



Delivering the renewable fuels aspiration: The role of biobutanol

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A joint venture between BP and DuPont



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Increasing renewables fuels in transport

Introduction to Butamax

Features of biobutanol

Manufacturing of biobutanol

Summary

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
Manufacturing of biobutanol


Summary


The “drop-in” fuel concept

- Ambitious targets for renewable fuels in transport
 - RFS2 & RED
 - LCFS & FQD
- Challenges in meeting targets due to incompatibility between fuel specifications, infrastructure and vehicle compatibility
- Drop-in fuels identified as biofuels that can be used in existing vehicles, and without the need for replacing existing refuelling and distribution infrastructure

Options to increase renewables in transport

	EV's	Biodiesel				Gasoline			
		FAME	HVO	Algae	S2D	E10+	E85	Bio-gasoline	Bio-butanol
Refuelling infrastructure									
Production infrastructure									
Existing vehicle compatibility									
Vehicle turnover feasibility									
Technology availability									
Feedstock availability									
Increased short term contribution									

 Potential drop in fuel

 Critical issue

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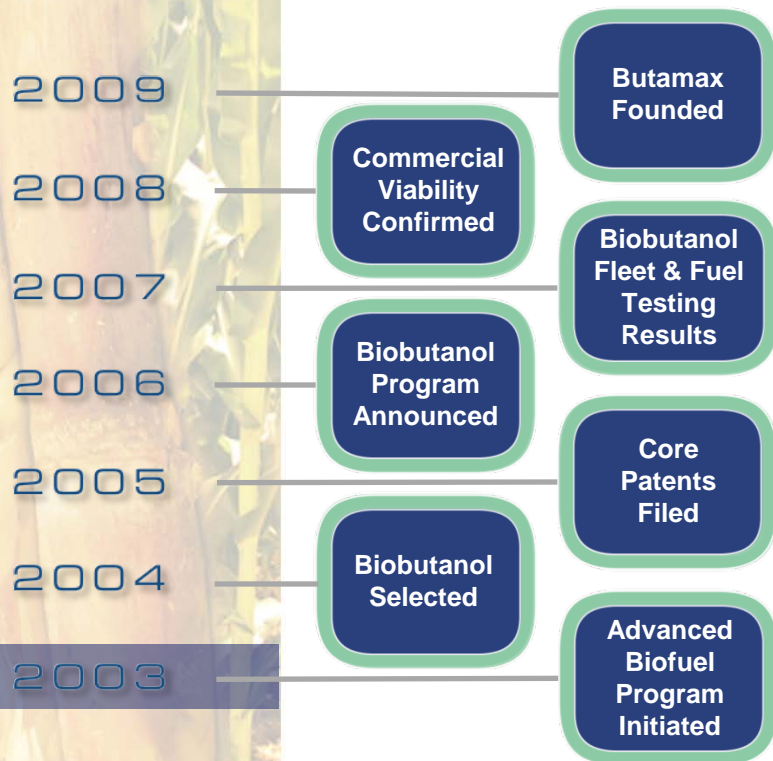
Summary

