Proper citation:
Hwa A. Lim, “Renewable and alternative energies”, *Symbiosis*, June, 2008, pp. xx–yy.

Renewable And Alternative Energies

by

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> *When Britain began industrializing, charcoal was used to make steel. This depleted Britain’s forests. The human mind responded to this challenge by mining for coal. This was hugely profitable as charcoal had become scarce. Over time, the woods of Britain re-appeared as coal became the chief source of energy. Yet this coal did not die out. Soon, Man discovered oil. And Britain found it cheaper to import coal and oil than to dig so deep for it. Today, you can take coal to Newcastle. There is no mining, but there is still coal under the ground. It has not been exhausted. Similarly, there will always be oil and natural gas, for the human mind will come up with alternatives. Even these non-renewable sources of energy will not be completely exhausted, ever. The price of energy will prompt the search for substitutes”*
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> - Barum S. Mitra, *Population, The ultimate resource*, (Liberty Institute Press, New Delhi, India, 2000).

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1 Green Fuels

When Dario Franchitti, a Scotsman Indy driver, won the 2007 Indianapolis 500 with his 670-horsepower car, he became the first driver ever to win the iconic American auto race on pure ethanol.

In fact, a century ago, Henry Ford’s (1863–1947) first car ran on alcohol, and Rudolf Diesel (1858–1913) fired his namesake engine with peanut oil. But these inventors soon discovered that “rock oil” held far more bang per gallon than plant fuel and was cheap to boot. In this race, oil soon left plant fuels in the dust. Only in periods of scarcity—like the OPEC oil embargo of 1973—did the U.S. and other countries turn back to ethanol, mixing it into gasoline to stretch supplies.[1]

It was not until 2000 that fuel alcohol staged a major comeback, again largely as an additive in less polluting gasoline blends. But now it looks like it is here to stay. The Indy 500 of fuel race has gone a full lap.

1.1 Not So New Biofuel Technology

Humankind has been turning grain into alcohol for eons. The corn is ground, mixed with water, and heated; added enzymes convert the starch into sugars. In a fermentation tank, yeast gradually turns the sugars into alcohol, which is separated from the water by distillation. The leftover, known as distillers' grains, is used as feed, and some of the wastewater—rich in nitrogen—is used as a fertilizer.[2–4]

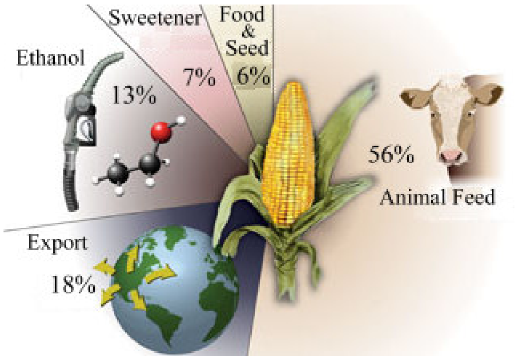

Figure 1. In 2004, U.S. growers planted 81 million acres of corn for food, animal feed, and inclusion in myriad food products. Corn is also an important material for many industrial purposes and products including rubber, plastic, fuel and clothing. (U.S. National Science Foundation).

The process also gives off large amounts of carbon dioxide (CO_2). Most ethanol plants burn natural gas or, increasingly, coal to create the steam that drives the distillation, adding fossil-fuel emissions to the CO_2 emitted by the yeast. This is where ethanol's green label starts to brown.[5]

Growing the corn also requires nitrogen fertilizer, made with natural gas, and heavy use of diesel farm machinery. Some studies of the energy balance of corn ethanol—the amount of fossil energy needed to make ethanol versus the energy it produces—suggest that ethanol may be a loser's game, requiring more carbon-emitting fossil fuel than it displaces; other studies give it a slight advantage.[6]

