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Carbon Sequestration and Waste Utilisation in the Built Environment

Both the earth system and economic system are homeostatic, the main differences being that the latter is utterly dependent on the former. The physical interface of our economic system is our techno-process and at the moment this interface and earth systems are not always or completely compatable and we must reduce the negative impacts of our techno-process on the total earth system on which it depends for survival in the long run. In the economic system energy is vital to the techno-process for industrial development whereas population growth is inversely correlated to it [1]. The paradox is that we need energy to grow economies to ultimately reduce our population and rate of growth of impacts on the earth system. At the same time to survive in harmony with nature we must massively reduce our per capita and total life-cycle impacts on the earth system that supports us.

The challenge is to manage the industrialisation of third world countries so they can achieve higher living standards without the take and waste impacts currently associated with the massive footprint of industrialised nations. We must incorporate sustainability principles including energy efficiency, constraint, substitution for alternatives as well as fundamental Pilzer first law substitutions into what the word industrialisation means and take seriously our role as planetary engineers.

It will not be possible to decouple our economies from energy and as under developed countries grow their economies they are choosing the cheapest form which is fossil fuel thereby further compounding the global warming problem. There are huge reserves of around 7,000 gigatonnes of irresistable cheap coal and over a 100,000 gigatonnes of methane hydrates[2] on the planet. (See Figure 5) It is essential that we therefore also seek fundamental Pilzer first law substitions.

We are in boom but worrying times. World physical industrial product (WIP) continues to rise and is strongly coupled with a correlation of 99.5% (di Fazio) to CO_2 emissions which are also rising at an increasing rate due to increasing rather than decreasing use of fossil fuels(BP 2007) as drivers of global economies.

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[1] The greater the economic well being of a country the lower the population growth.
[2] Methane hydrates or clathrates are the likely fossil fuel of the future. See http://www.fossil.energy.gov/programs/oilgas/hydrates.

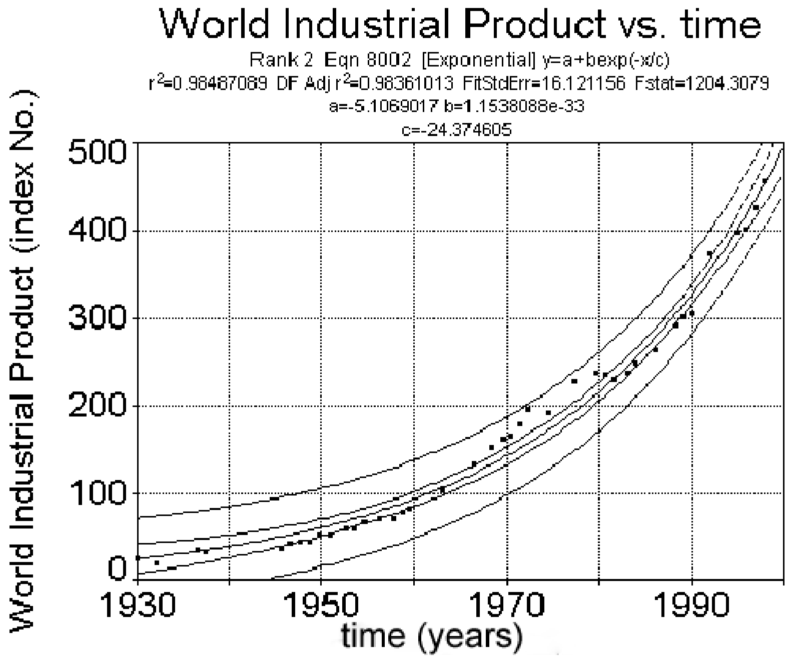

Figure 1 - World Industrial Product (deflated world `GDP' in real value - i.e. the physical equivalent)[3] (di Fazio)

Assuming Kyoto commitments are met (which is unlikely) it is estimated that global emissions will be 41% higher in 2010 than in 1990 (Ford, Matysek et al. 2006). The bottom line is that we are tracking on previously estimated worse case scenarios and making no progress towards reducing net emissions.

It will not be easy to achieve a decoupling between growth and emissions and more importantly the quantum of CO2 in the atmosphere and TecEco advocate what we call Pilzer first law substitutions that incorporate alternative technical paradigms that either convert CO2 to a resource or result in less or no emmissions to help solve the imbalance. Basically our moleconomic flows in current pradigm techno-processes in our economic system are resulting in too much CO2 accumulating in the air. Note that this bottom up approach TecEco advocate can be taken in relation to heavy metals, CFC's and other moleconomic inbalances as well.

There is an urgent need to find ways of achieving a higher standard of living particularly for developing nations whilst at the same time reducing net emissions. We are not going to achieve these combined objectives with strategies currently in place.

