INNOVATIVE AND UNIQUE RAW MATERIALS USED WORLDWIDE TO MANUFACTURE BIOFUELS

With a global rise in concern for ecological stability and climate change, we have seen that replacing fossil fuels is a must. While energy usage and individual responsibility can be an area to optimize: the replacement or supplementation of fossil fuels with biofuels in most traditional applications is recognized as a worthwhile investment for the future of our environment. Traditionally, biofuels are made with food crop feed stock, but there is a growing need for unique options on the path to biofuel production. The use of food crop feed stock has placed growing concerns on the markets and on governments with regards to usage of land, sharp price increases, and ecological concerns. Ideally, we would use feedstocks that are available but unneeded, and with global concern for environmental stability rising, teams all around the world have innovated in this field. From waste currency to discarded agricultural by-products, these unique feedstocks are allowing all areas of the world to take steps to reducing fossil fuel dependency. As well, though there are clear benefits to shifting away from fossil fuels, there are nuanced side-effects the integration of biofuel into our everyday lives. There will be economic, societal, and environmental impact, but whether it would net positive remains to be seen.

Municipal Waste

In Figure 1 above, it becomes apparent that the quantity of organic waste makes it an important and plentiful precursor to consider as it is readily available and is most under the control of municipal systems. Two examples are out of circulation currency [2], and sewage sludge [3]. Waste currency is a guaranteed byproduct of currency circulation and changes, so researchers in South Korea devised a method to reliably break down and process out of circulation currency into usable biofuel; and this could have worldwide applications. As can be seen in Figure 2 [4], in the United States, a dollar bill (depending on denomination) can last on average from six to just under twenty-three years [4], meaning that every day, millions of dollars in bills are shredded for disposal and recycling. These bill shreds used to be landfill, but recently became feedstock for enriching soil through composting, but they may yet find another application as a readily available alternative to food-crop based biofuels.

The importance of using readily available municipal waste cannot be understated. These feedstocks are widely available, dirt cheap, unwanted, and oftentimes would end up in landfill or other environmentally damaging waste areas. For example, sewage sludge from any municipal water treatment plant, and sawdust from common production, both of which produce desirable feedstocks for biofuel production. A team of researchers in Thailand found that certain ratios of sludge to sawdust produced an excellent biomass feedstock for biofuel production [3]. Through existing methods of mechanical, thermal, biological, or combined conversion processes [5], the team was able to test the feedstock and ultimately found only slightly lower yields of fuels than traditional petroleum feedstocks. Any feedstocks are a product of their environment, and the initiative of these researchers to show municipal waste could be better applied to biofuels over landfills demonstrates that biofuels are no longer limited to regions with farmable soil, but worldwide – wherever humanity chooses to live.

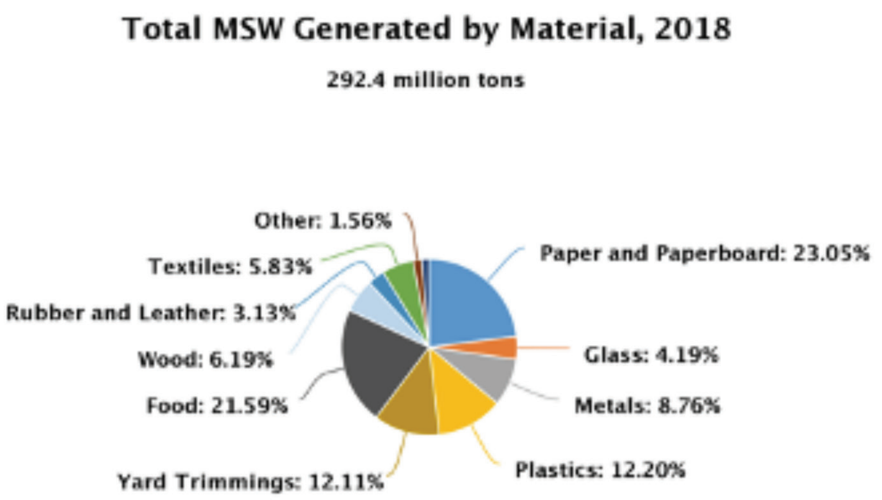

Figure 1 EPA data showing that biological products, like wood, paper, and yard trimming make up a significant portion of landfill material. As well, miscellaneous food product and other waste product also take up a large portion. (2018) [1]

