MARCH 2017

Algenol: Case study of an unsuccessful algae biofuels venture

EXECUTIVE SUMMARY

Algenol is a Florida-based biotechnology company that has received considerable attention as one of the most promising algae biofuel startups. Since its founding in 2006, the company has received $35 - $50 million in public support, alongside tens of millions in private-sector investment.

Despite significant hype, however, Algenol has remarkably little to show for its investments – a prime example of an industry kept aloft by empty promises, while developing technologies with potentially serious impacts on ecosystems and human health.

This briefing demonstrates that:

1. Despite rosy claims to the contrary, Algenol faces significant economic and technological hurdles to commercialization. This experience mirrors that of other algae and cellulosic biofuel startups that have received public sector support yet have so far failed to bring a product to market.

2. Algenol's genetically engineered (GE) cyanobacteria pose potentially significant threats should they be released into the wild. Such a release will be difficult to prevent in an industrial refinery environment.

We conclude that government support for algal biofuels – as with fossil fuels and other harmful energy sources – is a foolhardy use of taxpayer resources, given the lack of demonstrated environmental benefit or successful commercial application.

Public sector funding would be put to better use on research, development, and demonstration of proven measures to reduce energy waste and over-consumption while also ensuring equitable access and control over production and distribution.

INTRODUCTION

Algae play a key role in the regulation of the earth's systems, and are found in almost every ecosystem on the planet. While there is no universally agreed upon definition of algae, most biologists confine the term to photosynthetic life ranging from unicellular microorganisms to macro-scale seaweeds, as well as bacteria capable of photosynthesis – known as cyanobacteria, or "blue-green algae." Algae are thought to have played a significant role in drawing down atmospheric CO_2 levels in a previous spike around 50 million years ago, and are responsible for much of the oxygen we currently breathe.

Research on algal biofuels has been ongoing since the mid-20th century. Beginning in 1978, the U.S. government funded the Aquatic Species Program (ASP), which over its 18 years of existence identified two main pathways for producing algal biofuels – growing algae in open ponds or raceways, or inside of plastic tubes called photobioreactors.[1]

The ASP was eventually defunded in 1996, with its scientists concluding that raceways faced difficult hurdles due to contamination, while photobioreactors were too expensive for use in biofuel production. However, the program laid the groundwork for today's algal biofuels boom, especially in catalyzing research on genetically engineering algae species to promote certain traits beneficial to energy production.

Founded in 2006, Algenol was one of hundreds of startup algae-based biofuel companies that aimed to pick up where the ASP left off.[2] Many of these companies have since folded or gone bankrupt, but Algenol continues to attract private and public investment – despite its failure, after ten years of existence, to produce commercially viable biofuel.

Algenol was successful in attracting attention and investment based on the claim that its proprietary algae could cost-effectively transform CO_2, an industrial waste gas, into ethanol – a process that's been described as the "holy grail" of bioenergy production.[3] If successful, this process would allow large polluters to avoid measures to reduce emissions by substituting "reuse". They could potentially derive profits from sale of CO_2 derived products, and also command elevated prices in the context of renewable fuels standards or other subsidized markets for such biofuels.

Algenol's system involves vertically aligned closed plastic photobioreactors, filled with seawater and GE blue-green algae, into which CO_2 is pumped as a feedstock. The algae, which possess the natural capacity to secrete tiny amounts of ethanol, have been genetically engineered to produce significantly more ethanol, in addition to other traits beneficial to commercial production.

This ethanol leaks into the surrounding seawater medium and evaporates in the headspace at the top of the photobioreactor, condensing and draining off into an energy-intensive refining system designed to separate the fuel from water and other chemicals. The process eliminates the need to crush and kill each batch of algae to extract the oil – allowing for repeated harvests, in what the company likens to "milking the cow, as opposed to butchering it."[4]

However, technological and economic barriers have beset Algenol's roadmap towards commercialization from the very beginning. Despite years of research and development, the company's ethanol-producing algae continue to underperform, leading to the company's 2015 decision to shelve its ethanol pathway for the time being.[5] Prohibitively high costs plague the company throughout its production process, leading to a questionable profitability margin.