Butamax™ Advanced Biofuels LLC

A joint venture between BP and DuPont



Pathway to commercialization



150 dedicated experts worldwide



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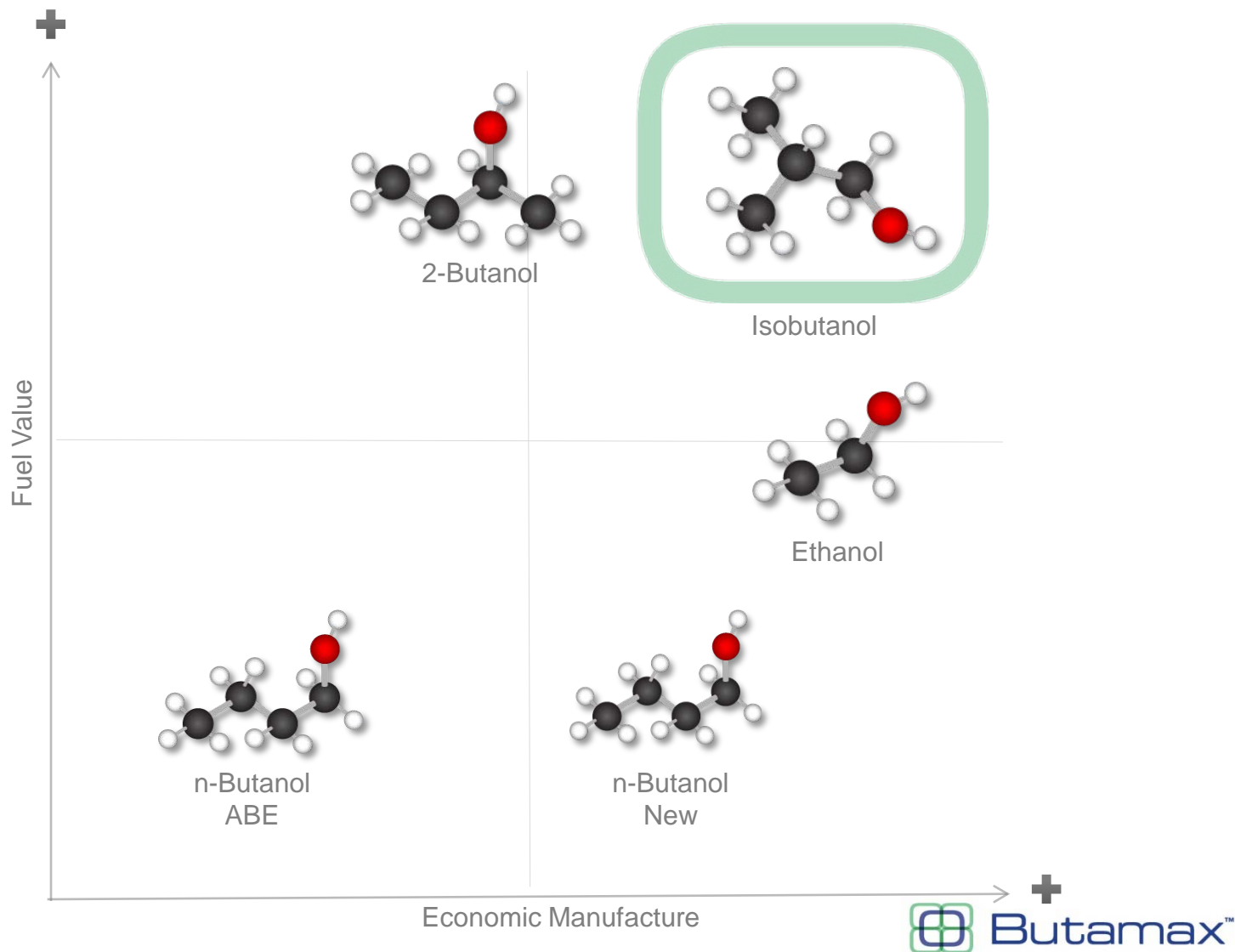
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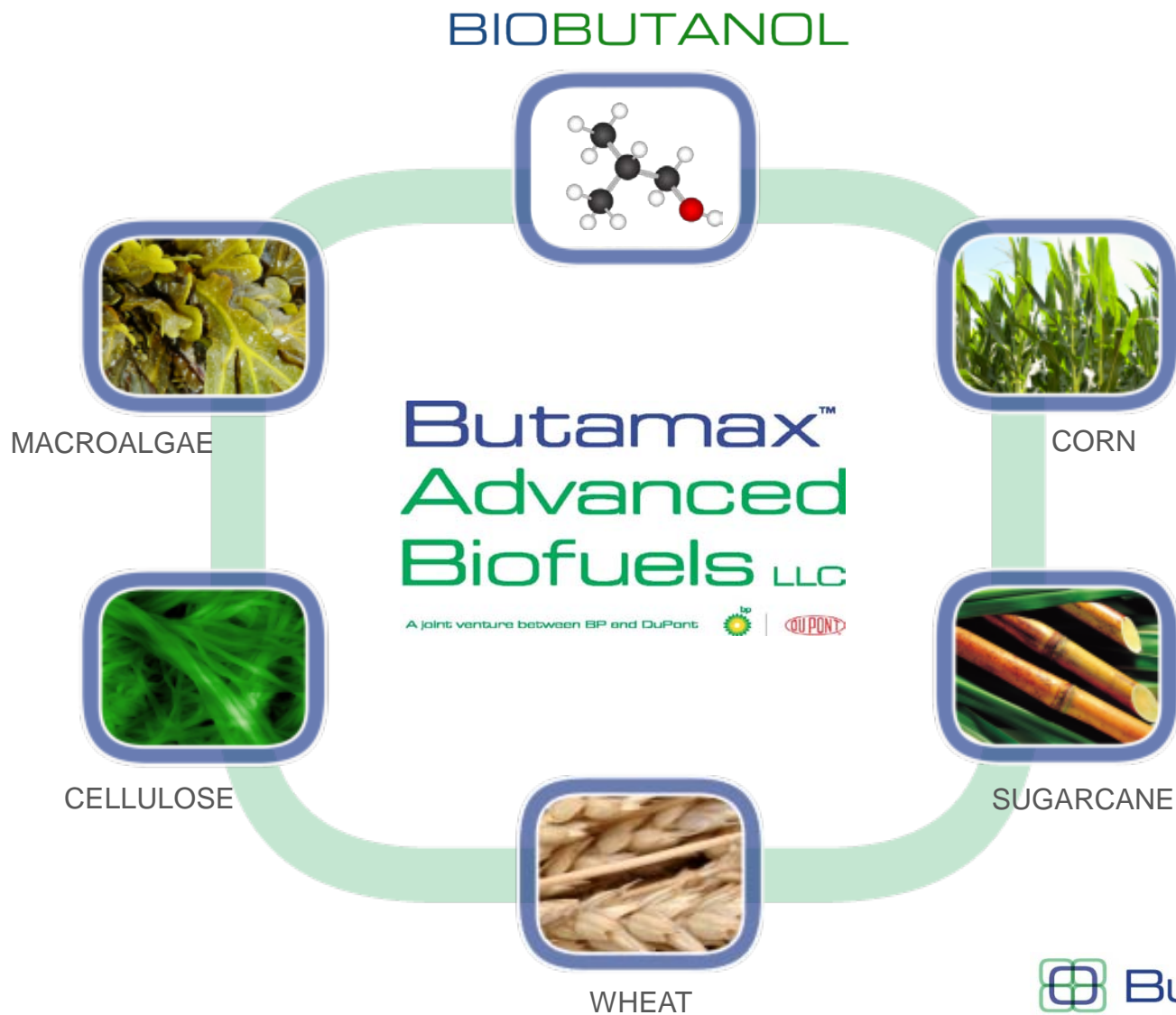
