Algae: Environmental and Economic Opportunities for the Coal Sector

Policy Memorandum to: The Governors of the top 10 Coal-Power States [1]

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Executive Summary: The energy density and global availability of coal will continue to make it an important source of energy in the U.S. and worldwide, but coal is a major source of water and air pollution – particularly greenhouse gases (GHGs) – which threatens the well-being of humans and the global ecosystems, i.e., the environment. If algal biomass[2] is produced from waste carbon dioxide (CO2) and coal plant wastewater, the algal crop can then be converted into a variety of products, such as bio-fuels, fertilizers and animal feed, while reducing pollutants. The Environmental Protection Agency's (EPA) new Clean Power Plan (CPP) opens the door to using emerging algae production and processing technologies to meet the plan's goals. Mass production of algal biomass is likely to offer coal-producing and using States an effective way both to reduce pollution, in line with the CPP, and to develop one or more new income streams. Our policy recommendation is that the governments of such States should foster cooperation between the coal and algae industries, particularly the addition of algae-producing facilities at or near coal-fired electricity plants.

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[1] The top 10 U.S. States, "ranked by the total amount of electricity each state produced from coal in 2011" were: Texas, Ohio, Indiana, Pennsylvania, Kentucky, Illinois, Missouri, West Virginia, Georgia and North Carolina. Sourcewatch. "Existing U.S. Coal Plants, State-by-state Output," sourcewatch.org, http://www.sourcewatch.org/index.php/Existing_U.S._Coal_Plants#State-by-state_output. (accessed April 5, 2016).

[2] One handy definition of "algal biomass" is: "Biomass, in ecology, is the mass of living biological organisms in a given area or ecosystem at a given time. It can include microorganisms, plants or animals. Algal biomass is the amount of algae in a water body at a given time." (Source: http://www.oilgae.com/ref/glos/algal_biomass.html .)

I. The Challenge of Coal

First, coal is an important source of energy for nations all around the globe, and an even greater source, globally, of certain GHGs. Specifically, "worldwide, coal supplies 29.7 [%] of energy use and is responsible for 44 [%] of global CO2 emissions."[1] Additionally, some 8 to 10 percent of "human-made methane emissions worldwide" are made up of coal mine methane. Other pollutants – notably sulfur dioxide and nitrogen oxides – are also generated by coal mining and use. Finally, the heavy use of water in coal processing, and/or the run-off from such activity, can result in serious water pollution.[2]

Despite its environmental downsides, coal is not going away. The use of coal is deeply embedded in modern civilization.[34] Nations today rely heavily on fossil fuels to produce fertilizers[5] and plastics, as well as energy. Overall, coal is now used to generate about 43% of U.S. electricity and nearly 30% of global energy use.[6]

Indeed, outside the U.S., increasing reliance on coal may be anticipated, particularly in Asia.[7,8] Coal is, in many ways, a very convenient energy source. As has been said, given "its high energy content, low cost per unit of energy, and abundant worldwide reserves, coal is the least-cost energy source for both developed and developing countries."[9] Coal production will be four times higher in developing countries than in developed ones, by 2040. Similarly, coal consumption may rise significantly[10], even though coal may drop to generating about "33% of global electricity generation in 2030," compared to coal-fired plants producing "41% of global electricity" in approximately 2012.[11,12]

II. Acting Globally and Locally: Putting Algae Use in Overall Context

It is widely recognized that both greenhouse gas emissions and other forms of pollution must be curbed in order to prevent further environmental degradation to the planet that might, in turn, lead to dire consequences for humans, their socio-economic systems, and many life forms.[13,14,15] Such concerns contributed to the development of the United Nations Framework Convention on Climate Change (UNFCCC) and to numerous international initiatives duringthe last 25 years.[16]

Despite diplomatic action, and some agreements, at the international level, it remains the case that primary responsibility for reducing GHGs remains with sovereign national governments. Moreover, notwithstanding various international declarations or efforts, GHG emissions grew by 46% between 1990 and approximately 2012[17,18], although there was apparently a slowdown in the rate of growth in 2014.[19] In short, notwithstanding considerable diplomatic and institutional activity at the multilateral level over the last 25 years, many practical steps require action at national and sub-national levels, such as at the level of the U.S. Federal Government and at the state level in the United States.