These fundamental issues, alongside poor market conditions, appear to underpin Algenol's recent turn towards non-fuel-based commodity production – a pattern that defines the trend among a slew of algae and microbial fuel startup companies. This trend, exemplified by companies such as Algenol and Solazyme, raises serious questions about why biofuel investors and the U.S. government continue to provide significant finance.[6]

A CHRONOLOGY OF ALGENOL

Algenol's roots go back to the 1980's, when co-founder Paul Woods spent $700,000 financing research on GE cyanobacteria with the capacity to produce ethanol.[7] The results of that research were published in 1999, with U.S. patents on two GE algae strains secured in 2001 and 2004.[8,9,10]

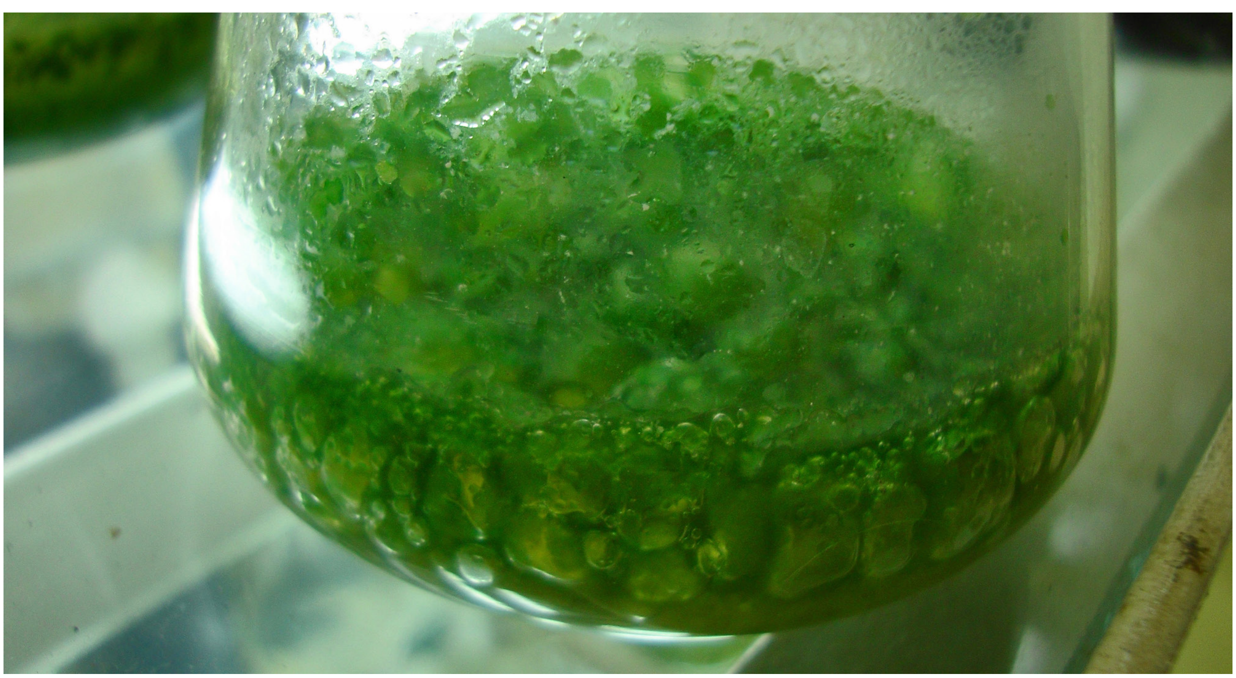
After oil prices surpassed $50/barrel, Woods teamed up with former pharmaceutical executives Craig Smith and Ed Legere to launch Algenol in March of 2006. The company had an immediate boost from Mexico City-based businessman Alejandro González, who contributed the bulk of $70 million in startup capital and also extended $100 million for the rights to use Algenol's proprietary technology in Mexico.[11,12]

With the support of González, the owner of a major cardboard recycling company and heir to the Corona beer fortune, Algenol quickly expanded its operations. The company opened laboratories in Germany, Spain and Florida to research and test algae systems, and hired researchers at Johns Hopkins and the University of Maryland to start a lab that would function, in their words, as "the world's largest algae library."[13,14,15]