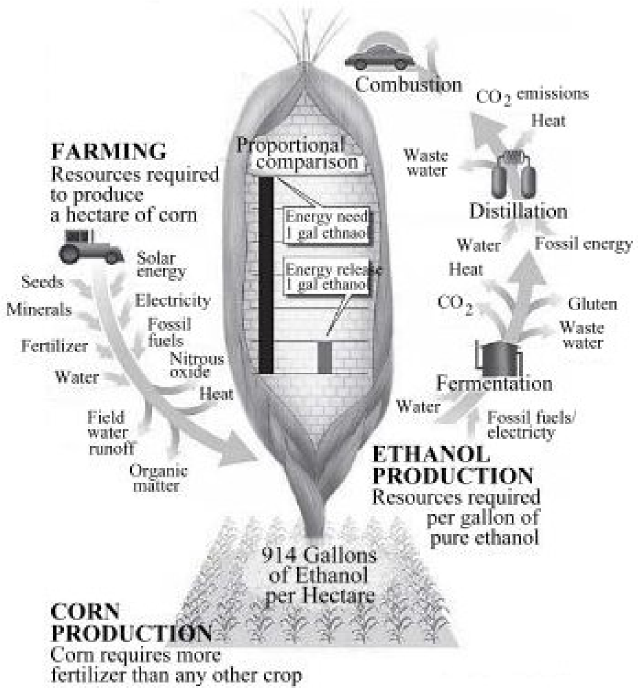

Figure 2. The ethanol cycle. The various resources and outputs for each gallon of ethanol produced. (Source: "Thermodynamics of the corn-ethanol biofuel cycle", Tad Patzek).

One may easily lose faith in biofuels if corn ethanol is the only biofuel one knows. A more encouraging picture unfolds in Brazil. The country had been burning some ethanol in its vehicles since the 1920s, though it was still importing 75% of its oil by the 1970s. When the OPEC oil embargo of 1973 crippled the nation's economy, Brazil's dictator at the time—Gen. Ernesto Geisel (1907–1996)—decided to kick the country's oil habit. He initiated in 1975 the Pró-Álcool program. The Pró-Álcool or *Programa Nacional do Álcool* (National Alcohol Program) was a nationwide program to replace automobile fuels derived from fossil fuels in favor of ethanol. By the mid-1980s, nearly all the cars sold in Brazil ran exclusively on álcool.

While corn ethanol's energy ratio hovers around breakeven, "we get eight units of ethanol for every one unit of fossil fuel," says Isaias Macedo, one of Brazil's leading sugarcane researchers. Experts estimate that producing and burning cane ethanol generates anywhere from 55 to 90% less CO_2 than gasoline. And Macedo envisions even greater efficiencies. "We can do the same thing with two-thirds or half of the bagasse, better manage tractors in the field, and approach levels of 12 or 13."

Virtually every scienstist studying the biofuel issue agrees that there is no magic-bullet fuel crop that can solve our energy woes without harming the environment. But most say that alga—a single-celled pond scum—comes closer than any other plants because it grows in wastewater, even seawater, requiring little more than sunlight and CO_2 to flourish. A dozen start-up companies have been trying to convert the slimy green stuff into a viable fuel.

Some of these companies have developed a process that uses algae in plastic bags to siphon CO_2 from the smoke-stack emissions of power plants. The algae not only reduce a plant's global warming gases (CO_2), but also devour other pollutants. Some algae make starch, which can be processed into ethanol; others produce tiny droplets of oil that can be brewed into biodiesel or even jet fuel. Mostt advantageously, algae in the right conditions can double in mass within hours. By comparison, each acre of corn produces around 300 gallons (1,135 liters) of ethanol a year; an acre of soybeans around 60 gallons (227 liters) of biodiesel; while each acre of algae theoretically can churn out more than 5,000 gallons (19,000 liters) of biofuel each year! With corn or soybeans, one harvests once a year; with algae one harvests every day.

Table 1. CO_2 emissions of emerging biofuels compared to that of gasoline and diesel. Emerging biofuels emit 20–91% less CO_2 than hydrocarbons. Energy balance is the fossil fuel used to produce the biofuel compared with the energy in the biofuel.

