The CarbonSafe Alliance

TECECO - GREENSOLS - SUBMISSION TO THE INQUIRY INTO GEOSEQUESTRATION TECHNOLOGY

House of Representatives Standing Committee on Science and Innovation

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Synopsis

Recognizing the fact that we are now “The Weather Makers” (Flannery 2005) becoming skilled as planetary maintenance engineers (Lovelock 1979) as quickly as possible is essential.

Australians have correctly concluded that technology will give us the tools to moderate our own impacts, the question remains as to what tools at what price and what profit. The pumping of vast amounts of CO2 underground has been proposed as one such tool. The CarbonSafe Alliance believe this may be useful in a few circumstances but that insufficient research has been done into lower risk, more profitable alternatives.

The CarbonSafe Alliance have proposed an alternative that is safer, potentially profitable and capable of sequestering vast quantities of CO_2 directly from the air as well as from power stations indefinitely.

The CarbonSafe Alliance

The CarbonSafe Alliance comprises businesses and individuals that see the solution to global warming in profitably finding uses for carbon and other wastes. At present the group consists of two companies. TecEco Pty. Ltd. (TecEco) specializing in economic solutions to global problems including energy, water, waste and pollution, loss and degradation of topsoil and global warming and Greensols Pty. Ltd., (Greensols) formed to develop and deploy a method of extracting magnesium and calcium carbonates from seawater.

The managing director of TecEco, John Harrison is well known as a materials scientist, and economist, inventor of Eco-Cement, speaker and writer about sustainability issues relating to materials. (See www.tececo.com). The managing director of Greensols Pty. Ltd., Prof Chris Cuff, is a private consultant in chemical mineralogy and crystallography. Prior to this he was Dean of Science at James Cook University. Over the last 30 years Chris has served on numerous national and international committees including the Council of the Australian Council of Nuclear Science and Engineering (see www.greensols.com.au).

Global Warming and CO_2 Sequestration

Excess atmospheric CO_2 created by the burning of fossil fuels is believed to be a major cause of global warming. To counter this, industries directed towards the uptake and sequestration of atmospheric CO_2 are being promoted through a system of Carbon Credits that can be traded with CO_2 producing industries. Major carbon exchanges currently exist in Brussels, Chicago and more recently NSW and potential opportunities still exist in Australia dependent upon legislative changes by State and Federal Governments.

A common form of carbon sequestration currently supported financially by Carbon Credits is the planting of biomass such as in tree plantations. Alternatively ocean nourishment is proposed as process for stimulating the sequestration of atmospheric carbon dioxide in the deep ocean by providing the nutrients needed to enhance the biogenic production of phytoplankton of calcium carbonate. Both have problems. The sequestration of CO_2 through the planting of biomass (e.g. tree plantations) is relatively short term in geologic and climatic time frames as the sequestered carbon is released as the biomass decays. Fertilising the oceans to the south of Australia with iron could have countless unforseen consequences and should not be done prematurely without much more research.

A solution is required that is safe, has other environmental benefits and is profitable because it converts CO_2 into a resource. Such a solution has been created by our allied companies. Economic solution to global problems are being promoted by the CarbonSafe Alliance and our reason for making a submission to the inquiry into geosequestration technology is that we are concerned with the over emphasis on a particular form of geosequestration, that of pumping liquefied CO_2 into underground storage reservoirs.

The term geosequestration is a jargon word derived from the Latin root "geo" meaning earth (geography, geology etc.) and sequester (ation) from the Latin for a depositary. The term was originally used generically for technologies for geologically sequestering CO_2 and included what is today referred to by many as mineral sequestration. The fossil fuel industry have attempted to take over the word to add credibility to pumping gaseous or liquid CO_2 into underground "storage" usually with the pecuniary advantage of also forcing up more oil. In this submission geosequestration is treated in its literal as well as original meaning.