In 2009, the company partnered with Dow Chemicals on a successful bid for an American Recovery and Reinvestment Act (ARRA) grant via DOE, netting $25 million to build a pilot-scale algae-to-ethanol biorefinery with a projected output of 100,000 gallons of ethanol per year."[16] The project was initially slated to be built at Dow's facility in Texas, but a souring relationship and a $10 million grant from Lee County, Florida enticed Algenol to move operations to the Sunshine State.[17,18]

Algenol continued expanding after Indian petrochemical conglomerate Reliance Industries sunk $93.5 million into the company, and by 2014, it was ranked the "#1 hottest U.S. biofuels company" by Biofuels Digest.[19,20] That year, the federal government approved three of Algenol's GE algae strands under the Toxic Substances Control Act (TSCA), and also approved Algenol's ethanol as qualifying for advanced biofuel credits under the Renewable Fuels Standard (RFS).[21,22]

In 2015, however, shortly after announcing a deal to build a $1.3 billion commercial biorefinery, Algenol's investors pushed through a major overhaul in their corporate strategy.[23] The company's board, led by González, announced plans to scale back from biofuels and pivot towards near-term commercial prospects in carbon capture, food additives and nutraceuticals. CEO Paul Woods resigned shortly thereafter.[24]



The commercial biorefinery plans were quietly scrapped.

In shifting to non-fuel-based products, Algenol is following a long line of algal biofuel companies scrambling for return on investment amidst poor energy market conditions and underperforming technologies. After $50 million in DOE support, Sapphire Energy now makes algal oil for nutritional supplements. Solazyme received $22 million from the DOE for algae biofuels, and after failing to succeed, now sells anti-wrinkle skin-care products.[25]

Biofuelwatch believes it is unlikely that taxpayers would knowingly approve of millions of dollars being handed to companies that only appear capable of producing niche cosmetic compounds made from risky engineered microbes.

ISSUES WITH ALGENOL'S TECHNOLOGY

A closer look at Algenol's production process reveals high capital and operating costs, a low energy return on investment, and – despite the green hype – less-than-stellar greenhouse gas emissions reductions.

Algenol has maintained that contrary to the findings of the Aquatic Species Program, it could cost-effectively produce algae biofuels with a photobioreactor system. However, the company's experience seems to be confirming, rather than refuting, the ASP's findings. In its initial horizontal PBR model, Algenol encountered chronic issues with photoinhibition (and hence, productivity), leading the company to switch to a hanging, vertical PBR model. However, it appears that the new model faces the same fundamental scale-up constraints due to capital expenditure, leading DOE to remark, in a peer review of Algenol published in 2016, "it is unclear whether closed photobioreactors will ever be a viable commercial option."[26]

An even more problematic situation arises from the productivity and stability of the algae itself. In 2013, Algenol reported a loss in productivity once its cell lines were subjected to outdoor conditions, alongside issues related to batch contamination by ethanol-consuming bacteria.[27] In a subsequent 2015 report, it once again flagged contamination as an issue, and placed ethanol productivity and genetic stability as top priorities for lowering capital and operating costs.[28] That's because the productivity of the algae has a determining impact on the entire production process – with low performance driving up costs and lifecycle greenhouse gas emissions, while driving down the energy return on investment.

Among the many energy requirements in the production process, the downstream separation of ethanol from the seawater medium stands out as a "major consumer of energy and a significant contributor to the carbon footprint."[29] Algenol begins with an initial concentration of 0.5% – 2% ethanol in the seawater medium, and uses a variety of energy-intensive technologies to concentrate it to 99.7%, fuel-grade ethanol.[30] A 2010 paper co-published by the company notes that, "Total greenhouse gas emissions from the algal ethanol process depend strongly on the initial ethanol concentration and on the energy system used to concentrate the ethanol."[31] Put another way – if the algae fails to produce at the expected levels, significantly more energy is required in the downstream refining process.

This dynamic also impacts Algenol's ability to receive credits (RINs) under the Renewable Fuel Standard, which obligates gasoline refiners and importers to purchase certain quantities of low-carbon fuels. Fuel producers are required to submit their production process to a lifecycle greenhouse gas analysis in order to demonstrate GHG reductions from a baseline. Algenol won approval for advanced biofuel RINs in 2014 for its algae-to-ethanol process.

