THE LAST BARREL OF OIL

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Writing 50

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ABSTRACT

With oil consumption at an all-time high, it is of fundamental importance that we know how much oil is left on Earth. In this paper we address the following questions:

(1) How much oil is left on Earth?
(2) Will we ever run out of oil?
(3) Are there sustainable alternatives to oil, and if so what are they?

Question (1) is answered by compiling data from the United States Geological Survey and Organization of the Petroleum Exporting Countries. Question (2) is answered using the same data. For Question (3), we explore what factors will motivate people to consume less oil and how hydrogen might be the ideal oil alternative. Ultimately, we find that Earth has at least 2,205 years worth of oil left (factoring in the exponential growth of oil consumption), that this amount of oil is sustainable, and that hydrogen is a viable alternative to oil so long as the necessary economic restructuring it would require is possible.[1]

[1] Chicago style citations are used throughout.

In 2009, an average of 84.4 million barrels of oil was consumed every day.[2] The Organization of the Petroleum Exporting Countries (OPEC) believes in 2010 there will be a 1.1% increase in oil consumption resulting in an average of 85.3 million barrels of oil being consumed each day.[3] Such extreme amounts of consumption raise the question of whether or not oil is a sustainable resource on which we can rely. To answer this question we need two pieces of information. First, we must find out how much oil there is on Earth. Second, we must find out the rate at which we consume oil, as well as how fast that rate is increasing. Relating these data points we can then assess how much longer we will be able to harvest oil. By comparing the rate at which we consume oil to the amount of oil we are discovering, it is evident that harvesting Earth's oil reserves is a sustainable practice. However in light of this finding, we should continue to look for alternative sources of energy as part of the quest to advance human technology and reduce the possibility of future energy crises.

PART I: HOW LONG OIL WILL LAST

Answering the question of how long we will be able to continue harvesting oil begins with first knowing how much oil the Earth has. In making this assessment we deal with two types of oil. First, we assess the amount of the Earth's oil in "proved reserves." Proved oil reserves are reserves that experts believe to be available for harvesting under current economic and political conditions. Second, we deal with "undiscovered oil," or the sum of the world's unproved reserves and oil believed to exist by credible oil surveys such as the United States Geological Survey's (USGS) World Petroleum Assessment or

[2] Organization of Petroleum Exporting Countries, "Monthly Oil Market Report: April 2010". *OPEC,* http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MR042010.pdf
[3] Ibid.

the Organization of the Petroleum Exporting Countries' (OPEC) Monthly Oil Market Reports. We begin with proven oil. As of January 1, 2009, there are 1,348,528,420,000 barrels of proven oil in the world.[4] [5] [6] For the world's undiscovered oil, we use two sources: the USGS World Petroleum Assessment and OPEC's April 2010 Monthly Oil Report. In the year 2000, the USGS's World Petroleum Assessment concluded there were 724,228,000,000 barrels of undiscovered oil.[7] It should be noted that since the year 2000, the USGS has determined there to be enormous amounts of petroleum in certain areas. The coast of West Africa is now believed to have 71.7 billion barrels of oil or a tenth of the amount of undiscovered oil in the 2000 World Petroleum Assessment.[8] Also since 2000, the USGS has estimated there to be 513 billion barrels of oil off the coast of Venezuela.[9] Hence from the USGS data we can conclude there to be at least 657.1 billion barrels of undiscovered oil, or 48.7% of the current proved reserve amount, that experts believe will eventually be included in proved reserved assessments. OPEC measures oil supply differently than the USGS. OPEC measures per month how many millions of barrels of oil were supplied per day. On average since 2008, about 85 million barrels of oil are produced each day.[10] Going back further, to 2005, there were 79 million barrels of

