CLOSING THE MATERIALS CYCLE

A ROUTE TO ECOLOGICAL SUSTAINABILITY

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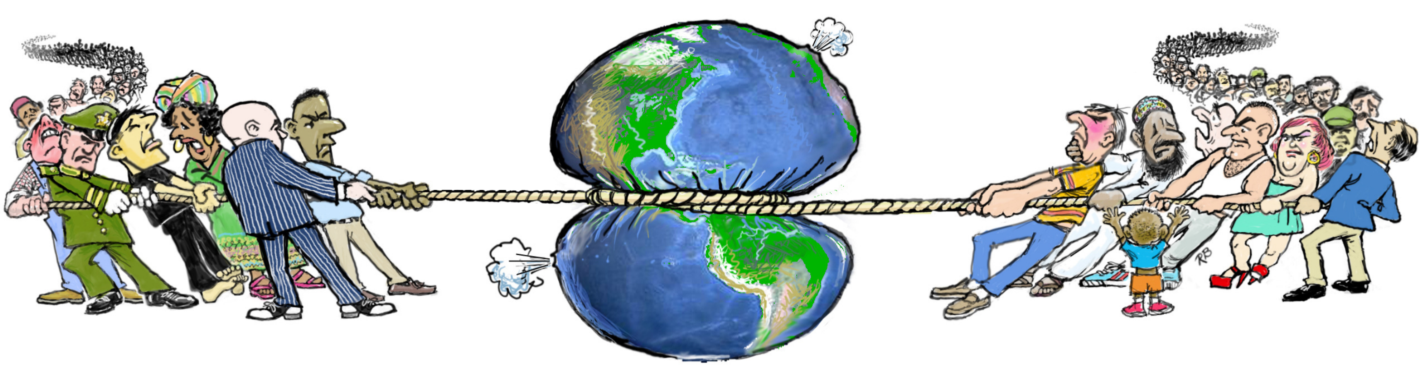
ABSTRACT:

Dr. Ruth-Inge Heinze said just before she died that this conference should begin to address the application of the shaman's consciousness to world issues. In the spirit of Ruth-Inge's wish this paper will focus upon the critical importance of closing the materials cycle to achieve a sustainable future. The science and technology needed to close the materials cycle from use to reuse will be presented as well as the environmental, economic, and social implications.

INTRODUCTION:

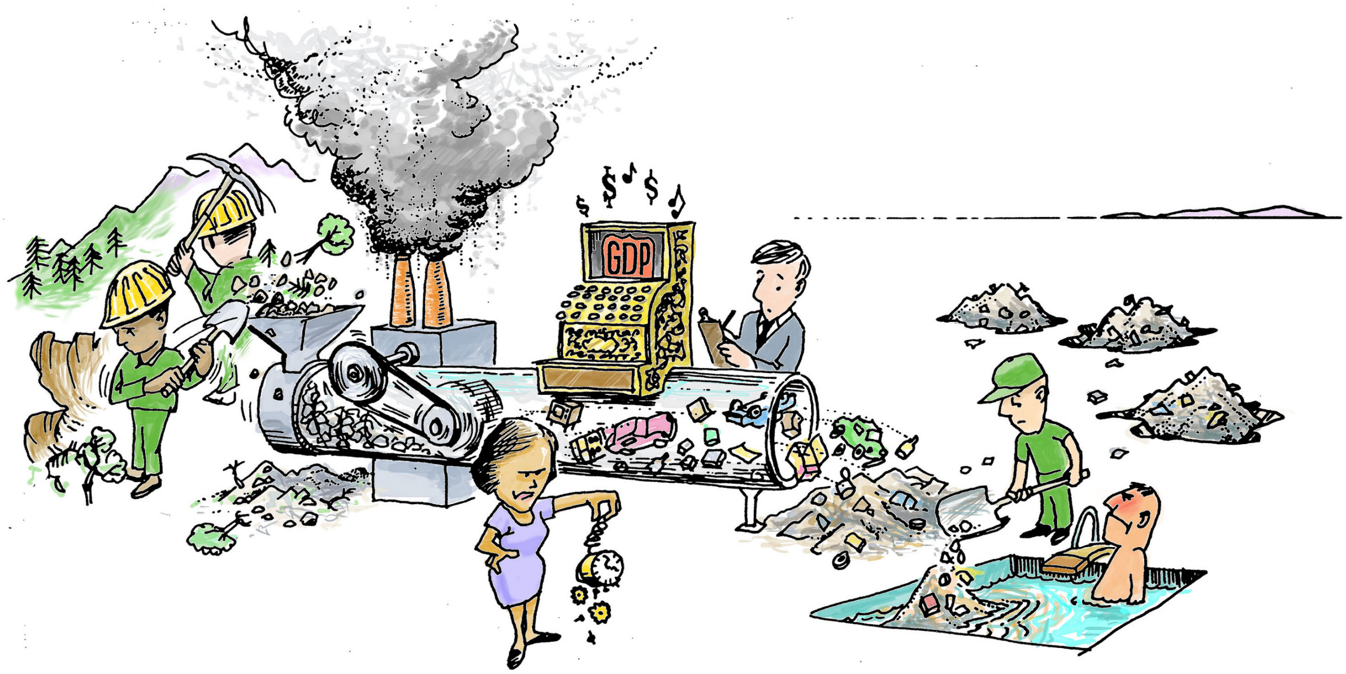
The general public is becoming aware that our earth is being "squeezed" to death because the people and governments of this planet are pulling in so many different directions. The **accelerating factors** driving the worldwide environmental and security/political problems are population growth and the rapidly expanding demands for greater material wealth and energy in the developing world -- China, India, Russia, Brazil, etc. World population is estimated by the United Nations to increase from 6.5 billion in 2005 to 9.2 billion in 2050 (United Nations, 2008). The U.S. Census Bureau predicts that the United States population will rise from the 304 million in 2008 to 439 million by 2050 (Swift, 2008). When I was attending grade school at the time of the Great Depression the U.S. population was 132 million.



