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Betting on Science

Disruptive Technologies in Transport Fuels

April 14th 2010

Report objectives and scope

12 Technologies

Evolution

- Next generation internal combustion engine
- Next generation agriculture
- Waste to fuel
- Marine scrubbers

Revolution

- Sugar to diesel
- Butanol
- Biocrude
- Algae
- Aviation biofuels

Game Changer

- PHEV engines and batteries
- Charging
- Vehicle to Grid

25 Companies



10 Markets



Things to keep in mind

- Competing views- the scientists don't agree with each other
- All the technologies are IN PLAY today
- There many more that we did not include- eg. hydrotreating renewable diesel, FT, hydrogen
- Not 1 winner (will differ by market), but not 100+ different technologies either
- 80% of the most important data/content is in the minds of the scientists in the companies and research centres (vs. in papers)

10 Key Messages

Key Message #1: The improvement potential of many existing technologies is underestimated

- Increasing yields without significantly increasing land use.
- Rewarding improvements in water and energy use
- Supporting the use of waste to create energy or fuel.
- Continuing roll-out of higher-efficiency standards

Corn Yield Trends			
(Bushel Per Acre)			
	1990	2000	2005
World Average	59	70	75
USA	113	137	149
Argentina	60	93	109
China	74	78	80
Brazil	33	47	54
India	23	29	31
Sub-Saharan Africa	22	24	25

Source: Ceres, Monsanto/Doane Forecast

“Already, farmers in Iowa are producing as many as 200 bushels an acre. Mr Grant (from Monsanto) believes that 300 bushels are achievable by 2030” (source: “The parable of the sower”, Nov 19th 2009 | ST LOUIS, From The Economist print edition)

“I do think 300 is attainable as a national average. Using corn, cobs and a portion of the stover we should be able to yield over 1000 gallons of ethanol per acre - as opposed to 450 today” (source: Accenture interview with farmer/ethanol producer)

Key Message #2: Biotechnology is transforming biofuel production

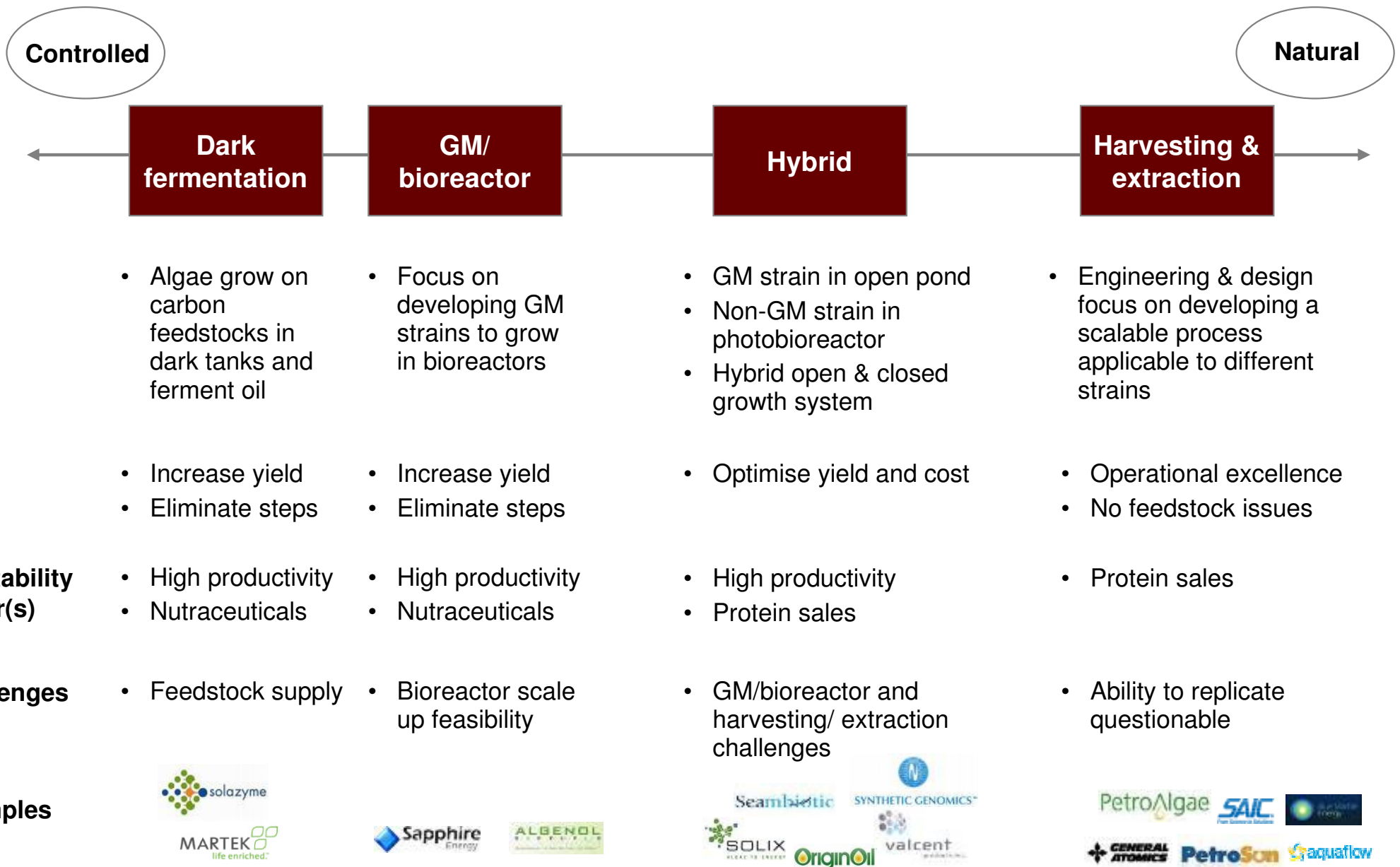
Examples (non-exhaustive)