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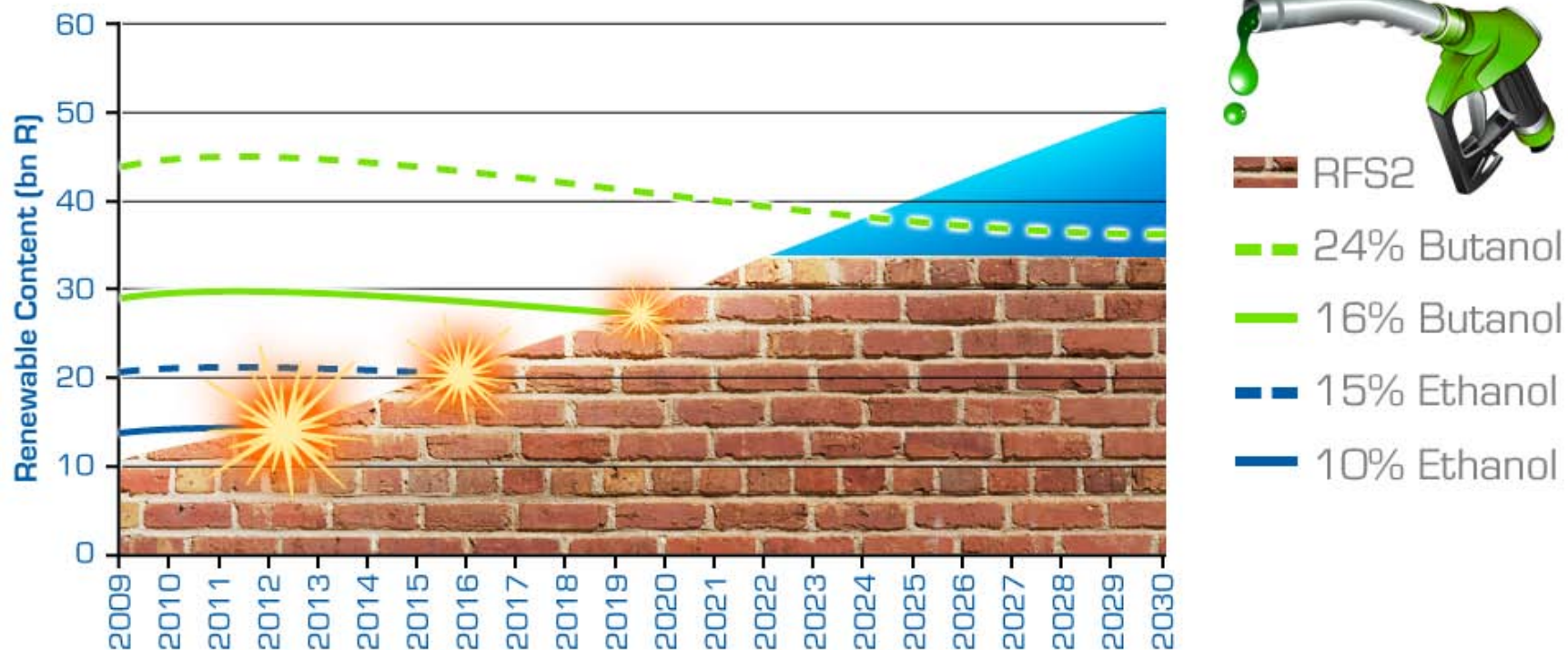
Optimum combination of fuel value and manufacturing cost