Fuel	Energy Balance	CO_2 Emission		
		Gasoline/Diesel	Biofuel	
Corn ethanol	1:1.3	20.4 lbs/gal	16.2 lbs/gal	22% less
Cane ethanol	1:8	20.4 lbs/gal	9 lbs/gal	56% less
Biodiesel	1:2.5	23.4 lbs/gal	7.6 lbs/gal	68% less
Cellulosic ethanol	1:2 – 1:36	20.4 lbs/gal	1.9 lbs/gal	91% less
Algae	-	-	-	-

1.2 Gasifier

Gasifier technology uses gases—hydrogen, carbon monoxide and methane—extracted from wood chips to heat a boiler. This process can generate 1.3 megawatts per hour.

Essentially, the technology involves four steps:

1. Gas collection: The gasifier heats the wood chips to 700 or 800 degrees, where they smolder, releasing hydrogen, carbon monoxide and methane. Spent wood chips disintegrate to ash. Water vapor is the only major emission.
2. Ignition: The gases travel to an oxidizer, where oxygen is added and the gases burn.
3. Steam: Hot gases travel to a boiler which heats the water to steam.
4. Electricity generation: The steam powers a turbine to create electricity. The steam finally will be used as hot water and to heat buildings.

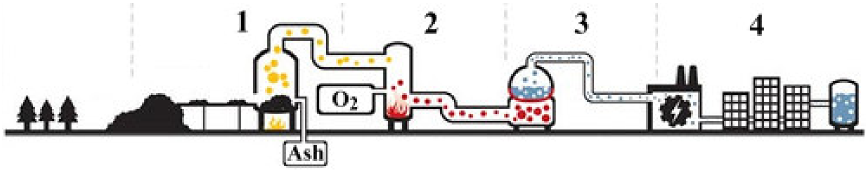

Figure 3. The USC wood gasifier involves 1. Gas collection; 2. Ignition; 3. Steam; 4. Electricity generation. (Source: Johnson Controls).

1.3 Genetic Engineering and Synthetic Biology

LS9 Inc. in San Carlos, California, using old-fashioned genetic engineering, has developed a strain of standard industrial microorganism that can produce hydrocarbons from treated agricultural waste.

The present strain is "very close to meeting an economic threshold" and will be tested in a pilot plant. The youthful microbe already produces an ethanol-like product, at 65% of the cost of corn-derived ethanol. LS9 fuels, the company claims, will meet the same diverse needs as petroleum does, can be transported in existing pipelines and be used in existing vehicles.

Synthetic Genomics' goal is also to make alternative fuels to oil and coal. Besides genetic engineering approaches, the company has applied for far-reaching patents on the uses of synthetic life forms. In any case, there are many hurdles to overcome before the vision of "life by design" is realized.[7]

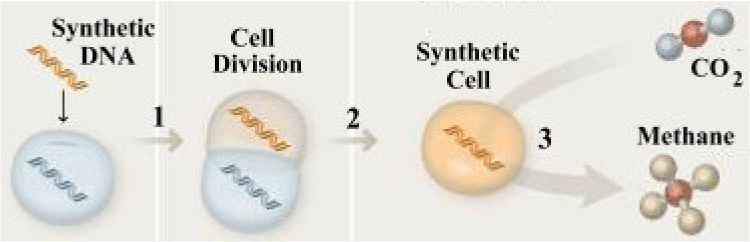

Figure 4. If researchers were able to create a synthetic genome, the transplantation process might be able to create synthetic cells. 1) A synthetic DNA is inserted into a species of bacteria. 2) When the cell divides, one of the daughter cells is a synthetic cell. 3) In theory, the synthetic cells could be designed to have useful properties such as the ability to efficiently convert carbon dioxide to methane.

2 Einformatics

Weaning ourselves from hydrocarbons is something what we humankind will undoubtedly do someday, but not soon. Scrubbing out the carbon dioxide (CO_2) at the smokestack is technically feasible. But given the massive amounts of carbon at issue, this would require enormous additional capital investment and concomitantly increases in consumption of fuel. Would it be viable depends on how seriously we take the claim that carbon emissions are changing the global climate.