During the cold war extensive work was carried out to determine the practicality of storing gas underground and the general conclusion was that doing so was not feasible. Pumping liquid CO_2 deep underground is a short term, risky and temporary solution to the now urgent global carbon dioxide concentration problem. We contend that it should only have a limited role to play in what should be a more hollistic approach to the issue. The reality is that compressing carbon dioxide and pumping it long distances and eventually underground is a risky, high cost waste of an as yet unrecognised resource. The technology would not have gained any credence at all if it was not promoted by the oil industry because it is also a useful technology for forcing oil out of the ground under pressure from dwindling reserves.

As distinct from pumping liquid CO_2 underground, permanent carbon dioxide (CO_2) fixation ('sequestration') is defined as the permanent immobilisation of CO_2 from the atmosphere by precipitation as solid carbonate mineral phases, typically calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$).

We therefore question the manner in which the Australian government has focussed only on depositing liquid CO_2 underground and examined none of the safer, more logical and more economic alternatives available.

What we should be doing is mimicking nature and finding uses for CO_2 as my company have done. The permanent fixation of carbon dioxide accomplished by the CarbonSafe process is an entirely different form of permanent sequestration with as yet no known downsides.

Terms of Reference

The House of Representatives Standing Committee on Science and Innovation is to inquire into and report on the science and application of geosequestration technology in Australia, with particular reference to:

- The science underpinning geosequestration technology;
- The potential environmental and economic benefits and risks of such technology;
- The skill base in Australia to advance the science of geosequestration technology;
- Regulatory and approval issues governing geosequestration technology and trials; and
- How to best position Australian industry to capture possible market applications.

The Science Underpinning Geosequestration Technologies

There are many different types of geosequestration technologies. A short description of the main contenders follows.

Pumping CO_2 Underground

Australia has 24 large power stations supplying 80% of our electricity burning coal and producing a quarter of a million tonnes of CO_2 every day (Horstman 2006).

Pumping CO_2 underground has been proposed so we can keep using oil and coal. It involves capturing the gas at power stations, compressing it into liquid CO_2, piping it to a suitable location (usually an oil well) and then injecting it deep underground where it is hoped it will remain trapped for thousands of years.

The concept of putting CO_2 back into the ground from whence it came is rock solid. Some 7% of the crust is carbonate sediment and along with oil and coal originated as atmospheric carbon through natural sequestration. Our concern is that, as a rule nature has not buried carbon dioxide as a gas in sediments, although it occasionally emerges in a concentrated form in volcanic areas causing loss of life. If we are to learn from nature's 4 or 5 billion year old experiment, then geomimicry principles require the burial of CO_2 by first making it a non reactive solid as has occurred naturally during the formation of carbonate sediment during previous periods of global warming including the Carboniferous and late Permian.

The earth is highly fractured and holding compressed liquid CO_2 at depth and preventing escape, adverse reactions and other catastrophies occurring is problematical. During the effluxion of time, unless the gas is converted to a chemically stable solid, it will naturally migrate to regions of lower pressure such as at the surface, or as has been demonstrated, combine with salt and react with country rock thereby migrating in this manner (Kharaka 2006). We submit that true geomimicry alternatives such as precipitating magnesium carbonate from seawater and using it to construct the built environment with Eco-Cements and other alternatives (not discussed here as they are not geo or of the earth) such as using genetically modified blue green algae to produce ethanol or cellulose, are more exciting and a much more economic and appropriate use of taxpayer funds.

The CarbonSafe Alliance are very concerned about the lack of understanding and knowledge in government about these other, more viable alternatives and appeal to this committee to rectify the situation.

Mineral Sequestration

Mineral sequestration is a term generally used in reference to using serpentines, olivines or peridotites to sequester CO_2. The technology was first mentioned by (Seifritz 1990) and discussed further by Dumsmore (Dunsmore 1992). However, Lackner and his associates (Lackner, Wendt et al. 1995) were the first to provide the details and foundation for current research into the technology.

It is our opinion that permanent sequestration as a solid stable carbonate mineral is much safer than pumping CO_2 as a liquid into underground reservoirs and to this extent support mineral geosequestration as suggested by the above authors and others.