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[4] United States Geological Survey, "World Petroleum Assessment." http://certmapper.cr.usgs.gov/rooms/we/index.jsp.
[5] Organization of Petroleum Exporting Countries. "Monthly Oil Market Report: April 2010". *OPEC,* http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MR042010.pdf
[6] Central Intelligence Agency. *World Fact Book*. (Washington D.C.: Central Intelligence Agency, 2009.)
[7] United States Geological Survey, "World Petroleum Assessment 2000." http://pubs.usgs.gov/dds/dds-060/index.html#TOP.
[8] M.E. Brownfield et al., *Assessment of Undiscovered Oil and Gas Resources of Four West Africa Geologic Provinces*. U.S. Geological Survey Fact Sheet, 2010.
[9] C.J. Schenk et al., *An Estimate of Recoverable Heavy Oil Resources of the Orinoco Oil Belt, Venezuela*. U.S. Geological Survey Fact Sheet, 2009.
[10] Organization of Petroleum Exporting Countries. "Monthly Oil Market Report: April 2010". *OPEC*. http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MR042010.pdf

oil produced per day, and in 2001 there were 75 million barrels of oil produced per day.[11] This steady decade-long increase in supply agrees with the USGS's assessment, as OPEC's assessed world supply of petroleum has correlated with the USGS's findings of undiscovered oil.

Next we must determine the rate at which we consume oil. Figuring this out is tricky though, as oil consumption is not increasing at a steady rate, but rather exponentially. Many believe that each decade our consumption of oil doubles; this corresponds to a 7% increase in the rate of consumption of oil every year.[12] This means that, if it is in fact true that each decade human consumption of oil doubles, then every ten years more oil is consumed than the total of all previous years in human history.[13] To determine other possible growth rates, we once again turn to OPEC's Monthly Oil Reports. We will draw our information from the time period of January 2001 until January 2010, a ten-year period. In January 2010, OPEC's Monthly Oil Report reported that 85.5 million barrels of oil were produced per day.[14] In January 2001 OPEC's Monthly Oil Report reported that 75 million barrels of oil were produced per day.[15] This information says that 12.2% more oil was used in December 2009 than in December 2000. This doesn't mean that oil consumption has increased 12.2% per year, but rather implies an increase of 1.22% on average each year, significantly less than the commonly believed 7% increase.

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[11] Ibid., "Monthly Oil Market Report: January 2005". *OPEC.* http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MOMR_012005.pdf. Also see Ibid., "Monthly Oil Market Report: January 2001". *OPEC*, http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MOMR_012001.pdf.
[12] A. Barlett, "Forgotten Fundamentals of the Energy Crisis," *American Journal of Physics.* 46, no. 876 (1978): 11.
[13] Ibid.
[14] Organization of Petroleum Exporting Countries, "Monthly Oil Market Report: January 2010" *OPEC*, http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MR012010.pdf.
[15] Ibid., "Monthly Oil Market Report: January 2001". *OPEC.* http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MOMR_012001.pdf.

We now find how long oil will last assuming both the 1.22% increase and 7% increase. We will assume there are 1.95 trillion barrels of oil in the Earth, or the sum of all proved reserves with that of predicted undiscovered oil. For both calculations we will use the fact that in 2009 an average 84.4 million barrels of oil were produced every day. First, assume increase in oil usage stands at 7% per year. The equation we will use is for exponential expiration time, or EET:

$$EET = (1/k)\ln(kR/r + 1)$$

In this equation, k = 7%, R = tons of oil (3.12×10^{11} tons for 1.95 trillion barrels of oil), and r is the current rate of consumption. Hence we have the expiration time for oil at 7% usage being 378 years. We now do the same calculation for a 1.22% increase in oil consumption. This calculation yields 2,205 years of oil. It is important to remember that OPEC's Monthly Oil Market Report is regarded as a standard in oil surveying, and we will thus adhere to its figures when making scientific judgments on oil consumption. In other words, we must take the past decade's 1.22% growth in oil consumption as the real increase, implying that we assume the yield of 2,205 years of oil is correct.

It is interesting to compare our finding of 2,205 years worth of oil to what leading scientists believed in 1974 immediately following the end of OPEC's freezing of exporting petroleum to the United States, commonly referred to as the Oil Crisis of 1973, and what scientists believed in 1998. We will limit ourselves to the predictions of two men widely regarded as the top authorities in the world of petroleum, K.M. Hubbert and Colin Campbell. In 1974, Hubbert predicted that oil would peak in the year 2000. When oil production in 2001 and 2002 fell short of production in 2000, Hubbert's theories were believed to be true.[16] The energy world ran awry when many believed we had achieved peak oil, or the maximum rate at which we can extract oil. Two years prior to this scare, in 1998, Colin Campbell, a renowned petroleum consultant, believed new discoveries would be limited to 85 to 100 million barrels of oil, an amount large enough to supply only three or four years of demand.[17] Both of these theories have been refuted, though, as over the past ten years the amount of oil discovered in West Africa and off the coast of Venezuela totals about 700 billion barrels of oil, and the 2010 oil supply exceeded the predicted supply of the year 2000.[18] Campbell and Hubbert were the most notable predictors of a so-called oil doom, and were given the most credibility by energy conservation communities, yet both of their theories are wrong according to our findings.

