# Hydrogen Engines – Efficient & Powerful with HyOx™ Hydrogen & Oxygen Engine Technology

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December 5, 2011

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### Earth – 2/3 Water

Our bodies are nearly 2/3 water; similarly, the Earth's Surface is nearly 2/3 water. This is while water is required for all life. As a major component of and supporting all life, our atmosphere manages the water cycle with evaporation, clouds and precipitation. As a part of the water cycle, our rivers, lakes and oceans move water across the Earth's Surface. All of this water and movement of water in the air and on the surface are important to our climate, our health and our world. Unfortunately, over the past century, humanity unknowingly created a support system which affects our water, our air and thereby the water cycle of our world. These affects are negatively affecting Earths' ability to support life.

Today, we know of past mistakes. We have the opportunity to improve upon our support system before irreparable harm is done to our home.

ClearValue's Vision has been that pure water and clean energy will become more important to humanity than oil. It is ClearValue's Mission to bring forth innovations to improve our water, our air, our health and our world. It is ClearValue's direction to bring forth innovations in the context of intellectual property so that capitalism will have an interest to implement ClearValue's innovations, thereby driving change to improve our water, our air, our health and our world. As profit is a great motivator, capitalism can be a great motivator to make improvements for all of humanity.

Earth's atmosphere, compared to the size of our planet, is comparatively as thin as the skin of an apple. This atmosphere, again, supports all life.

### A Most Significant Human Challenge

While humanity has been rather creative in the use of fossil fuels, it is without question that excessive fossil fuel use leads to environmental consequences which may be of biblical proportions. As Earth warms, due to $CO_2$, $NO_2$ and $CH_4$ in Earth's atmosphere, Earth adapts. Adaptation is causing changes in weather patterns, including record hurricane and tornado events, along with flooding and drought, depending upon location. Drought causes wildfires, while flooding destroys personal property. These events are seen with only a 1 °C increase in the average Earth Surface Temperature. Computer models predict a 3 to 5 °C increase in the Earth's Average Surface Temperature within the next 50 - 100 years, which will melt glaciers and polar ice caps. Such a melting and thereby dilution of the oceans may stop the oceans' warm water conveyance systems. Should this come to pass, we should remember how cold it is just outside our atmosphere, Space, where the temperature is only 100 K, e.g. – 260 °F. We should also realize that Space has an immense capability to adsorb heat; therefore, it is not hard to imagine that if the northern and southern portions of Earth are not heated via tropical warm waters, as today, that those northern and southern portions of Earth would cover with ice. Therefore, while human activity warms Earth, it is entirely possible that Humanity may cause the next ice age. And, should the ice age scenario not come to pass, that same melting of the glaciers and polar ice caps would raise Earth's oceans over 200 feet, thereby placing many coastal cities under water. The worst case scenario is a rising of the oceans followed by an ice age; as, humanity would have left the oceans for higher altitudes. Once located in the higher altitudes, such would be horrific.

### HyOx™ Technology

HyOx™ triples performance efficiency while capable of 5-10 times available power per displacement. HyOx™ has no carbon, nitrogen or sulfur footprint. This is because $H_2$ can be easily produced via electrolysis of water with Zero Carbon™ Energy, as well as wind, water, nuclear and photovoltaic sources.

The combustion of fossil fuels is the combustion of HYDRO-carbons. HyOx™ is the combustion of HYDRO-gen. The processes are chemically very similar; while, $H_2$ is very light compared to hydrocarbons, e.g. gasoline is 112 pound/mole, natural gas is 16 pound/mole and $H_2$ is only 2 pound/mole. On a molar basis, combustion and energy output from each fuel source:

$C_nH_{2n+2} + (2n+1)O_2 \rightarrow nCO_2 + (n+1)H_2O$ + energy
gasoline + 12.5 $O_2$ → 8$CO_2$ + 9$H_2O$ + 1,300 kcal
nat. gas ($CH_4$) + 2$O_2$ → $CO_2$ + 2$H_2O$ + 213 kcal

**Combustion of HYDRO-carbons**

$2H_2 + O_2 \rightarrow 2H_2O$ + energy
$2H_2 + O_2 \rightarrow 2H_2O$ + 137 kcal
$H_2$ has 3X the energy per pound

**Combustion of HYDRO-gen**

(Note: 112 lbs of gasoline converts to 1,300 kcal while 4 pounds of $H_2$ convert to 137 kcal. In comparison, then, 112 lbs of gasoline results in 1,300/112 = 11.6 kcal per pound while 4 pounds of $H_2$ (2 X 2) results in 137 kcal ⊳ 34.2 kcal per pound. And, 34.2/11.6 = 3.0.)