2.1 Carbon Calculus

Because carbon now figures so centrally in policy debates, we shall use carbon itself as the metric of disorder. Though this metric is imperfect, it does give us one systematic way to line up benefits and costs.

In this metric, one hour of the order we call 100-W light costs us, on average 0.05 pounds of atmospheric-carbon chaos; one bucket of ice from the refrigerator, 0.3 pounds; one average hour in a car, 5 pounds. These pounds do certainly add up. Worldwide, humans emit roughly 6.5 billion metric tons by burning fossil fuels, and another 2 billion metric tons through deforestation.

These are big numbers. Plants—the green kind, not the ones made of concrete—exhale about 59 billion metric tons of carbon in the form of CO_2 a year, and absorb roughly 120 billion in photosynthesis. Soil organisms, digesting the dead plants on which they live, emit 59 billion. A net of about 26 billion physically diffuse into the atmosphere out of the oceans, and about 28 billion diffuse back in. In short, green plants and carbon weathering, both powered by the sun, continuously establish new carbonaceous order.[8]

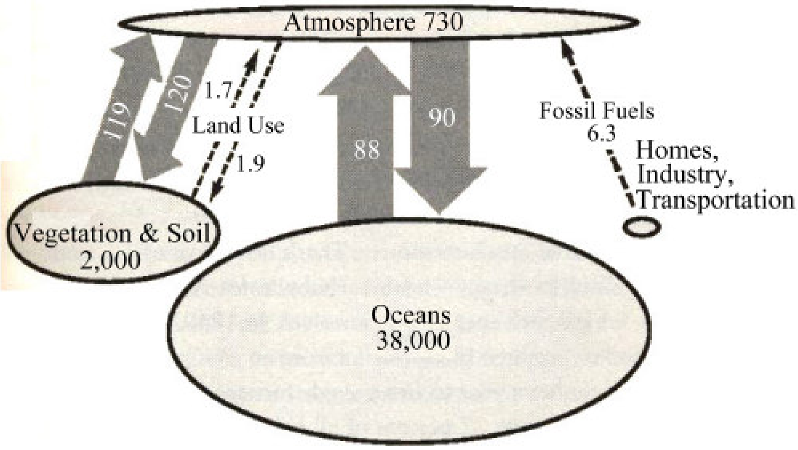

Figure 5. Global carbon flux in billion metric tons of carbon. Fossil fuel combustion and deforestation release carbon into the atmosphere, while agriculture and forest regeneration remove it. Much larger carbon fluxes are propelled by plant and animal life in the rest of the biosphere. (Source: EIA, *International Energy Review, 2002*, the data is for 1999).

On these carbon-based order/chaos books we are dealing with small differences between large and uncertain numbers. We do know that concentrations of atmospheric CO_2 rose about 20% in the past century—but we also know that concentrations have varied substantially in the past, long before fossil fuels entered the picture. CO_2 levels were only half as high some 50,000 years ago, but they were almost as high as today 150,000 years ago. Eight hundred million years ago the earth's air was mostly CO_2. Green plants evolved and flourished in profusion and absorbed most of it. Some of the plants sank into swamps, and then sank deeper, eventually becoming the fossil fuels that we now burn in such quantities.[9]

The fear is that if we dig up and burn all the fossilized plants of the Carboniferous period, we can expect to recreate the atmosphere of that period—a carbon-rich hothouse. On its own, the effects are still inconsequential—CO_2 in the quantities we add, does not act as a very effective atmospheric blanket to block the shedding of heat from the surface of the earth at night. But water vapor might amplify the impact significantly. Warmer air holds more vapor, which blankets the planet a bit more, which warms the air still more, which holds more vapor, and now the earth becomes a runaway greenhouse. Or so a good number of the climate models suggest. There is much uncertainty to these models, but the mere possibility that we might be changing our global environment is indeed worrisome.[10]

2.2 Closet Carbon

Ethanol is a prime example of a product which experts call "closet carbon." That is, CO_2 embedded in the production of what is supposedly a renewable product. For example, about 25% of pine tree cannot go to a lumber mill or paper mill and is usually left behind when the forest is clear-cut. If it is burned, it produces CO_2; if it rots, it produces methane (CH_4), an even more potent greenhouse gas (GHG). This "waste" can be used to make ethanol.