Cellulosic Materials

Looking back at natural production, it's well known that just as in the animal kingdom energy is lost up the chain to an apex predator per each prey, corn, among other feedstock food-crops is horribly inefficient in regards to the amount of energy it absorbs from the sun, being on average far lower than all plants. As well, much of corn, and other feedstocks, contains easily converted biomass, such as extractable oils, and difficult to convert biomass, such as shells and leaves which need to be shucked and disposed of, or used as a feedstock in a less efficient conversion process. Related to these "cellulosic" components, Furfural (a depolymerization of hemicellulose, a cellulosic component) is a common precursor

Denomination	Estimated Lifespan*
$1	6.6 years
$5	4.7 years
$10	5.3 years
$20	7.8 years
$50	12.2 years
$100	22.9 years

Figure 2 Estimated lifespans of different denominations of US currency from the federal reserve board of governors (as of 2018) [4]

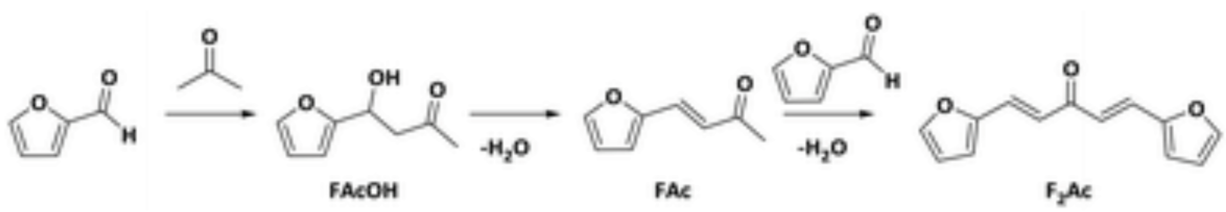

Figure 3 Schematic illustration of aldol condensation between furfural and acetone. [6]

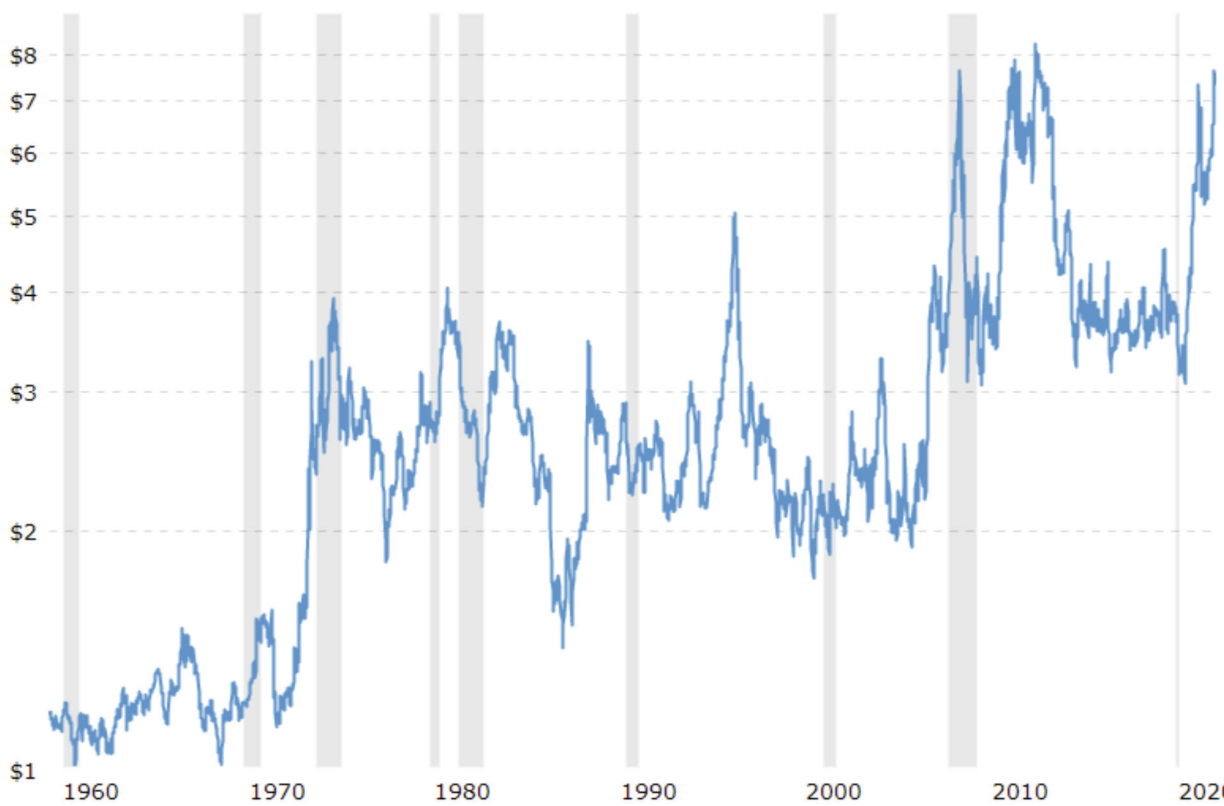

Figure 1 Rise in corn prices from $1 to $8 (1960 – 2020) [7]

Figure 4 Rise in corn prices from $1 to $8 (1960 – 2020) [7]

to many organic compounds (including biofuel), and recent experimentation from researchers in France revealed new methods of converting Furfural into biofuel precursors [6].