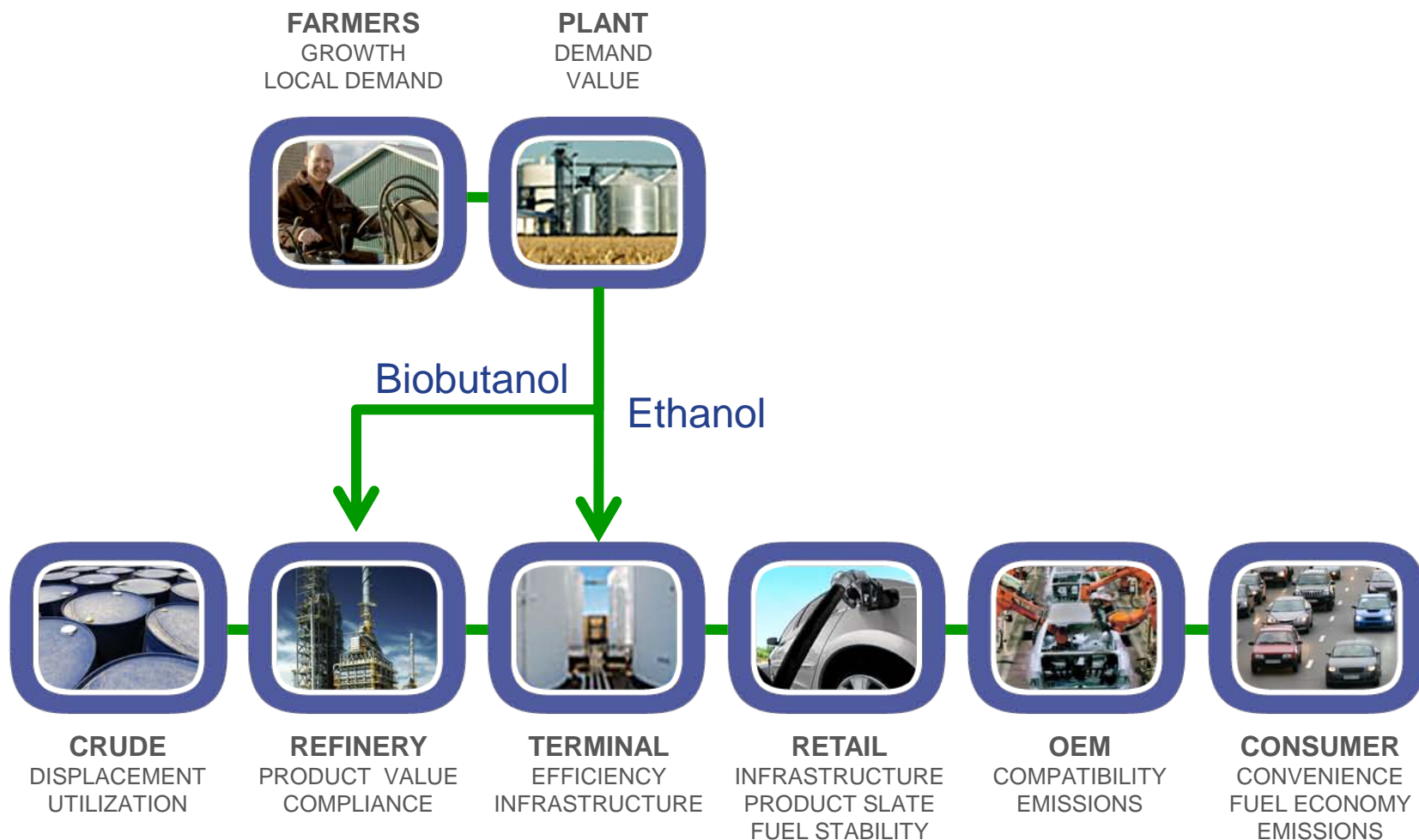
Economic manufacture from fermentable sugars