There exists great frustration in the scientific community since the clear warnings about the dangers ahead for the world's population are continually being ignored – long range planning and concrete actions by governments are falling far short of what is needed. To draw humorous attention to this serious issue, the Union of Concerned Scientists held a contest for the best cartoon that illustrated the distortion, manipulation, and suppression of scientific information on the major issues facing the world. The cartoon that won the competition shows a scientist in front of a large chart presenting his data. The chart says "Research concludes: WE ARE DESTROYING EARTH." On the opposite side a business executive stands next to a government representative who says to the scientist, "Could you kindly rephrase that in equivocal, inaccurate, vague, self-serving and roundabout terms that we can all understand?" (Union of Concerned Scientists, 2008).

Ecology a subsystem of Economy

The root structural cause underlying the global environment and security problems is the fact that ecology has become a subsystem of the economy. This occurred because the world is operating an open cycle economic system in which resources are extracted from the earth to enter the cycle and exit as wastes. The entire system has been powered by polluting energy sources. Each person in the USA is producing 4.5 pounds of garbage per day. Only 1% of the wastes we produce in the United States are being recycled, the other 99% is trashed in six months. For every can of garbage we produce, 70 cans are produced upstream in the production process. (Leonard, 2008). Even when material is recycled it eventually downgrades due to the buildup of chemical impurities. Then it is down-cycled to a lower purpose, such as filler material, and eventually becomes a waste (Hawken, Lovins A., & Lovins L. H., 1999, p.79). In this open cycle economy there are only three sinks for the waste material to be deposited. They are the air, water, and soil -- the life support systems for planet earth.