The main problem with this technology is the high cost which no useful products or by-products are created to offset.

CarbonSafe Sequestration

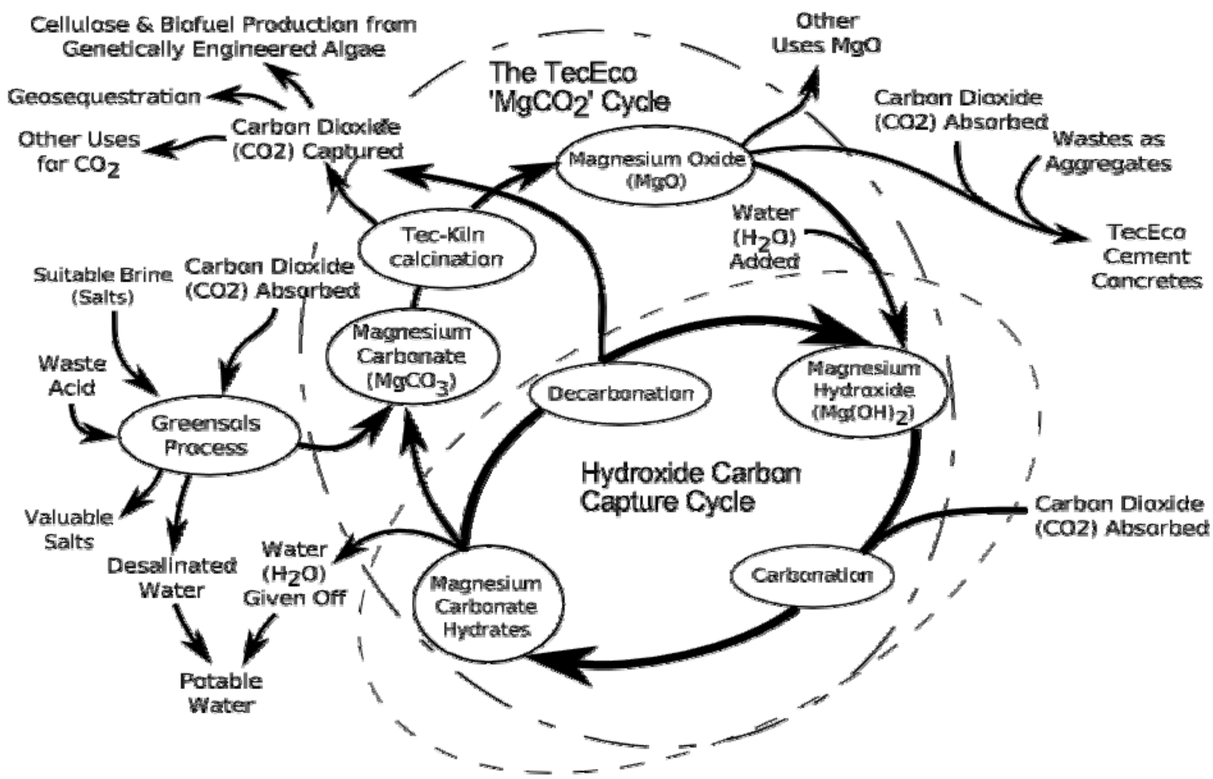

Figure 1 - CarbonSafe Process Vector Diagram for Seawater

The CarbonSafe Alliance believe that to be successful in the long run any sequestration process must convert CO_2 into a resource. To do this we have developed an economically viable industrial ecology referred to as “CarbonSafe” that mimics nature. This biomimicry-geomimicry process includes a number of components that together will make sequestration profitable. Valuable by-products are created as result of the process, include potable water[1], sodium bicarbonate, mineral salts and Eco-Cements, which themselves utilize waste and set by absorbing CO_2.

CarbonSafe is geo-photosynthetic in the way it mimics photosynthesis by reversing carbon flows from fossil fuel consumption. Most components are driven by non-fossil energy and working together, consume rather than produce wastes.

