



## ClearValue<sup>®</sup> Hydrogen Economy

Earth's atmosphere, supports all life and affects all weather; yet, it is as thin and precious as the skin of an apple.

All of Earth's energy is from our Sun. The Earth enjoys annually 3,850,000 Exajoules of solar energy, one hour of which equals annual world energy consumption. The hydrocarbons we enjoy, the natural gas, oil and coal are stored energy from Sunlight of years past.

Robert Burness of the USGS says "We need to reduce emissions by 70% to protect our planet from dramatic climatic change". NASA's Climate Scientist, James Hanson, stated before Congress in June of 2008, "We are at a point of planetary emergency... There are tipping points in the climate system which we are very close to, and if we pass them, the dynamics of the system take over and carry you to very large changes which are out of your control."



Combustion of hydrocarbons creates oxides of carbon, CO<sub>x</sub> (primarily carbon dioxide, CO<sub>2</sub>), which are demonstrated to reflect Sunlight in Earth's Atmosphere, thereby heating Earth's Atmosphere; oxides of nitrogen (NO<sub>x</sub>) that are toxic to all life, while catalyzing formation of ozone, O<sub>3</sub>, which is also toxic to all life; and oxides of sulfur, SO<sub>x</sub>, that create sulfuric acid in the atmosphere, causing acid rain, which affects plants and deforms Earth's Surface.

Even when wanted, change is most difficult. Our economic systems require Value for change; where, Value can be defined as the difference between perceived customer benefits, e.g. price, and produced product cost. The customer needs to be willing to buy, the producer willing to supply and capital willing to invest. If Value is created at the intersection of Supply and Demand, humanity will embrace change.

Therefore, government regulations help, but do not solve. Government subsidies help, but do not solve. Value must be created for change. With Value, markets will change; customers and producers will change.

In 2011, worldwide electricity production was 19,000 billion

kWhr. **Electricity is our largest energy use; we need clean electricity.**

Further, in 2011, there were near 600 million cars, trucks and buses operating worldwide. Transportation is the second largest energy need; and is therefore, the second largest source of CO<sub>x</sub> and NO<sub>x</sub> and SO<sub>x</sub>.

Today, in America, there are about 750 car for every 1,000 person; while in the Far East, there are only 10 car for every 1,000; and while, over 1/3 of Earth's population lives in the Far East. Therefore, regardless of environmental and economic needs, there is simply not enough oil to supply coming transportation needs. It is known that 1/2 of Earth's oil reserves are depleted. Therefore, **a new transportation energy source is needed.**

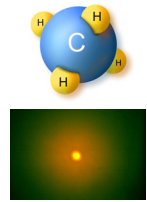
**We need a clean source of energy, for electricity and transportation.**

**Hydrogen** is the most abundant element in the Universe. Combustion of hydrogen only produces water; therefore, an economy based upon hydrogen would be clean. For decades, many have sought technical, business and economic means for the hydrogen economy. **ClearValue<sup>®</sup>** has the answer with **Zero Carbon<sup>™</sup> Energy, CONOX<sup>™</sup> and HyOx<sup>™</sup>.**

**Zero Carbon<sup>™</sup> Energy, CONOX<sup>™</sup> and HyOx<sup>™</sup>** form a **clean Value-added Hydrogen Economy.**



**ClearValue® Zero Carbon™ Energy** is a proprietary means to produce clean electrical power (e-) and hydrogen from a liquid or gas hydrocarbon and/or solar energy. **Zero Carbon™ Energy** provides e- in excess of 60% conversion efficiency, hydrocarbon to electron; and/or, 60% conversion efficiency, photon to electron. YES, that is right, **60% conversion of sunlight.**