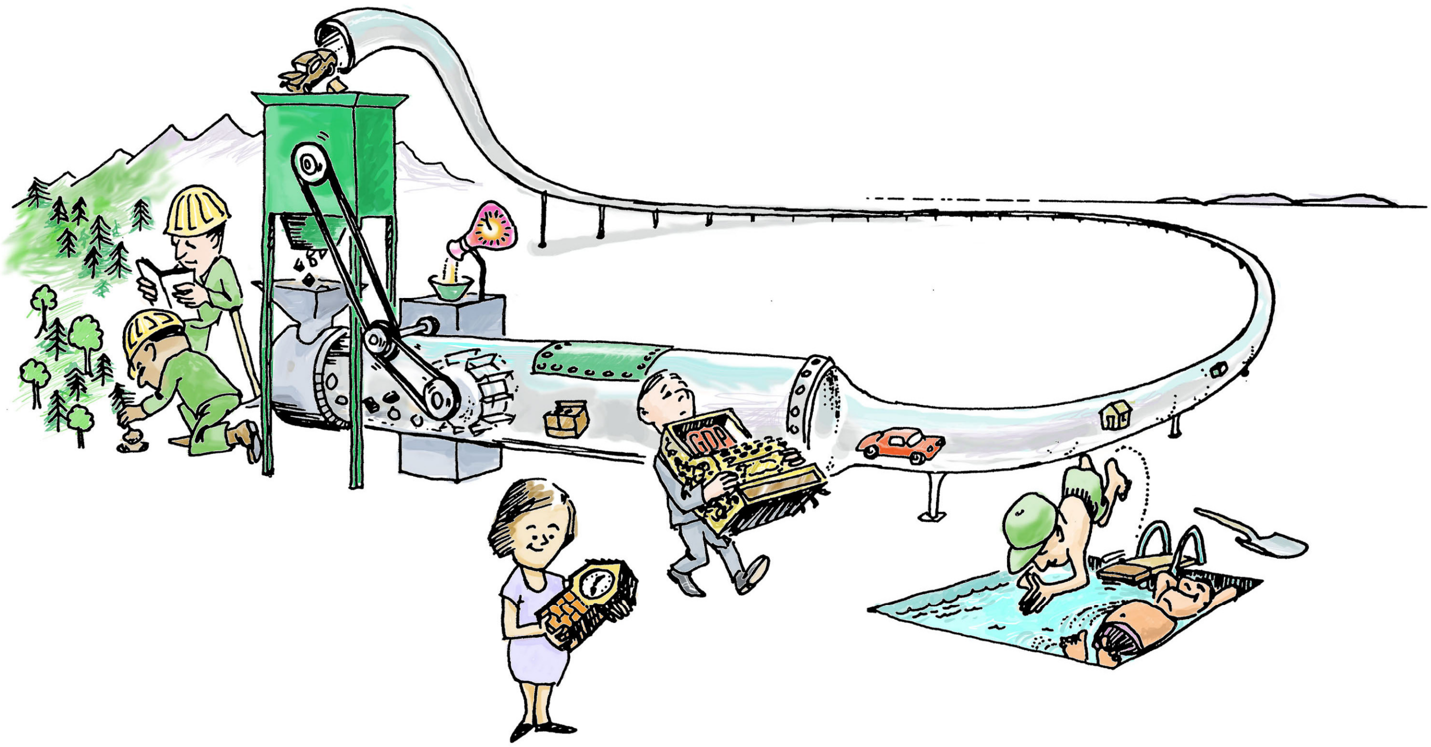


The citizens of our world need to become aware of the environmental, security, economic, and social implications of continuing to use an open cycle economic system. Nature operates as a closed materials system powered by a clean energy source, our sun. The human species cannot continue to operate and increasingly expand an open materials economy within Nature's closed materials system, and power this expansion with polluting energy sources. In fact if the developing world models our open materials economy and our lifestyle, we would require three to five additional planet earths (Leonard, 2008).

Humans need to develop the technologies necessary to close our materials cycle and this paper will suggest how that can be done. In addition we will need to adjust our current economic system. Economists now use the term "ecological economics," in the past this was called "closed cycle economics," or "stationary-state economics" (Daley & Farley, 2004; Daley, 1991; Boulding, 1973). In our current open cycle economics great emphasis is placed upon increasing the Gross Domestic Product (GDP). GDP is the total market value of all final goods and services sold in an economy in a particular time period. It is a measure of economic activity. Hence, the GDP indicates how fast we can push "things" through our open-ended system.

However, GDP is flawed as a measure of economic and societal wellbeing. Much economic activity does not improve quality of life – for example, low quality products, natural disasters, and war. In fact, GDP increases when we pay the costs of pollution, the costs of crime, and the economic losses from natural disasters like Hurricane Katrina. GDP also excludes volunteer activities, elder care by family members, etc. Even worse for our future, GDP does not measure the sustainability of growth. This can't continue since we are already observing the first negative effects of operating and growing as an open system while living inside of Nature's closed system -- earthship Earth (Robins, 2008; Mack 2006).

To achieve growth in the GDP the open system fosters planned obsolescence. How many of you have noticed that things tend to fall apart after a few years? It also encourages perceived obsolescence – the promotion of new clothing designs and new car styles, something we have come to expect and anticipate.