EPA's approval presents tight constraints on the energy sources used in production, detailing "only electricity and heat that [is] produced from an onsite combined heat and power (CHP) unit that is powered exclusively by a combination of natural gas and bio-methane," with no more than 50.8 MJ of natural gas per gallon of ethanol produced.[32] Moreover, it turns out that without being awarded credits for the co-production of bio-oil and biogas, Algenol's ethanol is unable to meet the 50% lifecycle GHG reductions to qualify for advanced biofuel RINs. EPA awards these credits on the assumption that biogas produced by gasifying residual organic matter is burned onsite in the CHP unit, and that bio-oil produced through hydrothermal liquefaction of spent algae would displace a hypothetical mass equivalent of soybean oil in the market.[33]

This data suggests that Algenol's claim to advanced biofuel RINs is tenuous at best. The company is unable to utilize even low-carbon grid electricity, and must rely upon natural gas delivery in order to continue qualifying for RINs. It also leaves the company vulnerable to fluctuations in the price of natural gas, which could make a particular commercial biorefinery unprofitable when combined with underperforming algae cultures.

WHAT IF GE ALGAE ARE RELEASED INTO THE ENVIRONMENT?

In its 2015 report on synthetic biology, the secretariat of the Convention on Biological Diversity notes that, "It is widely acknowledged among microbial biologists and ecologists that physical containment [of GE microorganisms] is never fail-proof."[34] However, rather than a holistic, systematic review of all relevant risk dimensions associated with a release of GE microorganisms, the U.S. Environmental Protection Agency relies upon an outdated regulatory regime, TSCA, that's incapable of assessing the novel risks of new biotechnologies.

Under TSCA, companies like Algenol are only required to file a Microbial Commercial Activity Notice (MCAN) when moving forward with commercialization of a new GE microorganism.[35] Research and development is thus exempt from proper risk assessment. This exemption, while originally promulgated under the assumption that R&D activities would occur in a closed laboratory, has been expanded to include activities in refineries and other industrial plants operated primarily by workers with no background in biosafety – creating a dangerous loophole that accelerates the likelihood of release.

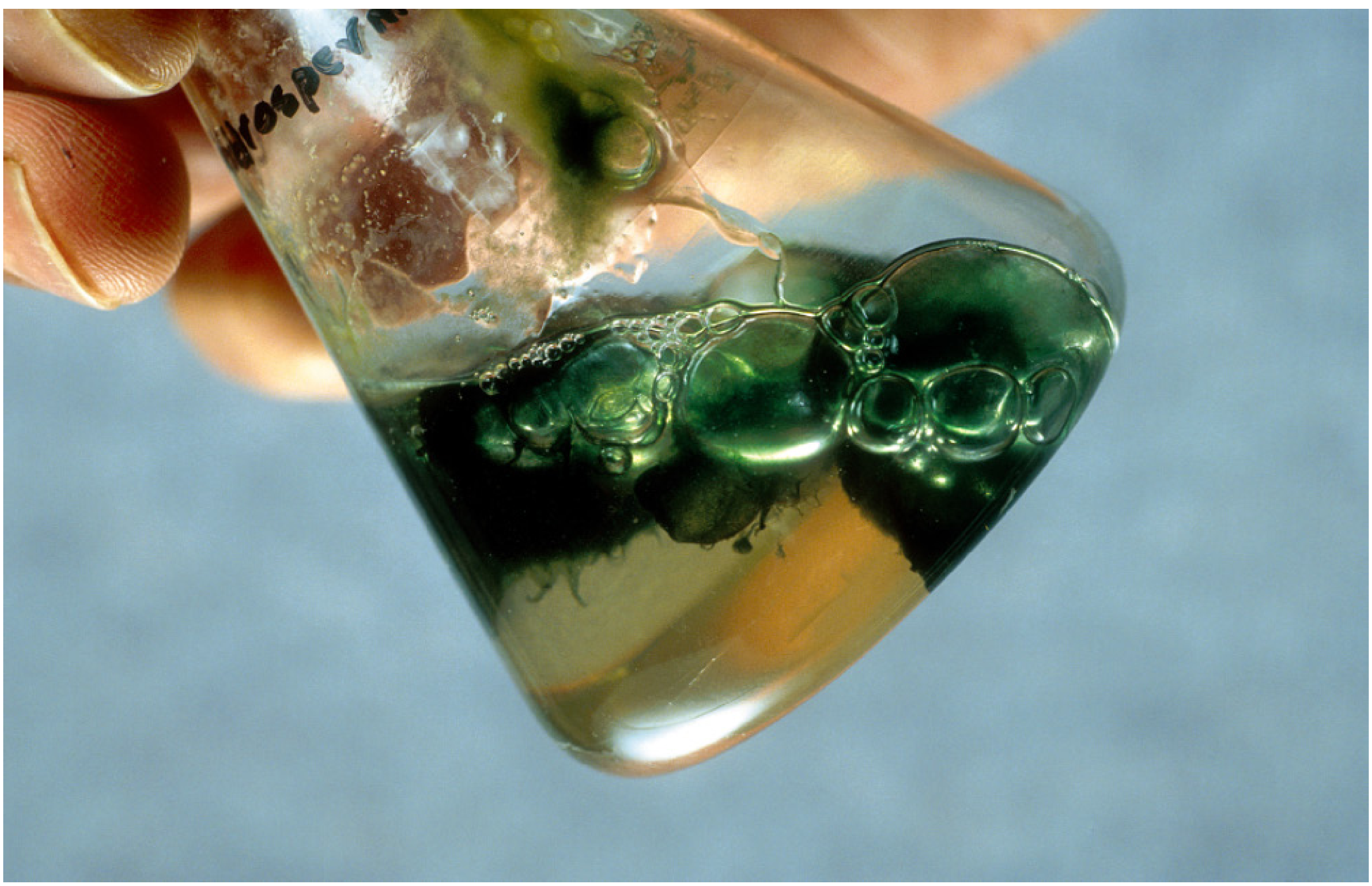
In 2014, EPA granted Algenol MCAN approval to commercialize three strains of GE cyanobacteria, with the condition (known as a 5e consent order) that Algenol consent to additional testing, recordkeeping, and restrictions.[36] While Biofuelwatch has not yet been able to access Algenol's MCAN submission or the 5e consent agreement, it is possible to analyze the company's claims based on written comments it submitted to EPA in the fall of 2015.[37]

