

A quick guide™ to

BioFuels:

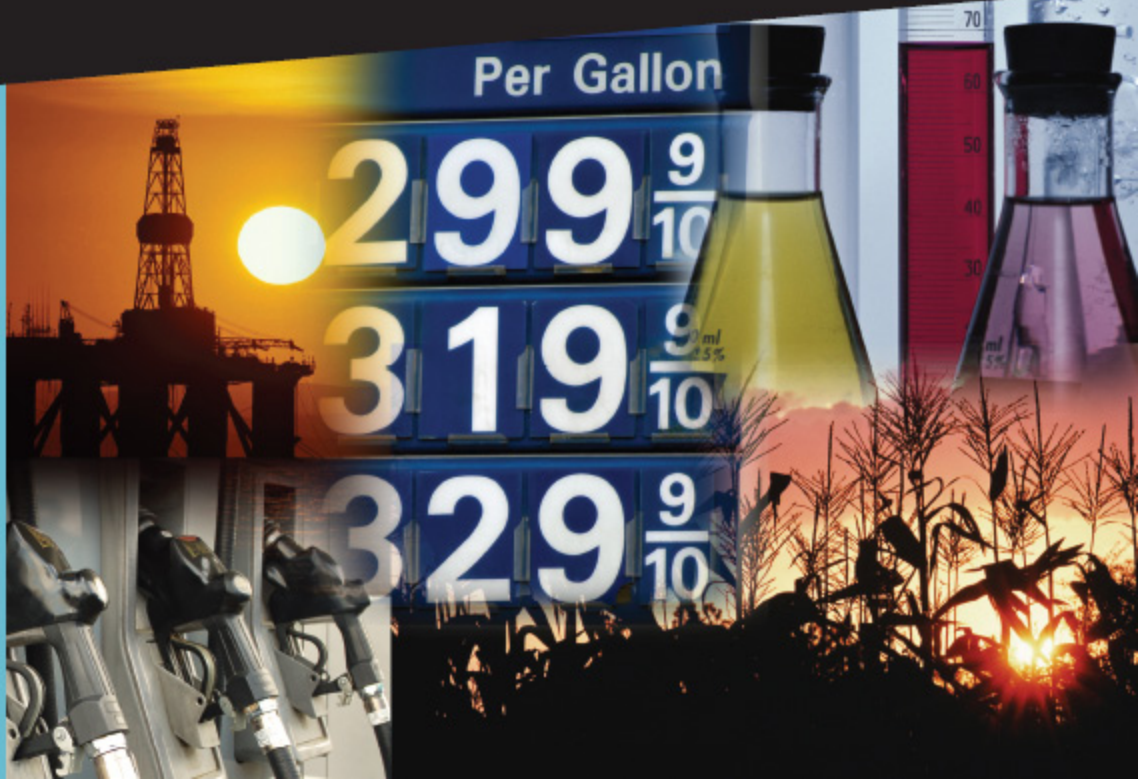
When the Oil Runs Out

“For the rest of us...”

By Dr. David Mousdale

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Dr David Mousdale

January 2010



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Rockville, MD**



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FOREWORD

BY BOBBY BRINGI, PHD.

We are at a global energy crossroads today. We face challenges related to worldwide energy demand, greenhouse gas emissions, limited fossil fuel resources, and concerns regarding energy security. The public is increasingly beginning to embrace the concepts of environmental and economic sustainability. In this emerging and turbulent milieu, there are more questions than answers, and certainly no silver bullet solutions.

There is broad consensus that renewable sources of plant and algal biomass could supply our future needs for energy, and materials. But this must happen in a way that does not compromise the expanding global needs for both human and animal nutrition, and without deteriorating the quality of our air, water, soil and ecosystems at large. Many researchers and practitioners feel that a productive, vibrant and sustainable bio-based economy is not only possible but very likely in the near future. The success of such a bio-based economy will depend on various intertwined forces, including government policies, science and technology advances, agricultural and fuel infrastructure, public acceptance, and market dynamics.

This book provides clear, concise and authoritative background and perspectives on the emerging story of biofuels. The book is useful because it:

- Captures the current global energy situation, outlining concepts and options clearly and without getting bogged down by too much detail
- Explains the basic technical underpinnings of how biomass can be converted into energy and chemicals, steering clear of technical jargon while providing enough solid data and specific information
- Provides a balanced perspective of the future potential and challenges surrounding biofuels, avoiding propaganda and helping readers to draw their own conclusions

Energy supply will be a massive global challenge. This book provides straight answers to the questions regarding the science, technology, engineering, and economics of biofuels, and will help

citizens to become better informed about this important topic that will be increasingly relevant to our future.

About Dr. Bringi: Bobby is President and CEO of Michigan-based MBI International, and brings broad expertise in bio-based technology development; scale-up and commercialization; strategic partnerships; licensing and intellectual property management; and entrepreneurial start-ups. Bobby received his Ph.D. in Chemical Engineering from Cornell University in 1991, with training in plant and biochemical sciences.