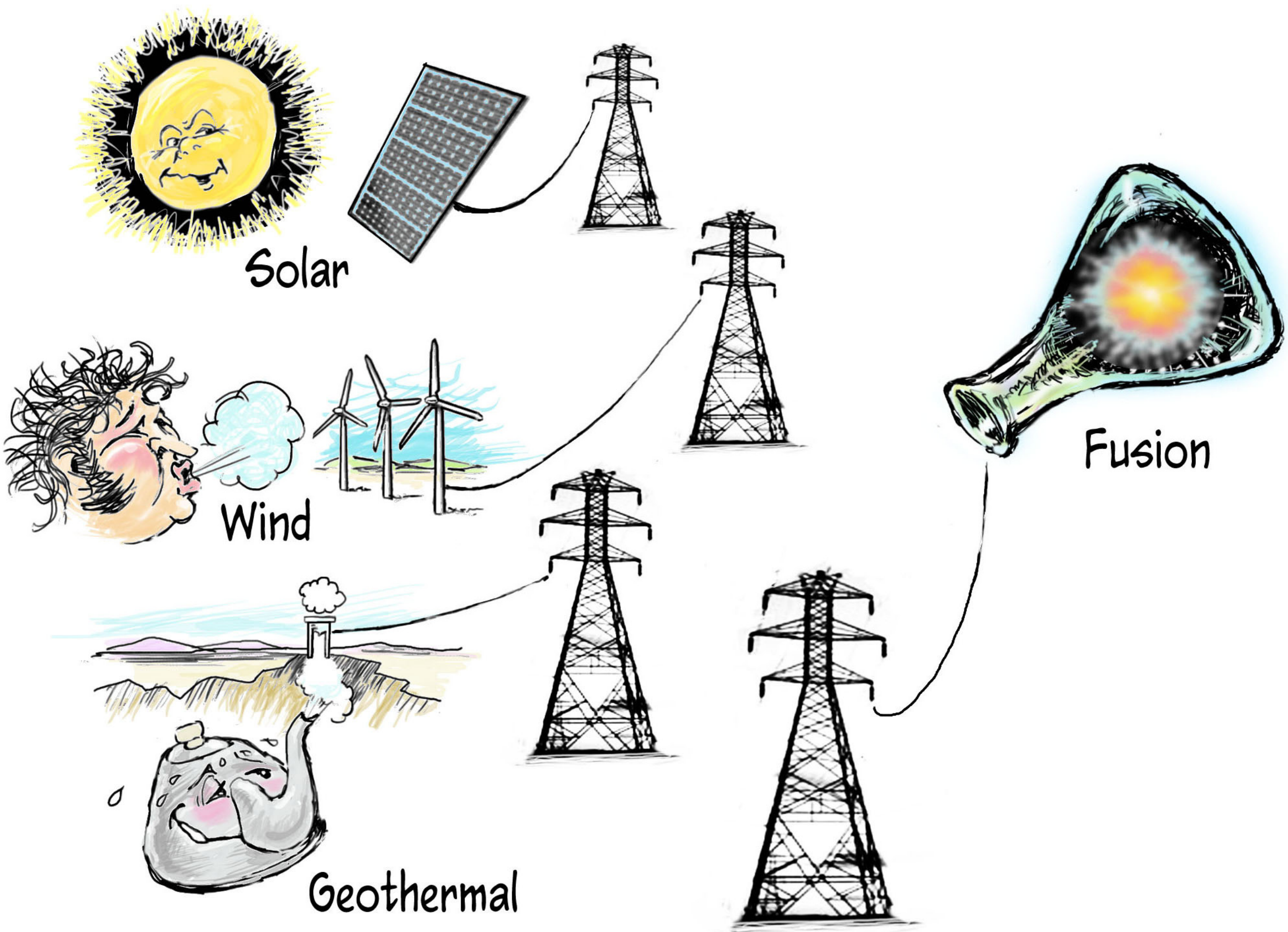


In a closed cycle economy the pressure is to minimize the recycling costs. Growth would be fostered in intellectual pursuits, the arts, music, and social activities. Financial rewards through a more equable distribution of wealth would need to evolve – society is beginning to recognize these needs, for example the efforts to increase teacher's salaries to strengthen our education system (Gough & Eastlund, 1971; Daley, 1991). At the present time the statistics of GDP are guiding this Nation rather than values. Society is paying a price for the focus upon growing the GDP. Research data shows a clear relationship of GDP to increasing unhappiness. The World Health Organization predicts that by 2020 depression will be the second leading cause of disability after heart disease (Robins, 2008).

Alternative indices are being proposed that account for societal and environmental factors related to real human development. We need this "Enlightened Economics!" For example, Friends of the Earth support the Index of Sustainable Economic Welfare (ISEW) (Friends of the Earth, 2008). Other indices being proposed are the Genuine Progress Indicator (GPI), the UN's Human Development Index, etc. (Robins, 2008). An urgent need exists to settle upon a new measuring index that can help guide our leaders and citizens. The GDP can still be calculated but it should no longer serve as the guide to national policy. It was a tool developed over 60 years ago to measure our increase productivity during World Was II and has lost its appropriateness as the driving index for society in the 21st century. Its principal creator Simon Kuznets cautioned that "the welfare of a nation can scarcely be inferred from a measurement of national income" (Wikipedia, 2008)

OPTIONS FOR THE FUTURE:

However, before these Ecologically Friendly indices can become a driving force for society, we need to develop the technologies for closing the materials cycle. We believe that society can create both clean energy sources and the technology to close the materials cycle. This is a clear challenge that we must face as we begin to recognize the implications of global warming and the effects of resource depletion and pollution. Failure to do so will lead the world into a precarious future. We have a number of technological options for producing clean energy. They are solar, wind, geothermal, and