In all, $O_2$ is the oxidant and $H_2O$ is a combustion product. In hydrocarbon combustion, though, carbon forms $CO_2$, a greenhouse gas. (During incomplete combustion, carbon monoxide (CO), a poisonous gas is formed.) To complicate matters, also, hydrocarbon combustion is performed with air instead of $O_2$. While air is 20% $O_2$, air is also 80% Nitrogen ($N_2$). A portion of the $N_2$ then combusts endothermically (adsorbing energy) to produce oxides of nitrogen, $NO_x$ (NO, $NO_2$ and $NO_3$); while, $NO_x$ forms ozone ($O_3$).

### Comparison of HyOx™ to Hydrocarbon ICE

**Efficiency -** In terms of efficiency, today's internal combustion engine (ICE) is only 15-20% (combustion energy to wheel energy), power generating turbines 30-35% and jet engines 25-30% efficient. In other words, out of every: $1.00 of fuel placed in an automobile, truck or bus, $0.85 is lost; $1.00 spent on your electric bill, $0.70 is lost; and $1.00 spent on jet fuel $0.75 is lost. Just as it costs money to heat your home, that hot engine block, cooling radiator and exhaust are all lost energy.

From the laws of thermodynamics:

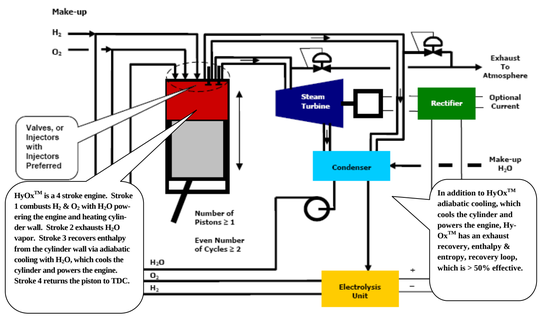
**Combustion Energy = Work + Enthalpy Losses + Entropy Losses + Friction and Combustion Losses**

Within hydrocarbon ICE, for every $1.00 spent on fuel, most unfortunately:

**$1.00 = $0.15 + $0.35 (Cooling) + $0.35 (Exhaust) + $0.15**

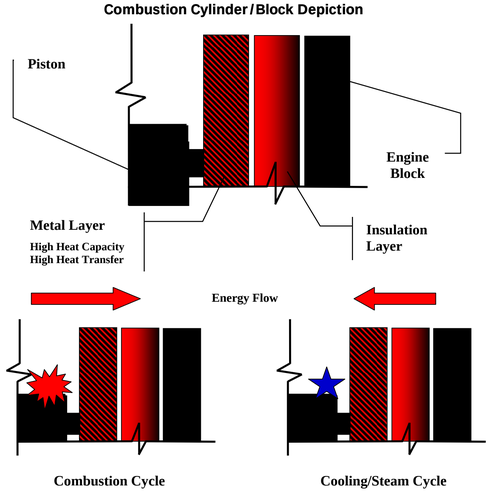
In thermodynamics, cooling losses are termed enthalpy (heat) losses and exhaust losses are termed enthalpy (heat) and entropy (pressure) losses. Therefore, the radiator has enthalpy losses; while, the exhaust has both enthalpy and entropy losses.

### Energy Recovery Loop Depiction




Further improvements may be made via an innovative adiabatic cooling/steam cycle, wherein engine operation has an additional cycle between two combustion cycles (a cycle is one revolution of the crankshaft, e.g. one revolution from Top Dead Center (TDC) to TDC). (This same improvement can be made in a turbine at a time/location after combustion.) During this new cooling/steam cycle, combustion heat energy previously absorbed into the combustion chamber is reclaimed as work. Low pressure steam is injected into the combustion chamber; and, heat energy is turned into steam energy (pressure) during cooling.