AOPA Photographer: Chris Rose

Even aircraft are now using bio-fuels. *Swift Enterprises, a Purdue University start-up, has developed a sorghum-based fuel alternative to current aviation fuel. Dave Hirschman, Aviation Writer at Aircraft Owners and Pilots Association, flew his stock 150hp Van's RV-3 from Indiana to Maryland on the new fuel, with no appreciable difference in performance. Says Hirschman, "Swift fuel has made the leap from the purely theoretical to a real product...shifting general aviation to a non-petroleum-based future."*

INTRODUCTION

BY ERIC S. LANGER

Energy is...

Biofuels today power Indy cars and airplanes as well as automobiles, trucks and buses. They appear in major TV series and are debated in international conferences. Today's most sold, traded and used biofuel – ethanol – is the alcohol in every beer, wine and spirit, and the biotechnologies that manufacture it are far older than the oldest bourbon or brewery.

But biofuels generate as many arguments as they offer routes to energy independence and security. Do biofuels help slow global warming or contribute to atmospheric CO₂? Will biofuels give a sustainable future or snatch food from the mouths of the world's poor as staple food crops are pushed aside in favor of “bioenergy” crops? Are rainforests being decimated so that plantations destined for biofuels reduce global biodiversity? Can we even afford biofuels?

One answer is easy: Plants (“biomass”) offer an alternative to the world's unhealthy addiction to fossil fuels, and especially to oil. Modern life depends on the products of the petrochemical industry, but the timeline of oil depletion be dangerously short. Mankind needs solutions for when the oil runs out – as it eventually will - within three decades or three centuries. Of those two extreme scenarios, the longer may prove catastrophic if global warming follows its relentless course. The shorter concentrates the mind but with the knowledge that biotechnological solutions exist *now*.

The following ten chapters explain how to best use that important know-how.

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ACKNOWLEDGMENT

BY DAVID MOUSDALE

We thank Larry E. Drumm for his expertise, wisdom, and editorial support, as we developed the concept for this book. His awareness of the industry ensured we covered all the critical issues. Larry Drumm has nearly 40 years of experience in the chemical and biotechnology industries focusing on business development, most recently with Industrial Biotechnology Corporation. In his career, he has held positions with Eastman Chemical Products, Inc., Genencor International, a DuPont/ConAgra joint venture, and Bio-Technical Resources, and has recently been intensively involved in new biotechnologies, biorefineries, and innovations in the chemical industry.

We also thank Eric Langer, President and Managing Partner at Bio-Plan Associates, Inc., for his understanding and helpful support while we attempted to deconvolute biofuels and their rapid, hotly debated, and changing interactions with the modern world. It was Eric's aim to put across to a broad section of society an informed and informative account of where biofuels stand at the end of the first decade of the 21st century.

We hope we have not disappointed him.

David Mousdale
— *January 2010*



Advisor: Larry Drumm has 40 years of experience in the chemical and biotechnology industries, and intensive involvement in new biotechnologies, biorefineries, and innovations in the chemical industry. Larry holds an MBA. from the University of Hartford and a BS in Chemical Engineering from the University of Cincinnati.

PREFACE

What went wrong for biofuels?

In the first five years after the Millennium, in those increasingly distant times, corn ethanol offered economic revitalization in the Midwest and energy security. Cane sugar ethanol promised a new world energy picture radically different from the OPEC-dominated Oil-dorado of the decades following World War II. Cane sugar ethanol even figured in the short-lived CBS TV series *Cane*. But starting in late 2006 and snowballing in 2007, media stories increasingly mounted an offensive against biofuels, citing environmental damage and – most damagingly – causing rocketing food prices and riots in Mexico, Egypt and in about 20 other countries in Asia, the Americas and Africa.

It was a crude travesty, obvious as little as three years later – with that extra hindsight, the cheap credit-fueled excesses that led to bank closures, global recession/depression and Ponzi schemes now appear as an era as bizarre as that of the Roaring Twenties. Rocketing oil prices triggered price hikes wherever oil contributed to production costs. This was a nearly all-pervasive effect in developed economies, reaching down to farmers dependent on fossil fuel-powered machinery (as they certainly are in the Midwest), as well as to the global chemical industry. China's economic surge sucked in not only raw materials but also massive influxes of food, as the world's largest single national population began its march toward progressive enrichment and new appetites.

Environmentalists had been highly suspicious of the claims made for those "first generation" biofuels (corn ethanol, sugarcane ethanol and – in Europe – highly subsidized sugar beet ethanol and rapeseed biodiesel). Their benefits were too often over-hyped as alternatives to fossil fuel depletion, CO₂ and other greenhouse gas emissions, and global warming. Suddenly, opponents had a clinching argument: Biofuels starved the world's poor, chasing them off quality land while new monoculture crops took over to feed the demands of Western motorists for gasoline substitutes. At the same time, rain

forests from Amazonia to Indonesia were being cleared to make way for new plantations, and endangered species became...well, more endangered.