- Genetically engineered feedstocks that increase the yield density and reduce the intensity of pre-treatment and required enzyme
- A “diesel” solution through synthetic biology that allows sugar cane to be converted into a clean diesel.
- Microbes that have been able to overcome the toxicity challenges of converting starches and sugars to butanol.
- Genetically modified algae that have higher yields and are lower cost to cultivate, harvest and extract

Wider Applications Of Biotechnology

	Application	Examples of players
Feedstock	<ul style="list-style-type: none"> • Genetically modified crops, with improved characteristics: <ul style="list-style-type: none"> - Drought/disease resistance - Faster, improved yield, more uniform growth - Decreased nutrient requirement - Greater seed durability - “Single harvest only” growth 	<ul style="list-style-type: none"> • Mendel • Ceres • Monsanto • Syngenta
Enzyme	<ul style="list-style-type: none"> • Genetically enhanced microbial enzymes that are: <ul style="list-style-type: none"> - More efficient: achieve higher sugar yields - More cost effective: requires lower dosage, lower temperatures - More resilient to range of inhibitors produced upstream • Crop-produced enzymes (hydrolytic enzymes to reduce subsequent pre-treatment) 	<ul style="list-style-type: none"> • Genencor • Novozymes • Edenspace • Zymetis
Conversion	<ul style="list-style-type: none"> • Biofermentation/biocatalytic conversion: microbe-based conversion of either sugar-to-fuel (diesel, gasoline) or syngas-to-ethanol • Microbes are cheaper than conventional catalysts, continually regenerate, can be engineered to be tolerant to more impurities and operate at a broader range of temperatures/pressures 	<ul style="list-style-type: none"> • Mascoma • QTEROS • Amyris • LS9, Inc. • Gevo • Solazyme
By/co-product upgrading and other products	<ul style="list-style-type: none"> • Engineered organisms produce chemicals, with increased yield and productivity • Upgrading of byproducts of biofuel production (e.g., glycerin) process using modified organisms for the fermentation process (cheaper than traditional petrochemical route) 	<ul style="list-style-type: none"> • GlycosBio

Key message #3: Algae is a diverse and complicated landscape and still 10+ years away



Key message #4: Technologies and assets will be combined and will evolve because the lines between them are gray

- Custom application of novel technologies (e.g. synthetic biology) for multiple, differing processes
- Maximising the opportunity to leverage existing assets (e.g. retrofit, co-production)
- Combining biochemical and thermochemical processes
- Recognising that technologies or practices can be leveraged across multiple pathways (e.g. pre-treatment)

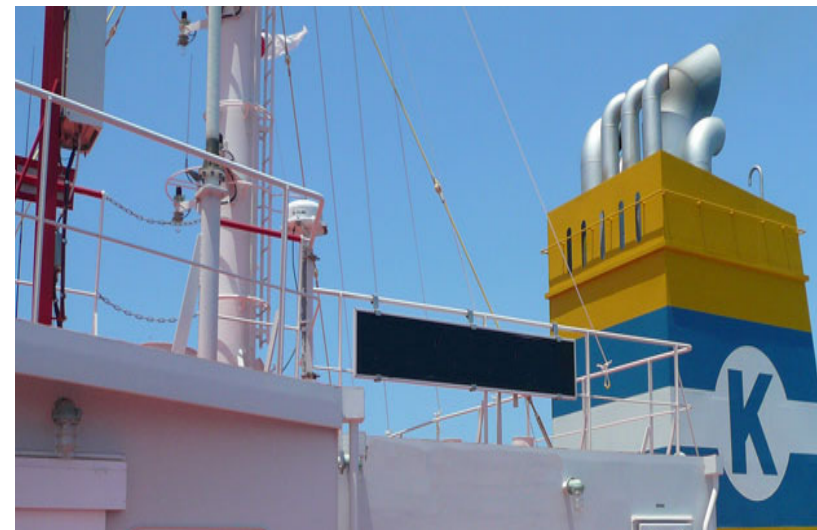
1st And 2nd



POET's Project Liberty – Emmetsburg, Iowa

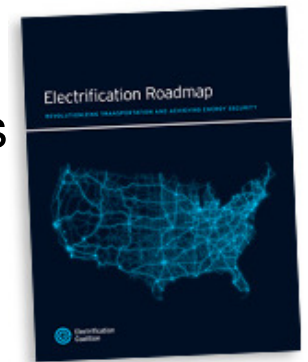
Key message #5: There will be increased activity in the airline and marine industries on options to reduce GHG