Pilzer's first law[4] (Pilzer 1990) dictates that we can change the materials flow and hence the damaging underlying moleconomic flows by changing the technological basis of what we do. The current response to global warming is minor sideways substitution of energy sources and major eforts to increase thermodynamic efficiencies. The former does not change the underlying moleconomic flows and the latter will eventually reach a point of uneconomic diminishing returns. Pilzer first law substitution involves bottom up rather than top down or sideways change.

Before such bottom up change can occur it is essential that the research, development and deployment of new technical paradigms including alternative energy production and technical innovations that are more sustainable and that can recycle wastes including CO_2[5] are prioritised.

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[3] The unit is an index number, set as base=100 in 1963. To obtain with good approximation the value in US$ (1990 value) multiply by 212.1 billion. Doubling time is approximately 17 years. Data: the World Bank; statistics : GDI World Physical Industrial Product

[4] Stated briefly as the technology paradigm defines what is or is not a resource.

[5] As nature would teach us

Cultural changes are occurring, technical innovations such as that offered by TecEco are available, yet governments and the big end of town have just not caught up with how we can move forward as we must.

To move the supply curve in the pursuit of sustainability in the following diagram, research and development is essential to change the actual supply delivered by the techno-process, possibly even years beforehand because of take up lags. Unfortunately research support policies are based on inadequate real time markets deciding priorities and governments have failed to foster sufficient research to solve pressing externalities such as the carbon problem. Furthermore if technical innovations such as TecEco's Eco-Cement are not supported by government purchasing power and there is little incentive for their adoption.

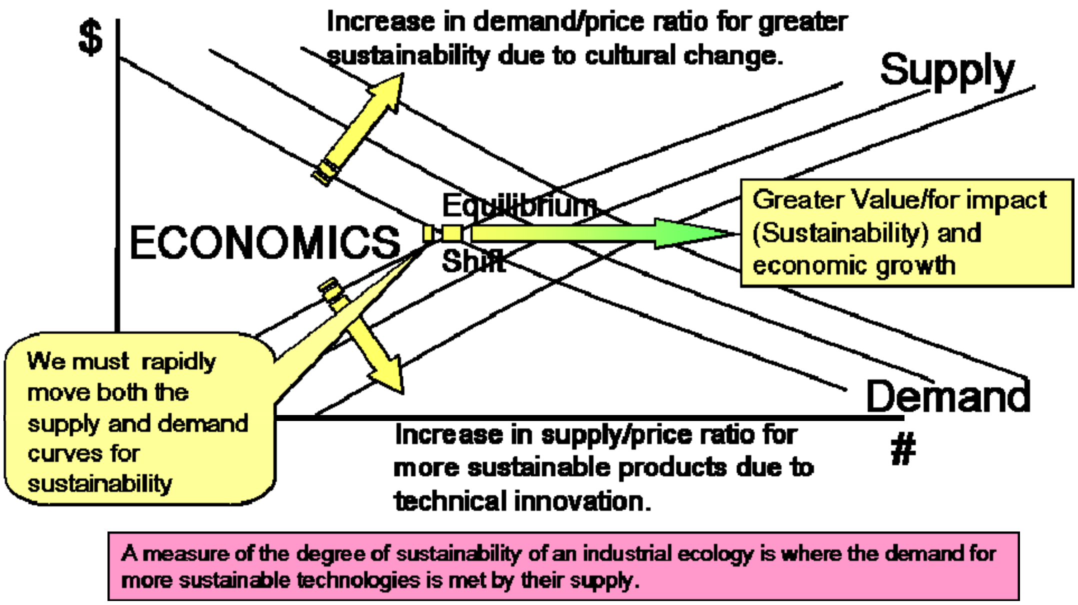

Figure 2 – Sustainability is Where Culture and Technology Meet

There are two main conditions for the technical change required to move the supply curve in response to the demand curve in the above diagram. The new technologies required will only be adopted if they are profitable and because of time lags the required research and development must be on a timely basis.

Some governments are in fear of such change yet modern economic theory (evolutionary economics in particular) is based on the fact that change is the major driver of economic growth. This process, called creative destruction by Schumpeter (Schumpeter 1954), is whereby new innovation destroys old and less efficient process and is the drive engine of modern economies. The economic truth is that that change is a driver not a brake.

