

## Energy Problem and Oil Crisis ♦ Is the Problem Solved and the Crisis Over ?

*A guide to manufacturing your own energy in your garage or garden ♦ Energy Self-Sufficiency*

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ABSTRACT • Energy Self-Sufficiency as a Driver for the Energy Agnostic Global Economy • eAGE

Do you have a cell phone or iPod? You probably know that these and several other devices we use everyday use some form of computing as a part of their normal function. In other words, you hold the ability to perform computing functions in the palm of your hand, each day. It didn't happen overnight. ENIAC, the first computer weighed 30 tons (more than 27,000 kilograms) but the iPod weighs 120 grams. Imagine the gasoline you pump in your car or the light you turn on in your bedroom by flicking a switch. What is the source of the gasoline or the electricity for your bedroom light? Of course, you have some idea how we get oil from the ground and electricity from utility providers. Fast forward to the near-future: both forms of energy can be manufactured by you, in your home. Not only in your home, but in every home, worldwide. In other words, you manufacture your liquid fuel for your car or automobile which runs on unleaded gasoline and you automatically convert the liquid fuel (you have just manufactured) in an electric generator (you can buy from Home Depot) to provide the electricity you need for your new electric vehicle as well as appliances, lights, heating and cooling in your home or small business. Taken together, you may claim to be self-sufficient for energy. It changes the world. Doesn't it? Yes, you can change the world.



Energy self-sufficiency is not only possible but almost within our grasp. If the cost of energy ceases to plague our economy then the global economy may expect to make positive strides. We can create new jobs and worry less about energy availability and its increasingly volatile cost. This is the concept of eAGE or energy agnostic global economy. eAGE is easy to appreciate if you consider the ***distributed*** ability of computing at the hands of any person who owns an iPad or notebook ***computer*** versus the first computer, ENIAC, which required 30 separate floor units occupying 1800 square feet and weighed 30 tons. Sources of oil (gasoline) and electricity today are analogous to the grotesque ENIAC if we consider oil exploration, drilling, refining and transportation to gas stations. Similarly, the electricity producing power plants of the utility behemoths generate 60-80% of the electricity by burning fossil fuels. These activities continue to add green house gases (GHG) to our atmosphere which may influence the quality of our environment. Steps to reduce or restrict GHG emissions in an uneven global economy fuels acrimony between nations which fractures global goodwill and catalyzes a geo-political power game in the name of the science of climate change.

Hence, the importance of the computing analogy if we recognize that advances in science and technology succeeded in the progress of civilization by shifting the paradigm of computing from a feeble ENIAC weighing over 27,000,000 grams to the high performance iPod weighing 120 grams.

This article advocates a revival of the spirit that led to the iPod from the ENIAC. A similar shift is necessary to relieve the world from the vagaries associated with fossil fuel sources. The world seeks freedom from the cartels which control our economy and jobs, hence, sequestering our ability to invest in education, healthcare and global public goods to improve the quality of life on earth.

The paradigm shift in energy is technologically at hand but difficult to inculcate and disseminate because of geo-political issues and the lobbying power of the energy behemoths. The shift is based on the fact that we have succeeded in producing a four carbon molecule, butanol (which can directly replace gasoline) from micro-organisms using sunlight as the primary energy source. We are now able to **manufacture energy**, albeit still dependent on a primary source (solar energy). Fossil fuels are products of drilling industry because oil, gas or coal must be excavated. Nuclear energy depends in part on mining the raw material but the bulk of the industry is manufacturing.

Thus, what we have achieved is the ability to use sunlight and carbon dioxide from the atmosphere, as renewable raw materials, through the medium of microbial growth, to manufacture liquid fuel, butanol, which is a direct replacement for gasoline. The rate-limiting step in this manufacturing process is the yield, that is, the volume of butanol produced per unit may be small, at this time.

Small refers to volume and in that respect it is a **relative** term. Let us explore the scenario where you require 10 gallons of gasoline for your transportation every day. Perhaps you are travelling 50-500 miles per day depending on your vehicle. Are you? Boston to New York is less than 200 miles. On an average, we add less than 33 miles per day or about 12,000 miles per year on our car. At 10 miles per gallon that is 1200 gallons of gasoline over 365 days or about 3.3 gallons per day. For an average household of four we need 13.2 gallons of gasoline per day if all four individuals travel the average distance. Butanol can act as a direct replacement for gasoline but butanol is not as efficient as gasoline and releases about 90% energy equivalent of gasoline. If the household demand is 13.2 gallons per day of gasoline then the equivalent demand for butanol is 15 gallons per day per average household of four in the US.