The “food versus fuel” argument still rages, of course. Still, oil prices have halved from their 2008 peaks and the overheated machine of globalization has had the chance to cool down. New phrases have become highly significant in the global energy landscape:

- Cellulosic ethanol
- Second-generation biofuels
- Advanced biofuels
- Nonfood crop bioenergy sources
- The Hydrogen economy and Hydrogen Highways
- Fuel cells and microbial fuel cells
- Green diesel
- Renewable diesel
- Biomass-to-fuel programs
- Biorefineries and
- Biobased sustainability...to name a few.



The traditional oil and refining industries have cleaned up their collective act, developing low-sulfur diesel and successively eliminating first lead then toxic and polluting MBTE oxygenate from road fuels. “Clean Fuels” is now the catchphrase, and biofuels are firmly established in the industry’s trade journal under that benign heading. The major oil companies all have energetic and wide ranging biofuels agendas while – at the other end of the manufacturing scale – “make your own” initiatives for biofuels expand year by year.

What does all this mean? Estimates of how much oil remains untapped beneath the ground varying from centuries to a few decades. We can devise new means of exploiting physical energy sources easily – at a cost. Solar, hydrothermal, wind, wave, tidal: the technologies are known. But oil has fueled the world’s chemical industries, via petrochemical feedstocks, since the middle of the 20th century,

and that supply of material can never be substituted by sunlight alone. The carbon (and hydrogen) in oil and natural gas hydrocarbons is essential for modern commodity engineering. There is only one alternative source: plant biomass carbon (and hydrogen, oxygen, nitrogen, and sulfur), from both land plants and marine seaweeds. Both land and marine plant sources are massive in scale and – crucially for the future – can routinely do what animals, mammals and humans cannot accomplish, i.e., “fix” carbon from gaseous CO₂ in the atmosphere.

Biotechnology can now offer the means to both manufacture biofuels (including hydrogen, the only truly carbon-negative fuel) and also use the collective “genius” of thousands of natural and genetically engineered microbial species to generate in bulk all the compounds and molecules on which modern chemistry depends. Some of this knowledge is ancient (alcohol as a social commodity), while much of the remainder can be traced back for over a century of scientific endeavor – indeed, some bio-based industries have already risen and fallen into disuse within living memory.

This book aims to provide a brief but inclusive guide to the science of biofuels and to put that scientific knowledge in a practical everyday context. To what extent will biofuels affect mass transportation and how may highly uncertain energy prospects in the next 30-50 years impact people’s daily lives? What revolutionary changes are on the horizon for vehicle technologies? Are practical timelines possible for technical development and economic stability? Each chapter will cover technical issues, cite further sources of information, and point clearly to sources of real numbers to back up conclusions and predictions.

If the present text inspires interest in the enormous range of possible solutions offered by modern biology to problems as pressing as energy security and fuel inflation, that will count as success. While no one can accurately predict the course of global events in the coming decades, we can start by knowing where the road begins, how “road maps” can be constructed to clearly establish what is known (as data, numbers, and information) so the unknown can be understood.

Addicted to oil?

Searching for a way you can help reduce greenhouse gases?

Biofuels are widely touted as one means of doing both – but what about food versus fuel?

In the coming years, energy supply will be a massive global challenge. In this book we give answers from science, technology, engineering, and economics:

- *How will biofuels impact our lifestyle and economies?*
- *What is happening around the world in biofuels?*
- *What can an individual citizen do?*

We start from biotechnology, exploring the know how to convert plants on the land and in the seas into fuels that are already here – like ethanol and biodiesel – and then plot a future for advanced fuels like hydrogen that will give the 21st century a nonpolluting sustainable answer to today's top fears for the future of the Earth.

“Doctor Mousdale provides a fine survey of the state-of-the-art in biofuels production coupled with insightful looks at the potential and need for expansion.”

*Dave Rinebolt, Exec. Director, Ohio Partners for Affordable Energy,
Author: Turning Manure Into Gold: Converting Agricultural Waste to Energy.*

“Should be a mandatory read for all politicians and journalists before they comment or write about biofuels.”

*Giles Clark, Editor, Biofuel Review —
a primary news resource for the Biofuels markets*



David Mousdale, Ph.D. is Managing Director of beocarta Ltd., a Scottish based biotech R&D company that pioneered detailed metabolic analysis of large-scale industrial fermentations, and has worked with international clients in the U.S., Japan, Korea, India, and throughout Europe.

Recent projects have included marine bacteria, biofuels (ethanol and biodiesel), fungi synthesizing extracellular polysaccharides, and an industrial antibiotic process.

David holds an M.A. from the University of Oxford and a Ph.D. from the University of Cambridge.

“A concise and uncomplicated history, status and outlook for the biofuels agenda that is applicable for layman as well as the industry insider. The information presented here on this imperative topic is beneficial to everyone, whether you'll be financing biofuels, producing it or just pumping it into your fuel tank.”

*Michael Harris, Executive Editor, BioWorld Publications,
Author: BioWorld Biofuels Report: Lane-Changing Trends*