Whilst emissions trading may deliver peace of mind to participants and profits to some, it has not and will not reduce the order of magnitude of greenhouse emissions. So far it has essentially involved taking profitable thermodynamic efficiency gains or minor sidways substitutions that do not change the fundamental underlying moleconomic flows. We are not going to solve the problem doing the same as we have done in the past more efficiently. As we approach thermodynamic limits to efficiency, the laws of diminishing returns will impact outcomes and substitution to alternatives (many of which will result in bottom up change such as substituting solar for fossil fuel energy or materials changes in favour of converting current damaging wastes such as CO_2 to resources) will become essential. Technical substitution fortunately also provides the greater opportunity

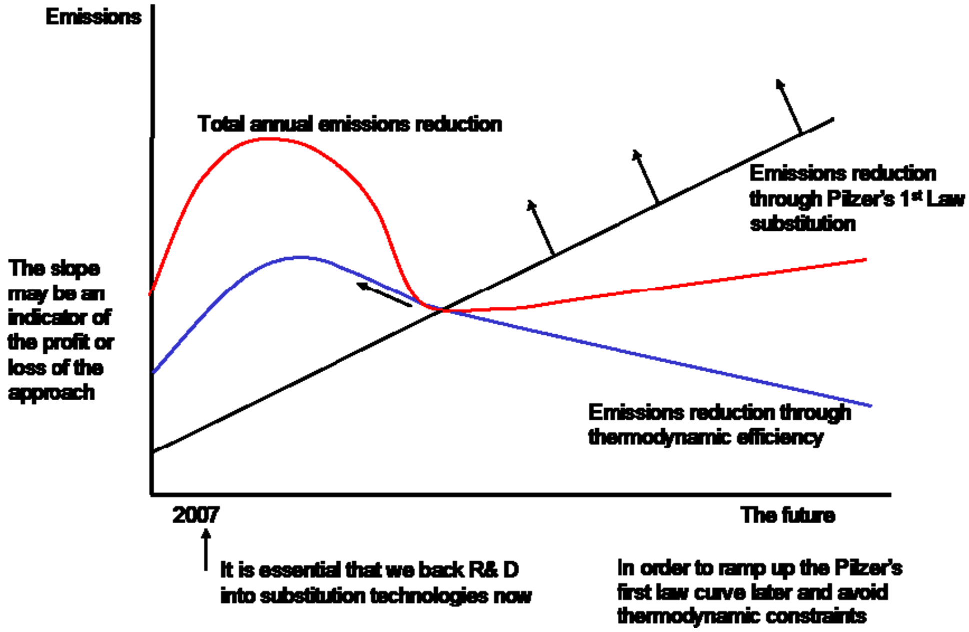

Figure 3 - Avoiding Reduced Response through Thermodynamic Constraints

The above discussion leads to one conclusion. It is essential that we support innovations like TecEco's Eco-Cement with research and development money now if we are to move the supply curve for more sustainable technologies later. If we do not do this quickly enough then our responses to global warming will reduce, not increase, as we encounter the law of diminishing returns on thermodynamic efficiency improvements and run out of mnor sideways substitutions.

It is inevitable that the concrete industry will have to be a major player in greening the planet. They may as well start now with the research and development required into major innovations including TecEco Eco-Cement and Gaia Engineering.

Fortunately emissions trading will to some extent encourage the development of offsets which will help fund the Research and development required but there are real problems in developing the required imprimatur in the area of building and construction for offsets to be confidently purchased and traded in markets. In other words we have a long long way to go!

Another reason the concrete industry should move now is that a disproportionate impact due to carbon restraint is likely. According to Amanda McCluskey (Hannam 2000)[6], deputy chairwoman of the Investor Group on Climate Change "Australia's cement industry would be among the hardest hit by a greenhouse gas emissions trading system, with the sector's annual profit dropping as much as 60 per cent, or $160 million, under worst-case measures" The basis for such a profit cut include an emission price of $25 a tonne of carbon dioxide equivalent, and the absence of any free permits, conditions unlikely to be imposed at the start of an emission market in Australia.

TecEco are offering the cement industry an opportunity to leapfrog technology thereby neatly overcoming the business risk of carbon taxes or being left behind as governments and consumers rush towards technologies that solve rather than exacerbate the global warming problem. By selling man made carbonate and carbonating binding agents that could potentially be used for the Pareto proportion of applications the industry could lead the world.

There are very good commercial reasons for the industry to take up this offer. Consider the alternative options. Slowing industrial progress is not feasible and in spite of all the rhetoric from politicians about

[6] Amanda McCluskey was formely manager in sustainability for Portfolio Partners in Melbourne and as of 9th July 2007 took up a new role as general manager, sustainability at the Commonwealth Bank. The concrete industry should note that even bankers are looking closely as environmental issues!

impossible to meet emissions "targets"[7] approximately four new power plants are being commissioned a week and two of these are in China. Energy consumption continues to grow from all sources including fossil fuels as the graph in Figure 4 from the 2007 BP statistical world review shows.