### Combustion Cylinder / Block Depiction




Computer models demonstrate this cooling/steam cycle to be rather efficient in work and efficacious in displacement. One such model:

| Moles of $H_2O$ | | 0.8 | 0.7 | 0.6 | 0.5 | 0.4 | 0.3 | 0.2 | 0.1 |
|---|---|---|---|---|---|---|---|---|---|
| Initial Temp | K | 773 | 773 | 773 | 773 | 773 | 773 | 773 | 773 |
| Initial volume | L | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| Final volume | L | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| Initial pressure | atm | 725.3 | 634.6 | 544.0 | 453.3 | 362.6 | 272.0 | 181.3 | 90.7 |
| Work | L-atm | 81.2 | 71.1 | 60.9 | 50.8 | 40.6 | 30.5 | 20.3 | 10.2 |
| Heat | cal | 10569.6 | 9248.4 | 7927.2 | 6606.0 | 5284.8 | 3963.6 | 2642.4 | 1321.2 |
| | L-atm | 435.0 | 380.6 | 326.2 | 271.9 | 217.5 | 163.1 | 108.7 | 54.4 |
| Delta T | K | 2113.9 | 1849.7 | 1585.4 | 1321.2 | 1057.0 | 792.7 | 528.5 | 264.2 |
| Final pressure | atm | 20.31 | 17.77 | 15.23 | 12.69 | 10.16 | 7.62 | 5.08 | 2.54 |
| Final temp | K | 278 | 278 | 278 | 278 | 278 | 278 | 278 | 278 |

Now, with HyOx™, every $1.00 spent on fuel becomes:

**$1.00 = $0.55 + $0.15 (Cooling) + $0.15 (Exhaust) + $0.15**

**Powerful –** HyOx™ has the capability of producing 2 to 10 times the power of hydrocarbon ICE per displacement:

The HyOx™ oxidizer is $O_2$, not air. Air is 80% $N_2$, while $N_2$ produces $NO_x$. Further, $NO_x$ formation takes power away from combustion as $NO_x$ formation adsorbs energy. Therefore, HyOx™ operates with a 4 to 5 fold increase in available $O_2$ while limiting $NO_x$ formation.

HyOx™ has the capability to add $H_2$ fuel and pure $O_2$ oxidizer to the combustion chamber under pressure. Therefore, HyOx™ has the capability to add $H_2$ and $O_2$ to the combustion chamber in amounts here-to-fore unavailable with hydrocarbon fuel and air combustion systems.

HyOx™, incorporating the Haase Cycle, a variant of the traditional Otto Cycle, furthers the power envelop, as presented in PCT/US2006/048057.

HyOx™ Computer models demonstrate that the above advantages provide significant power improvement.

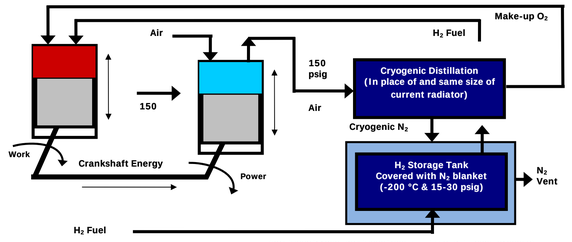
## HyOx™ Computer Model – High Torque

(PCT/US03/11250, PCT/US06/48057 and U.S. Pub. 2005 0198958)