We have, naturally, used the US (~300 million) as the model in the above rationale. What about Europe or the 27 countries that make up the European Union (~500 million)? Do you think EU households may travel as much by private transportation and demand 15 gallons of butanol per day? The distance between London and Paris (in two countries) is just above 200 miles, each way.

Let us re-visit the issue of “small” with respect to the volume of butanol which may be currently produced by photosynthetic (sunlight or solar energy) micro-organisms. Critics may point out, justifiably, that we have not, thus far, addressed the electricity demands of the US household to run washing machines, dishwashers, refrigerators, electric stoves, lights, heating and cooling. Estimates reveal that an average US household of four uses about 150 kWh (kilo Watt-hours) of electricity per day (about five times the global average but only one third if compared to Iceland). Converting the numbers in terms of butanol reveals that we need another 5 gallons of butanol per day per US household. If combined, an average US household may be *energy self-sufficient* if the household manufactured about 20 gallons of butanol per day and converted 25% for electricity while using the rest for transport.

Hence, the question of “small” volume must explore butanol manufacturing capabilities at hand (micro-scale manufacturing) and its relationship to daily demand of 20 gallons per US household.

With the butanol bio-energy manufacturing technology we have at hand or improvements which are imminent, we must explore whether “small” is 2 gallons or 20 gallons per day? If the answer is 20 gallons per day (per unit or per machine) then we have the global energy problem solved. But, let us exercise cautious optimism and assume the hypothetical manufacturing volume limited at this time to only 2 gallons per day per unit. What good can come from 2 gallons of butanol per day?

To create new markets for business growth one must move beyond US and EU (market of ~800 million) to China and India (market of ~2500 million) as well as South-East Asia (market of ~840 million). For average households in China, India and Asia (including Pakistan, Bangladesh) the average daily energy consumption may be well below 5 kWh (as little as 0.2 kWh per person per day in Bangladesh). Therefore, energy from the “small volume” of 2 gallons of butanol per day per unit may be sufficient to power 10 households for a market of 3.5 billion or about half of the world’s current 7+ billion population.

This is the real global value of a small volume butanol manufacturing unit or machine fashioned as a domestic appliance producing only 2 gallons of butanol per day. Providing renewable energy relief to half of the world's population may work wonders for economic growth and global peace.

This is the concept of ***distributed*** energy manufacturing which whittles away the impediments from lack of scalability. By distributing the ability to produce butanol to households, the system benefits from micro-scale energy autonomy. When aggregated by function, the micro-scale segues to macro-scale energy availability and helps pave the road to global sustainable energy security.

Hence, distributed micro-scale energy autonomy may be analogous to distributed computing which was achieved when the functions of the 30 ton ENIAC were delivered in every pocket by the iPod. The scope of the imminent geo-political tsunami from butanol driven micro-scale energy autonomy may send shudders through the OPEC cartel and the global petroleum oligopoly. Yet, the energy Genie still remains locked out of its ability to change the world. Why?

Critics will point out that the dependence on solar energy for the photo-production of butanol makes it less attractive to industrial nations in the Northern Hemisphere (US, EU) where the ability of every household to access sunlight is limited. Fortunately, there is an elegant alternative which leads us to a win-win scenario. It promises to be an economic revitalizer for the tropics and create new lines of commodities business for the energy supply chain. In addition to butanol, the solution is to produce the six carbon molecule, glucose, as the secreted end product from micro-organisms in countries with abundance of solar energy, eg, Africa, Asia, Central America and the Middle East.

Several methods are available to produce butanol ***without the need for sun light*** as long as the microbes are fed with a source of glucose as the primary energy (glucose replaces the need for solar energy). Corn, sugar cane and other food sources as well as biomass are vegetation-dependent raw material source for glucose currently used for production of cellulosic ethanol. Vegetation-dependence has caused much consternation and ignited the food versus fuel debate as the price of food continues to increase since food sources are used for manufacturing of high value molecules.

Biotechnology similar to photo-production of butanol can also produce glucose in bacteria in the presence of sun light. Thus, nations with abundant sun light may manufacture butanol for domestic use and glucose as a cash crop for sale as an energy commodity. Isn't it a win-win scenario?