Biobutanol enables higher levels of renewables...



Biobutanol creates value throughout the supply chain



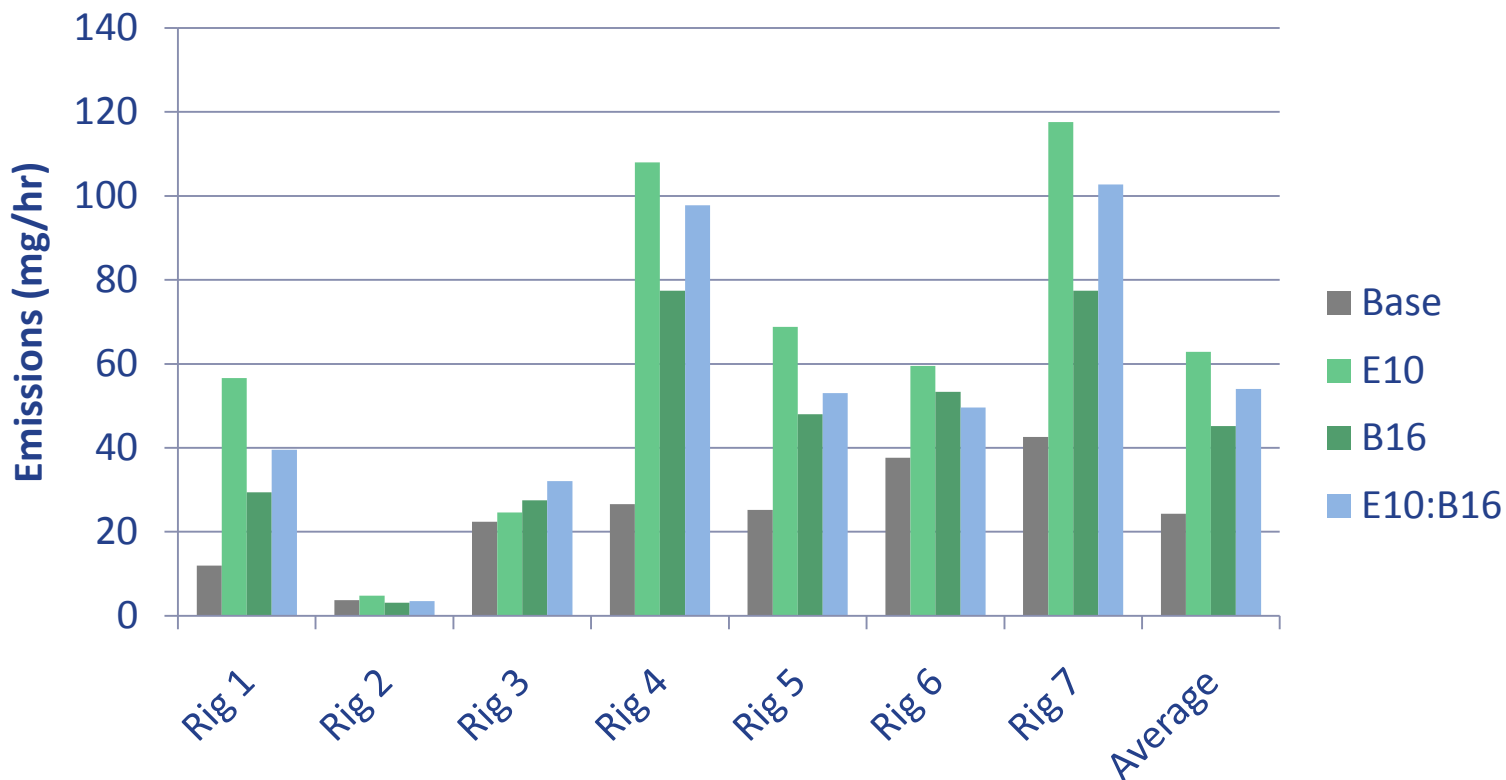
Gasoline blending value

- Butanol is not water-soluble, so it can be blended at refineries and shipped via pipeline
- Butanol has low RVP, enabling refiners to blend incremental volumes of butanes and pentanes
- Butanol does not depress T50
- 16vol% butanol plus incremental butane and pentane
 - enables substantial dilution of sulfur, benzene, olefins, etc
 - Increased optionality for heavy naphtha between gasoline and distillate
 - Increases yield of light products per barrel of crude

Butanol properties			
	Gasoline	Ethanol	Iso-Butanol
RON	95	109*	105*
MON	85	90*	91*
Anti-knock Index	90	100	98
RVP (psi)	7 – 15	~19	5.2
Density, 20°C [kg/m ³]	720-775	794	801
Boiling point (°C)	<210	78.3	108
Heating value [MJ/L]	32.2	21.1	26.6
% Heating Value of Gasoline	100	66	84
Oxygen (%w/w)	<2.7	34.7	21.6

* Octane values of neat material

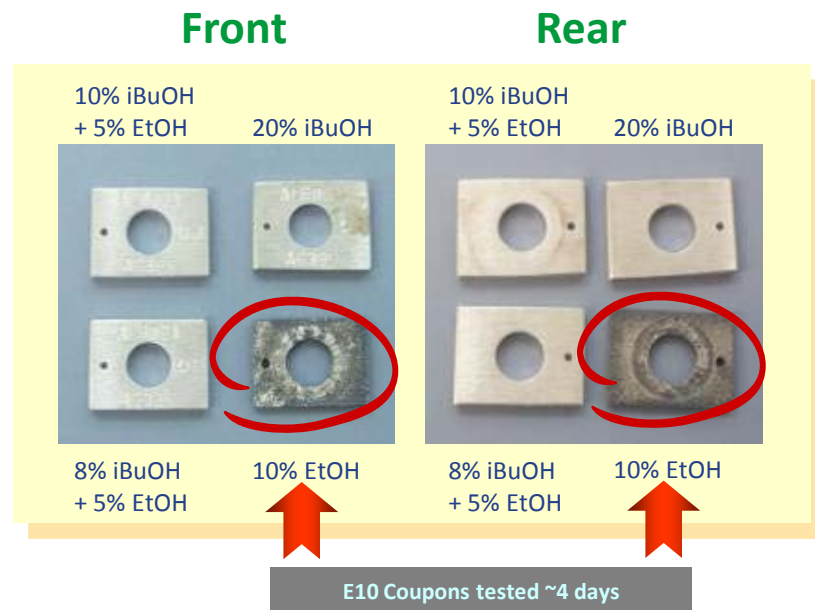
Permeation emissions (steady state, 40 C)



- Permeation emissions testing indicates equivalent or better VOC emissions compared to ethanol
- Ozone reactivity of permeate lower with butanol than with ethanol