| C.R. = | 10 | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D.S. = | 0.069 | Liter | | | | | | | | | | | | | | | |
| Vo = | 0.69 | Liter | | | | | | | | | | | | | | | |
| To = | 300 | K | | | | | | | | | | | | | | | |
| | | | | Compression | | | | Combustion | | | | Expansion | | Output | | | |
| Ps | n (H2O) | n (H2) | Po | gamma | P1 | T1 | Q | delta T | T2 | P2 | P3 | T3 | W 0-->1 | W 2-->3 | net work | net work | HP |
| atm | moles | moles | atm | | atm | K | kJ | K | K | atm | atm | K | l-atm | l-atm | l-atm | kJ | |
| 1 | 0.0000 | 0.06 | 3.21 | 1.40 | 80.7 | 754 | 17.22 | 7757 | 8510 | 607.6 | 24.2 | 3388 | -8.38 | 63.08 | 54.70 | 5.541 | **1114** |
| 1 | 0.0000 | 0.07 | 3.75 | 1.40 | 94.1 | 754 | 20.09 | 7757 | 8510 | 708.8 | 28.2 | 3388 | -9.77 | 73.59 | 63.82 | 6.465 | **1300** |
| 1 | 0.0000 | 0.08 | 4.28 | 1.40 | 107.6 | 754 | 22.96 | 7757 | 8510 | 810.1 | 32.3 | 3388 | -11.17 | 84.11 | 72.94 | 7.389 | **1486** |
| 1 | 0.0000 | 0.1 | 5.35 | 1.40 | 134.5 | 754 | 28.70 | 7757 | 8510 | 1012.6 | 40.3 | 3388 | -13.96 | 105.14 | 91.17 | 9.236 | **1857** |
| 2 | 0.0100 | 0.06 | 3.57 | 1.39 | 88.0 | 740 | 17.22 | 6649 | 7388 | 615.4 | 24.5 | 2941 | -9.31 | 63.89 | 54.58 | 5.529 | **1112** |
| 2 | 0.0100 | 0.07 | 4.11 | 1.39 | 101.5 | 742 | 20.09 | 6787 | 7529 | 716.7 | 28.5 | 2997 | -10.71 | 74.41 | 63.70 | 6.453 | **1298** |
| 2 | 0.0100 | 0.08 | 4.64 | 1.39 | 114.9 | 743 | 22.96 | 6895 | 7638 | 817.9 | 32.6 | 3041 | -12.10 | 84.92 | 72.82 | 7.377 | **1483** |
| 2 | 0.0100 | 0.1 | 5.71 | 1.40 | 141.8 | 745 | 28.70 | 7052 | 7797 | 1020.4 | 40.6 | 3104 | -14.90 | 105.95 | 91.05 | 9.224 | **1855** |
| 3 | 0.0200 | 0.06 | 3.93 | 1.39 | 95.4 | 729 | 17.22 | 5818 | 6546 | 623.1 | 24.8 | 2606 | -10.24 | 64.70 | 54.46 | 5.517 | **1109** |
| 3 | 0.0200 | 0.07 | 4.46 | 1.39 | 108.8 | 732 | 20.09 | 6033 | 6765 | 724.4 | 28.8 | 2693 | -11.64 | 75.21 | 63.58 | 6.440 | **1295** |
| 3 | 0.0200 | 0.08 | 5.00 | 1.39 | 122.3 | 734 | 22.96 | 6205 | 6939 | 825.7 | 32.9 | 2763 | -13.03 | 85.73 | 72.70 | 7.364 | **1481** |
| 3 | 0.0200 | 0.1 | 6.07 | 1.39 | 149.2 | 737 | 28.70 | 6464 | 7201 | 1028.2 | 40.9 | 2867 | -15.83 | 106.76 | 90.93 | 9.211 | **1852** |

**$O_2$ and Cryogenic $N_2$ –** As a safety measure, HyOx™ stores little to no $O_2$. HyOx™ makes its own $O_2$ as needed with cryogenic air distillation, which is the same process used for decades in the chemical industry. Further, this cryogenic distillation is "free" compared to hydrocarbon ICE. This is because HyOx™ requires no engine backpressure to atomize fuel; backpressure is negative energy, taking away power. $H_2$ is gaseous; therefore, HyOx™ has no need to atomize fuel. Hydrocarbon engines have about 150 psig of backpressure to atomize fuel; while, only 150 psig air is required for cryogenic air distillation. Therefore, HyOx™ obtains a significant power increase and eliminates $NO_x$ formation by simply moving a negative energy, backpressure, of 150 psig from the combustion chamber to an air compressor.

### Air Separation / Fuel Storage Depiction




(PCT/US03/11250, PCT/US06/48057 and U.S. Pub. 2005.0198958)

Another benefit of air distillation is cryogenic $N_2$, which is a good heat sink (absorbs heat). Cryogenic $N_2$ provides HyOx™ an ability to store $H_2$ at cryogenic temperatures, about -350 °F. At -120 °F and below, $H_2$ is easily chilled or liquefied, thereby increasing fuel storage density while storing $H_2$ at reasonable and safe pressures, e.g. 15 to 30 psig. This is a significant safety improvement over fuel cell applications at 1000's of psig.

The same thermodynamics which make HyOx™ a success in ICE, presents combustion solutions in power and jet propulsion applications. Attached is a diagram of a turbine power application along with a description of the minimal changes necessary within a jet engine to provide for HyOx™ jet propulsion.

