Algae for Energy, Security, and Development

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POLICY BRIEF

The United States currently depends on imports from a small number of countries, many undemocratic and unfriendly, to meet its liquid energy needs. Though demand for oil has fallen with the global economic crisis, it is unlikely to remain low as developing world economies – particularly India and China – grow and demand more fuel.

At the same time, global population and affluence growth have caused upward pressure on food prices that has led to food insecurity in the developing world. Conversion of corn to ethanol, or the use of arable land and fresh water for biofuel crops like corn, sugarcane or jatropha, has exacerbated this situation, and linked food and energy in a dangerous way.

To satisfy energy needs and avoid putting pressure on food stocks, an alternative biofuel is needed. Water algae's superior yields, combined with its ability to grow without arable land or fresh water, mean that algae is a far better biofuel candidate to replace oil than any land crop. An algae-centric energy independence strategy would provide greater energy security while promoting poor-country development and without threatening food security.

Energy independence is often defined as the ability to provide for all of one's own energy needs through domestic supply, but only a handful of countries – mostly those with large petroleum reserves and modest populations – can hope to achieve this goal. Energy independence should be thought of in terms of lack of dependence on any one state or small clique of states (such as OPEC) for raw energy needs, as well as maintaining sufficient domestic refining capacity.

Energy independence of this sort is characterized by a wide, diverse network of suppliers, each producing a small portion of overall energy. The disruption of any one of these suppliers affects the overall energy market only in proportion to its share of production, which for most producers will be very small.

The promise of Algae: Energy Security

Algae offer the greatest promise of energy security for three reasons:

Yield - Algae yields more than ten times as much oil per unit area than palm oil, the most productive land-based biofuel crop.[i] (Corn, by comparison, produces about half of palm oil's yield.) Algae's yield depends upon exactly what species is used and especially upon the oil content, by weight, of that species. The estimate of ten times palm oil's yield is based on a relatively modest algae that is only 30% oil by weight; species that are 55% oil by weight exist in nature and up to 70% is theoretically achievable with correct cultivation techniques.[ii] Algae's greater yield comes from basic biological differences from land plants, and could be improved with research over time.

Diversity of Supplier Base - Over fifty states worldwide possess the appropriate temperature range (20-30^{o} Celsius)[iii] for year-round cultivation of algae across Central America, South America, Africa, and Southeast Asia and Oceania. While some are larger than others and some are better suited to production than others, there is likely no state that could be to algae what Saudi Arabia is to petroleum. Algal productivity depends upon a set of climatic conditions prevailing across most of Earth's equatorial region, and monopoly or oligopoly of algae is very difficult to envision. Both coastal and inland states have unique advantages for cultivation, as coastal states possess direct access to saltwater for algal culture as well as bays and coasts where algae could be cultivated using no land at all. Inland states fitting this temperature range typically have desert climates ideal for high-yield culture.

Sustainability - Algae can be cultivated in almost any area as long as it is flat, hot, sunny, and has access to salt water. It requires no arable land and no fresh water, and so will not compete for agricultural resources that are often scarce in areas best for algal growth. Its far greater positive energy balance relative to corn and other land crops allow algae to be grown with relatively fewer inputs and commensurately less impact on the environment.

A quick survey of states suitable for algal culture (see attached spreadsheet) reveals that almost all lie within the developing world and include some of the poorest countries on earth. Many of these states suffer from poverty at least in part because they contain large swaths of arid, un-farmable land. Algae thrive in land that is too dry and too hot for conventional crops, and can be grown in these climates without displacing food plots. Algal culture represents a significant opportunity for these developing states for several reasons:

Non-competition with subsized crops - Algae could provide these states with a cash crop that does not compete with subsidized crops grown in Europe and the United States. Powerful domestic agricultural lobbies represent a significant obstacle to large-scale import of agricultural products, particularly from the developing world, but feel less threatened when the product in question is mainly produced elsewhere for reasons of climate.

Non-competition with local agriculture - Algae can be grown in saltwater, adding no additional pressure to rivers and lakes already overdrawn by freshwater irrigation[iv] and reducing the number of minerals and nutrients that need to be added to culture media for growth.[v] Saltwater exists in nearly limitless quantity, and could be piped from coasts to inland deserts to fill algae ponds at modest expense. This sort of culture would not threaten the livelihood of local farmers or domestically-produced food supplies, leading to greater food security and greater political unity.

Positive Environmental Externalities - Algae thrive in polluted waterways and areas affected by fertilizer runoff.[vi] With developing world aquifers under increasing pressure from pollution, algae could help to turn a problem into an asset. Algae cultivation would also provide excess biomass, similar to peat, that could be used as a fuel source in local furnaces, as fertilizer, or as food in aquaculture.

Developing an Algae Economy

The poverty of most potentially productive regions thus presents both an opportunity and an obstacle. Those areas most naturally suited to cultivation will require a good deal of help in order to allow them to produce algae efficiently, but these same areas are also those in which investment could do the most to improve the lives of local citizens. A national energy policy does not exist as a result of development concerns, but in this case the concerns overlap.

While the benefits of algae detailed above are potentially extraordinary, they face a gulf of logistical challenges that must be met in the following ways:

Foreign Aid to Potential Producer Countries - Many regions ideal for growing algae are poor in physical and institutional infrastructure. Both will need to be improved. Roads, electricity grids, and local education systems will in many cases require investment in order to allow these regions to produce efficiently. Though the production process is not electricity intensive, a small amount is required to drive paddlewheels in the algae ponds, and though mostly unskilled labor is required, management of culture will require some education. In inland regions, saltwater pipes to oceans or bays will be necessary to get the proper growth medium. Most of these investments are multipurpose, creating development benefits for producer states that will contribute to both prosperity and security. If the United States does not make these investments and another power, such as China, were to do so, the United States will have missed an opportunity both to develop relationships conducive to mutually beneficial trade and to influence the opinions of much of the developing world.

