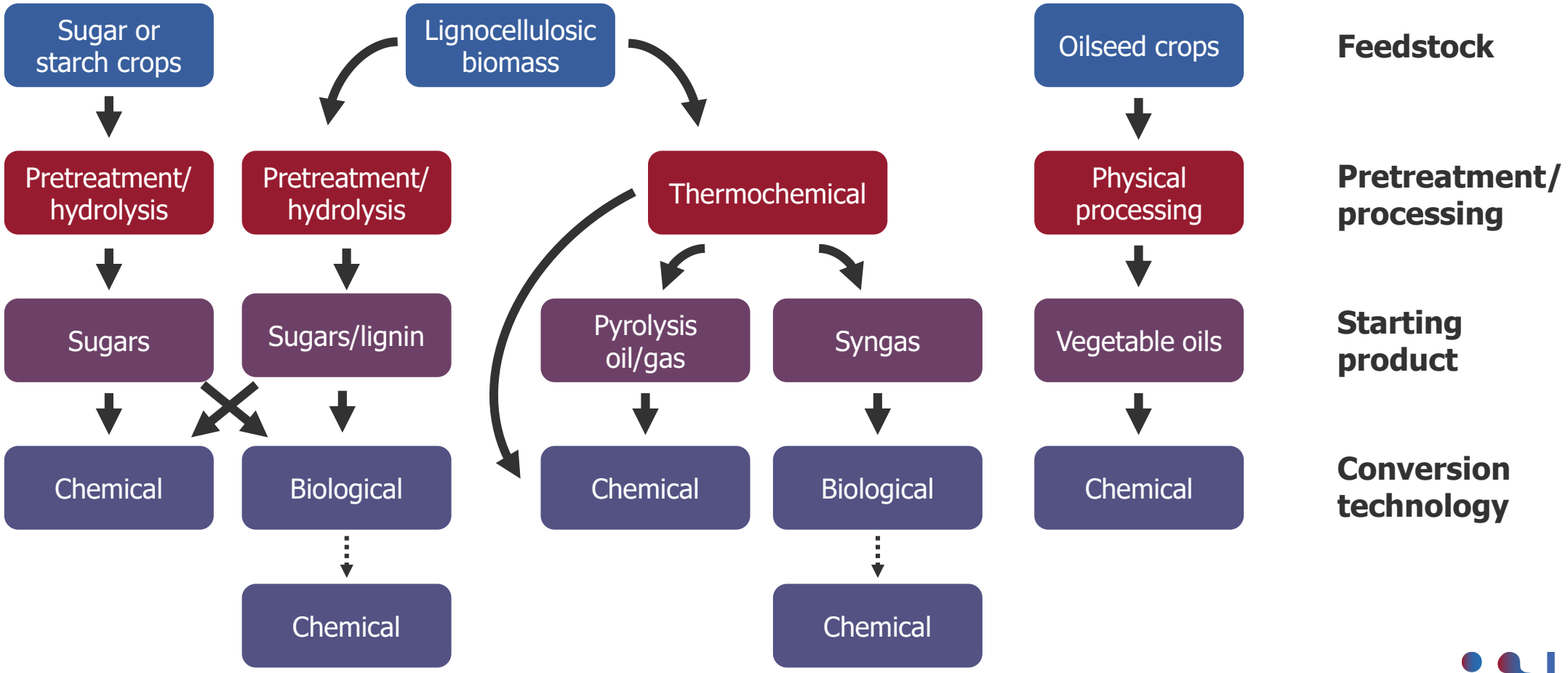
*Bubble size represents relative total expected bio-based market size

In the full report we evaluate bio-based intermediate chemicals and highlight pain points and opportunities

BACKGROUND:
While high oil prices have largely driven development activities in the bio-based industry, the space has suffered over the past five years as a result of consistently low oil prices. Despite worldwide crude oil projected to remain around $60/barrel and $70/barrel, price volatility in the intermediate chemicals market and demand for more environmentally friendly products is driving renewed interest in bio-based or renewable alternatives. Yet, given the historical challenges in bringing bio-based products to market (in terms of both scale-up and penetrating downstream markets), it is important to first evaluate where and how best to proceed.

SCOPE:
The present report aims to identify the bio-based intermediates with the greatest potential for adoption over the next 10 years and the sizes of the markets they can capture. The report evaluates 24 intermediates based on production technology and market potential and presents scenarios beyond high oil prices that are likely to positively or negatively impact adoption.