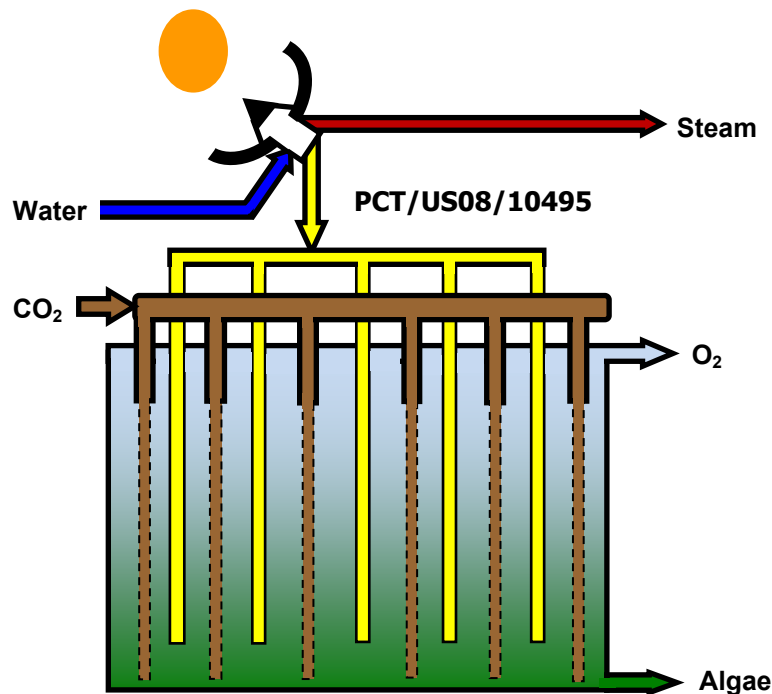


**No one else has even approached such a conversion.** All is while, **Zero Carbon™ Energy** produces no CO<sub>x</sub>, NO<sub>x</sub> or SO<sub>x</sub>. In e- production, **Zero Carbon™ Energy** is a significant efficiency improvement over current e- generation means, which are at best 30% efficient. Therefore, whether oil, natural gas or propane fuel, **Zero Carbon™ Energy** produces twice as much e- per pound of fuel; and, **Zero Carbon™ Energy** produces three times as much e- per Watt of Sunlight.

**Zero Carbon™ Energy** units are planned from 10 kW to 500 MW; each produces e- at < \$0.02 per kWhr and hydrogen (H<sub>2</sub>) at < \$2 per pound at competitive capital cost. Further, **Zero Carbon™ Energy** produces heated water, as a byproduct, for combined heat and power (CHP) operation.

Further still, **Zero Carbon™ Energy** economically produces chilled nitrogen for A/C and refrigeration needs, thereby often eliminating separate A/C and refrigeration compressor equipment.

**Zero Carbon™ Energy** incorporates **ClearValue® CONOX™** algae 3dPBR, thereby converting CO<sub>2</sub> into oxygen (O<sub>2</sub>) and algae, a natural organic product that can be a source of protein, organic fertilizer or bio-fuels.



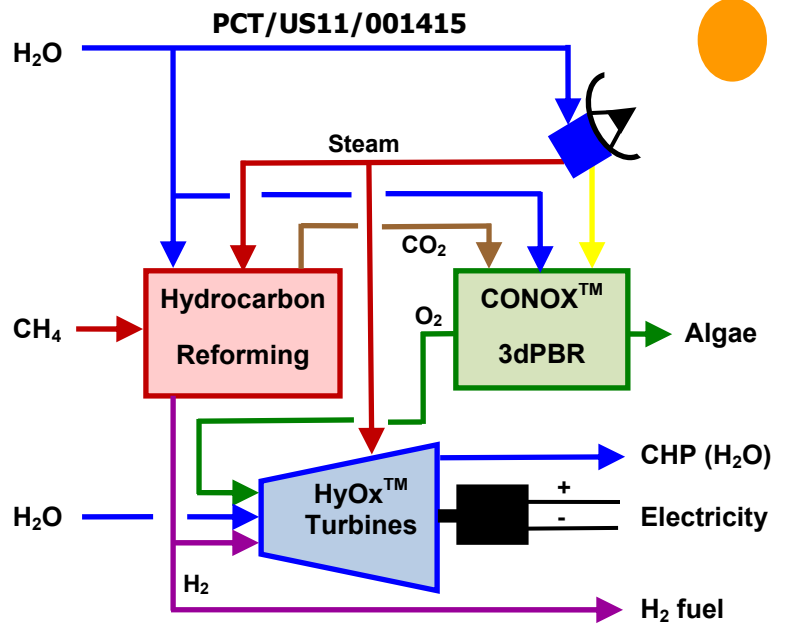
**ClearValue® CONOX™** is a proprietary three-dimensional (3d) photo-bio-reactor (PBR) that converts CO<sub>2</sub> and water (H<sub>2</sub>O) into O<sub>2</sub> and algae. In strong contrast to other two dimensional (2d) algae systems, e.g. ponds, raceways, etc., which can only grow algae on a water surface, the **CONOX™** 3dPBR grows algae throughout a water volume, thereby significantly reducing required land and water. Further, as algae can only use 20 W/m<sup>2</sup> of Sunlight, are inhibited at 25 W/m<sup>2</sup> and incapable of converting UV or infra-red wavelengths, **CONOX™** filters and distributes sunlight for algae consumption, thereby further reducing required land by a factor of 10 - 20. Finally, by having a totally enclosed PBR, **CONOX™** provides control of reactor conditions, e.g. temperature, contamination, pH, algae concentration, etc. And, with light spectrum separation, **CONOX™** is able to utilize infra-red light energy to produce steam. No other PBR design has such capabilities. Finally, algae are an excellent source of protein or of specialty chemical products, having market value.