The method proceeds via aldol condensation with acetone, seen in Figure 3 [6], over magnesium hydroxide fluorides, and with a balanced composition of the catalyst, the process can proceed without needing an activation step, which saves on cost [6]. The importance of this is obvious considering that although the potential energy that is lost from primary feedstock is acceptable (to current societal use of biofuels), this is not the case for cellulosic materials, and so methods as the above are pivotal to reducing the cost and complexity of cellulosic feedstock conversion. Looking ahead, not only would this allow existing food-crop feedstock to be used more efficiently, but would allow cellulosic materials, which are landfilled, or processed less efficiently, to be processed more efficiently, and increase biofuels production while requiring less farmland to go to producing more food-crop feedstock. Lastly, though corn was used as an example, many other food-crops are available for use directly and through their cellulosic material.

Concerns

While these innovations are appealing, it is important to discuss the drawbacks and side-effects of any new technologies, even those as promising as biofuels. Most directly impactful is the incentive shift of farmers from food-crop to fuel-crop. Since the advent of modern farming practices, the amount of food a farmer could produce far exceeded the demand, so governments introduced financial incentives for farmers to grow less, or otherwise reduce the supply of their crop through reasonable means. While this technique was effective for stabilizing food prices, it forces farmers to rely on subsidies rather than the volume of crop they produce. With the increasing demand of food crop as biofuel feedstock, there was greater financial incentive to grow crops as feedstock for biofuel production instead of for human consumption. The effects of this are clear; as can be seen in Figure 4 [7], the price per bushel over the past decade has been averaging around $6, which compared to the previous averages of around $3, held from the 1970's all the way to the late 2000's, is nearly double!

Another indirect concern involves the impact of processing waste, particularly municipal waste, on the production of municipal waste itself. Although it is fair to assume that in the immediate future, municipalities will continue to treat their wastewater, garbage, and recycling materials, it stands to reason that the idea of biofuel conversion may lead to an increase in diversion of material to biofuels. This is counterintuitive, as we would assume more biofuel production is positive, but Occam's razor suggests that instead of making use of unused sludge, landfill material, etc… municipalities would boldly shift away resources from other recycling methods, refurbishment processes, and cleanup efforts, and hedge all their eggs in the basket of biofuels. This is a human error, but an error nonetheless we must consider. It is important to keep hope and an open-mind for the future of biofuels, but it is more important to retain realism, especially when communication of biofuel-related information is prone to misinterpretation.

With regards to the purpose and application of biofuels in general, these terms also fall unfavorably against the biofuels. The main hope behind all biofuel feedstocks is that the net carbon emissions, that is the carbon emitted from processing and using the biofuels, is negated by the carbon used to produce the feedstock itself (i.e., growing crops). The reality of the situation is that this is not the case. At the moment, inefficiencies in production, wasteful/unused material (cellulosic for example), and lack of application all serve as stoppers for biofuels as being induced into the mainstream. While production and efficiency are being improved upon every day by researchers around the world, it's important to recognize most biofuels are not compatible with the machines that require them in the first place. Take for example automobiles: most biofuels are ethanol, while most engines are made to work with the thermochemical properties of higher carbon hydrocarbons, such as octane. Though there is now a requirement for gasoline to contain a percentage of bioethanol (which leads to inflated price of feedstock due to government mandate resultant market), we are not in the realm where the everyday driver can load their car with biofuels. As well, planes and heavier vehicles that rely on kerosene or higher chain fuels like diesel are out of luck in most cases, whereas the production of high carbon biofuels is far more complex, thus less favorable.

Simply put, this boils down to the fact that as a source of energy, biomass does not well utilize the energy it receives from sunlight. On average, the efficiency of photosynthesis is low [8] enough to where solar panels readily outperform their chlorophyll counterparts, making oftentimes far greater utilization of the sun's energy, while requiring no preparation, processing, or waste management. As well, with regards to water consumption, solar panels are greatly more water efficient (so is traditional petroleum), quite literally blowing biomass feedstock out of the water.