Industrial nations or corporations may lease high insolation real estate (regions with abundant sun light) and set up glucose plants in the Sahara Desert or Bihar (India) or Indonesia. Entrepreneurs in Singapore leased islands from Indonesia to set up chemical plants. Similarly, innovative groups in South America may use the Atacama Desert or North Americans can use parts of Arizona, New Mexico, Nevada and California as glucose factories. Packaging and transporting solid or semi-solid glucose is a less expensive logistics operation compared to liquid fuel. Stockpiles of glucose with its long shelf-life may offer much needed energy security and may end the cryptic reason for oil wars.

It is, therefore, a conundrum as to why such an important and transformational change which is poised to revolutionize the future of the global economy appears to be a light shining in obscurity. To understand this quagmire, albeit in part, it is important to recall that this proposal presents the need for an unit or machine or domestic appliance which will produce the butanol. The mechanical “product” to produce the liquid butanol may be analogous to a bread machine. But the process is continuous since the photosynthetic micro-organisms will secrete the butanol in the medium from which it must be separated and extracted. This “product” will be sold for domestic manufacture of butanol. This machine may be limited in its liquid fuel production volume, at this time. We have chosen the hypothetical volume of production from this machine to be 2 gallons of butanol per day.

US investors, keen on maximizing return on investment, may demand a “bigger” machine to scale the production to improve margins and profit. But, biological processes are not always easy to scale because the chemical reactions that constitute the biological processes are influenced by an array of factors which may be increasingly difficult to optimize with increasing volume. The production cost of a domestic appliance capable of manufacturing 2 gallons of butanol per day may pose problems. Investors may view the open source micro-scale manufacturing approach to provide global public goods to be an anathema or oxymoronic to the concepts of investment, equity and returns.

Investors may also agonizing over cost of scalability (per kilo Watt hour). Progress of technology leads to price reduction. Reviewing the history of random access memory (RAM) one finds that 1MB RAM in 1957 cost US\$411 million. In 2010 it declined to 1 cent per 1MB RAM. Similarly, the first VCR manufactured, by AMPEX in 1956, cost \$50,000.00 each. VCR production ceased in 2006.

Convergence of ideas, tools and technologies necessary to create this product to manufacture butanol or glucose in every household will also advance and become simpler but it is not simple.

Biological processes may not scale in a linear manner. For example, if you add two oranges to a juice machine you can expect a certain volume of orange juice. Let us assume you can obtain one cup of juice from two oranges. If you add 20 oranges to the machine you expect 10 cups of juice. The same linear relationship may not hold in the attempt to increase butanol photo-production in bio-reactors for scalability from 2 to 20 to 200 gallons per unit per day.

Photo biosynthesis suffers from other drawbacks which include the availability of average hours of direct normal irradiance (DNI). Of course, indirect sun light, diffuse, reflected and refracted light as well as high-angle-of-incidence solar irradiation may be useful but not all of the energy spectrum in the sun light can be used. In plants, the photosynthetic pigment chlorophyll works best in the blue (430 nm) and red part of the spectrum (680 nm). Hence, the quality of sun light may be an issue. Because the growth of the microbes require energy from the sun light, it follows that increasing the volume of medium may be counter-productive because penetration of sun light decreases with increasing volume (think about sun light penetration in the sea or ocean). But, the optimizations necessary are far from insurmountable because commercial photo bio-reactors are widely in use.

In the end game, the cost of this unit or domestic appliance will determine the rate of its adoption. The demand for this appliance may break records if a small volume unit producing 2 gallons of butanol per day may cost US \$500 or less. Let us use the numbers from India and China where retail gas prices are US \$5 and US \$4 per gallon, respectively. Let us assume that this is also applicable to SE Asia, in general. In this scenario, the use of one US \$500 domestic butanol unit may serve the domestic electricity demand for 10 households. Investing US \$50 per household is equivalent to about 10 gallons of gas in India or domestic electricity for 50 days assuming 0.2 gallons per day per household. Even if the product has a life cycle of one year, the investment to buy a new unit every 12 months may be well worth it because the return on investment may take less than 2 months.

Therefore, in the market of 3.5 billion, assume 500 million households. The demand for this product in Asia alone may exceed 50 million units (one unit for every 10 households). Factor in increasing demand, growth of other electricity consuming appliances and electric vehicles. In a decade, every household may need their own unit. Hence, the small volume 2 gallon per day micro-scale butanol unit is a renewable energy manufacturing business with a market for about 50 million units (Asia alone) if we assume shared unit usage or if only 10% of the households decide to own an unit.