Compatibility with aluminium

Aluminum after 18 days exposure to solutions in p-Xylene at 100°C

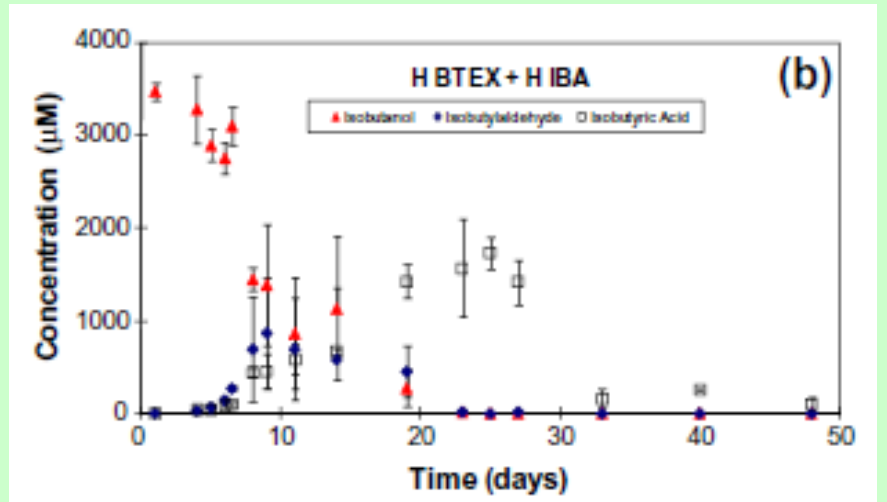


- Corrosion is strongly dependant on alcohol type:
 - ethanol > propanol > 1-butanol > iso-butanol
- Increase in alcohol content leads to acceleration of corrosion
- Water inhibits the corrosion (confirms literature)
- Increasing temperature accelerates corrosion
- Corrosion inhibitors show impact (in some cases inhibition, in others acceleration)
- **Aluminum parts which resist ethanol corrosion will resist butanol corrosion**

Low risks to water and soil if spilled

• Biodegradation

- Biobutanol degrades relatively quickly under both aerobic and anaerobic conditions; metabolites also degrade quickly
- Reduced inhibition of BTEX degradation
- Published - Chemosphere (October 2010)



• Additional work in progress

- Detailed kinetics and pathways experiments
- Work on partition coefficients
- Soil Sorption studies
- Model of BTEX plume behavior with biobutanol

Odor thresholds intermediate between gasoline and ethanol

Odor Thresholds	Detect (ppm)	Recognize (ppm)
Conventional Gasoline	0.94	1.24
Butanol-10	0.66	0.86
Ethanol-10	0.34	0.50

Similar health effects as ethanol

- **Isobutanol has been well studied**
- **Human Health (OECD SIDS)**
 - Exposure to iso-butanol in neat or concentrated form may produce skin and eye irritation and CNS depression.
 - Potential effects are transient, reversible and occur only at very high exposures.
 - **Ethanol produces the same transient health effects**, also at very high exposures.
- **Ecological**
 - The octanol:water partitioning coefficient ($\log K_{ow}$) for iso-butanol and its calculated bioconcentration factor indicate that **bioaccumulation in food webs is not expected**.
 - iso-Butanol released to the environment will primarily partition into water and soil.
 - iso-Butanol will only slowly evaporate from water surfaces into the atmosphere.
 - The photochemical removal of iso-butanol occurs relatively slowly ($T_{1/2} > 24h$).
- **Acute Oral and Acute Dermal Toxicity**
 - Iso-butanol has a **low order of acute toxicity** by all routes (OECD SIDS dossier).

Successful vehicle and supply chain demonstration



- Fuels technology program since 2005 to underpin biobutanol adoption by fuel producers, retailers, Autos, regulatory agencies and consumers
- Extensive fleet and fuel performance testing in USA and Europe
- 135 cars, including 1995 – 2009 model years, tested to date with 1.5 million miles driven
- Retail demonstration completed in the UK (2008/9)
 - 10m liters of biobutanol blend supplied to ten retail sites as EN228 compliant gasoline
 - Approximately 250,000 vehicle fills and 80 million miles driven
 - Real world confirmation of extensive favorable laboratory, engine, and vehicle demonstrations
 - Biobutanol can be treated as a normal fuel component & used without special procedures