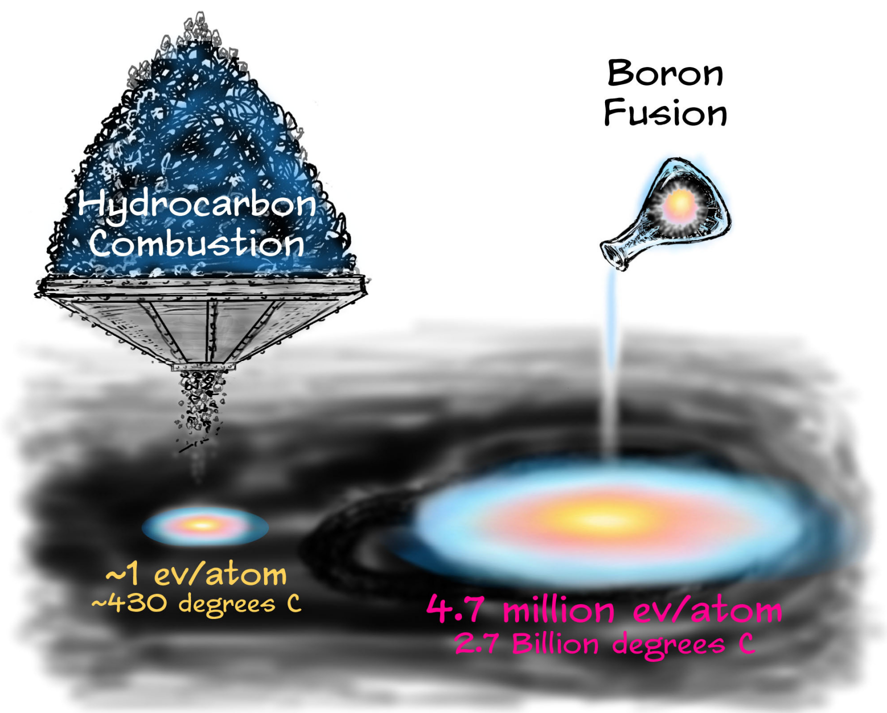


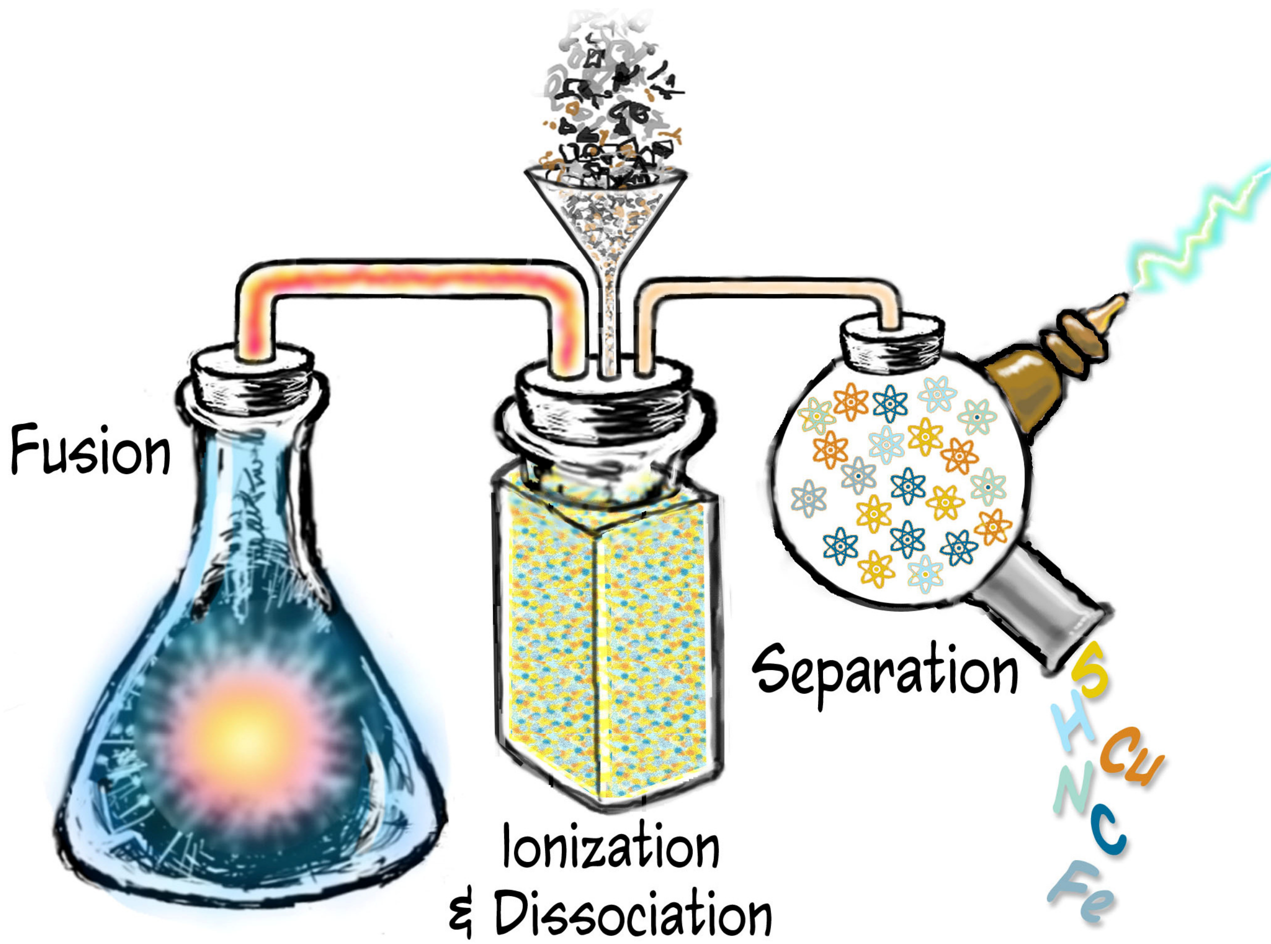
controlled fusion power. Extensive research and development are required to bring these energy sources into widespread commercial use, especially for fusion power. The key missing link for solving the environmental and associated political and security problems is the need for a technology for closing the materials cycle. The technological options for achieving that option will now be discussed. The technologies are available to solve this problem, they need to be integrated into a system capable of closing the materials cycle from use to reuse – no laws of physics exist that would prevent humanity from achieving this goal.

However, public awareness of the urgency of the need to close the materials cycle must exist before sufficient funding will become available for this to become a national priority. The driver for major social change has always been the introduction of new technologies. Dr. Ervin Laszlo, President of the Club of Budapest, states, "The transformation of society is not a chance-ridden haphazard process. – In society, fundamental change is triggered by technological innovations that destabilize the established structures and institutions. The decider, however, -- is the rise of new thinking, i.e., new values, perceptions, and priorities, in a critical mass of the people who make up the bulk of society (Laszlo, 2006).

