

The following are general comments about the structure and content of an academic essay written for university – they are not prescriptive and intended as an educational guide only.

Q: What's next after ethanol and biodiesel in the biofuel market?

Introduction

In recent years biofuels have largely become a central topic in the global theatre. The 2002 US-led Iraq invasion and recent events in Libya have driven oil prices to record heights, \$147.27 and \$110.62 per barrel respectively. With worldwide transportation systems closely tied with oil derivatives, the international search for alternative fuels to mitigate the effects of events in the oil supply chain is far more intensive than ever (Tyner, 2008). Additionally, the growing awareness of human impact on Earth has been decisive for the growing support of biofuels. International studies on climate change and green house gas emission show with unfathomable certainty that without energy changes, there will be irreversible disastrous consequences (Warren et al., 2011).

Biofuels refer specifically to a liquid or gaseous fuel produced from biomass for the transportation industry. Currently the two leading biofuels in use are ethanol (C₂H₅OH) and bio-diesel (Bringezu et al., 2009). Ethanol is majorly used in Brazil and the United States and its widespread use as an additive/blend with gasoline is known to produce higher antiknock properties, and lower pollutant emissions than gasoline alone (Wongyao et al., 2011). Biodiesel is synthesized by transesterification of vegetable oil and is also used as a blend with conventional diesel fuel without any requirements of engine modification (IEA, 2007). The key advantage of increasing our use of biofuels offers a future that will help stabilize the turbulent global impacts of green house gases that fossil fuel use has instigated. It also builds on other large areas of weaknesses such as sustainability, security of supply and foreign exchange losses, and may even stimulate regional and social structural development in 3rd world nations (Hunt, 2008).

Despite this, ethanol and biodiesel have begun to attract criticism over technical, economical and environmental unfriendliness (Williams et al., 2009). The production of ethanol and biodiesel directly conflicts with the supply of corn and soy as food, otherwise known as the fuel vs food debate, and therefore directly inflate global food prices and instigates social controversy (Rotman, 2008). A well publicized and controversial article in *Science* argues that the need to grow and cultivate agricultural land for biofuels requires destruction of precious rainforests and prairies; therefore a complete lifecycle assessment of ethanol and biodiesel would indicate higher carbon release and environmental damage than fossil fuels (Plevin et al., 2010). Nevertheless the general consensus is that growing demand of environmentally friendly biofuels cannot be met by ethanol and biodiesel alone (EIA, 2011).

The next wave of biofuels must build on the weaknesses of ethanol and biodiesel, such as indirect and direct environmental concerns, effects on global food supplies and prices (Hunt, 2008). The most promising crop of biofuels prospects are biohydrogen, Fischer-Tropsch Diesel, cellulosic ethanol and biomethanol (Bringezu et al., 2009). This report will explore each of these potential biofuels and discuss key advantages, disadvantages, recent progress and challenges to entering the market.

Comment [A1]: There is no need to write the question at the top of your assignment. This is just for information purposes only. Your introduction should paraphrase the question, so that the reader understands.

Comment [A2]: The introduction should follow a general-to-specific writing pattern. It first provides background information to the topic. As it progresses, the focus more specifically considers the question.

Comment [A3]: Here, to help orientate the reader, the introduction starts with general background information. This sets the scene for the report.

Comment [A4]: Note that this student is not using Harvard UTS referencing. Be sure to check the referencing style you are expected to use.

Comment [A5]: In this section the student is providing a definition of the report's broader research topic, biofuels. This provides context for the reader.

Comment [A6]: In this section, the student is providing a brief historical background of significant events leading up to the present research. This provides further context for your reader.

Note: If the explanation of the context is lengthy, you may want to make it a separate section and call it Background/Context/Definitions/Key terms.

Comment [A7]: By identifying the current problem/gap in the biofuel market, the student is indicating to the reader the need for their research. This is a common feature of a research report, and helps to convince the reader that the research will be useful/significant.

Comment [A8]: Here is the student's main line of argument (thesis statement), which indicates their answer to the report question. The following sections of the report will support this thesis statement.

Comment [A9]: This paper is written in report format. Use of headings and sub-headings as well as succinct paragraphs are all appropriate for report writing.

Comment [A10]: Towards the end of the introduction, the student outlines the general sequence of the following sections. This lets the reader know what to expect in the paper.