We must remember that both Hubbert and Campbell had their eyes on a bigger goal, though, namely the same as we have now – to determine whether is oil a sustainable resource. While our finding of at least 2,205 years worth of oil disproves both Campbell and Hubbert's claims, it now transcends upon us the task of answering if oil, in its current abundance, is a sustainable resource or not. We find that it is. First note that the argument that oil is finite and thus unsustainable fails because if we had only six million years worth of oil, regardless that it is a finite amount of oil, the amount would still be so great that it would last longer than expected human life on Earth. There are two important things that allow us to determine that 2,205 years worth of oil is a sustainable amount. First, based on aforementioned OPEC and USGS reports and assessments, there is reason to believe that we will continue to find mega-reserves of oil whose sizes might possibly

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[16]Kenneth S. Deffeyes, *Hubbert's Peak*. (Princeton: Princeton University Press, 2003), 2 – 13.
[17] Kenneth Reich, "Gauging the Global Fuel Tank's Size." *Los Angeles Times* (June 11, 2001): sec. A8.
[18] Organization of Petroleum Exporting Countries. "Monthly Oil Market Report: January 2010" *OPEC* http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MR012010.pdf. See also Ibid.,"Monthly Oil Market Report: January 2001" *OPEC*. http://www.opec.org/opec_web/static_files_project/media/downloads/publications/MOMR_012001.pdf

exceed that of the largest reserves we currently know of. The likelihood of at least one major finding in the near future is huge, and one such finding could add hundreds-of-years worth of oil (such as the West African and Venezuelan findings mentioned earlier). Hence, we may regard 2,205 years to be a conservative estimate on a significantly larger set of estimates that could arise within the next decade. Second, we must remember that only recently has major work toward alternative sources of energy has been done. Countless times in the past human achievement has exceeded what seemed possible, and there is strong reason to believe scientific advancements might trivialize a number such a 2,205.

PART II: THE OIL AGE AND AN ALTERNATIVE

Oil is extremely efficient, abundant, and profitable, hence an almost indispensable resource in the modern economic and social climate. However oil is an imperfect resource. The imperfections of oil are best highlighted by its environmental impacts, most notably the effects of carbon dioxide emissions and oil spills. As a result, finding alternatives to oil, whether it is by way of natural discovery or technological advancement, is essential to preserving our environment. Furthermore, it is through such technological advancements that our dependence on oil will subside and allow for the end of the oil consumption age.

The environmental risk associated with harvesting oil is high. The most obvious risk is that of an oil spill. As the demand for oil has steadily increased over the past twenty-one years, nine of the world's thirty-five largest oil spills have occurred.[19] Among these are the 1989 Exxon Valdez spill, where 37,000 tons of oil leaked into Alaska's Prince William Sound, and the 2002 Prestige oil spill in Spain, where 77,000 tons of oil destroyed 1,400 kilometers of coast and resulted in the collection of some 159,000 tons of contaminated waste.[20] [21] Most recent was the Deepwater Horizon oil spill, where a BP oil rig exploded on April 20, 2010, opening a 1,500-meter deep leak the effects of which are ongoing. Many believe the BP disaster will eventually constitute the worst oil spill in United States history, as some sources have pinned the leak to be 25,000 barrels of oil per day for the 39 days the spill has gone on thus far.[22]

The believed cause of global warming is the rise of carbon dioxide emissions from using oil.[23] Since 1949, there has been a steady increase in carbon dioxide emissions, and almost all emissions since then have been from transportation waste. Cars and airplanes attribute to this statistic, as both of which burn some crude oil derivative in order to run, as a means of travel.[24] We cannot use the atmosphere as a permanent waste dump forever, hence, finding oil alternatives, most importantly in the transportation sector, would be a great start in keeping ourselves from further polluting the atmosphere.