The CarbonSafe industrial ecology comprises an evolving number of key sub-processes, which as they are as of May 2006 are depicted in Figure 1 above. They are:

- The Greensols Process, for precipitating magnesium carbonate, sodium bicarbonate, gypsum and other salts and potable water from seawater.

- TecEco's Tec-Kiln, for low-temperature, non fossil fuel calcination of magnesium carbonate converting it to magnesium oxide, and

- A Hydroxide Carbon Capture Cycle (The HCCC) for additional CO2 capture.

- TecEco Eco-Cement sequestration.

The concept of using CO_2 as a resource to build the built environment is without equal, that this can be achieved whilst at the same time utilising wastes to produce other valuable product including much need fresh water is an outstanding, yet unrecognised Australian achievement.

If adopted on a large scale the CarbonSafe process would sequester significant amounts of atmospheric CO_2 and convert significant wastes to resources. All of the outputs from the process uniquely provide revenue to help make the overall process economic.

The Potential Environmental and Economic Benefits and Risks Of Such Technology

Pumping CO_2 Underground

The crust of the earth is always prone to tremors and earthquakes and there is a high probability that pumping liquid CO_2 underground will not always work as expected. Should the technology fail the consequences will be significant.

Consider the Costs and Risks.

Costs

The International Panel on Climate Change estimate burial costs of between 15-75 dollars per tonne of CO_2, depending on the method (Metz and Loos 2005). The actual figure is still a guess. The point is that pumping liquid CO_2 underground will be very expensive. Much more expensive than our CarbonSafe proposal as no useful product is involved other than

[1] Water is a scarece resource in Australia and many other parts of the world.

in the remote possibility in Australia that it may be used to extract previously economically unviable oil deposits, further compounding the problem.

Energy Usage

Estimates abound of up to a third as much energy would be required to capture compress, pump and store the CO_2. Regardless of the exact extent of this unknown energy cost, it will be high.

Risks

The earth is highly fractured and compressed gases have a habit of wanting to migrate to zones of lower pressure and once again become gases. During the cold war extensive research concluded that storing gas underground was too risky – nothing has changed?

CO_2 has escaped before as in the 1986 Cameroon disaster that killed some 1700 people and the consequences would be disastrous if it happened on a large scale as a result of underground storage of massive amounts of the gas.

There are many geological reports outlining the risks such as recently reported by New Scientist (Kharaka 2006) and it is not our intention to reiterate them further.

Mineral Sequestration

The main problem so far recognised with mineral sequestration is that of cost. The CarbonSafe Alliance think that this will only get worse with the rising price of fuels as the process involves mining and transport.

Cost and Energy

Cost estimates for the industrial-scale implementation of current mineral carbon sequestration processes range from $60-100/ton CO_2 avoided for the direct carbonation of olivine to several hundred dollars per ton of CO_2 avoided for the direct carbonation of serpentine. (Krevor and Lackner 2005)

Risk

Calcium or magnesium carbonate solids are the thermodynamic ground state of carbon and to this extent there is very little risk of catastrophic failure. The problem is more a risk that in spite of continued research viable chemical processes for reacting magnesium silicates with CO_2 sufficiently rapidly will not be found.

CarbonSafe Sequestration

To John Harrison and other The CarbonSafe Alliance members, adding value to carbon dioxide by developing uses for it is by far the most sensible option. Pilzers “first law” stated simply is that the technology paradigm defines what is or is not a resource (Pilzer 1990). Uses are found by changing technology paradigms and to this end John Harrison has invented Eco-Cement whereby carbon is used to bind together other wastes to create the built environment.

Eco-cements are a perfect example of geomimicry whereby material that is indefinitely stable is created out of carbon dioxide in the air.

Costs

The long run costs of making Eco-Cements for use in constructing the built environment using the CarbonSafe process should be very low, especially since other valuable product is also produced. The process temperatures are low, the energy efficiency high and the source of magnesium is abundant, universally available in sea or groundwater and cheap. Given current emissions, only around 7.5 billion tonnes of man made magnesium carbonate (magnesite) are required to be deposited a year to reverse global warming. This is in the same order of mass as the concrete we already make. The key is to use some of that magnesite to replace concrete. Our calculations show that magnesium in sea water would last over a billion years with natural replenishment. With replenishment – probably indefinitely.