**Zero Carbon™ Energy** creates e- by incorporating **ClearValue®** proprietary **HyOx™** combustion technology, within a combustion/steam turbine system that is a thermodynamic redesign of hydrocarbon systems in use today. **HyOx™** provides efficient and powerful H<sub>2</sub>/O<sub>2</sub> combustion and steam/energy conversion, being 60 to 70 % efficient to convert H<sub>2</sub>/O<sub>2</sub> combustion energy to e-. This is a significant improvement over natural gas systems in use today, which are only 30 % efficient. **HyOx™** produces no CO<sub>x</sub>, NO<sub>x</sub> or SO<sub>x</sub>, only H<sub>2</sub>O vapor. Therefore, **Zero Carbon™ Energy** obtains over twice the electrical power per cubic foot of natural gas, as compared to systems in use today. In fact, **Zero Carbon™ Energy** obtains 250 kWhr per 1000 cubic feet (Mcf) natural gas; this is a significant improvement over systems in use today that only obtain 100 kWhr per Mcf. 150% additional power, all clean power!

**Zero Carbon™ Energy** is an innovative and proprietary innovation comprising 1) hydrocarbon reforming, 2) **CONOX™** and 3) **HyOx™**. **Zero Carbon™ Energy** is powered by sunlight and a hydrocarbon, preferably natural gas, CH<sub>4</sub>. Electrical power is generated by either infra-red light energy, which is converted into steam, or by **HyOx™** combustion of H<sub>2</sub> and O<sub>2</sub>.



H<sub>2</sub> is obtained by hydrocarbon reforming, a known and practiced means to produce H<sub>2</sub> that also produces CO<sub>2</sub>. The CO<sub>2</sub> produced is transferred to a CONOX™ 3dPBR which converts the CO<sub>2</sub> and H<sub>2</sub>O into O<sub>2</sub> and algae. Algae are valuable as a bio-fuel, protein food source, fertilizer or specialty chemical product. The O<sub>2</sub> from CONOX™ is combined with the H<sub>2</sub> and with H<sub>2</sub>O in a HyOx™ combustion/steam turbine system that turns a generator to produce e-. Hot H<sub>2</sub>O from the HyOx™ steam turbine system can be used in CHP. Excess infra-red light energy is further used to produce steam and thereby e-. Produced H<sub>2</sub> is available for transportation applications. It is important to note that the molar balance of H<sub>2</sub> to O<sub>2</sub> is such that the hydrocarbon reformer produces 2X the requirement for H<sub>2</sub> in the HyOx™ combustion/steam turbine system; therefore, **Zero Carbon™ Energy** is an excellent and efficacious means of distributed e-generation and the production of transportation fuels.



**ClearValue® HyOx™ Engines** are 50 to 70 % efficient, a significant improvement over hydrocarbon, which are only 15 to 30 % efficient. Therefore, a \$4 per pound H<sub>2</sub> retail price equates to an operating fuel savings compared to gasoline at \$4 per gallon.