Cellulosic Ethanol

Cellulosic ethanol has shown to be a potential next generation replacement for traditional starch based ethanol. Unlike its predecessor, cellulosic ethanol uses lignocellulosic biomass: a non-food feedstock drawn from cornstover, switch grass and other forms of agricultural waste (Bringezu et al., 2009). Using lignocellulosic biomass does not affect global food prices, and is cheaper and easier to obtain in comparison to starch-based bioethanol feed stocks (Dwivedi et al., 2009). Studies have also shown that lignocellulosic biomass can be produced from municipal solid waste or even on infertile lands thus eliminating the need for destruction of rainforests and other wildlife habitats (Chester and Martin, 2009).

There are currently two broad production methods for cellulosic ethanol:- hydrolysis and thermo-chemical conversion. Under hydrolysis production, the lignocellulosic biomass is hydrolysed using sulphite (SPORL) pre-treatment to separate solids from liquid, cut through strong physical structures of wood and recover the sugars in cellulose, hemicelluloses and lignin (Zhu et al., 2009) (Cheng et al., 2011). The cellulose recovered from the pre-treatment are fermented using enzymes, usually *Saccharomyces cerevisiae*, which convert the sugars into ethanol (Jeon et al., 2009). The lignin recovered from this process has shown the ability to provide renewable thermal energy for cellulosic ethanol plants and thus eliminates the need for fossil fuels. This is certainly a significant advantage over traditional bioethanol plants which do require fossil fuels for power and electricity (Jones, 2010). In the second production process, thermo-chemical conversion, the cellulosic feedstock is heated via pyrolysis and converted into a gas called 'syngas'. Syngas is a mixture of CO, H, CO₂ methane and nitrogen which is synthesized into ethanol (YongMan and Ping, 2009).

Lifecycle assessments of ten cellulosic ethanol pilot plants across the United States reveal zero biogenic carbon emissions, meaning only naturally captured carbon by plants is released into the atmosphere. The main concerns with current pilot plants surround the concentration and release of air pollutants (Menetrez, 2010). Data reveals that higher amounts of particulate matter (PM), SO_x, NO_x, carbon monoxide, volatile organic compounds (VOCs), acetaldehyde and hexane are released into the environment (Jones, 2010). Unless these plants are able to filter and remove the air pollution, they will be subject to heavy air regulations.

One of the most important barriers to the introduction of cellulosic ethanol into the commercial market is its production cost. An assessment of cellulosic ethanol prices show decreasing costs per gallon on a yearly progression and increasing plant size (Zhuang, 2007) (Huang et al., 2009). Currently the cost per gallon of cellulosic ethanol from pilot plants are \$2.25, with the bulk of the cost associated with pre-treatment processes (Woodson and Jablonowski, 2008). The US Department of Energy has set a target to produce renewable cellulosic ethanol at \$1.33 per gallon by 2012. At this price, cellulosic ethanol would be cheaper than starch-based ethanol and gasoline (EERE, 2009).

Biomethanol

Biomethanol (CH₃OH) is a liquid alcohol fuel, also known as "woody alcohol", and is usable in internal combustible engines or as a blend with gasoline which is known to produce much higher octane ratings and CO₂ mitigation in comparison with an ethanol-gasoline blend (Hasegawa, 2010).

The production of biomethanol can be split into two steps. In the first step, the biomass is converted into carbon monoxide, carbon dioxide, water and hydrogen, which is also known as

Comment [u11]: Use of a topic sentence – tells the audience what the paragraph will be about.

Comment [u12]: The paragraph subsequently builds up with supporting points/arguments throughout the body of the paragraph. These points will build on the idea outlined in the topic sentence.

Comment [A13]: Here the writer is using 2 references together as they both share the same opinion. This is good to show that you have critically reflected on your background reading and noticed similarities.

Comment [A14]: The student has made a judgement about the significance of the information, and in doing so is further demonstrating their critical thinking skills.

Comment [u15]: Throughout the report the student has paraphrased literature to support their ideas.

Note: most of the references you use should be paraphrased in your writing. As a general rule, try to keep 'direct quotes' to a minimum in your work.

Comment [u16]: By specifying that this is one of the most important barriers, the student is establishing the significance of this information. In addition, they have subsequently supported this claim with their readings. Establishing the significance of information is useful to demonstrate that you have critically considered your readings and made a judgement.

Comment [u17]: By using the transition signals 'first' and 'second', the student is clearly articulating the sequence of this process. This can help divide your topic into parts, making it easier for the reader to understand your ideas. It also improves the 'smoothness' of your writing.

synthesis gas or 'syngas'. The biomass is converted by catalytic reforming of feed gas and steam or partial oxidation. In the second step, the biomethanol is catalytically synthesized from 'syngas'. This occurs in a large reactor vessel under extreme pressures and temperatures, where synthesis gas is fed in the presence of a catalyst. The carbon dioxide and hydrogen combine to create biomethanol (Demirbas, 2008).