In contrast, corn ethanol is made using natural gas or coal that also contains carbon, but could have stayed in the ground if not for the ethanol manufacture. Ethanol advocates say that some gallons of corn ethanol have twice as much closet carbon as others.

2.3 Carbon Negative

Some researchers think there could even be products that are carbon negative. Two papers discuss using renewable energy to displace fossil fuel and to remove carbon from the environment.

One is built on the 80-year-old technology of making liquid motor fuel from a gas consisting of hydrogen and carbon monoxide (CO). The Nazis pioneered the technique in the 1930s, making the gas, called "synthesis gas," from coal, and some companies in the U.S. would like to revive it, again using coal. But the "synfuel" has more than a closet full of carbon; it produces about twice as much CO_2 per mile driven as ordinary oil does, counting the CO_2 released in production.

But synthesis gas can also be made from biomass: wood chips, corn stalks or paper in garbage. Getting synthesis gas that way is carbon neutral, since next year's production will come from new trees or agricultural waste, which gets its carbon from the atmosphere.

At Princeton, however, Robert H. Williams, a physicist, is pushing carbon negative bioenergy, in which the carbon monoxide (CO) is burned for heat to drive the process, but the resulting carbon dioxide (CO_2) is captured chemically, pressurized into a liquid, and pumped underground. This process uses plants to make syngas and capture the CO_2; the CO_2 is thus not a byproduct but a co-product.[11]

2.4 Economic Externalities

A change in the works could go a long way toward making alternative energy less alternative, but more attractive to consumers and businesses. It is not a technological fix from some solar-cell laboratory in Silicon Valley or wind-turbine researcher in China or the development of some super bug to turn wood waste into ethanol.

Rather, the change would come from policy-makers, if they carry through what they have been talking about and putting a price tag on greenhouse-gas (GHG) emissions. Suddenly the carbon content of fuel, or how much carbon dioxide (CO_2) is produced per unit of energy, would be as important as what the fuel costs. In fact, it might largely define what the fuel costs.

This could shake up the economics of energy. Those that produce hefty emissions, like coal and oil, would likely be handicapped; and some—sunlight, wind, uranium, even cornstalks and trash as well as natural gas—would probably be favored. “Carbon-negative” fuels that take CO_2 out of the atmosphere as they are made might even become feasible.

Carbon dioxide is what economists call an “externality,” something that imposes a cost on somebody other than the manufacturer. At some point, the thinking goes, policy-makers will force industries to pay those costs, either with a tax or a cap-and-trade system in which allowances will cost money.

Staff at the Electric Power Research Institute (EPRI), a nonprofit utility consortium in Palo Alto, California, estimates the effect of a charge on CO_2 emissions on the price of a kilowatt-hour. At $10 per metric ton, the impact is minimal, but at $50 a ton, for example, the cost of a kilowatt-hour produced by coal goes from about 5.7 cents to about 10 cents. Wind power currently is not competitive, according to the institute’s calculation, but it becomes competitive when CO_2 costs $25 a ton. By their calculations, nuclear energy, with negligible CO_2 emissions, looks sensible at a small carbon charge.