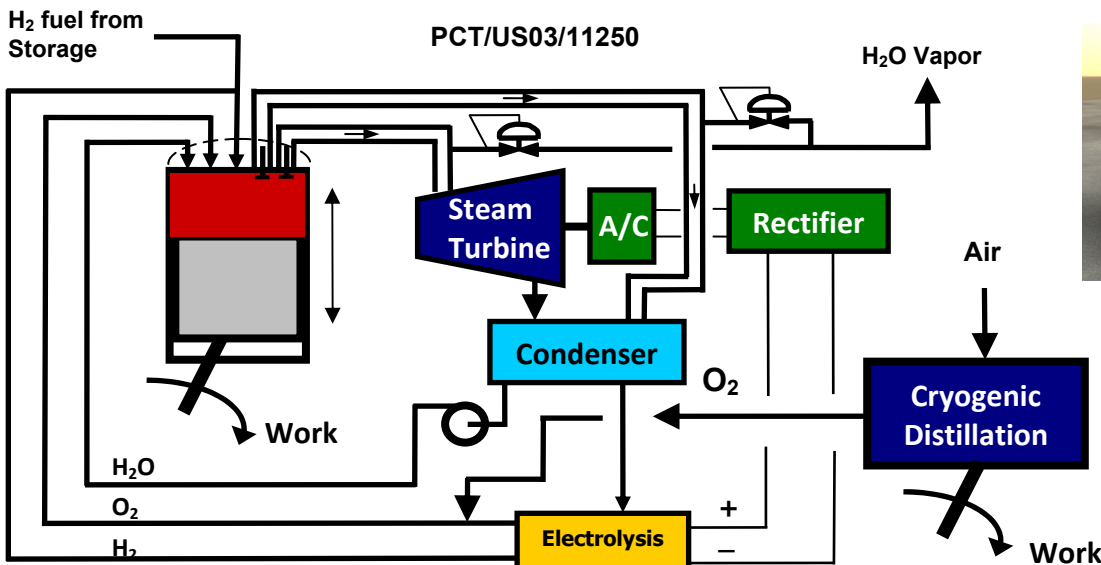
**HyOx™ Engines** are powerful, offering 100 to 300 ft-pound of torque, e.g. 90 to 270 HP, per Liter of displacement. (Today's 4L V-6 → 3200 ft-pound)

**HyOx™ Engines** provide effective energy storage density; as, **HyOx™** stores hydrogen cryogenically with little pressure.

**HyOx™ Engines** last longer; as, there are no carbon deposits to wear engine parts. **HyOx™** engines have a planned 300,000 mile life in automotive and 1,000,000 mile life in trucking applications.

**HyOx™ Engines** require minimal retooling; as, **HyOx™ Engines** are a thermodynamic redesign of the combustion engine, known worldwide; and are therefore, capital cost competitive.

In a full **HyOx™ Engine**, H<sub>2</sub> and O<sub>2</sub> are combusted in the presence of water to create pressure and heat. The pressure



is used to turn a crankshaft, thereby creating mechanical energy. At this point, the **HyOx™ Engine** is similar to a traditional hydrocarbon combustion engine; as, only 15 to 20 % of combustion energy converts into mechanical energy;

wherein, 35% of combustion energy remains as heat in the combustion chamber and 35% of combustion energy forms an exhaust gas comprising H<sub>2</sub>O, steam. From this point forward, the **HyOx™ Engine** is a significant improvement upon the traditional combustion engine.

Exhaust gas, H<sub>2</sub>O (35% of combustion energy), enters a steam turbine (turbocharger); wherein, steam energy (enthalpy and entropy) are converted into mechanical energy (90% efficient); further, the mechanical energy drives an alternator (90% efficient) to convert the mechanical energy into electrical energy; further yet, condensate from the steam turbine is collected; wherein, the electrical energy converts the collected condensate into H<sub>2</sub> and O<sub>2</sub> via electrolysis (80% efficient) for recycle to combustion. Recovered exhaust energy, in the form of H<sub>2</sub> and O<sub>2</sub>, is recycled to combustion. With a recycle efficiency of 65%, a **HyOx™ Engine** exhaust recovery system recovers 22% of otherwise lost combustion energy.