Nuclear and "clean coal" have been mentioned as alternatives and fixes for the current paradigm. Nuclear generation may only produce about a third as much CO_2 per kWh as conventional state of the art mid-sized gas-fired electricity generation as the concentration of ores declines (van Leeuwen and Smith). Thorium or fusion reactors show some promise however. On the downside, given global terrorism the proliferation of weapons is of great concern.

The fact is that we will continue to build and run coal and gas fired power stations for years to come because there are still abundant reserves of cheap coal and methane hydrates[8] that will be utilised by developing nations. This will particularly be the case with third world countries as they desperately try to catch up.

Given this scenario increasing energy efficiency cannot solve the CO2 problem because it is limited by thermodynamic constraints; sidways substitutions such as conversion to a hydrogen economy will, at least to the extent hydrogen is produced from petroleum, coal, natural gas or methane hydrates only exacerbate the problem. Proponents of so called "clean coal" have no way of dealing with CO2 safely [9]. Nuclear is a possibility that carries with it a number of caveats and the fear of proliferation concerns us all.

It is possible that all the actions to date have merely been for political feel good reasons and in the pursuit of profit through efficiency gains. In the future these strategies will ultimately become ineffective.

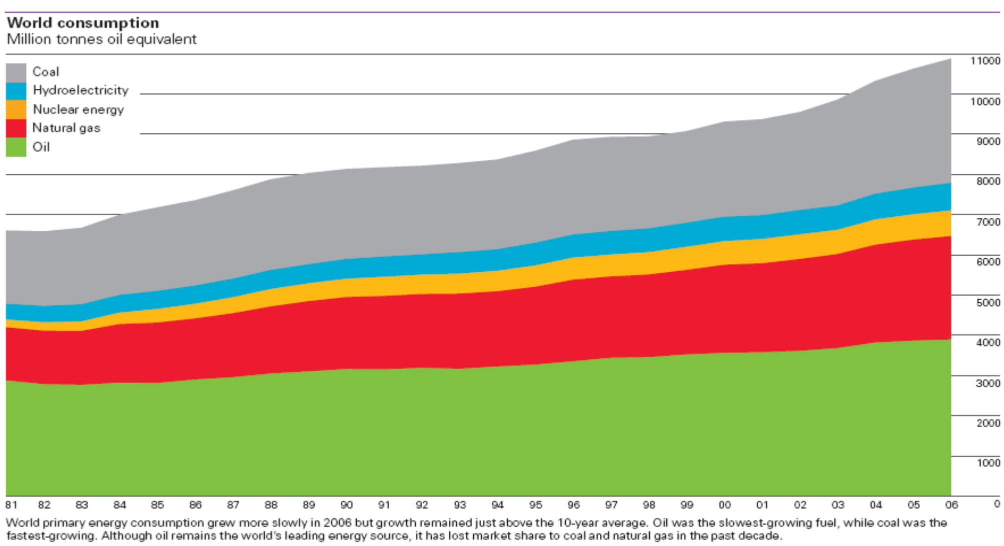

Figure 4 - World Energy Consumption (BP 2007)

The most sensible and eventually only route forward will be fundamental bottom up Pilzer first law substitution technical substitution. As correctly pointed out by Sir Richard Branson at the launch of the virgin Earth prize we must "come up with a way of removing lethal carbon dioxide from the earth's atmosphere" - Once equilibrium is reached our custodial role will then be to balance emissions of CO2 and other greenhouse gases with their sequestration so as to not follow a natural trend towards glaciation based on Milankovitch cycles. In this way we will mimic the role of nature throughout the Holocene that we have now substantially usurped.

[7] In Australia Labour has committed to a 60 % reduction from 1990 emission levels by the year 2050. The Liberal government says it will commit to a target, but not until after the next election. Elsewhere around the world the emissions targets called for by various politicians vary from achievable to impossible.
[8] Methane hydrates or clathrates can be processed to produce methane, the main component of natural gas.
[9] Many geologists consider "geosequestration" unsafe.

Around the world debate rages as to how the problem can be solved and more recently the IPCC have recognised the importance of buildings as major contributors to CO2 (Age 2007). According to researchandmarkets (Markets 2007) “Buildings make a large contribution to the energy consumption of a country. It is estimated that, of the total energy generated in the industrialised world, 40% of it is used in the construction and operation of residential, public, and commercial buildings. Approximately one third of primary energy world-wide is consumed in non-industrial buildings such as dwellings, offices, hospitals, and schools where it is utilised for space heating and cooling, lighting and the operation of appliances. In the European Union (EU), energy consumption for buildings-related services accounts for between 33% and 40% of total EU energy consumption. Energy used for heating, lighting and powering buildings can account for up to half of a country’s total energy consumption. In an industrial economy domestic water heating can account for over 5% of total energy use, domestic space heating up to 20% and appliances and lighting up to 30%. In terms of the total energy end use, consumption of energy in the building sector is comparable to that used in the entire transport sector.”