### Comparison of HyOx™ to Fuel Cells and Electric Vehicles

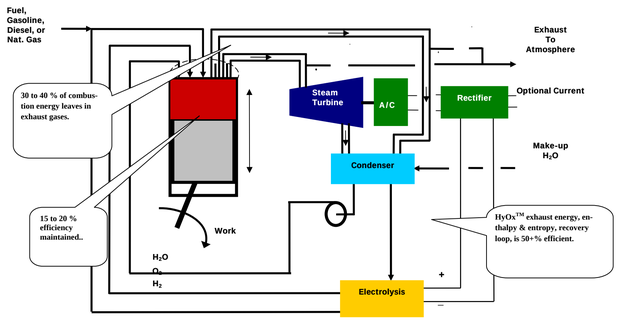
First and foremost, literally billions of research $ have been invested in fuel cells worldwide. With these research $, fuel cells remain: 1) requiring platinum, wherein there is not enough platinum in the Earth's Crust for 1 year's automotive production, 2) expensive, wherein there is still no capability to manufacture a fuel cell vehicle at less than $100,000, 3) requiring overhaul, as fuel cells require a complete cleaning every 40,000 – 50,000 miles, 4) with fuel storage challenges, as $H_2$ is stored at 1,000's of psig, which is a safety issue, and 5) having power limitations, while the consumer has come to appreciate the power and feel of ICE.

In addition, literally decades and billions of research $ have been invested in batteries. Electric vehicles are energy storage limited, thereby distance and/or power limited.

### HyOx™ Interim / Assist

While the before mentioned HyOx™ presentation is the preferred means for HyOx™, at this time humanity has not developed an infrastructure for $H_2$ or electric vehicles. In any event, should a $H_2$ infrastructure be available today, there exist in excess of 600 million vehicles in the world today which operate with gasoline, diesel or propane. HyOx™ Interim is utilization of HyOx™ with hydrocarbon fuel. In combination, HyOx™ Interim increases fuel efficiency by near 100%; yes, a doubling of fuel efficiency, which means a reduction of 50% in fuel and a 50% reduction of $CO_x$ and $NO_x$ emissions.

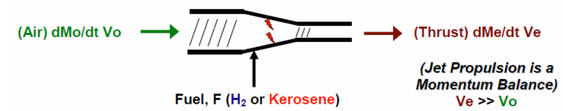
### HyOx™ Assist Depiction




PCT/US03/11250, PCT/US06/48057, U.S. Pubs. 2005. 0198958 & 2009.0194996.

## HyOx™ - Jet Propulsion

(U.S. Pat. Pub. 2005.0198958)




Thrust = dMe/dt Ve – dMo/dt Vo, Let Me = Mo + $M_F$, $M_F$ = mass of fuel.

$F = \int_{to}^{t1} {}_{Vo}\int^{Ve} Me - Mo = \int_{to}^{t1} {}_{Vo}\int^{Ve} Mo + M_F - Mo = \int_{to}^{t1} {}_{Vo}\int^{Ve} M_F$

$F_{WCT} = \int_{to}^{t1} {}_{Vo}\int^{Ve} \{M_{H2} + M_{O2} + M_{H2O} + M_{AIR}\}$, for Kerosene $F = \int_{to}^{t1} {}_{Vo}\int^{Ve} \{M_{FK} + M_{AIR}\}$

Is, $F_{WCT} \geq F_K$ ?; ∴ is, $\{M_{H2} + M_{O2} + M_{H2O}\} \geq \{M_K\}$ ?
And, if air is used instead of $O_2$, then is $\{M_{H2} + M_{H2O} + M_{AIR}\} \geq \{M_K + M_{AIR}\}$ ?

$\Delta H_{H2}$ = 51,571 BTU/lb., $\Delta H_K$ = 19,314 BTU/lb.,

$H_2 + ½\ O_2 \rightarrow H_2O$ lb.+ 8 lb. → 9 lb.

$C_{14}H_{30} + 43/2\ O_2 \rightarrow 14\ CO_2 + 15\ H_2O$ 1 lb. + 3.47 lb. → 3.11 lb. + 1.36 lb.

$Cp_K$ = 0.6 BTU °F/lb., $Cp_{H2O}$ ≈ 0.46 BTU °F/lb., $Cp_{H2}$ = 3.45 BTU °F/lb., $Cp_{AIR}$ = 0.46 BTU °F/lb., $\Delta H_{V,H2O}$ = 974 BTU/lb., $\Delta H_{F,H2O}$ = 144 BTU/lb., Kerosene(K) a liquid, $H_2$ vaporizes @ STP

**ΔH Combustion = Σ ΔH's**

$\Delta H_K = Cp_K$ (lb. K)(1000) + $Cp_{AIR}$ (3.47/0.18)(1000) + $Cp_{AIR}$(lb. AIR)(1000)
19,314 = (0.6)(1)(1000) + 0.46(3.47/0.18)(1000) + 0.46(lb. Air)(1000) .