FUSION TORCH:

The new technology that we are suggesting to close the materials cycle is the use of the ultra-high temperature plasmas developed by the fusion power research program. The temperature of such ionized gas plasmas are hotter that the core of our sun. A technique for achieving the objective of closing the materials cycle from use to reuse was discovered in 1968 by Dr. Bernard Eastlund and William C. Gough, and was named the Fusion Torch. (Eastlund & Gough, 1969; Miley, 1976) The fusion torch concept consists of a chamber designed to contain an ultra-high temperature plasma (ionized gas). This plasma can be produced by the use of injectors that accelerate particles to energies that create a dilute plasma equivalent to many hundreds of millions of degrees. At these temperatures and by using the appropriate fusion fuels, large amounts of energy can be produced with very little fuel, assuming adequate plasma confinement can be achieved. For example, fossil fuels produce about 1 electron volt per atom, hydrogen – boron fuel (p-B11) produces 4,700,000 electron volts per atom. A portion of this plasma flows into a second chamber where the plasma density is increased by adding material, which lowers the temperature to the optimum temperature level for completely ionizing and dissociating the added materials into their basic elements.

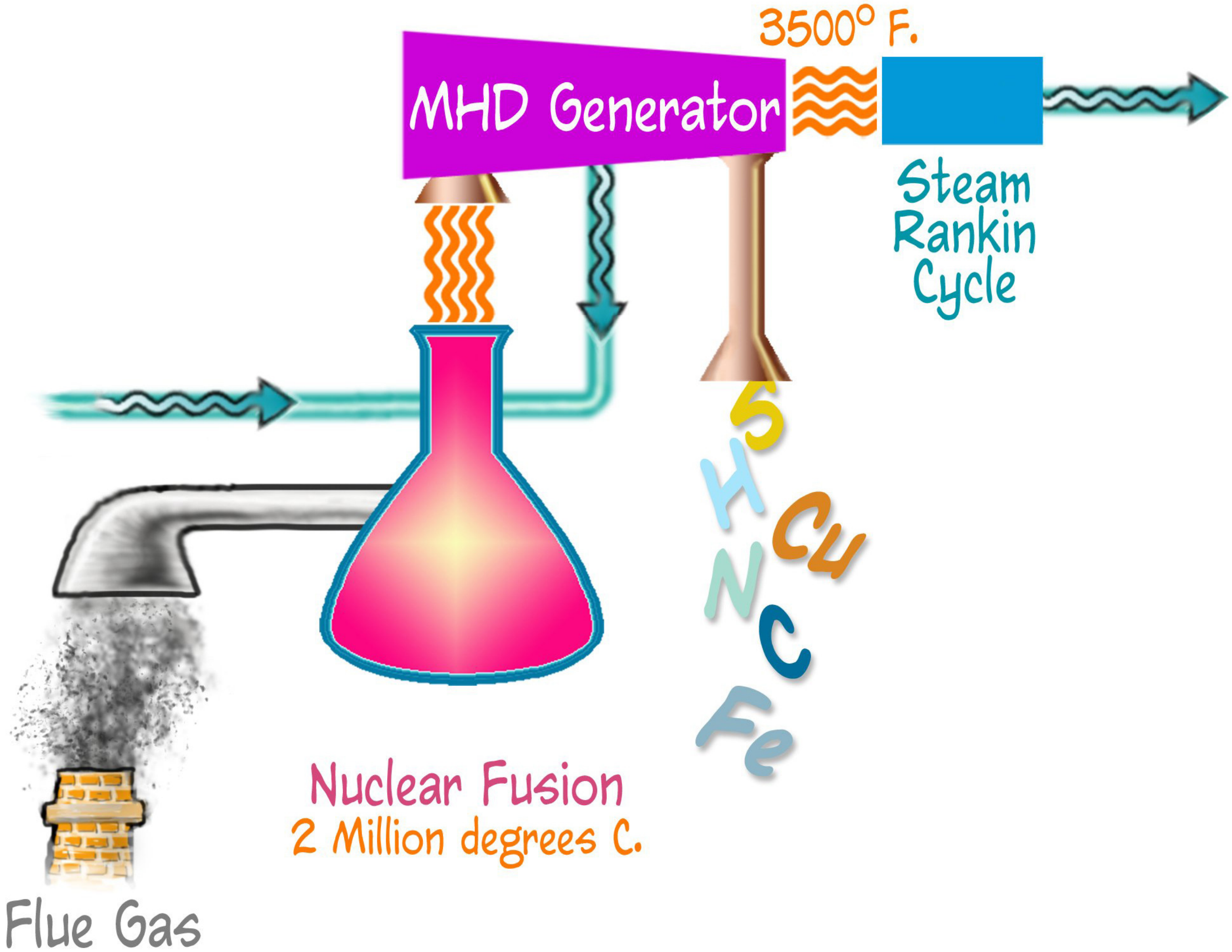




This plasma mix of materials then flows into a region for element separation and energy extraction. Since all materials must be ionized and dissociated the use of ultra-high temperature plasmas appears to represent the **only** route to completely close the materials cycle. The possibility of injecting and ionizing material in a fusion plasma has been accomplished and over 300 scientific papers address this technique. The challenge remaining is to do this on a large scale with multiple materials. The plasma process is unique because it provides multiple separation options, since elements can be separated by mass, charge, electronic state, or by combinations of these. At least nine different separation processes have been shown to be useful with the fusion torch after an investment of over $100 million with the issuance of many patents. (Gough & Miley, 2008; Eastlund, 1997 & 1999; Gough & Eastlund, 1971, April 26-27)).