In spite of huge difficulties in developing the imprimatur of carbon offsets in the building and construction industry there are significant gains to be made in this market both in relation to improved design for lower lifetime energies and improvements in the materials used in terms of their life cycle impacts, embodied energies and emissions. For TecEco building and construction is the only market large enough to profitably use large tonnages of man made carbonate.

All of the above point to the need to develop new and powerful technical ways of solving the problems we have and to do it now before diminishing returns set in on our current efficiency based strategies to avoid climate disaster.

The oil industry have woken up to the large amount of money that governments will spend on even remotely viable options for sequestering CO_2 yet the cement industry with the obvious solutions in front of them cannot see the opportunity TecEco Gaia Engineering technologies represent yet it is likely at least equivalent funding would be available should the industry wake up.

For a method of removing the CO2 from the air to succeed it must be economic otherwise it will not be universally adopted and part of what we all do in our everyday lives. Techincal innovation that is not economic does not survive and innovation that does not survive will not invoke Pilzers first law and change the materials and hence underlying damaging moleconomic flows. To solve the most important problems of our era and more, TecEco uniquely advocate mimicking nature by building with man-made carbonate incorporating other wastes as a profitable way of removing CO2 from the atmosphere and to this end have developed many technologies which working together in Gaia Engineering can solve the problem profitably.

All involved have missed the obvious solution John Harrison of TecEco propose first announced by New Scientist Magazine on the 13th July, 2002 (Pearce 2002). What Fred Pearce said then is even truer now “There is a way to make our city streets as green as the Amazon Forest. Almost every aspect of the built environment from bridges to factories to tower blocks, and from roads to sea walls, could be turned into structures that soak up carbon dioxide – the main greenhouse gas behind global warming. All we need to do it is the change the way we make cement.”

M K Singhi from India commented at the recent Cement Industry National Conference in Melbourne in relation to his country “we want the concrete industry to be the saviour of the world” (Singh 2007) The cement and concrete industry don’t know it yet but will be the saviour of the world because it is the only industry with sufficiently large flows to reverse global carbon flows.

To be successful the solution to the carbon sequestration problem must be economic and produce saleable outcomes that have unlimited markets in size and over time otherwise it will not be implemented by business or the masses in the economic system given their short term view in imperfect markets, nor sequester sufficient carbon. Gaia Engineering is conceptually a simple solution based on geo and biomimicry that does all this and more. Depending on the front end process selected to create carbonate from sea water, brines or bitterns it has variable outputs of valuable salts or acids, carbonate building materials and cements to bind them as well as fresh water - all of which are saleable in very large quantities.

40 million gigatonnes or around 7% of the crust is carbonate sediment (See Figure 5) and this represents the major proportion of billions of years of natural permanent sequestration and durable structures have been built using this natural carbonate for thousands of years. The technology developed for Gaia Engineering

mimics this natural process by sequestering carbon dioxide using salty water or bitterns as sources for calcium and magnesium carrier ions and further substitutes the major material flows on the planet by profitably putting the gas to use to make building materials for constructing the built environment. It is not a giant leap of faith from what we already know has worked in the past.

The technology developed by John Harrison of TecEco for Gaia Engineering mimics natural sedimentation processes (which are unfortunately not rapidly enough taking up CO_2) by sequestering carbon dioxide using salty water or brine as a source of magnesium or calcium and further substitutes the major material flows on the planet by profitably putting the gas to use to construct the built environment.

In substance Gaia Engineering involves building with man made carbonate and wastes and John Harrison, TecEco's managing director has developed enabling technologies including more sustainable and technically superior binders including Eco-Cement the flagship product which sets by absorbing CO_2 and binds to almost anything[10]. A kiln is also under development by TecEco for making the binders required without releases and software for implementing the companies cement formulations is being written by a subsidiary company TecSoft Pty. Ltd.