Residing in the Netherlands, *bioMCN* is the first large scale commercial biomethanol plant in the world. BioMCN's large scale facilities produce 250 million litres of biomethanol from crude glycerin, a sustainable biomass from the fatty acid and vegetable oil industry. Glycerin is the waste product of biodiesel plants and hence bioMCN does not require destruction of forests and prairies for feedstock. Overall lifecycle assessments of biomethanol from *bioMCN* reveal 78% reductions of CO₂ emissions in comparison to natural gas based methanol (BioMCN, 2011).

By converting biomass from agricultural, forest and municipal wastes into biomethanol, countries can gain significant environmental and economical benefits (Suntana et al., 2009). A study by Dr. Kristtiina A Vogt demonstrates there are opportunities to take full advantage of biomethanol in the United States. Within five different states, calculations show that biomethanol can replace almost all or most of the gasoline consumption. When the biomethanol are harnessed into power fuel cells, they will have the potential to generate 12-25% of electricity consumed on an annual basis and reduce 2-29 Tg of carbon release, a 23-81% decrease (Vogt et al., 2009).

Fischer-Tropsch Diesel

Fischer-Tropsch Diesel is a synthetic diesel fuel chemically similar, substitutable and compatible with biodiesel and conventional diesel fuels. Their use in diesel engines has shown to exhibit lower pollutant emissions and environmental benefits in comparison to biodiesel (Lapuerta et al., 2009, Gill et al., 2010).

FT diesel is synthesized by taking advantage of the existing Fischer-Tropsch process which involves gasification of feed stocks and converting the mixture of carbon monoxide and hydrogen, essentially 'syngas', into liquid hydrocarbons as described in the equation below (1) (Dry, 2002).



The Fischer-Tropsch process has been used with coal and natural gas since the 1940's in Germany and currently is employed for large scale production in China, India and Qatar. Biomasses-to-liquid methods are more novel and expensive, however still based on the same concept: gasification of biomass and converting the CO and H₂ into liquid diesel (Osa 2011).

'SUNdiesel' is a German-made commercially available Fischer-Tropsch diesel produced from woodchips. Studies have shown to exhibit lower THC, CO, NO_x, PM, (NG et al.) aromatic and sulphur content in combustible engines in comparison to traditional diesel fuel (Gill et al., 2010, Vliet et al., 2009). This indicates that Fischer-Tropsch Diesel builds on both the weaknesses of biodiesel: environmentally friendliness and effects on global food prices.

Biohydrogen

Biohydrogen is considered a very important biofuel for the next generation of transport. It has unique ability to store and release, via fuel cells and burning, electric energy without any release of carbon dioxide and therefore has the lowest GHG emissions in comparison to other biofuels (Meher

Comment [A18]: Here the student has used the reporting verb 'demonstrates' to indicate that they agree with what the author has said. Reporting verbs can be used throughout your response to show your attitude (either positive, negative or neutral) to the sourced information.

Comment [u19]: Headings form sign posts and assist the reader to focus on the most important content. The use of headings should be as 'noun phrases'. Do not use questions or statements as headings in your work. Just put 'nouns' together to work as headings and sub-headings.

Comment [A20]: The student sums up their analysis of what the literature means. This is an important feature in academic writing.

Comment [A21]: The transition signal 'therefore' has been used to show cause and effect. Transition signals (e.g. consequently, however, therefore, moreover etc.) can help your ideas to flow more smoothly and express the logical relationships between ideas.

Note: You do not need to use transition signals in every sentence in your paragraph.

Kotay and Das, 2008). This fact has led to the term “hydrogen economy” where energy processes in the future are powered by biohydrogen fuel.

Despite this, less than 1% of the current world’s hydrogen production is produced from biomass (Tomczyk, 2009). The majority of electricity harnessed in novel hydrogen fuel cell technologies are heavily drawn from natural gas, hydrogen carbons and coal, thus a lifecycle assessment hydrogen production would indicate high green house gas emissions due to its feedstock (Ogden et al., 2004). Hydrogen production produced through thermal and chemical methods are heavily energy intensive and expensive. Biohydrogen from biomass could provide energy-saving, cost cutting and environmentally friendly solution (Strahan, 2008).

Currently there are two methods of biohydrogen production from biomass: photo and dark fermentation. Both methods involve bacteria or algae fermenting organic substrates to produce hydrogen in large quantities. Photo fermentation, frequently *cyanobacteria* or *Rhodobacter sphaeroides*, utilizes sunlight as the source of energy (Akroum-Amrouche et al., 2011). Dark fermentation involves fermentation of sugars in order to create organic substrates and hydrogen with anaerobic bacteria such as *clostridium* (Skonieczny and Yargeau, 2009).