Responding to concerns about the release of GE algae into the environment, the company states that "the burden should not be on the submitter to 'demonstrate' that a containment system is secure," noting that EPA's standard practice in reviewing MCANs has "generally acknowledged that contained systems cannot prevent all accidental release."

This dismissive claim flies in the face of the precautionary principle, and belies a surprisingly cavalier attitude in the face of a serious possibility – the irreversible release of novel organisms into the wild. Algenol's facility is surrounded by storm water drainage canals and is about 5 miles from Estero Bay, on the southwest tip of Florida. The company itself in 2013 flagged a "major hurricane strike" as a top future risk, but focused on the attendant costs and delays – with no comments about the potential impacts of a release of GE cyanobacteria into the surrounding ecosystems.[38]

In the event of a release, there are still many questions yet unanswered. Algenol simulated a spill amid dry soil conditions by mixing GE cyanobacteria and soil in uncovered, illuminated petri dishes in the lab, noting that the strain was unable to re-grow "to visible levels" after 9 days of simulated exposure. Similarly, the company filled incubation bottles from five local water bodies, added GE cyanobacteria "at a high cell concentration," and left them for a week, noting that the organism "failed to proliferate" and that the green coloration in the bottles cleared after a week.

Simple laboratory experiments like these are far from adequate in capturing all of the potential unknowns associated with the release of fast-multiplying, novel microorganisms into a dynamic tidal ecosystem. While it is unclear whether Algenol is required to carry out more comprehensive tests as part of its 5e consent agreement, given what we know about TSCA, it's likely that the company's GE cyanobacteria will not undergo a systematic review of all relevant risk dimensions – thus amplifying potential risks to human health and ecosystem stability. Furthermore, Algenol's inability to maintain stable genetics even under controlled cultivation raises additional concerns about unforeseen genetic alterations or gene transfer should the company's species be released into the wild.



THE HYPE OF SUCCESS WITHOUT THE RESULTS

Like many other algae-based biofuel startups, Algenol relied heavily upon hype in generating public and private-sector investment. Algenol's colorful CEO and co-founder, Paul Woods, led the charge, issuing grandiose statements such as "This planet has one chance at diverting climate change, and it's Algenol" – despite any demonstrated evidence of commercial success for its technologies.[39]

The Sonoma Fields Green Project, which appears to have been on hold for over five years, serves as an excellent early example of this dynamic.