- **Global industries** with strong industry bodies and are difficult to regulate at a market level
- **Time** is required for the industry and regulators to have the **dialogue** that road transport players and regulators have been having for the past five or so years
- Aviation biofuels and marine scrubbers are **not commercially competitive** to traditional fuels today, and will be additive to what is being done today
- For aviation, there is a question of whether there will be **enough biofuel feedstock** to meet both the road and air biofuel demand
- For marine, a further constraint is **when** improvements can be made to **existing fleets** and **how often** ships are replaced



The case for electrification is compelling but the development of the industry faces major challenges

- Key message #6: Batteries are the “feedstock” of electrification and constrain its potential
- Key message #7: Electrification heralds two key players in transport fuels—utilities and battery manufacturers
- Key message #8: At least in the next five years, possibly even 10, PHEV scale up is not dependent on comprehensive “smart” grids
- The electrification consortiums are coordinated and powerful
- Leveraging close link between governments and utilities
- Recipients of significant stimulus in US, EU and China
- Stressing both energy security and green objectives
- Alliance between utilities and high tech (batteries and software) is powerful
- Industries delivering competing technologies- eg. biofuels - are not aligned



Key message #9: Markets will optimize around their own domestic agenda, resources, and economic development opportunities



	Evolution				Fungible Fuels					Electricification			
	Next Generation ICE	Next Generation Agriculture	Waste-to-Fuel	Marine Scrubbers	Sugar to diesel	Butanol	Bio-crude	Algae	Airline drop-ins	PHEV/EV+ Electrification on Engines	Batteries	Charging	Vehicle to Grid
US	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI	PI
Canada	PI	PI	PI	PI			PI	PI		PI	PI	PI	
UK	PI	PI	PI	PI	PI	PI	PI*			PI	PI	PI	
Germany	PI	PI	PI	PI	PI		PI	PI		PI	PI	PI	
France	PI	PI	PI			PI*	PI*			PI	PI	PI	
Netherlands	PI	PI	PI				PI	PI*	PI	PI	PI	PI	PI
China	PI	PI	PI			PI	PI	PI		PI	PI	PI	
Japan	PI		PI			PI			PI	PI	PI	PI	PI
South Korea	PI	PI	PI		PI					PI	PI		
Brazil	PI	PI	PI		PI			PI		PI		PI	

Key

Neither regulation/targets <i>nor</i> gov't incentives/investment	PI - Is there a company or plant developed with this technology
One of either regulation/targets <i>or</i> gov't incentives/investment	PI*-Investment by an IOC (for example, Shell, BP, Total) not in IOCs headquarters country
Both regulation/targets <i>and</i> gov't incentives/investment	Note: investor can be from another market but the company and investment is in this country

Key message # 10: The trajectory of supply, demand and GHG footprint of transport fuels is being reshaped now

Evolution is cumulative, new technologies are added but existing ones continue to be improved

	<5 Years	5-10 Years	10-15 Years	15+ Years
Internal Combustion Engine	<ul style="list-style-type: none"> OEM developments (e.g. VW Bluemotion) 	<ul style="list-style-type: none"> New gasoline technologies enter market 	<ul style="list-style-type: none"> 100mpg test car Very efficient gasoline engines 	
Biofuels	<ul style="list-style-type: none"> 1st AND 2nd Waste to fuel Butanol Sugar to diesel 	<ul style="list-style-type: none"> New energy crops Biocrude Biorefineries Advanced enzymes and deconstruction 	<ul style="list-style-type: none"> Algae Combined pretreatment, deconstruction and possibly even conversion steps 	
Electrification	<ul style="list-style-type: none"> PHEVs become commercially available 	<ul style="list-style-type: none"> Batteries improve Fast charging piloted and tested 	<ul style="list-style-type: none"> Scale-up starts 	<ul style="list-style-type: none"> V2G
Aviation	<ul style="list-style-type: none"> Trial flights and debate continues 	<ul style="list-style-type: none"> Slow and limited roll-out of small blends Expansion of production 	<ul style="list-style-type: none"> Roll-out at one or more hubs 	<ul style="list-style-type: none"> Volumes increase
Marine	<ul style="list-style-type: none"> Scrubbers commercially available but limited take up as regulation not enforced 	<ul style="list-style-type: none"> Lighter, more efficient scrubbers Start to integrate into ship design 	<ul style="list-style-type: none"> Economically competitive scrubbers Wider deployment 	<ul style="list-style-type: none"> Volumes increase

Actions for high performance

Ongoing

- Close to government and policy makers
- Execution—project management excellence, supply chain optimization
- Contracting and risk management
- Market-specific strategy

NEW

- Place scientists and engineers in leadership positions
- Partnering and business model flexibility
- Know how active tracking of the market will change baseline assumptions
- Strategies to secure long-term and flexible capital