∴ **For Kerosene, 1 lb. K/40.3 lb. air = 41.3 lb. thrust @ 1000°F.**

$\Delta H_{H2}$ = 3.45(1)(1000) + 0.46(8/0.18)(1000) + 0.46(lb. $H_2O$)(1000) + 974(lb. $H_2O$)
51,571 = 3450 + 20,444 + 1434(lb. $H_2O$), $H_2O$ cooling = 19.3 lb., Air = 8/0.18 = 44.4 lb.

∴ **lb. $H_2$/44.4 lb. air/19.3 lb. $H_2O$ = 64.7 lb. thrust. (Requires 10% air increase @ 1000°F).**

∴ **$H_2$ w/air cooling, 0.37 lb. $H_2$/39.22 lb. Air = 39.6 lb. Thrust**

∴ **Lb. thrust/lb. fuel: $H_2$/Air = 39.6; Kerosene/Air = 41.3; $H_2/H_2O$ = 3.18**

∴ ***Previous $H_2$ issues now obvious; $H_2$ w/air simply requires more air.***

∴ **$H_2$/air Engines Require Increased Air Compression to Balance Thermodynamics, e.g. about 160% more air.**

∴ **Liquid $O_2$ and $H_2O$ supplement combustion at high altitudes, and**

∴ **$H_2O$ & $H_2O$/Air JtC Can Cool Exhaust Reducing Heat Trail.**

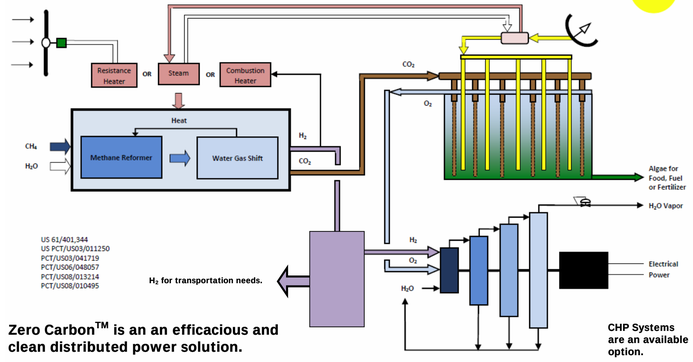
**Zero Carbon™ –** comprises two previous ClearValue innovations, CONOX™ and HyOx™. Zero Carbon™ Power is an innovative and proprietary means to produce clean electrical power from a liquid or gas hydrocarbon. Zero Carbon™ Power provides electrical power at 60+% efficiency, hydrocarbon to electron, while, producing no $CO_2$, $NO_x$ or $SO_x$. Zero Carbon™ Power units are sized from 1 kW to 500 MW. While the larger units are more efficient than small, Zero Carbon™ is efficient and scalable. Zero Carbon™ units are capable of producing electrical power at $0.04/kWh, depending on fuel price. Zero Carbon™ units are capable to produce hydrogen at less than $2/pound, depending on fuel price.

**CONOX™ Technology –** Bacteria are Nature's (God's) little housekeepers. Bacteria provide that clean lake, that beautiful stream and that picturesque field. Algae are Nature's (God's) little terra-formers. Over time, algae developed the Earth's Atmosphere. Algae grow hundreds of times faster than any other plant. Algae convert every pound of $CO_2$ to ½ pound of algae and ¾ pound of oxygen.

CONOX™ uses sunlight, $CO_2$, nutrients (ammonia/phosphate) and water to produce marketable products, including hydrocarbon fuels. While the $CO_2$ can be obtained from any source, a point source is preferred. CONOX™ incorporates innovative means of photon collection and photo-bio-reactor (PBR) design while incorporating established bio-mass handling techniques, as known in the water treatment industries. CONOX™ concentrates algae into a 3-dimenional PBR (3dPBR), thereby improving upon 2-dimentional PBR means and significantly reducing required footprint. CONOX™ further collects sunlight, transferring to and filtering sunlight for the photo-bio-reactor. Within the PBR, optimal algal growth is obtained by managing: photon concentration, pH, temperature, $CO_2$, nutrients, algal strain and contaminants. 2-dimensional systems do not have these capabilities.

### Zero Carbon™ Energy Depiction

**PCT/US2011/001415**




**Zero Carbon™ is an an efficacious and clean distributed power solution.**

**CHP Systems are an available option.**

In combination, Zero Carbon™, CONOX™ and HyOx™ provide efficacious and clean energy solutions in both power generation and in transportation.

Natural gas is a plentiful resource; while, there exists enough landfill natural gas, which converted to $H_2$, and used in HyOx™ engines, could power about 1/2 of our transportion needs, regardless of well production.