In 2008, Algenol announced that it was teaming up with Biofields, a company owned by González, on a massive $850 million biorefinery project in the desert of Sonora, Mexico.[40] The company decided to locate the project in the small seaside town of Puerto Libertad, on the Sea of Cortes and home to one of Mexico's largest thermoelectric plants.

To manage the project, Alejandro González recruited a former Mobil Petrochemicals executive, along with a former executive of Southern Copper Corporation, Eduardo González. Eduardo González would go on to serve as the chair of Algenol's board of managers from 2011 – 2016.[41]

Biofields and Algenol purchased 22,000 hectares of land surrounding Puerto Libertad, planning to use CO_2 from the thermoelectric plant – owned by the Mexican federally owned utility company, CFE – as feedstock for the algae.[42] The developers of the "Sonora Fields Green Project" initially announced that it would aim to produce 100 million gallons of ethanol by the end of 2009, and 1 billion gallons by the end of 2012.[43] Their intention was to take advantage of renewable fuel standards by selling ethanol to the Mexican oil company, Pemex, in addition to meeting the US demand for advanced renewable fuels.

But the company continually pushed back dates on commercial production.

In February 2009, after Biofields had invested $30 million in land, personnel, and research, the company announced it sought to produce 250 million gallons by 2013, with a long-range goal of 2 billion gallons by 2020.[44] By December of that year, the company had pushed back its 250 million gallon mark to 2014, and cut its 2020 target by half, to 1 billion gallons.[45]

By May 2010, questions were being raised about the state of the project, including an article in Green Tech Media noting that Algenol has "hitherto over-promised and under-delivered," having "made splashes with an announcement of an $850 million commercial project in Sonora Fields, Mexico that has yet to materialize."[46]

It is unclear what the current status of the $850 million "Sonora Fields Green Project" is. On December 15th, 2011, the project received a conditional authorization from the Mexican Secretary of Environment and Natural Resources, but there is no evidence that it has moved forward since then.[47]

Why would a project of this scale be mothballed for over five years? One can only surmise that it ran aground on poorly performing technology, combined with a difficult energy market due to low oil prices.

CONCLUSION

The experience of Algenol, with its potentially insurmountable technological hurdles, poor energy balance, and high environmental risk, should present a major red flag for private actors and government agencies considering investment in advanced biofuels. Far from a silver bullet to solve the climate crisis, so-called next generation biofuels represent at best, a black hole for investors, and at worst, a new catalyst for land and resource conflicts and ecological disruption.

Politically, it appears that US government support for next generation biofuels will be discontinued, as part of a broad attack by the Trump administration on government's ability to serve the public good and intervene in energy markets. This presents a double-edged sword for energy justice campaigners – cutting off financial and ideological support for false solutions to climate change, at the same time as strengthening the power of the fossil fuel industry to deflect any efforts to transition to a genuinely renewable energy regime.

For more on the consequences of the Trump administration for energy justice campaigning, view this Biofuelwatch statement here:
http://www.biofuelwatch.org.uk/2017/statement-about-trump/