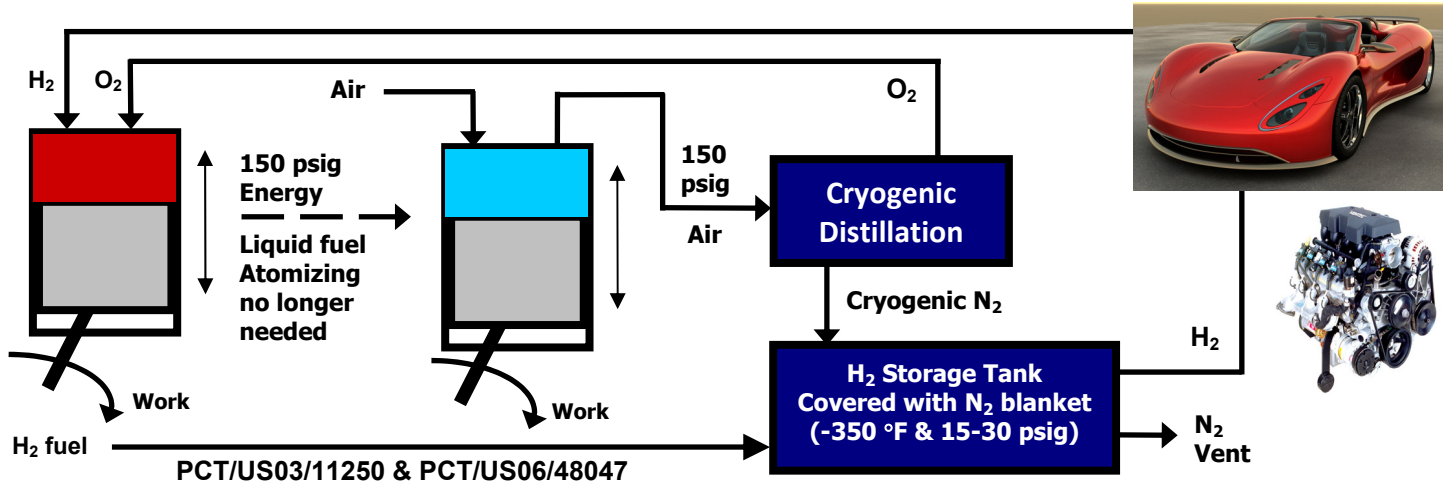
A full **HyOx™ Engine** further recovers combustion heat energy (35% of combustion energy) via adiabatic cooling of the combustion chamber. A full **HyOx™ Engine** comprises two cycles, a combustion cycle and a cooling steam cycle.

Moles of H <sub>2</sub> O		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

During the combustion cycle, H<sub>2</sub> and O<sub>2</sub> are combusted in the presence of H<sub>2</sub>O, to form H<sub>2</sub>O; wherein combustion heat energy (35% of combustion energy) is absorbed into the wall of the combustion chamber, which is insulated; such that, the combustion chamber acts as a heat sink. Then, during the cooling/steam cycle, low pressure steam is added (no H<sub>2</sub> or O<sub>2</sub>)

to the combustion chamber; wherein, adiabatically (as temperature is the driving force) the combustion chamber wall cools and high pressure steam is created therein for additional mechanical energy. **HyOx™ Engine** adiabatic cooling recovers 22% of otherwise lost combustion energy. **(PCT/US06/48057)**

A full **HyOx™ Engine** is powerful and stores H<sub>2</sub> fuel with significant energy density, creating O<sub>2</sub> on demand.



Combustion of pure H<sub>2</sub> with pure O<sub>2</sub> improves combustion chamber effectiveness by 80%; as otherwise, air is only 20% O<sub>2</sub>; yet, is 80% nitrogen (N<sub>2</sub>). Ironically and nicely, the amount of energy required to separate air is near that of the backpressure required to combust liquid hydrocarbon fuels; therefore and in comparison to the traditional combustion engine, a **HyOx™ Engine** produces pure combustion O<sub>2</sub> for free.

For a video of **HyOx™ Engines** and the **ClearValue® HyOx™ Team**: [http://www.youtube.com/watch?v=x3A\\_BKdsCvo](http://www.youtube.com/watch?v=x3A_BKdsCvo).

In combination, **ClearValue® Zero Carbon™ Energy**, **CONOX™** and **HyOx™** create a clean **Value-added Hydrogen Economy**. By value-added, electrical power and transportation are less expensive and more powerful; therefore once commercial, economics and market forces will drive use of **Zero Carbon™ Energy**, **CONOX™**, **HyOx™** and therefore, drive the **ClearValue® Hydrogen Economy**. Regulation is not required for market translation/implementation.

Market forces will naturally drive implementation of **ClearValue's Clean and Value-added Hydrogen Economy**.