Manufacturing the units will create new jobs for the local and global economy. In addition, there will be a need for business services (maintenance of microbial replenishment) which will continue to generate micro-revenue for the entire lifecycle of the product.

In the US and EU the parameters of the US \$500 unit producing 2 gallons of butanol per day will be influenced by sun light. The unit may produce butanol directly (photo bio-reactor) or indirectly using glucose as the starting material but without need for sun light (bio-reactor version). US and EU consumers may view this as a US \$5,000 monstrosity (and maintenance at US \$1 per unit per day) because an array of 10 units are required for the daily demand of 20 gallons of butanol.

Return on US \$5,000 investment at an average gas price of US \$4 per gallon is 85 days. ROI in the UK may be under one month or just above a month in EU. In general, gas prices in EU are twice or thrice compared to US. If only 10% of the households in US and EU aspire for energy self-sufficiency then estimated sales may be 200 million micro-scale units if each array contains 10 units to meet the demand for 20 million households from a total of 200 million households in the US and EU.

The revolutionary advantages of distributed micro-scale butanol manufacturing may be rendered obsolete if advances from other walks of science can deliver renewable energy in a manner that is cheaper and promises rapid rates of adoption or perform better due to economies of scale. No matter how optimistic the arguments may be in this article, there is nothing absolute about any particular approach or solution. Most have caveats, known unknowns and unknown unknowns.

Renewable energy and liquid fuel from micro-scale butanol manufacturing is promising and may lift many boats but it is not a panacea. It may well serve domestic users in emerging economies and in the developing world. It may remove the threat of environmental embargo on nations that are aggressive in their development and must have the freedom to build infrastructure. It may also help small and medium businesses to escape carbon taxation and gain carbon credits. But large offices, industries, factories, organizations, government operations, emergency services may still require conventional energy from the electricity grid.

Nuclear energy from fission and fusion may be the long term solution if their safety features improve and provide the public with a greater degree of confidence. The ability to use hydrogen as fuel, especially for transportation, may be a remarkable step forward if the infrastructure grows. Advances from scientists like Nate Lewis and Daniel Nocera may also fuel disruptive innovation.

**TEMPORARY CONCLUSION • Energy Self-Sufficiency as a Driver for the Energy Agnostic Global Economy • eAGE**

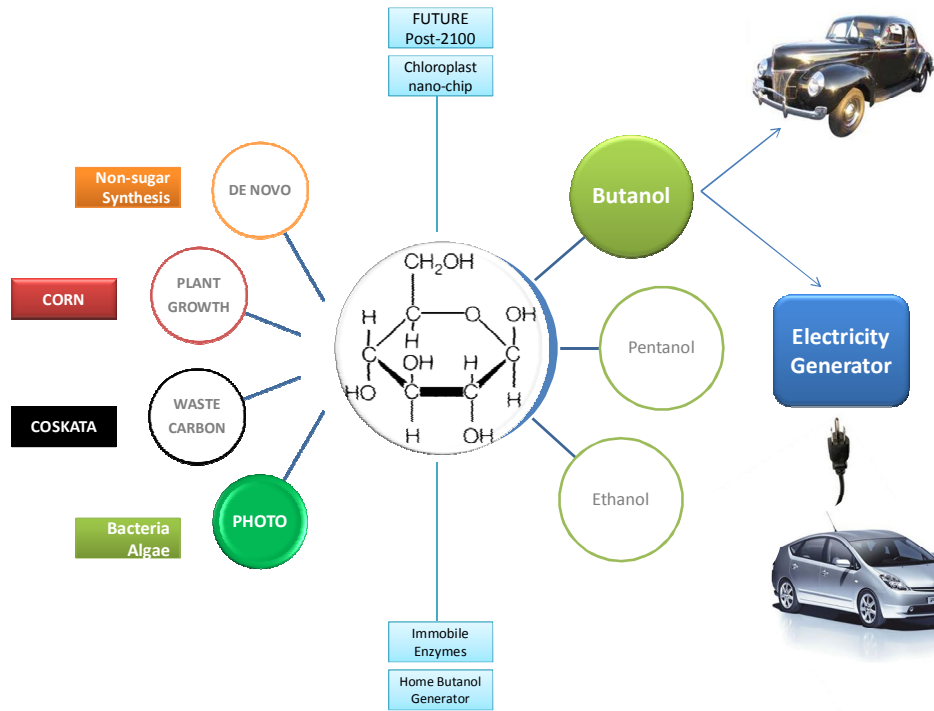
Renewable butanol is certainly not a replacement but a parallel liquid fuel from non-fossil sources which does not add to the global GHG emissions due to its carbon neutrality. If users produce more energy, it may lead to an energy cottage industry where users sell or auction their excess capacity to the electricity grid. We are assuming that the smart grid will be operational and enabled for bi-directional flow of electricity. It will also require cloud based business services offering dynamic pricing incentives from grid operators to manage demand versus capacity in a manner that also makes it lucrative for households or cooperatives to intelligently transact with utility vendors.