Biomass conversion pathways vary widely, with different benefits and drawbacks



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We evaluate bio-based intermediates based on production technology and market potential

Production Technology | Reflects the potential of production processes to achieve widespread adoption over the next 10 years based on technology readiness, cost, and the amount of innovation activity to overcome barriers to growth.

KEY FACTORS:

- Number of developers
- Technology readiness level (TRL)
- Technology barriers
- Cost & performance

Market Potential | Reflects the ability of intermediates and their derivatives to penetrate downstream markets and the expected market size, including consumer and regulatory factors that make bio-based products more favorable for target markets.

KEY FACTORS:

- Established market
- Addressable market volume
- Expected bio-based market size
- External factors

We selected 24 bio-based intermediates targeted by startups or highlighted in the literature for having high potential

C2	C3	C4	C5	C6
Acetic acid	Acetone	Butadiene	Furfural	Adipic acid
Ethylene	Acrylic acid	1,4-Butanediol	Isoprene	Caprolactam
Ethylene glycol	3-HPA	n-Butanol	Itaconic acid	FDCA
	Lactic acid	Isobutene	Levulinic acid	Glucaric acid
	Malonic acid	Succinic acid		para-Xylene
	1,3-Propanediol			
	Propylene glycol			

The 24 intermediates evaluated in this report were selected based on two reports funded by the U.S. Department of Energy – "Top Value Added Chemicals from Biomass (2004)" and "Chemicals from Biomass: A Market Assessment of Bioproducts with Near-Term Potential (2016)" – as well as an assessment of the startups Lux has covered targeting bio-based intermediates.

On the next two slides, we present a sample evaluation of one intermediate. Contact us to request access to the full evaluation of all intermediates.

Example Evaluation: Levulinic acid

Production Technology

Commercial routes for the production of levulinic acid involve the dehydration of hexoses to HMF, which is hydrolyzed to levulinic acid and formic acid. Lignocellulose materials can be impregnated with dilute acids and exposed to steam in the presence of a catalyst to form levulinic acid and various byproducts. While GFBiochemicals plans to use lignocellulosic feedstock in the future, the company currently uses sugars from corn.

Key Players

Biofine Technology

GF Biochemicals

Market Potential

Levulinic acid is a non-drop-in intermediate that has two functional groups that allow it to react as a carboxylic acid or a ketone. Hence, levulinic acid to can be used for a wide range of potential applications. Key derivatives include methyl tetrahydrofuran (fuel additive), aminolevulinic acid (herbicide), and diphenolic acid (replacement for bisphenol A). Before being acquired by GFBiochemicals, Segetis focused on ingredients for personal care and cleaning products based on ketals from levulinic acid.

Activity

Biofine Technology unveiled a new pilot plant of unknown capacity at the University of Maine in 2017. GFBiochemicals acquired U.S.-based Segetis in 2016 to both expand into the U.S. market and expand its levulinic acid derivatives. The company started operations at its 10,000 MT/year facility in Italy in 2015.