Ultimately our goal should be to minimize the environmental risk associated with all types of energy. In the context of oil, we can minimize our environmental risk by

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[19] The International Tanker Owners Pollution Federation Limited. "Statistics." ITOPF Information Services. http://www.itopf.com/information-services/data-and-statistics/statistics/index.html.

[20] The International Tanker Owners Pollution Federation Limited. "Case Histories – E." *ITOPF Data and Statistics – Case Histories* http://www.itopf.com/information-services/data-and-statistics/case-histories/elist.html#EXXON

[21] Ibid., "Case Histories – P." *ITOPF Data and Statistics – Case Histories*, Date, http://www.itopf.com/information-services/data-and-statistics/case-histories/plist.html#prestige.

[22] Ian Talley, "Oil May Be Leaking at Rate of 25,000 Barrels a Day in Gulf." *The Wall Street Journal* April 30.

[23] John Fialka, "Emissions of CO2 Continue to Rise Despite Pledges." *The Wall Street Journal* October 2006.

[24] PEW Center on Global Climate Change. "4E. Trend in CO2 Emissions from Oil Combustion." *PEW Center*, http://www.pewclimate.org/global-warming-basics/facts_and_figures/us_emissions/co2oil.cfm.

finding an alternative. This is complex—it is impractical for people to stop driving their cars and stop traveling in planes. Hence, the environmental risks of using oil are not enough to convey the urgency with which we must find an alternative. Thus, we need an alternative source of energy that allows for efficient transportation, as well as a cheap, safe, and clean means of acquiring it so people will be compelled to use it by virtue of economic gain and environmental safety. While it seems like a fantasy that we could create something more efficient and useful than oil, history has shown us time and time again that innovation takes us to unimaginable places. The Stone Age did not end because we ran out of stones. Analogously, the age of oil consumption will not end because we will run out of oil. The end to our mass consumption of oil will happen because human innovation will take us beyond oil, and soon an alternative will be found that allows us to cut our dependence on oil.

Of the current candidates to potentially replace oil, namely diesel; methanol; ethanol; and synthetic liquids, none proves a more viable candidate than hydrogen. [25] In efficiency alone, hydrogen as a fuel trumps gasoline. A hydrogen combustion engine would be 20-25% more efficient than a gasoline engine,[26] but as a fuel cell, the primary means of using hydrogen as a source of energy, hydrogen's efficiency would range from an astounding 60-83%.[27]

The hallmark of hydrogen as an alternative source of energy is how environmentally sound it is compared to gasoline, the latter of which constitutes over half of greenhouse gas emissions.[28] Unlike gasoline combustion, which releases harmful

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[25] Joan Ogden, "Hydrogen: The Fuel of the Future?" *Physics Today (*April 2002): 69.
[26] Ibid.
[27] Ibid.
[28] Ibid.

greenhouse gases into the atmosphere, hydrogen combustion's main by-product is water, and an insignificant amount of pollution.[29] To demonstrate how the pollution produced is insignificant, we only need to note that hydrogen combustion produces 200 times fewer greenhouse gases than current gasoline combustion engines.[30]

The roadblock that lies ahead of hydrogen is finding a way to make the logistics of widespread hydrogen equal to or better than oil's logistics. If hydrogen is to become a mainstream source of energy, we must find an efficient means of producing hydrogen for mass distribution. To this extent, hydrogen technology has done extremely well with thermo chemical production and water electrolysis,[31] but research for better methods is ongoing. Once an efficient method of hydrogen production is determined, the next step would be finding ways to transport hydrogen in the same quantities that we transport oil. It is here where much work needs to be done. Major pipelines would be necessary, and a cheap yet safe storage system would be indispensible.[32] In other words, we would need new technologies, such as carbon nanostructures, installed in new tanker-trucks and ships, and we would also need to construct pipelines equivalent to that of the Trans-Alaska Pipeline System.[33]

The safety of hydrogen as an alternative source of energy has been called into question at times, and if adopted as a replacement to oil, widespread safety features would be necessary. In some ways hydrogen is safer than gasoline, namely in it being non-toxic, less flammable and more buoyant than gasoline.[34] However hydrogen is more