Risk

As stated earlier, magnesium carbonate is very stable. As the Eco-Cement technology has already been proven there is no risk. The Greensols process has been laboratory tested and will work.

The skill base in Australia to advance the science of geosequestration technology

Skills acquired are somewhat proportional to the money spent to acquire them and what is occurring in Australia is that so much money is being literally thrown at the concept of pumping liquid CO_2 underground that all sorts of experts are emerging from the CSIRO to universities and jumping on what is rapidly becoming an academic “gravy train”.

This seems obvious to most thinking persons except those involved. There was some justifiable concern that those recommending this technology also stood to benefit from taxpayer investment in it however this did not prevent the announcement of considerable government funding to a small number of major industry players.

We agree money has to be thrown at a solution. It is just that the smell of the fossil fuel industry lobbying for money is overpowering.

What is needed is a solution that is safe, permanent and can not only sequester concentrated CO_2, but CO_2 out of the air. Our alliance are offering such a solution with the added advantage that it is potentially profitable. Unlike the fuel industry we have no lobbyists, nor axe to grind, just an altruistic desire to solve the problem because it is the right thing to do. We know we will not achieve this goal unless doing so is profitable and that is why we have invented new technology paradigms that are potentially profitable, especially if Australia exploits the competitive advantage of becoming an early adopter.

Regulatory and approval issues governing geosequestration technology and trials

Pumping CO_2 Underground

The regulatory regime will be a mine field. There are inherent dangers in pumping a gas that is lethal to human and other life underground in a crust which is always moving, sometimes slowly and sometimes more rapidly as evidenced by earthquakes. As a result of this movement gases do not in the long term remain underground and there is as a consequence proportionally not much gas in the crust.

Who will be responsible? Will it be considered an act of god if the CO_2 gets away as a gas or into ground water and we end up with giant soda fountains all over the place near which nobody can live?

We know that in the long run the gas will escape. Will people (if they are still around) in a millions years blame us for their woes?

It is in our interest as a species to survive and in the short term pumping CO_2 underground may increase the probability of doing so. In the medium or long term however there are substantial risks we should not be burdening our successors with.

The CarbonSafe Alliance do not consider that a potential life threatening technology such as pumping CO_2 underground should be funded without extreme legally enforceable precautions. Other methods have no obvious risk and thus would not require the same scrutiny.

How to best position Australian industry to capture possible market applications.

Unfortunately other countries are well advanced with technologies to pump CO_2 underground so we do not consider there are significant opportunities other than in niche allied technologies.

On the other hand the opportunities with CarbonSafe are significant. All components of the technology are patented and Australian or public domain.

The know how is also Australian and even though it can be used to sequester more concentrated gases at power stations, unlike pumping CO_2 underground concentration is not required for either the hydroxide carbon capture cycle or Eco-Cements to work.

The most relevant salability factor is that the CarbonSafe process is potentially profitable.

Summary

It is our considered view that the government should not have allocated over half a billion dollars of taxpayers money to a special interest group (the petroleum and coal industries) without having made proper enquiry into other alternative forms of geosequestration.

We believe a much more economic proposal is to develop industrial ecologies that use CO_2 and wish to draw to your attention that for some time now our alliance have been promoting CarbonSafe processes to do just that.