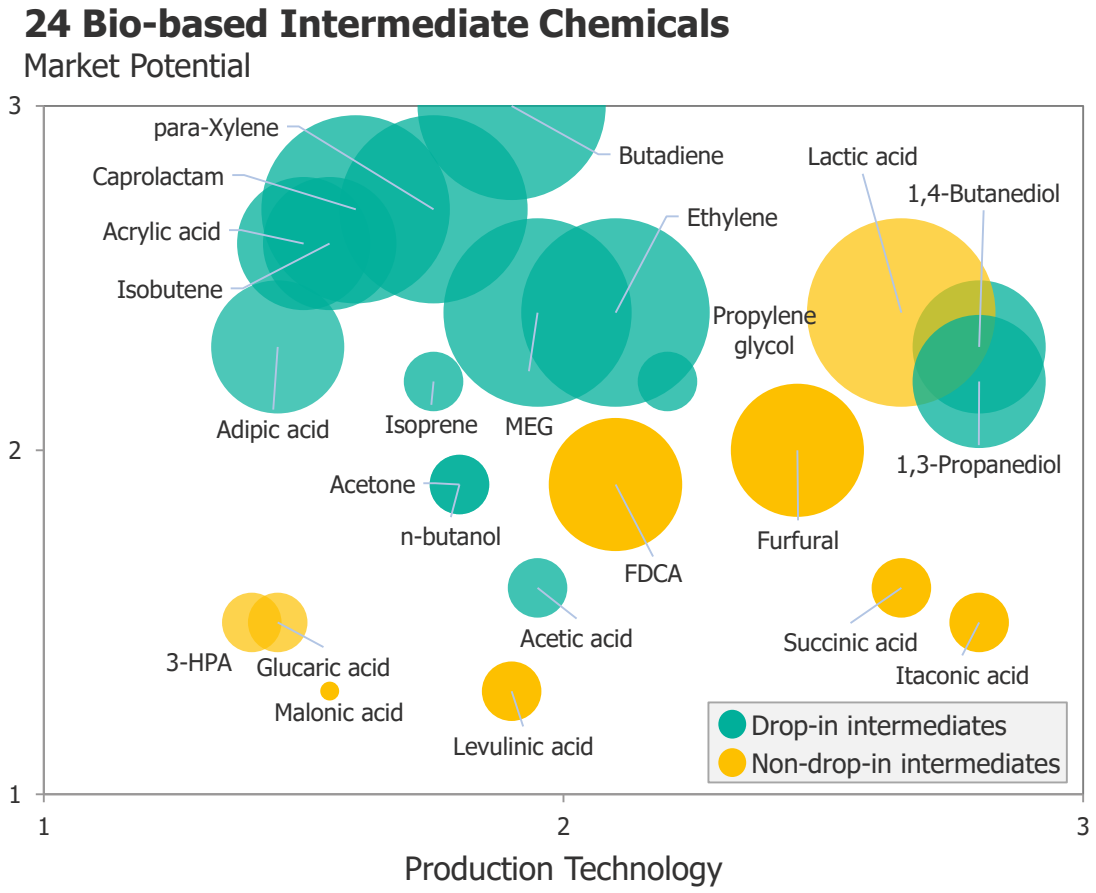
Example Scorecard: Levulinic acid

	Category	Score	Description
Production Technology	NUMBER OF DEVELOPERS	1	Key players attempting to commercialize levulinic acid include GFBiochemicals and Biofine Technology; large players like Neste and DSM have been granted patents on levulinic acid production over the past five years but have unclear plans
	TECHNOLOGY READINESS	2	TRL 7; GFBiochemicals started operations of a 10,000 MT/year plant in 2015, and Biofine Technology unveiled a new pilot in 2017
	TECHNOLOGY BARRIERS	2	The use of inorganic acid catalysts leads to waste disposal and corrosion problems; inefficient separation/recovery is another challenge, and the development of reactive extraction methods is being explored; GFBiochemicals, Biofine, and other larger developers are actively developing solutions to overcome these problems
	PRODUCTION COST	2	Non-drop-in with derivatives likely to have premium but potential performance advantages
Market Potential	ESTABLISHED MARKET	1	Downstream markets must be developed; esters can be used for flavors, fragrances, plasticizers, and fuel additives; ketals can be used for detergents and plasticizers
	CURRENT MARKET VOLUME	1	Current market volume <100,000 MT
	TOTAL EXPECTED BIO-BASED MARKET SIZE	1	<$500 million based on partial penetration into niche markets; high cost and lack of current market limits the timeline for adoption
	EXTERNAL FACTORS	2	Regulations/consumer concerns surrounding bisphenol A, demand for bio-based herbicides, and demand for natural personal care products may help adoption

Production technology limits large-scale adoption; niche applications have the most short-term potential

Overall, non-drop-ins have notably higher production technology scores but lower market potential scores than drop-ins. This is reflective of the historical tendency of developers to try and push novel technologies without much market development effort. **Non-drop-ins are limited by the high costs and long timelines of downstream development**, and players have failed to take advantage of the unique performance attributes that enable them to capture new markets.

While drop-ins have lower production technology scores, they are less restricted by downstream market development timelines. **The drop-in intermediates able to capture the most market value are those able to first tap into niche markets and later expand into commodity markets,** especially markets having high volatility where chemical producers are looking to diversify feedstocks. Initially targeting niche markets is important, as bio-based production technologies and supply chains are still being optimized.