There are at least ten active p-B11 research and development programs underway with many of these funded by private investment money. Inertial Electrostatic Confinement (IEC) permits these experiments to be done in small sizes and therefore at a relatively low cost, with reasonably rapid R&D turn-around times. The supply of boron is abundant and ubiquitous with the United States being a major producer. 80% of boron is the fuel isotope B11. Thus, the United States energy supply could become self-sufficient (Gough & Eastlund, 2007).

The environmental problems are rapidly increasing in severity. Most people are now familiar with the global warming issue and how we are polluting our life support system of the atmosphere. One important near-term ecological application would be to combine an electrically driven fusion torch unit with current fossil fuel plants. The flue gas from a coal power plant would be directed into the electrically driven IEC-produced plasma to separate the carbon and other elements. Electricity could be generated by cascading the high electrical conductivity exit gas through a magneto hydrodynamic process (MHD)



followed by a steam Rankin cycle. The carbon would have valuable uses, such as for electrical conversion via fuel cells. Dr. Bernard Eastlund calculated that if the energy equivalent of the carbon is added to the MHD electrical production, a net energy output from the overall system appears possible despite the electrical input required to the generate the IEC plasma. In the longer run, achievement of a p-B11 fusion plasma would add a key positive energy boost to the process, enabling the economic large-scale units needed for complete recycle of materials into elemental products (Gough & Eastlund, 2007).

Here are a few examples of what is happening to another of our life support systems – the water on this planet. Our industrial society has been producing many new chemicals including nylon, plastics, medicines, pesticides, etc. that have been mixed with other materials to create a pollution "soup" that is poisoning this planet. For example, let's look at plastics -- simple molecular configurations of carbon and hydrogen that we have been making from fossil fuels. Except for a small amount that's been incinerated, every bit of plastic manufactured in the world for the last 50 years remains somewhere in the environment. A total of over one billion tons of plastics have been produced, which includes hundreds of different plastics with untold permutations. A large amount of this plastic is ending up in the oceans even though most (80%) of this plastic was originally discarded on land. It is being concentrated in areas of the ocean known as gyres -- there are seven. These are created by a slowly rotation high-pressure vortex of hot equatorial air causing the water beneath to make slow whorls toward a depression at the center. The North Pacific gyre is estimated to contain on the surface 3 million tons of plastic with much more sinking to deeper depths. This gyrating Pacific dump is 10 million square miles, almost the size of Africa. Besides the effect on sea life of the larger pieces of plastic in the oceans, there are bite-sized pieces of plastic known as nurdles that are being swallowed by little sea creatures. About 5.5 quadrillion, approximately 250 billion pounds, are manufactured annually. Environmentalists are now documenting the effects of this plastic upon sea live and our food supply (Weisman, 2007).

There are increasing dead areas of the seas where life (our food supply) cannot survive due to lack of oxygen. In the Gulf of Mexico one exists that is the size of the state of New Jersey (Hawken, et al, 1999). The problem is spreading exponentially. In the decade of the 1940s the cumulative number of aquatic dead zones worldwide reported in scientific papers was 19, by the 1960s it was 43, by the 1980s it was 137, and for the first seven years of the 2000 decade it has already reached 405 (R.Diaz & R.Rosenberg, 2008).

If the total U.S. waste generation was ionized for recycling into basic elements via the "boron fusion torch" it would require less than 1% of the total U.S. energy consumption. In addition to separating out toxic elements like mercury and strategic metals like titanium, the process would produce enough hydrogen fuel to power about 56 million cars (U.S. Department of Energy, 2004). Hydrogen also could be produced directly from water using the IEC fusion torch (Miley, Gough, & Leon, 2008).

WHERE WE ARE TODAY:

How far down the path to using plasmas to recycle municipal wastes have we progressed? Today municipal solid wastes are already being processed using arc plasmas. Arc plasmas operate at about the temperature of the surface of our sun, i.e., a thousand degrees centigrade or so. They cannot completely dissociate and ionize all materials, although they can greatly reduce the volume of the waste. Their residue is sludge and syngas, which has an energy potential – however, CO_2 will still be released.