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Appendix 1
A Simple but More Detailed Description of the CarbonSafe Processes

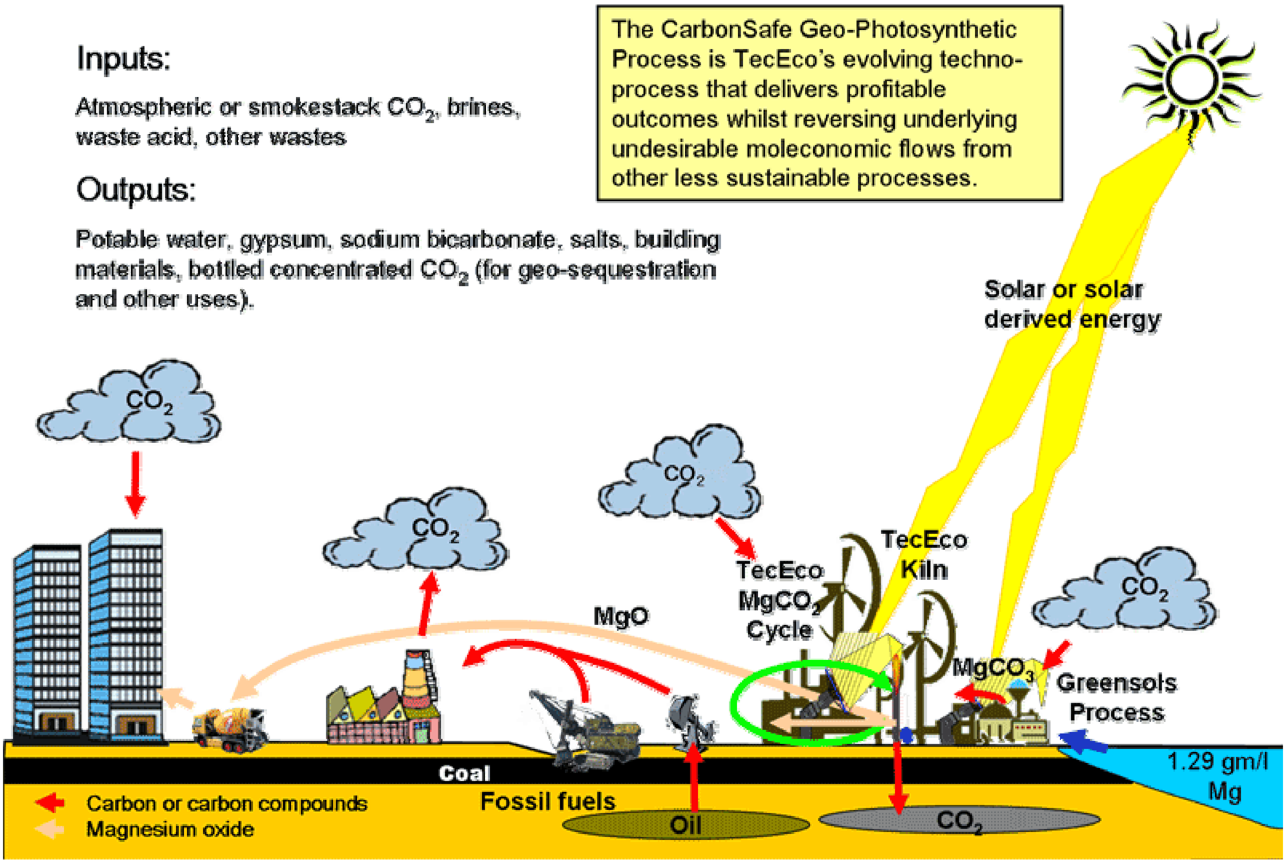


Figure 2 - Graphic Illustration of the CarbonSafe Process for Seawater

TecEco, a member of the CarbonSafe Alliance, have taken mineral sequestration much further by developing a system that sequesters CO_2 as mineral carbonate building components in the built environment.

Together with alliance partner Greensols a method of sequestering CO_2 and supplying the magnesia required as well as producing useful product as part of the process, including fresh water is now available.

Rather than mining minerals containing calcium or magnesium the alliance partners propose to use the bountiful supplies of magnesium contained in sea water which will be precipitated using CO_2 in the presence of waste acid.

