Viability analysis of algae biofuels and assessment of the future energy situation

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Abstract

Energy is a key element in human life, and in all life in general. Humankind uses energy for a variety of things, from transportation, heating water, cooling houses, to the most basic one which is producing food. Industrial agriculture has allowed humans to greatly increase food production in order to feed and overpopulated planet. Because world population is still increasing, the energy demand is rapidly increasing while the fossil fuel sources are vanishing, and on the meantime climate change is worsening because of GHG emissions.

Algae biofuels are a solution to both problems, energy reserves depletion and GHG emissions. In this project the current situation of algae biofuels is analyzed, from both techno-economical and sustainability points of view. In addition, improvements to the production process will be analyzed in order to predict the viability of this technology in the future. Finally other renewable energy sources will be briefly analyzed to determine other possible solutions for energy shortage and climate change.

The importance of energy

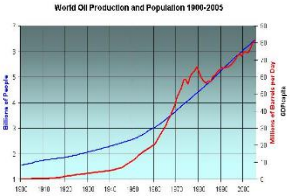

Figure 1. Correlation of increase in world population and oil production over time.
Source: [1]

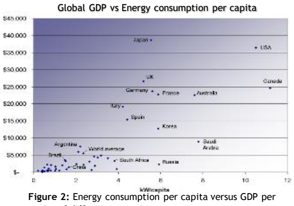

Figure 2: Energy consumption per capita versus GDP per capita of different countries.
Source [11]

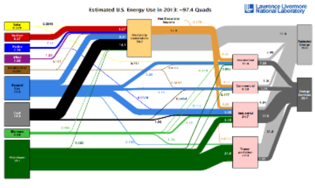

Figure 3: The figure depicts how many quadrillions (10^{15}) of BTUs are used from every source and its destination.
Source [6]

Energy production is very important for humankind because it allows this overpopulated world to survive. It has enabled human population to dramatically increase, as can be seen in figure 1, and it also allows civilizations to become more industrialized and develop further technology, which is clearly shown in figure 2. As human population grows, the energy demand also grows, and even if it does not grow, the huge economic grow of undeveloped countries like India and China is increasing energy demand. Fossil fuels are currently the main source of energy supply [figure 3], but as these are being diminished and global climate change worsens the need for sustainable energy sources becomes imperative.

The biofuel production process

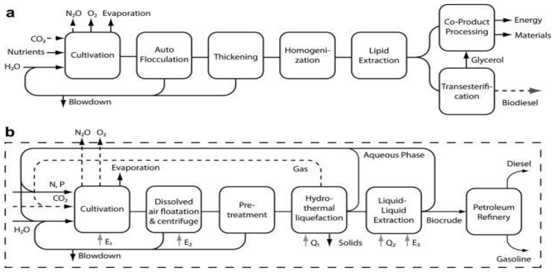

Figure 4: Flow chart of the biofuel production process. A) Old production process, producing biodiesel by transesterification. B) New production process, producing diesel and gasoline by HTL.
Source [7]

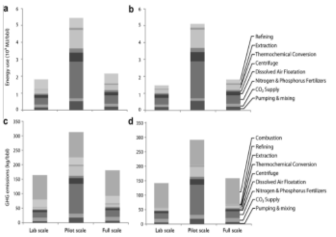

Figure 5: Energy use and GHG emissions for each part of the process. A) Energy use in the diesel production. B) Energy use in the gasoline production. C) GHG emissions in diesel production. D) GHG emissions in gasoline production.
Source [7]

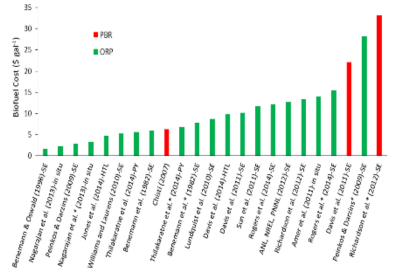

Figure 6: Comparison of the cost of a gallon of biofuel from different studies showing the level of variability of the results. The cost is in 2014 $.
Source: [9]

In figure 4 we can see the old and new algae biofuels production process. The old one only uses lipids accumulated in the algae to obtain biodiesel through a transesterification while the new one uses the totality of the algae biomass to produce a biocrude, which similar composition to that of petroleum, that will be refined into diesel, gasoline and jet fuel. This difference is very important since now the algae strains used are focused on fast growth instead of lipid accumulation.