Increased Domestic Refining Capacity - Algal oil is unlikely to be suitable for a standard refinery, meaning that either new refineries will need to be constructed or existing ones would need to be retrofitted to handle the different type of oil. Neither option is cheap, and both could be helped along by tax incentives, subsidies, or other government measures. Ideally the United States would want enough capacity to refine domestically all algal oil used within the country.

Basic Biological Research - Basic biological research on algae has little direct application and, therefore, attracts few private research dollars. However, more knowledge about basic biological processes in algae – such as photosynthesis, photoinhibition, and reproduction – could inform a great deal of applied research on algal culture and lead to significant future benefits. Decades of understandable focus on land plants mean that, in general, more is known about the functioning of plants like corn and soybeans than about water algae, which only in the last thirty years or so has been of much commercial interest. Despite the potential benefits of this research, because much of it is not directly profitable the government is best positioned to provide funding.

Targeted Applied Biological Research - Applied research on algal culture shows much room for improvement. Genetically enhanced algae that survive better in open systems could be extraordinarily useful in many developing countries, as one drawback of open-pond, low-input culture systems is their susceptibility to contamination. Historically, only a handful of very hearty strains of algae have proved capable of repeated culture in an outdoor growing system.[vii] Better processes for the conversion of algae to oil and the conversion of algal oil to usable fuel would also make algae a far more efficient fuel source. As both of these technologies have only recently been considered viable, both are primitive compared to other parts of the process or to analogous processes with petroleum. While unlike basic research the proposed applied research is potentially profitable, and therefore potentially attractive to private investment, given the strategic importance of fuel it is in the best interests of the United States to move these technologies along as quickly as possible. Further, those technologies developed with government money should be shared with American private research firms to the greatest extent practical.

Bold Effort Needed for Great Potential Benefits

None of these proposals is cheap, and all are best taken as a package rather than one at a time. This plan should not be undertaken tepidly. But the costs should be weighed against the benefits, of which there are many:

Increased Energy Security - If most potential producer countries were utilized, the production base for algae would extend around the length of the equator and encompass nearly fifty states. While adverse climatic conditions or a political crisis could affect some of these states at a given time, no one country would have market power similar to that of Saudi Arabia or Iran in petroleum. If scientific estimates are correct, the United States could hope to displace half of its liquid fuel usage with algal oil on the equivalent of between 2% and 10% of arable land on earth,[viii] although actual arable land would not be used. Though some tropical states – particularly those that experience monsoons or rainy seasons – might be more productive at certain times of year than others, the breadth of suppliers shows a wide distribution of productivity over the months of the year, and it is unlikely that there is any one month in which overall production would be significantly lower than in others. The wide geographic distribution of candidate states ensures that no one storm or one political crisis could imperil the majority of supply. Further, algae are unlike corn or soybeans in that there are not separate sowing and harvesting seasons. Their great yield owes to algae's ability to reproduce far more quickly than any land plant, and productivity should remain consistent through all seasons.

Indeed, not all potential producer countries are friendly to the United States – such as Sudan and Venezuela – but a mutually beneficial relationship could be fostered with most. Overall, decreased reliance on petroleum imports from the Middle East and Russia would carry numerous political benefits, as well as decreased exposure to turmoil or anti-American sentiment in those regions.

Improved Relationships with and Improved Security in the Developing World - Removing the pressures of ethanol production from food prices will stem rising anti-American sentiment that the practice has produced. Allowing arable land and fresh water to be used for food will contribute to food security in many countries, lessening the likelihood of unrest or conflict between nations over water or land resources. Reduction of poverty and perceived injustice in developing nations lessens the likelihood that populations will radicalize along anti-American lines, increasing security for the United States and developing world alike. Countries that experience starvation as the United States converts corn into ethanol are in a position to craft a dangerous narrative to which radicals could rally.

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[i] Dismukes GC, Carrieri D, Bennette N, Ananyev GA, and Posewitz MC. 2008. "Aquatic phototrophs: efficient alternatives to land-based crops for biofuels." *Current Opinion in Biotechnology*. Volume 19, Issue 3, p235-240

[ii] Chisti Y. 2007. "Biodiesel from microalgae." *Biotechnology Advances*. Volume 25, Issue 3, p294-306

[iii] Ibid.

[iv] Dismukes GC, Carrieri D, Bennette N, Ananyev GA, and Posewitz MC. 2008. "Aquatic phototrophs: efficient alternatives to land-based crops for biofuels." *Current Opinion in Biotechnology*. Volume 19, Issue 3, p235-240

[v] Schenk PM, Thomas-Hall SR, Stephens E, Marx UC, Mussnung JH, Posten C, Kruse O, and Kankamer B. 2008. "Second Generation Biofuels: High-Efficiency Microalgae for Biodiesel Production." *Bioenergy Research*. Volume 1, Issue 1, p20-43

[vi] Ibid.

[vii] Qiang H, Sommerfield M, Jarvis E, Ghirardi M, Posewitz M, Seibert M, and Darzins A. 2008. "Microalgal triaglycerols as feedstocks for biofuel production: perspectives and advances." *The Plant Journal.* Volume 54 Issue 4, p621 – 639

[viii] Schenk PM, Thomas-Hall SR, Stephens E, Marx UC, Mussnung JH, Posten C, Kruse O, and Kankamer B. 2008. "Second Generation Biofuels: High-Efficiency Microalgae for Biodiesel Production." *Bioenergy Research*. Volume 1, Issue 1, p20-43