The methods discussed above are only suitable for laboratory or small scale production. Industrial level production methods of photo and dark fermentation do not currently exist due to high investment requirements, low research funds, low infrastructure and lack of political incentives (Balat and Kirtay, 2010). Recently the Obama administration cut funding for biohydrogen research from the federal budget in 2010 and reasoned biohydrogen would not be a cost-efficient viable green technology within the next 20 years (Service, 2009). The idea of a biohydrogen economy may be exceptionally optimistic at this moment of time; nevertheless when that day comes, biohydrogen will be classed a superior biofuel due to its ability to completely mitigate all fuel-related environmental effects on our planet.

Challenges with the next generation of biofuels

Bioethanol, biomethanol, fischer-tropsch diesel and biohydrogen are, without doubt, the next biofuels to make a large impact on the fuel market. However there still remain a large number of challenges to be overcome. The majority of production methods discussed in the report are limited by scalability largely due to lack of investments for research and development. Construction of a large-scale commercial biofuel facility, such as *bioMCN*, may cost over \$700 million USD and in the current economic climate, a large proportion of investors remain uncertain over the market successfulness of untested biofuel products (Huber, 2009, Weber, 2009).

Moreover, the critical step to using biomass as a feedstock highly depends on the pre-treatment processes that exist to transform biomass into a usable material in biofuel production. Current pre-treatment processes are inefficient and recovery of usable material remains extremely low and uneconomical (Zhu et al., 2010). In particular the Fischer-Tropsch process, discussed earlier, used to produce biomethanol and Fischer-Tropsch diesel requires highly selective biomass. For example, the production of *SUNdiesel* is only possible from woodchips. New pre-treatment processes must be able to deal with larger ranges of biomass properties and compositions in order to reduce costs and improve economic feasibility.

Additionally the cost of transporting biomass from their source to processing facility to production plant is a major economical barrier for new biofuels. At present ‘CoolPlanetBiofuels’, funded by Google Investments, is developing a thermal/mechanical transportable plant capable of

Comment [A22]: Here the writer’s voice is visible through the use of hedging language such as ‘could’. This is a common feature of academic writing and conveys the writers opinion or attitude (modality).

Comment [A23]: Again the student is conveying their opinion through the use of hedging language such as ‘may’. Also see comment A22.

Comment [A24]: The student adds their analysis here of what the literature means and links it to their thesis statement. This is an important feature in academic writing.

Comment [A25]: Here the student is directly referring back to their thesis statement (see comment A8). This is important, as it demonstrates to the reader that you are addressing the question and remaining on-task.

Comment [A26]: Here the student has shown an awareness of possible counter-claims to the issue. Doing this helps to demonstrate that you are considering the breadth of the subject matter

Comment [A27]: This word helps link this paragraph to the previous one. For more transition signals, see comment A21.

Comment [u28]: Here the student is providing a concrete example to indicate relevance to the argument and to substantiate/support it.

processing biomass such as woodchips and crop wastes (Fehrenbacher, 2011). This solution may possible reduce costs, lower emissions and increase yield for biofuel plants that require biomass feedstock.

Comment [u29]: As above, the student has provided another concrete example to support their argument.

Conclusion

The next generation of biofuels have great potential to alleviate the concerns fossils fuels have brought upon the international society for many years to come. Using sustainable non-food biomass will reduce the dependency of the global community on major oiling nations, improve security of energy supplies, diminish effects on vital food supplies and, most importantly, reduce human environmental impact. With constant improvement across science and increasing global political support, it will only be a matter of time before biofuels will overcome its current challenges and begin to benefit and, perhaps, save our species.

Comment [A30]: The conclusion is the final review of the assignment and should contain no new information. It follows a specific-to-general writing pattern. It first draws together the findings/analysis of the report, and ends with a consideration of the wider implications of the findings.

Comment [A31]: The student has reiterated and confirmed the thesis statement. This shows that they have addressed the question.

Comment [A32]: Here the student has summed up the arguments of the whole report, while making reference to the key terms of the assignment question.

Comment [A33]: At the end of the conclusion, the student has indicated the significance of his/her findings within a broader context.

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Comment [A34]: Generally speaking a reference list must accompany your assignment.

This should be submitted on a separate page at the back of your essay and be formatted appropriately as per the referencing style you have been instructed to use.

Be sure to check what referencing style you are expected to use, as each style will have different conventions.

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