The current price of biodiesel varies greatly as can be seen in figure 6, but a reasonable approach would be 5-7 $ per gallon[9] with a EROI of approximately 2.5[7] which is not competitive with petroleum based diesel that costs 2.9 $ per gallon and has a EROI above 4[7]. In order to make algae biofuels more competitive the cost of each step of the process has been analyzed, which can be seen in figure 5. The algae cultivation and harvesting accounts for about the 75% of the energetic cost and the GHG emissions, which probably means that it accounts for 75% of the economic cost, therefore the improvements must be focused on these parts of the process.

Algae strain	Cultivation techniques	Harvesting	Other strategies
• Improve light-harvesting antenna efficiency[2] • Crop protection strategies[3] • Improve growth rate	• Development of new production media formulas • ARID system: improved energy use and increase productivity through temperature management[2]	• Ultrasonic harvesting[2] • Crossflow membrane filtration harvesting[2] • Electrocoagulation harvesting[2]	• Use of wastewater • Recycling nutrients • Co-products credit

Other renewable energy options

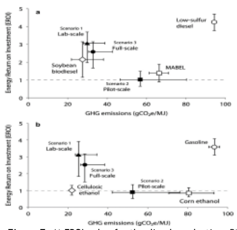

Figure 7: A) EROI value for the diesel production. B) EROI value for the gasoline production.
Source [7]

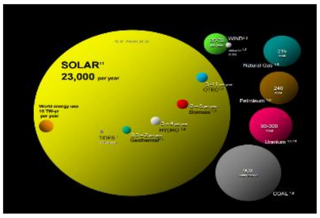

Figure 8: Maximum capacity of different renewable energy sources and maximum reserve of different non-renewable energy sources.
Source [10]

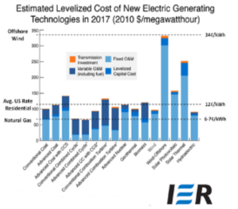

Figure 9: Estimated levelized cost of electricity production from different energy sources in 2017.
Source [4]

There are other renewable energy options that must be analyzed. However, there is a big difference between energy sources that supply fuel, which is stored energy, and those that generate electricity, which is power and as such it can only be used immediately or else it dissipates into heat. It is for these reason that until electric batteries are further developed, fuels are irreplaceable in transportation.

Currently, the most used biofuel is first generation bioethanol, but second generation bioethanol is likely to overcome its predecessor. However, algae biofuels show more potential since it EROI value is two fold bigger and its maximum energy production capacity is bigger too [figure 7].

Nevertheless, the only energy sources that clearly show enough capacity to provide enough energy to the whole humankind are solar and wind power [figure 8]. These energy sources are becoming cheaper [figure 9], and with the huge capacity they have, they are likely to become the main energy source in the long term future.

Conclusions

The conclusion that can be extracted from the results observed is that algae biofuels are not cost competitive in the present moment since its cost ranges from 5$ to 7$ per gallon of diesel and an EROI of 2.5 approximately, compared to 2.9 $ per gallon of fossil diesel and an EROI of above 4.

In the next few years second generation bioethanol supply is likely to increase, but algae biofuels are more prone to become the most affordable fuel option within the next decade.

The long term future is likely to be dominated by solar and wind power since they are becoming cheaper every year and its huge capacity cannot be matched by other energy sources. However, its full deployment relies on the development of efficient electric batteries.

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