III. The CPP and Mainstreaming Algae Production with Coal Use: Issues & Opportunities in the United States

In the United States, both a significant case, and a great opportunity, for action on GHGs exist, as regards the coal industry. First of all, a Clean Power Plan (CPP) was issued by the EPA in October 2015.[20] In that document, the EPA found that "Fossil fuel-fired electric utility generating units (EGUs) are by far the largest emitters of GHGs among stationary sources in the U.S., primarily in the form of CO2, and among fossil fuel-fired EGUs, coal-fired units are by far the largest emitters."[21] As importantly, the final version of the Clean Power Plan allows for the use of algae in conjunction with carbon capture and utilization (CCU). The CPP requires that States' plans provide analysis showing how "proposed qualifying CCU technology results in CO2 emission mitigation from affected EGUs."[22] Moreover, the EPA's National Center for Environmental Economics has, separately, already recognized algae as a "third generation" feedstock for biofuels.[23]

These determinations have allowed the budding algae industry, in the form of the Algae Biomass Organization (ABO),[24] to claim a victory and promote the potential advantages of algae.[25,26] In particular, the mass-production of algae offers the potential to capture CO2 from coal plants and to reduce water pollution generated during the mining of coal and its combustion in power plants.[27,28] Moreover, using algae biomass for co-firing might prove more advantageous than the use of many other feed-stocks since it is possible to grow massive amounts of algae using CO2 from coal plants without the need to use valuable croplands or cut down forests for crops (such as corn) that might otherwise provide biomass. Ultimately, widespread production of algae might enable the preservation or restoration of a good number of land-based "carbon sinks,"[3] thus off-setting the combustion of algae biomass and/or biofuels.[29]

Yet, several uncertainties exist with respect to using large-scale algae production to mitigate CO2 from coal production and use. First, the challenge exists – as the EPA recognizes – of determining the degree to which algae *permanently* captures or eliminates CO2, and/or the degree to which it *displaces* the use of more fossil fuels (and thus, overall, curbs CO2 emissions).

A second major challenge is that of the "price point" at which it is economically beneficial to utilize algal biomass, particularly in the production of biofuels.[30] Although the recent drop in petroleum prices has stymied the expansion of power generation or biofuel production from algae, there are several algae-based energy projects underway[31,32,33] and there are recent reports of technical breakthroughs.[34] Moreover, it can be argued that the true measure of the benefit of algae-based biofuels only emerges from comprehensive life-cycle GHG analyses. If algal biofuels can result in a 68% reduction in GHG[35], and if, as in California, GHG reductions are monetized in the form of credits, then the price competitiveness of algal biofuels improves significantly. Certainly, the algae industry is pursuing the production of high-value products such as fish feed, Omega 3 products, and/or fertilizer, as those products currently appear more profitable than algal-based biofuels.[36,37]

Third, there is the challenge of finding, or developing, the just the right mix of algae species to achieve maximum algae production in the face of, *inter alia*, invasive species that might eat the algae being cultivated or infect and kill such algae.[4] A fourth challenge, to seizing the opportunities that algae offer, may be inertia in the coal industry and perhaps in coal communities – an inertia nourished by lack of information, or by some of the technical and economic uncertainties outlined above. For instance, an excessive degree of comfort with current technologies for chemically "scrubbing" CO2 from coal-plants' flue gas may exist – despite the apparent advantages of "biological mitigation" of CO2.[5] Of course, any institutional inertia may better be viewed as a reason for more, not less, far-sighted policy development and public-private efforts.

Indeed, it is reasonable to posit that (i) although the above-mentioned challenges apply particularly to producing algae for biofuels, the conversion of algal biomass into other products (or, for co-firing at plants) might well be less adversely affected by most of those considerations; and (ii) given certain financial and technical uncertainties, the importance of policy signals – such as the CPP – to stimulate relevant research and investment is all the greater. That is, it behooves the leaders of State governments to encourage relevant parties to work together to mainstream the use of algae in conjunction with coal production, so as to generate potentially lucrative products (e.g., fertilizers, feed-stock, plastics, and/or biofuels), and to curb GHGs and water pollution. Significantly, then, the

[3] "A carbon sink is anything that absorbs more carbon that it releases, whilst a carbon source is anything that releases more carbon than is absorb. Forests, soils, oceans and the atmosphere all store carbon and this carbon moves between them in a continuous cycle." FERN, "What is a Carbon Sink?," FERN.org, http://www.fern.org/campaign/carbon-trading/what-are-carbon-sinks (accessed April 3, 2016).