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[29] Gustav P. Dinga, "Hydrogen: The Ultimate Fuel and Energy Carrier". *Journal of Chemical Education* (August 1988): 688.
[30]Ibid.
[31] Joan Ogden, "Hydrogen: The Fuel of the Future?" *Physics Today (*April 2002): 70.
[32] Ibid., 71.
[33] Ibid., 72.
[34] Ibid., 71, 73.

susceptible to leaks and has a higher flame velocity (if ignited, hydrogen can spread very quickly), hence it would need usually be stored outside or in areas with lots of airflow. Another key issue is the invisibility of ignited hydrogen. Fire detectors would need to be replaced by infrared detectors and hydrogen-carrying items would need to be marked by special paints that would change color when hydrogen is ignited.[35] A recent fear of hydrogen was that it could create a massive explosion if compressed correctly in an automobile accident. However, these fears were dispelled after makers who were considering producing hydrogen cars, such as General Motors, put their cars through rigorous crash tests in search of such dangers.[36] If hydrogen were adopted as an alternative source of energy, then a reliable system to maintain hydrogen safety would be necessary and such a system would need to be worked out before hydrogen could be put into use.

Inherent in hydrogen's requiring new safety and storage technologies, as well as massive construction projects, is the economic and monetary feasibility of such a transition. Undoubtedly, the first way such large amounts of money could be raised is by private investors, but the international scope of such a project (for example, hydrogen lines running through both the United States and Canada) could create tensions, economic and political, between nations. Hence it would take the cooperation and financial support of governments for such a project to be feasible. At least in the realm of the United States, this would require an increase in taxes or some other system by which

[35] Ibid., 73.

[36] "GM's Hydrogen Fuel Cell-Fleet Holds Up in Crashes." *USA Today*, May 31, 2010, http://content.usatoday.com/communities/driveon/post/2010/03/gms-hydrogen-fuel-cell-fleet-getting-real-crash-experience/1).

the American people are taxed (carbon credits, etc.).[37] This brings yet another potential roadblock to hydrogen as tax increases are highly unfavorable in the United States and abroad. One possible solution to such a problem lies in the fact that hydrogen would be priced at about 17.5 cents per gallon of gasoline equivalent.[38] Using this fact, hydrogen could be taxed at 300 or 400 percent, which would raise its price to either 70 or 87.5 cents per gallon of gasoline equivalent, with the tax going toward further investments in hydrogen technologies. Even at the comparative 87.5 cents per gallon, hydrogen would be significantly cheaper than gasoline. When coupled with the ease of mass-producing hydrogen, this makes for an unbelievably cheap commodity that can produce huge amounts of revenue for reinvesting in technologies. However, as mentioned before, to reach this point would require huge monetary investments in hydrogen technology. The economic roadblock of hydrogen is what has kept it from being *the* alternative to oil thus far, and will continue to do so as long as progress toward large hydrogen fuel and production systems remains stagnant. While the advantages of hydrogen are huge, first there must be money behind its implementation; unfortunately, there is not enough available at this moment.

Oil is sustainable as long as we continue looking for alternative sources of energy. With 2,205 years worth of oil at our fingertips, we have a lot of energy and a lot of time to use that energy. However even with more oil expected to be discovered, it is our job to use this generous amount of time and energy to find new means of transportation, processing, and other things in our everyday lives that naturally involve oil use. Whether or not hydrogen, as cheap; efficient; and abundant as it is, will be the successor to oil and

[37] Ogden, Joan. "Hydrogen: The Fuel of the Future?" *Physics Today* (April 2002): 74.
[38] Dinga, Gustav P. "Hydrogen: The Ultimate Fuel and Energy Carrier"*Journal of Chemical Education (*August 1988): 689.

its derivatives depend on whether we can invest the right resources into the right things, examples being storage and safety methods. The author would like to think that along with advances in physics, computer science, engineering, chemistry, and geology that at some point the relatively new field of environmental science would have a unique hand in advancing society beyond oil dependence. The Stone Age did not end because we ran out of stones, and the oil age will not end because we will run out of oil. At some point something better will come along, and we will, just as we did for oil, adopt it as an essential element to our lives. We can only hope that collectively as a species, humans can forgo personal gain and generational hedonism in the name of preserving what we already have for generations to come. In the meantime, we should aggressively seek alternatives, both through public and private ventures, and reward those who make significant contributions toward ending oil dependence. We have at least 2,205 years to find it.

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