Nevertheless, this is a very important step in the application of plasma technology. Many companies world-wide are pursuing the use of high temperature plasmas for processing wastes. These include: GeoPlasma, InEnTec, StarTech, EER, Pasco Energy Group, EnerSol, Recovered Energy, PyroGenesis, and EuroPlasma. For example, InEnTec has a

25 ton/day demonstration plant in Richland, Washington and is building a $120,000,000 facility near Reno, Nevada. This plant is designed to handle 90,000 tons of municipal wastes per year and produce 10,500,000 gallons of ethanol (Integrated Environmental Technologies, 2008; Greentech Media 2008; InEnTec, 2008; Miller, 2006; Stickland 2007 & 2008; EER, 2008; Pasco Energy Group, 2008; Euro Plasma, 2008; Recovered Energy, 2008; EnerSol, 2008; Startech, 2008; PyroGenesis, 2008).

The ultra-high temperatures being produced in fusion research are orders of magnitude hotter than arc plasmas. Under construction in France is the International Thermonuclear Experiment Reactor (ITER). The cost estimate for this large international fusion experiment has increased by 1.2 billion to 1.6 billion euro which means ITER Tokamak will cost up to $12.5 billion U.S. dollars and be delayed to 2018 (Clery, 2008). The ITER tokamak confinement system is designed to achieve fusion power breakeven conditions. Tokamak systems are inherently very large because they depend upon a volume to surface area ratio to reduce loses.

Almost all controlled fusion power research over the last 50 years has focused upon magnetic confinement. Initially it was believed that the hydrogen-boron fusion fuel cycle (p-B11) was not a possible option. New theoretical research has shown that this original assessment was wrong. The unique fusion system we propose to close the materials cycle would use inertial electrostatic confinement (IEC) with p-B11 fuel being injected. This is the ideal fuel since neutron activation and tritium contamination of the materials are avoided. The IEC is chosen for the demanding task of the fusion torch since its characteristic non-Maxwellian plasma is favorable for burning p-B11 and the hot plasma can be conveniently coupled out via a jet-like electrostatic “divertor” into the processing region. Unlike the ITER tokamak, the core density and electron temperatures are the main issues for IECs. The IEC ion energy (effective temperature) is set by the injector’s operating voltage. Applying ~150 kV is desirable for burning p-B11. The required ion temperature conditions for p-B11 have already been achieved in IECs at several labs (Miley & Shresha, 2007). However, to burn p-B11 IECs require a factor of 15 increase in confinement beyond the international fusion reactor now under construction, plus the stability of the IECs non-Maxwellian plasma must be maintained.

Although the road to a net fusion power producer (Q>1) using IECs remains challenging, there are many possible practical applications along the path (Q<1) that could have commercial value. Today IEC plasma units have been operated with deuterium-tritium (DT) to produce neutrons. In addition to their use in research, application of these neutron sources include the production of positron emission tomography (PET) isotopes, the detection of weapon grade uranium and the C-4 explosive, and the study of high temperature material behavior under particle bombardment (Kulcinski, et al, 2008). In the near-term to compete with plasma arc systems we propose a new type of plasma system, the “IEC plasma jet” using argon or similar inert gas, be used for onsite waste destruction and waste-to-energy conversion. Because arc temperatures are relatively low, the ultra-high temperature plasma produced in an electrically driven IEC system would provide improved waste conversion and valuable fuels. Specific IEC units could also be designed for the processing and recovery of elements from E-wastes, toxic chemical and biological wastes, for producing fuels from plastic, and for ionizing and dissociating greenhouse gases into their constituent elements (i.e., CO_2 into carbon and oxygen).

In summary, Inertial Electrostatic Confinement (IEC) is one of the few approaches to fusion that has the possibility of burning the non-neutron producing fusion fuel cycle that uses hydrogen and boron (p-B11). If achieved, such a power source would enjoy wide availability of the fuel, no greenhouse emissions, and essentially no radioactivity or radioactive wastes. It is the non-equilibrium plasma contained by the IEC that provides it with this unique ability to effectively burn p-B11. That capability of using p-B11 fusion fuel in turn leads to charged-particle reaction products that are non-radioactive (it produces helium). This makes the p-B11 fusion fuel cycle ideal for closing the materials cycle from use to re-use. Because of the inherent nature of IECs, all the research and development can be done on small sized devices reducing costs dramatically and providing short turn-around times for improvements and upgrades. The closing of the materials cycle represents the primary objective of this program. However, an IEC fusion power generator operating on p-B11 fuel also would enable the development of a modular direct conversion electrical power plants operating at more than 80% efficiency, ship propulsion units, and space mission options. Because of the national security implications of failure to close the materials cycle and the need for clean energy sources, it would be appropriate to fund these objectives in a manner similar to that used in the past for high priority military and space objectives.

CONCLUSIONS:

There exist two basic technological requirements for achieving a sustainable modern world. These interrelated requirements are the availability of clean energy **and** the ability to close the materials cycle from use to reuse. Only then will we be able to duplicate Nature's cycle and achieve sustainability. Thus, to sustain the ecological foundation that Nature has provided us, humanity must alter the technological base that modern society has created. We believe that the technological potential to achieve this goal exists today. The appropriate technologies when combined and developed into a system will permit all nations to have material wealth without destruction of the environment. The fusion torch provides a unique opportunity for mankind to achieve these objectives, and this in turn would produce a gigantic leap toward sustainability of life on earth.

Economy a subsystem of Ecology

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