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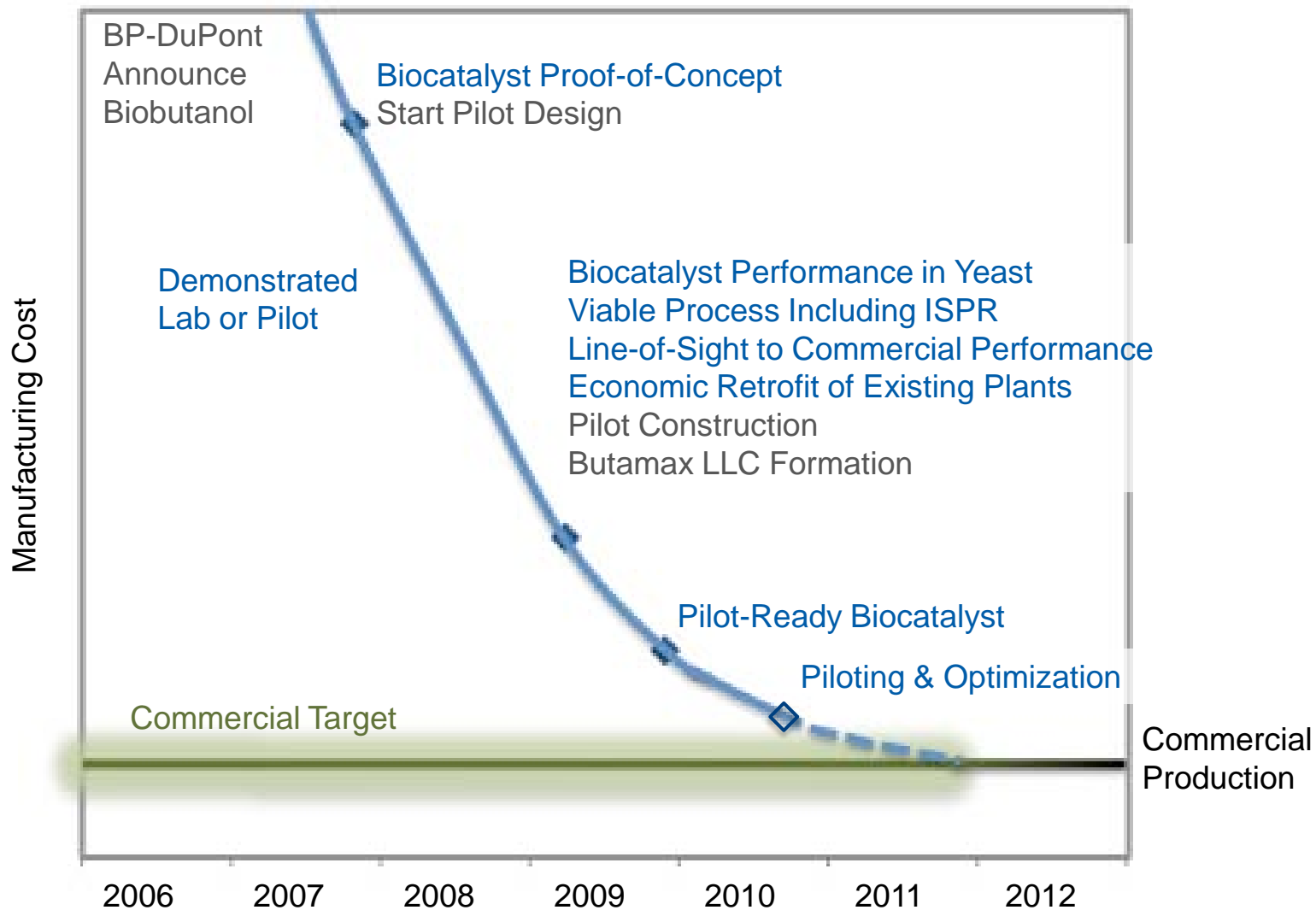
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On track to commercial target



Butamax facility openings

Technology Demonstration Facility

Hull, England

- Fermentation and process optimization for profitable and sustainable biobutanol manufacture
- Design and engineering basis for full-scale commercial plant design
- Biobutanol and distiller's grains for product qualifications

Butamax Technology Laboratory

Paulinia, Brazil

- Optimization of fermentation process with representative feedstocks
- Vinasse trials to support regulatory approval and market development



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Biobutanol enables renewable fuels growth by:

- Combining excellent fuel properties and attractive production economics, and is applicable to a range of important feedstocks
- Overcoming current vehicle and infrastructure constraints to allow much higher renewable content in gasoline
- Offering existing and future ethanol producers the opportunity to transition to a higher value product while leveraging investments
- Providing refiners with a lower cost and higher value route to increase renewable content of gasoline and to reduce carbon intensity