[4] Shurin, J. B. *et al*., "Industrial-strength ecology: trade-offs and opportunities in algal biofuel production," *Ecology Letters* (2013) 16: 1393-1404. As that paper puts it (page 1398), "Understanding trade-offs is critical to maximizing the performance of cultivated strains in terms of multiple functions, including growth, lipid concentration, nutrient demands and resistance to enemies."

[5] As a short report out of the University of Kentucky puts it, "Biological mitigation has become a more attractive CO2 option because biomass is generated through photosynthetic reactions, and the biomass contains energy that can be used later. This biomass energy can also help decrease demand for fossil fuels, which in turn would decrease the amount of CO2 emissions." See: Crofcheck, C., *et al*., "Algae-Based CO2 Mitigation for Coal-Fired Power Plants," Cooperative Extension Service, University of Kentucky College of Agriculture (Lexington, KY), AEN-116, Issued 1-2013; at: http://www2.ca.uky.edu/agcomm/pubs/AEN/AEN116/AEN116.pdf .

CPP clearly states that the EPA will be "working collaboratively with stakeholders to evaluate the efficacy of alternative utilization technologies, to address any regulatory hurdles, and to develop appropriate […] protocols to demonstrate CO2 reductions."[38]

IV. Final Observations and Recommendations

Can algae offer solutions to curb GHGs and water pollution while helping a declining U.S. coal industry, and mitigating the negative impacts of increasing coal usage in the United States and elsewhere? It does appear that algae production could meet those goals[6], but uncertainties exist – particularly as regards accounting for GHG savings and generating income from some algae-based products. In the face of such uncertainty, the importance of policy and regulatory signals grows – thus the significance of the EPA's decision to allow States to include algae technology in their plans to address pollution from power plants, including the EPA's explicit reference to the possibility of using algae technology for purposes of CCU.[7]

It is also worth noting that the ABO says the coal industry of the United States increasingly sees the potential of curbing CO2 emissions via algae technology. Moreover, the ABO foresees that coal industry working with algae companies to raise financing for algae-biomass production facilities near power plants, which biomass could then be sold for use in the production of a variety of products. Meantime, the ABO is already working with States on the technicalities of emissions accounting.[39]

Certainly, beyond the intricacies of trying to measure precisely how the use of algae can reduce GHG emissions, algae do offer distinct advantages: They grow rapidly and various forms can be grown at radically different temperatures and thus can potentially be used all around the world; they "feed" on CO2 and/or sulfur, while releasing oxygen; they can grow in waste, salt, or polluted water; they can purify polluted water – thus reducing stress on fresh water resources; and they can be turned into many helpful products.[40,41,42]

In sum, given the on-going importance and availability of coal in meeting humans' ever-increasing desire for energy, it is imperative that the public and private sector work jointly to reduce pollution from coal in the most beneficial ways possible. In particular, the aim should be to foster efficient ways of converting CO2 into algal biomass for co-firing and/or for sale to third parties for the production of feed, fertilizers, plastics, etc… Doing so would likely provide coal companies with new income streams, help the U.S. meet its clean power goals, and – through the sale of such algae technology to developing nations[43,44,45,46] – help the world to achieve sustainable development. U.S. States that produce or use large amounts of coal should, and are well-placed to, spearhead such efforts.

[6] University of Kentucky researchers appear to have few doubts about the matter, stating, "In a region where coal-fired power plants are common, using microalgae for CO2 mitigation from flue gas would help reduce GHG emissions without requiring the elimination of [such] power plants." Crofcheck, AEN-116, *op. cit*.

[7] Intriguingly, the CPP places the mention of algae and CCU in between a discussion of using algae for purposes of manufacturing certain things (e.g., cement) and of a discussion of co-firing using bio-mass. This may suggest that the EPA would be open to seeing States use algae technology in those contexts too, so that co-firing of algal biomass at coal plants should also be considered by States in their emissions-reduction plans.

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