REFERENCES

1. http://www.nrel.gov/docs/legosti/fy98/24190.pdf
2. http://www.motherjones.com/politics/2009/09/algae-energy-orgy
3. http://www.markey.senate.gov/GlobalWarming/files/HRG/FullTranscripts/110-47_2008-07-31.pdf
4. http://www.algaeindustrymagazine.com/a-i-m-interview-algenols-ceo-paul-woods/
5. https://energy.gov/sites/prod/files/2016/11/f34/beaudry-losique_bioenergy_2016.pdf
6. http://www.biofuelsdigest.com/bdigest/2015/10/25/algenol-ceo-exits-staff-cut-by-25-investors-re-up-for-two-years-new-direction-tipped/
7. http://www.businessobserverfl.com/print/Fuel-the-World/
8. http://aem.asm.org/content/65/2/523.abstract?sid=2247d1fe-0f89-4352-860b-0c990e56791e
9. http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=%22Enol+Energy+Inc%22&OS=%22Enol+Energy+Inc%22&RS=%22Enol+Energy+Inc%22
10. http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=2&f=G&l=50&co1=AND&d=PTXT&s1=%22Enol+Energy+Inc%22&OS=%22Enol+Energy+Inc%22&RS=%22Enol+Energy+Inc%22
11. Hamilton, Tyler. (2011) Mad like Tesla, underdog inventors and their relentless pursuit of clean energy. Retrieved from http://books.google.com
12. Bhatia, S.C. (2014) Advanced Renewable Energy Systems. Retrieved from https://books.google.com
13. http://www.prnewswire.com/news-releases/algenol-announces-acquisition-of-cyano-biofuels-gmbh-117182813.html
14. http://articles.baltimoresun.com/2009-05-08/news/0905070142_1_blue-green-algae-ethanol-carbon-dioxide
15. ibid.
16. http://energy.gov/sites/prod/files/2014/08/f18/de-0002867_algenol_part2.pdf
17. http://www.forbes.com/sites/jeffmcmahon/2012/02/28/why-did-obamas-favorite-algae-biofuels-company-break-up-with-dow/#4104e15a1cd7
18. http://www.prnewswire.com/news-releases/algenol-partners-with-lee-county-as-commission-votes-to-approve-incentive-funding-for-florida-based-biofuels-and-green-chemistry-facility-83441277.html
19. http://www.biofuelsdigest.com/bdigest/2012/10/25/algaes-secret-investor/
20. http://www.ascension-publishing.com/ABLC15/Woods.pdf
21. https://www.epa.gov/sites/production/files/2015-08/documents/

algenol-determination-ltr-2014-12-4.pdf
22. https://www.epa.gov/regulation-biotechnology-under-tsca-and-fifra/tsca-biotechnology-notifications-status#mcan
23. http://www.psc.state.fl.us/Files/PDF/Utilities/Electricgas/EPACarbonRules/AlgenolBiofuels.pdf
24. ibid.
25. http://www.independentsciencenews.org/environment/biofuel-or-biofraud-the-vast-taxpayer-cost-of-failed-cellulosic-and-algal-biofuels/
26. https://energy.gov/sites/prod/files/2016/04/f30/2015_peer_review_report.pdf
27. https://energy.gov/sites/prod/files/2016/05/f31/ibr_legere_51112.pdf
28. https://www.energy.gov/sites/prod/files/2015/05/f22/demonstration_market_transformation_legere_3323.pdf
29. http://pubs.acs.org/doi/abs/10.1021/es1007577
30. http://www.energy.gov/sites/prod/files/2014/08/f18/de-0002867_algenol_part10.pdf
31. ibid.
32. https://www.epa.gov/sites/production/files/2015-08/documents/algenol-determination-ltr-2014-12-4.pdf
33. ibid.
34. https://www.cbd.int/ts/cbd-ts-82-en.pdf
35. https://www.epa.gov/reviewing-new-chemicals-under-toxic-substances-control-act-tsca/regulatory-actions-under-tsca
36. ibid.
37. https://projects.erg.com/conferences/oppt/docs/Biotech_Workshop_Report_Final_2015-12-21.pdf
38. https://energy.gov/sites/prod/files/2016/05/f31/ibr_legere_51112.pdf
39. http://www.eenews.net/stories/1059997616
40. http://expansion.mx/expansion/2009/02/12/sonora-alberga-megaplanta-de-etanol
41. https://www.linkedin.com/in/jeduardogonzalez?authType=NAME_SEARCH&authToken=urTj&locale=en_US&srchid=5323380041480440057608&srchindex=1&srchtotal=1&trk=vsrp_people_res_name&trkInfo=VSRPsearchId%3A5323380041480440057608%2CVSRPtargetId%3A179945402%2CVSRPcmpt%3Aprimary%2CVSRPnm%3Atrue%2CauthType%3ANAME_SEARCH
42. ibid.
43. http://www.reuters.com/article/us-algenol-ethanol-idUSN1032368520080611?pageNumber=1&virtualBrandChannel=0
44. ibid.
45. http://www.ipsnews.net/2009/12/energy-mexico-big-plans-for-ethanol-from-algae/
46. https://www.greentechmedia.com/articles/read/valero-invests-in-algenol
47. http://sinat.semarnat.gob.mx/dgiraDocs/documentos/son/resolutivos/2011/26SO2011G0003.pdf