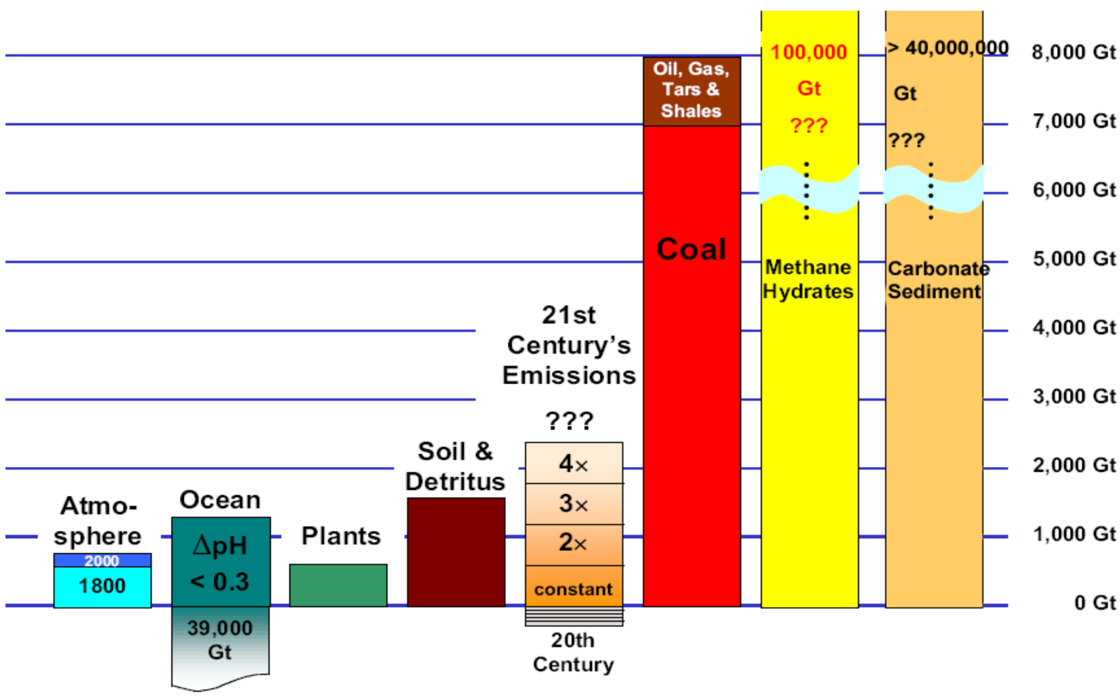

Figure 5 -Carbon Sinks and Anthropogenic Actual and Predicted Consumption of Carbon (Ziock and Harrison) [11]

Although the Gaia Engineering process is simple in concept the detail is more complex and a flow chart is included as Figure 6. A brief more technical explanation follows.

Gaia Engineering starts with a front end process to capture carbon dioxide using the magnesium contained in bitterns, seawater or brine and to date there are several promising candidate methods that all require further research and development. They include the Greensols process which involves chemical precipitation, a pyrohydrolysis process that can be run in association with salt manufacture, an ultra high speed centrifuge process and biomimetic process.

Outputs will vary according to the ultimate process selected for the concentration of CO_2 needed and are as hereunder:

[10] Magnesium compounds bind well because of their strongly polar surfaces to any other surface that is or is potentially differentially charged.
[11] Modified from Figure 2 in Ziock by the inclusion of a bar to represent sedimentary sinks

- Greensols - sodium bicarbonate, mineral salts, carbonate building materials and aggregates, Eco-Cements and fresh water

- Ultra Centrifuges - provided materials can be found to withstand the forces involved, potentially similar outputs as the Greensols process.

- Hydropyrolysis - magnesium oxide and hydrochloric acid. The magnesium oxide can be used for sequestration and hydrochloric acid is used in industry.

- Biomimetic Routes – calcium and magnesium carbonates.

All of these "front end" processes are being researched by others and will use carbon dioxide from for example power stations and cement kilns to produce carbonate utilising the naturally occurring calcium and magnesium found in seawater, suitable brines or from residual minerals after the extraction of table salt. What John wants to do is couple with these front end processes economic uses in building and construction of the carbonate produced to drive them.

As there are 1.29 grams of magnesium and around .41 grams of calcium in every litre of seawater there is enough of it to last billions of years with natural replenishment given current needs for sequestration. Both the Greensols and ultra centrifuge processes also represent a superior low energy alternative to reverse osmosis de-salination for the production of fresh water.