*Bubble size represents relative total expected bio-based market size

“Long pathway to market” intermediates are limited by costs, especially in low-oil price environments

Intermediates in this category have high market potential but a long pathway to market, especially in the current low-oil-price environment. Many of the drop-ins have both upstream and downstream drivers, but adoption is currently only for downstream marketing purposes (e.g., Braskem’s I’m Green Polyethylene). Intermediates in this category have the most to gain from a rise in oil prices or an increase in volatility in the raw materials market.

Alternative routes to butadiene, isobutene, and acrylic acid are all being incentivized by a shift in the use of natural gas instead of naphtha for ethylene production. The petroleum-based precursors for these intermediates are higher-carbon byproducts of naphtha-based ethylene production in which supplies are being threatened by the shift to lower-molecular-weight natural gas feedstocks that are cheap and abundant.

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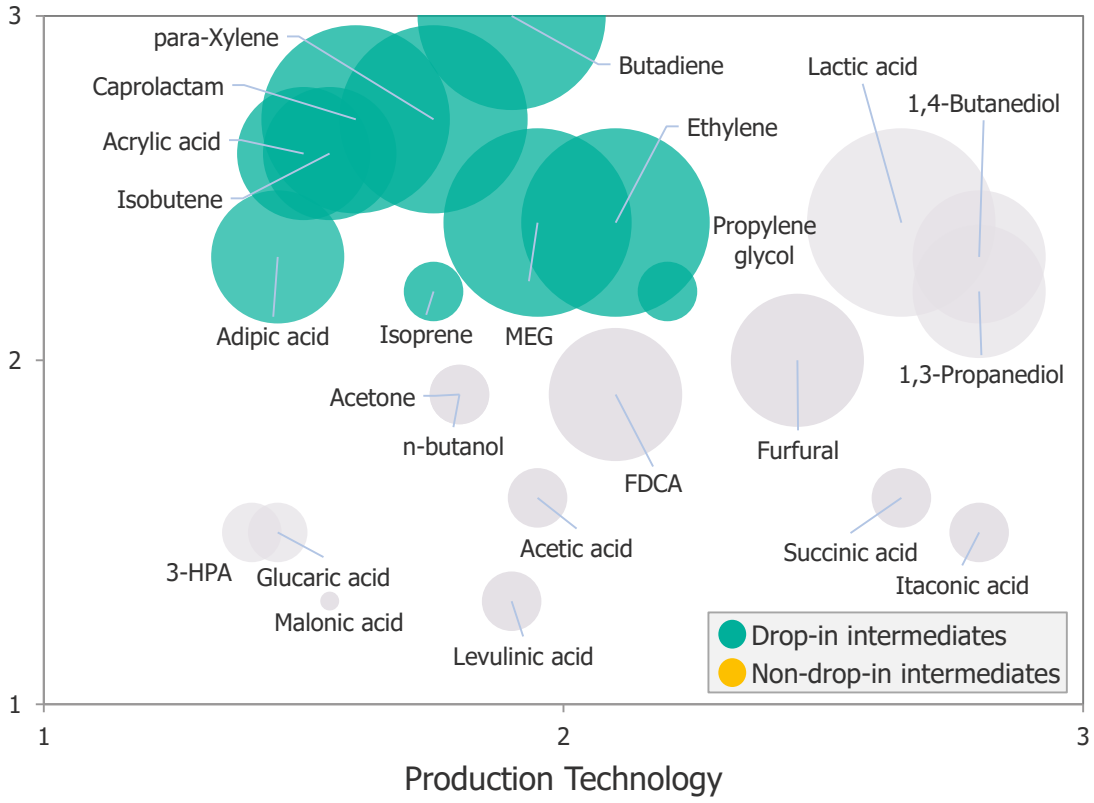

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“Niche opportunity” intermediates have mature production technologies and unique performance attributes, presenting an opportunity for novel market development

This category contains non-drop-ins having relatively mature production technologies and unique performance attributes that may justify their longer market development timelines. If developers find applications where performance/cost is prioritized over bio-based content, these and similar non-drop-in intermediates have the potential to be adopted, even in low-oil-price environments.

While commercial production is possible, the key to success is downstream intervention. Developers should have a strong understanding of the strengths and limitations of their technologies, but downstream partners are important for providing the product expertise and market insight necessary to translate these intermediates’ unique performance attributes to commercial products.