Conclusion

In conclusion, though there are many innovations in the field of biofuels, there are also many possibilities to consider. Undesirable economic and social effects have come up as this technology has matured, but it is universally accepted that it would be a better alternative compared to fossil fuel extraction and burning. There are equally compelling arguments to pursue other forms of renewable energy, but as we have seen, biofuels allow previously wasted and problematic materials to become feedstock, so perhaps we can see a future where biofuels are a supplementary energy source as a by-product of waste management. In the end, pursuit of ecologically friendly alternatives to landfills and dumping are always preferable, so we shall wait eagerly to see what other unique and innovative biofuel feedstocks can be discovered.

References

[1] - "National Overview: Facts and Figures on Materials, Wastes and Recycling." EPA, Environmental Protection Agency, https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials.

[2] - Sheikh, Md. Mominul Islam, et al. "Production of Bioethanol from Waste Money Bills – A New Cellulosic Material for Biofuels." Food and Bioproducts Processing, vol. 91, no. 1, Elsevier B.V, 2013, pp. 60–65, https://doi.org/10.1016/j.fbp.2012.09.001.

[3] - Ali, Liaqat, et al. "Physicochemical Characterisation and the Prospects of Biofuel Production from Rubberwood Sawdust and Sewage Sludge." Sustainability (Basel, Switzerland), vol. 13, no. 11, MDPI AG, 2021, p. 5942–, https://doi.org/10.3390/su13115942.

[4] - Board of Governors of the Federal Reserve System https://www.federalreserve.gov/faqs/how-long-is-th0e-life-span-of-us-paper-money.htm.

[5] - Mu, Dongyan et al. "Comparative life cycle assessment of lignocellulosic ethanol production: biochemical versus thermochemical conversion." Environmental management vol. 46,4 (2010): 565-78. doi:10.1007/s00267-010-9494-2

[6] - Xu, Minrui, et al. "Upgrading of Furfural to Biofuel Precursors via Aldol Condensation with Acetone over Magnesium Hydroxide Fluorides MgF2−x(OH)x." Catalysis Science & Technology, vol. 9, no. 20, 2019, pp. 5793–802, https://doi.org/10.1039/C9CY01259A.

[7] - "Corn Prices - 59 Year Historical Chart." MacroTrends, https://www.macrotrends.net/2532/corn-prices-historical-chart-data

[8] - "Biological Energy Production." Chapter 1 - Biological Energy Production, https://www.fao.org/3/w7241e/w7241e05.htm#1.2.1.

Authors

Dr. Raj Shah is a Director at Koehler Instrument Company in New York, where he has worked for the last 27 years. He is an elected Fellow by his peers at IChemE, CMI, STLE, AIC, NLGI, INSTMC, Institute of Physics, The Energy Institute and The Royal Society of Chemistry. An ASTM Eagle award recipient, Dr. Shah recently coedited the bestseller, "Fuels and Lubricants handbook", details of which are available at ASTM's Long-Awaited Fuels and Lubricants Handbook 2nd Edition Now Available (https://bit.ly/3u2e6GY). He earned his doctorate in Chemical Engineering from The Pennsylvania State University and is a Fellow from The Chartered Management Institute, London. Dr. Shah is also a Chartered Scientist with the Science Council, a Chartered Petroleum Engineer with the Energy Institute and a Chartered Engineer with the Engineering council, UK. Dr. Shah was recently granted the honorific of "Eminent engineer" with Tau beta Pi, the largest engineering society in the USA. He is on the Advisory board of directors at Farmingdale university (Mechanical Technology) , Auburn Univ (Tribology) and Stony Brook University (Chemical engineering/ Material Science and engineering).
An Adjunct Professor at the State University of New York, Stony Brook, in the Department of Material Science and Chemical engineering, Raj also has over 500 publications and has been active in the alternative energy industry for over 3 decades. More information on Raj can be found at https://bit.ly/3sayVgT

Allen Rakhamimov and **Blerim Gashi** are part of a thriving internship program at Koehler Instrument company and are students of chemical engineering at State University of New York, Stony Brook, where Dr. Shah currently heads the External advisory board of directors.

Author Contact Details

Dr. Raj Shah, Koehler Instrument Company • Holtsvile, NY 11742 USA • Email: rshah@koehlerinstrument.com • Web: www.koehlerinstrument.com

Allen Rakhamimov • **SUNY, Stony Brook University**

Blerim Gashi • **SUNY, Stony Brook University**


Allen Rakhamimov


Blerim Gashi


Raj Shah