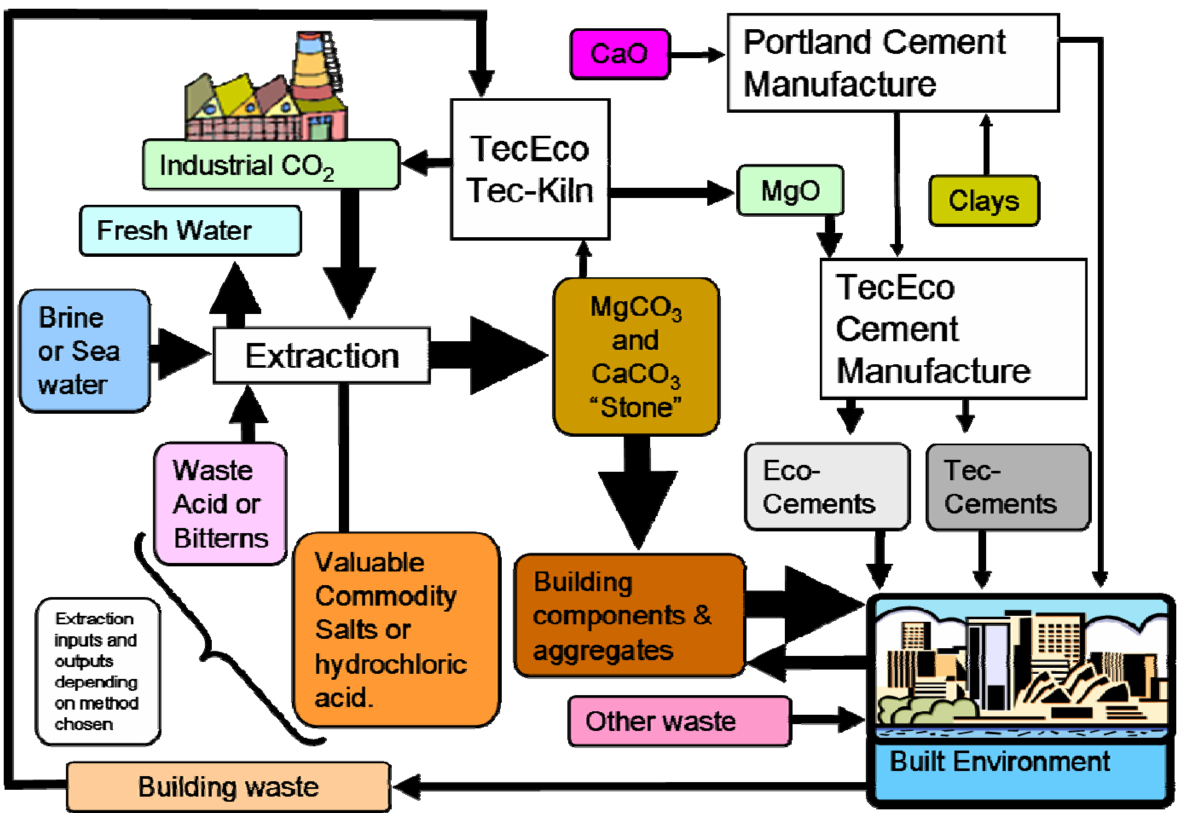

Figure 6 - Gaia Engineering[12] Flow Chart

The front end processes in Gaia Engineering will produce massive amounts of man made carbonate which will be reconstituted and put to good use by TecEco as building materials for construction. Given the size of, volume of and potential reduction in impact of associated flows, TecEco binders used to cement together

[12] Gaia engineering is probably best described as a low energy bottom up economic solution to the world's most pressing problem that will work because it profitably changes the fundamental flows that are damaging.

wastes and to form carbonate building materials in a way that mimics nature are a potential solution to global warming and an essential part of Gaia Engineering.

A proportion of the calcium and magnesium carbonates produced will be calcined in the TecEco Tec-Kiln which removes and captures the gas for recycling in the front end processes and produces quicklime and magnesium oxide, the latter being the main ingredient of TecEco Tec, Eco and Enviro-Cements. Eco-Cements absorb atmospheric CO_2 as they harden and together with other wastes will be used to bind together the man made carbonate building components including stone, cast components and aggregates.

TecEco undertake the manufacture of building materials holistically on a whole of material basis and the formulation strategy for the company's carbonate building materials will be best communicated as software being developed by its subsidiary TecSoft Pty. Ltd. that will in effect be a recipe book for man made carbonate materials of the future which solve rather than create problems.

The sequestration in the next ten years or for that matter one thousand years will depend on the take up of the technology. It is important to note however that there is plenty of scope as materials flows in the built environment are some 50 billion tonnes and that only some 22 billion tonnes of solid man made magnesium carbonate a year is required to equate to annual anthropogenic emissions[13].

Funds are required for further analysis, however the preliminary graphs shown as Figure 7 and Figure 8 demonstrate the potential enormous sequestration the technology can provide as they are for cement and concretes only, not all building products, and the use of carbonate components and aggregates is also anticipated.

A built environment of man made carbonate and waste materials could be recycled indefinitely and would store a massive amount of CO_2 and other wastes, more than enough to solve the global warming and waste problems if compulsorily adopted by all nations[14].