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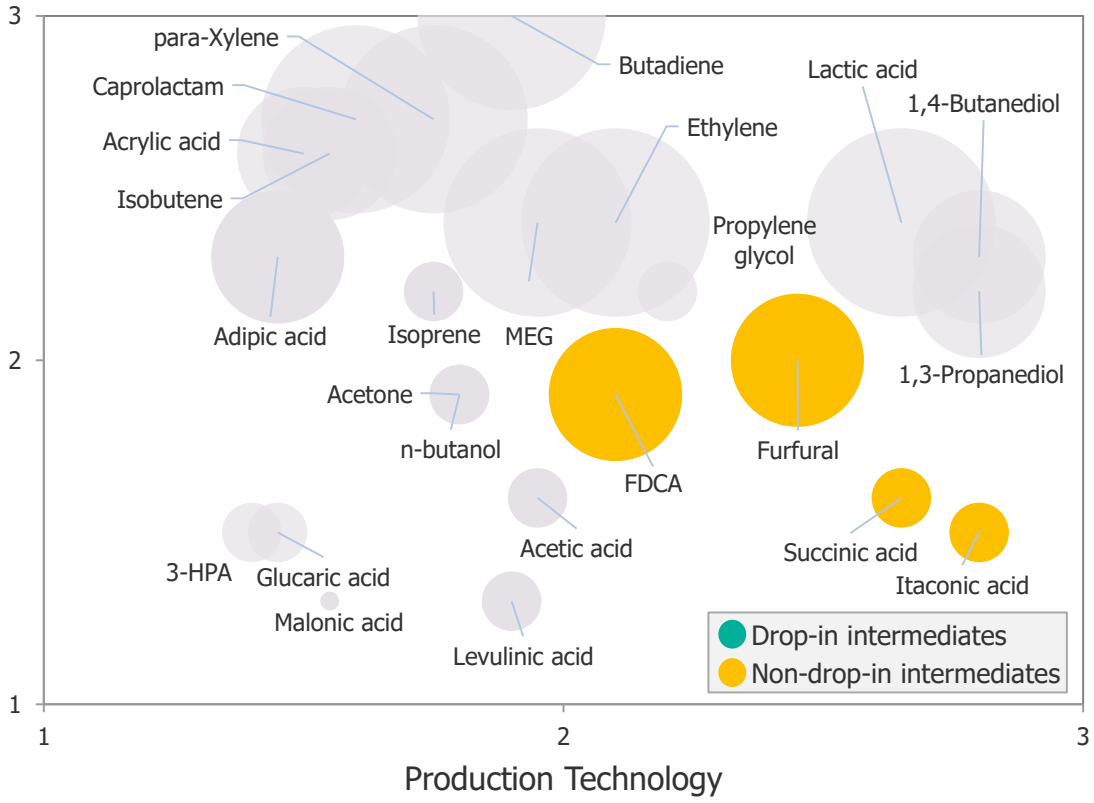

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While initial development in the bio-based intermediate space was driven by high oil prices, there are other motivating factors for growth and adoption

These market dynamics include the negative perception and fear consumers have of petroleum-based products, the growing war on plastic waste, global commitments surrounding climate change, and the continued desire of individual nations to minimize their foreign dependencies on oil. All of these variables must be considered when forming a bio-based intermediates strategy.

High Impact

Consumer pressure and policy against substances of high concern provides opportunities for non-drop-ins and their derivatives, especially in application areas like phosphate replacement in detergents, where brand owners are open to reformulation (e.g., poly[itaconic acid] for water conditioning products).

Nations minimizing foreign oil dependencies and global commitments surrounding climate change will drive the most opportunity for drop-in commodities (e.g., those in the longer pathway to market category), where large volumes have the most impact on reducing foreign oil consumption and mitigating greenhouse gas emissions (especially if production is carbon-negative).

Low or Negative Impact

The war on plastic waste may drive some opportunity for bio-based drop-ins where recycling infrastructure is already established (e.g., MEG and PX for PET) or bio-based intermediates where biodegradability/industrial compostability is confirmed (e.g., BDO for PBAT and lactic acid for PLA), but, in general, we view this megatrend as having limited impact on the bio-based intermediate space. In fact, the adoption of advanced recycling techniques could introduce more "renewable" low-carbon feedstocks, thereby negatively impacting the demand for bio-based alternatives.

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