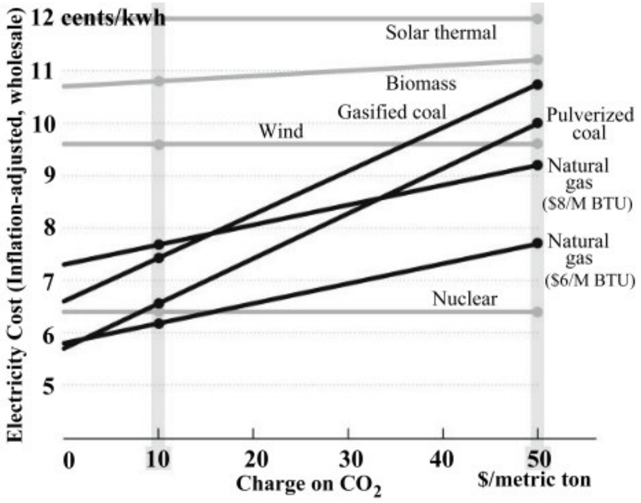

Figure 6. A charge on carbon emission may allow alternative energy sources to compete with coal or gas. At $10 per metric ton of CO_2, little change would be seen in the relative electricity costs. Energy alternatives would remain more costly than coal, natural gas (and nuclear). At $50 per metric ton of CO_2, pulverized and gasified coal would be more expensive than wind and nuclear power. Note the average cost of solar power range from 12 cents to 26 cents.

Here is how the new economics might work for solar power. Solar power from photovoltaic cells is currently relatively expensive, about 25 to 30 cents per kilowatt-hour. Comparing a kilowatt-hour produced by such cells, which emit no CO_2, with one produced by a conventional coal plant (coal produces 1.9 pounds of CO_2 per kilowatt-hour), at \$20 or \$30 a ton, the 1.9 pounds of CO_2 emitted in producing that kilowatt-hour costs 2 to 3 cents. That cuts into coal's price advantage and—when coupled with progress in reducing the cost of solar power through manufacturing and economies of scale—gives solar power a much larger chance to be relevant. Solar thermal systems, which use mirrors to concentrate sunlight to boil water, might benefit even sooner.

3 Conclusion

At the beginning of the 20th century, the world derived about 60% of its energy from coal, crude oil and very little natural gas. A century later, the three kinds of fossil fuels account for about 80% of the world's total primary energy supply. The rest is about equally split between primary electricity—hydro and nuclear—and phytomass (live biomass) fuels.

Biomass energies have been with the humankind ever since we mastered the use of fire: wood, charcoal, crop residues and dung are still used by hundreds of millions of peasants and poor urban residents in Asia, Latin America, and particularly throughout sub-Saharan Africa, mainly for cooking and heating. But most of the biomass is burned very inefficiently in primitive stoves.

We have only just begun to harness the other major indirect solar flow—wind—but it is too early to predict if large-scale wind farms will translate into worldwide and sustained contributions. Potentially the most rewarding, and by far the largest, renewable energy resource is the direct solar radiation that brings close to 170 W/m^2 to the earth. But so far its direct conversion to electricity by photovoltaics has succeeded only in small niche markets that can tolerate the high cost. Silicon Valley, the clean energy capital of the world, has been making some of the greatest advances in solar power.[12]

But as we argued, the carbon content of fuels can be a major factor in deciding in the near future which fuels will be the most favorable, economically and environmentally speaking. The sun is shining the brightest in this sense.

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This work is based on a forthcoming book:
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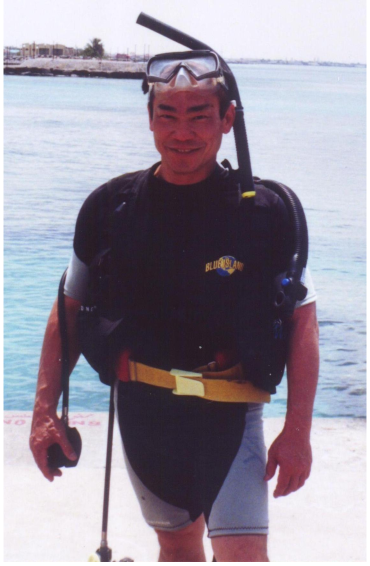
About The Author



Hwa A. Lim, aka Hal, scuba diving in the Red Sea to check out the flora and fauna.

Dr. Hwa A. Lim, Ph.D. (science), and MBA (strategy and business laws), is credited with coining the neologism "Bioinformatics" in the 1980s, establishing and shaping the field, and initiating the world's very first bioinformatics conference series. These credits earn him the title "The Father of Bioinformatics". He has served as a bioinformatics expert for the United Nations to help set up biotech research parks, and has the distinction of being a key member of separate teams that took companies IPO in the United States.

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