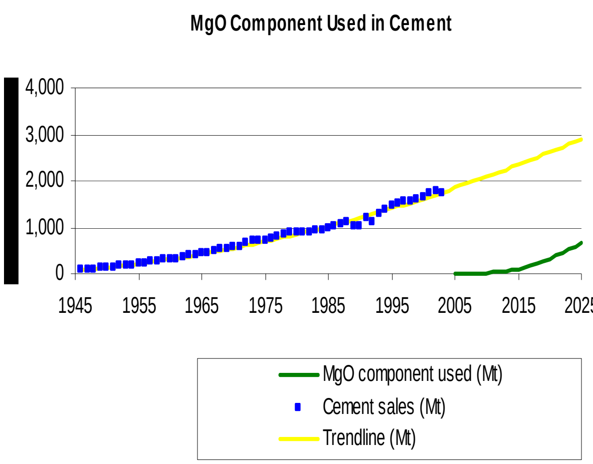

Figure 7 - Take up of MgO in Cements Only

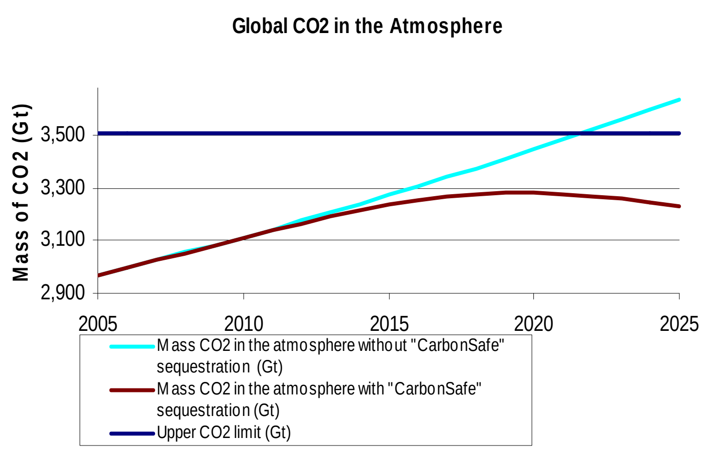

Figure 8 - Reduction in Global CO_2 - Cements Only

The commercialisation strategy of TecEco is one of attracting shareholders to provide resources and continuing efforts to engage larger players with a view to them adopting the technology and methods as only with the involvement of larger companies and governments will there be rapid acceptance and implementation.

[13] See http://www.tececo.com/files/newsletters/Newsletter60.htm

[14] It will be necessary for a world carbon regulatory system with Gaia Engineering to make sure too much carbon is not removed as the only limiting factor is likely to be waste acid, which is also an environmental hazard.

John Harrison comes from a long line of inventors and both James Watt[15] and John Harrison[16] the inventor of the chronometer are ancestors. He is working impossible hours to meet impossible deadlines because of a strong commitment to bring this solution to the world in his lifetime. His company TecEco are trying to increase the rate of exemplar building particularly in niche, difficult to implement applications and making efforts to connect with carbon trading to provide an incentive to overcome the conservatism, perceived risk and lack of financial incentives for larger companies to get involved.

Significant funding is required to fully develop the commercial potential of Gaia Engineering which should be mandatory for all countries to adopt if we are to survive the future. Several large companies are now talking to TecEco including players in financial markets. TecEco now have in place several "option to licence" agreement with respect to its cement technologies. Any publicity would be useful to spread information about the very important technology paradigm we are creating and could even ensure the continuing "survival of our species".

As Gaia Engineering and in particular the TecEco technology sub-components result in considerable value adding we are most interested in bringing it to the attention of the cement and concrete industry as an obvious way for that industry to make money solving rather than exacerbating what could become the biggest problem of the history of human life on this planet.

Gaia Engineering incorporating Eco-Cements is a profitable low energy solution with massive sequestration resulting in useful product for constructing the built environment. In the process there will be solutions to the water and waste problems as well.

Humankind have built with everything from dung to mud, metal to timber, grass to gravel, plastic and cardboard. There is hardly a material that has not been tried and used throughout the millennia. Building with man made carbonate and wastes should not therefore faze players in the cement and concrete industries and governments desperate for a quick fix to the global warming and waste problems. On the contrary TecEco bio/geomimicry solves the problems of global warming, water and waste and should excite industry as all are new markets in the sense that they represent new materials and methods paradigms. Gaia Engineering is simply the most exciting, brilliant and necessary technology on the planet right now. What is more, compared to so called clean coal or nuclear there are no downsides. It's been proved to work with many exemplar structures[17] and could rapidly be deployed.

Although the process is simple in concept the detail is more complex and more information is available at www.gaiaengineering.com and www.tececo.com or can be provided on request.

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[15] James Watt improved the rankine cycle steam engine. He lived from 1736 to 1819.
[16] John Harrison (1693 to 1776) perfected the chronometer.
[17] See www.tececo.com, Exemplars on menu.

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