Butanol, which can replace gasoline, can be produced by micro-organisms but suffers from low yield in photo bio-reactors which use sun light as the primary source of energy. The debate rages on whether the method is scalable for mass production. ***The suggestion here is to transform this handicap into an advantage.*** Small scale or micro-scale energy production serves the distributed concept of energy self-sufficiency. If every household or unit product produced some energy or enough, then, scalability may not be an impediment to energy self-sufficiency. To supply utility providers with high volume demand one can imagine the potential for growth of ***butanol farms*** in high insolation zones on arid inhospitable land in a manner akin to the growth of ***server farms***.

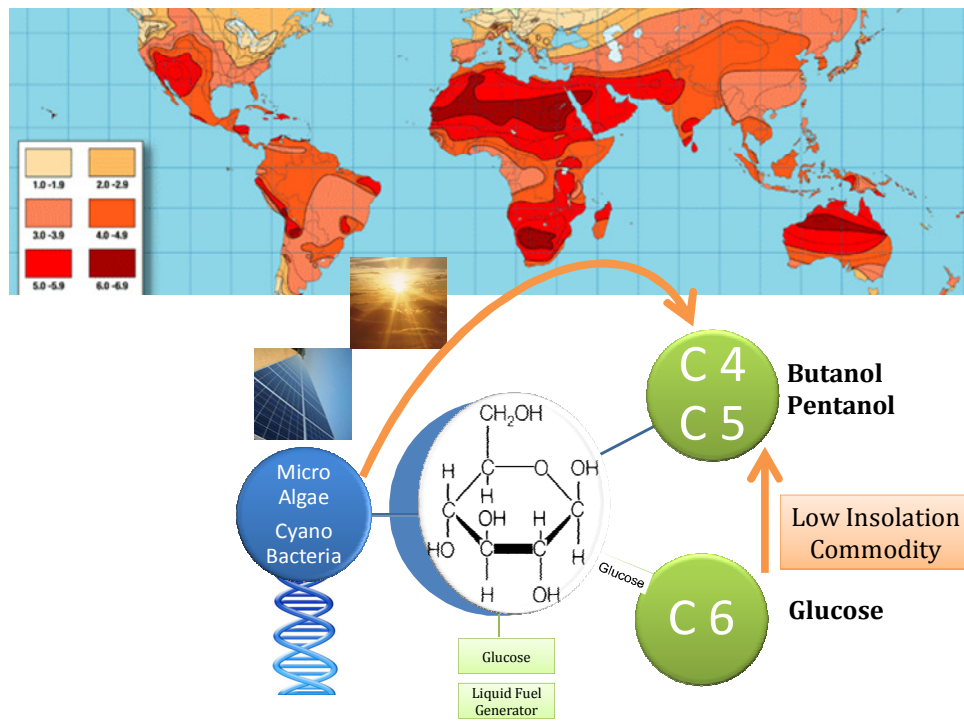
Liquid fuel driven internal combustion engines may not become extinct even if global production of electric vehicles and hybrid cars were to accelerate. In a parallel vein, renewable energy from wind turbines may slow down, too, not because winds will dwindle but because in a decade or less, the world may exhaust current sources of rare earth metals necessary to make the special magnets.

Hence, bio-energy tools are at hand to produce micro-scale bio-butanol or related products. It may liberate the economies of the developing world and improve the lives of about 80% of the global population whose ability to earn a basic living is eviscerated by and is at the mercy of fuel prices. Bio-butanol does not deplete food sources because its manufacturing uses renewable solar energy and carbon dioxide from our atmosphere. Therefore, it is carbon neutral and does not add to green house gas (GHG) emissions and may prevent further deterioration or may even help improve the quality of the global environment.





Salvation from the Food vs Fuel Debate & Energy Security from Photosynthetic Glucose – The New Petroleum



Solar energy is necessary but not mandatory. Glucose is an alternative commodity in the energy supply chain.