The CarbonSafe process starts preferably with the Greensols process although magnesium silicates could be used. In the case of silicates, magnesium carbonates are produced using proven mineral sequestration technology and then transferred to the $MgCO_2$ cycle shown in the diagram below. The preferred Greensols process on the other hand uses carbon dioxide from power stations and waste acid to extract magnesium carbonate and other salts from seawater or suitable brines and if required produce potable or near potable water as a by-product. The magnesium carbonate ($MgCO_3$) from either process is then calcined in the TecEco kiln which removes and captures carbon dioxide (ready for incorporation into ethanol, cellulose, fuel or other compounds) and produces magnesium oxide. The magnesium oxide can either be used to make TecEco Eco-Cements which utilise other wastes and absorb more atmospheric CO_2 as they harden or alternatively used to sequester more CO_2 in a hydroxide/carbonate slurry capture process.

The $MgCO_3.3\text{-}5H_2O$ produced by the hydroxide slurry process can be de carbonated and cycle around that process indefinitely as in the diagram below.

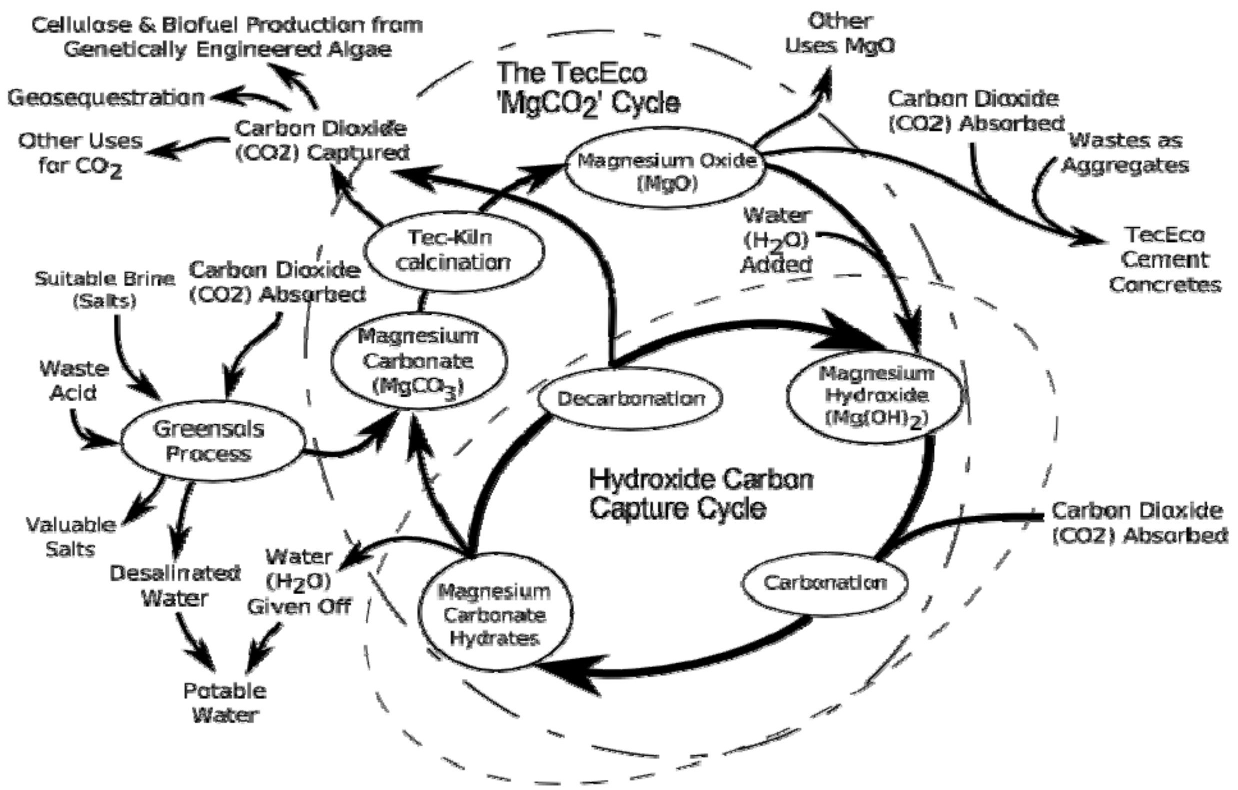
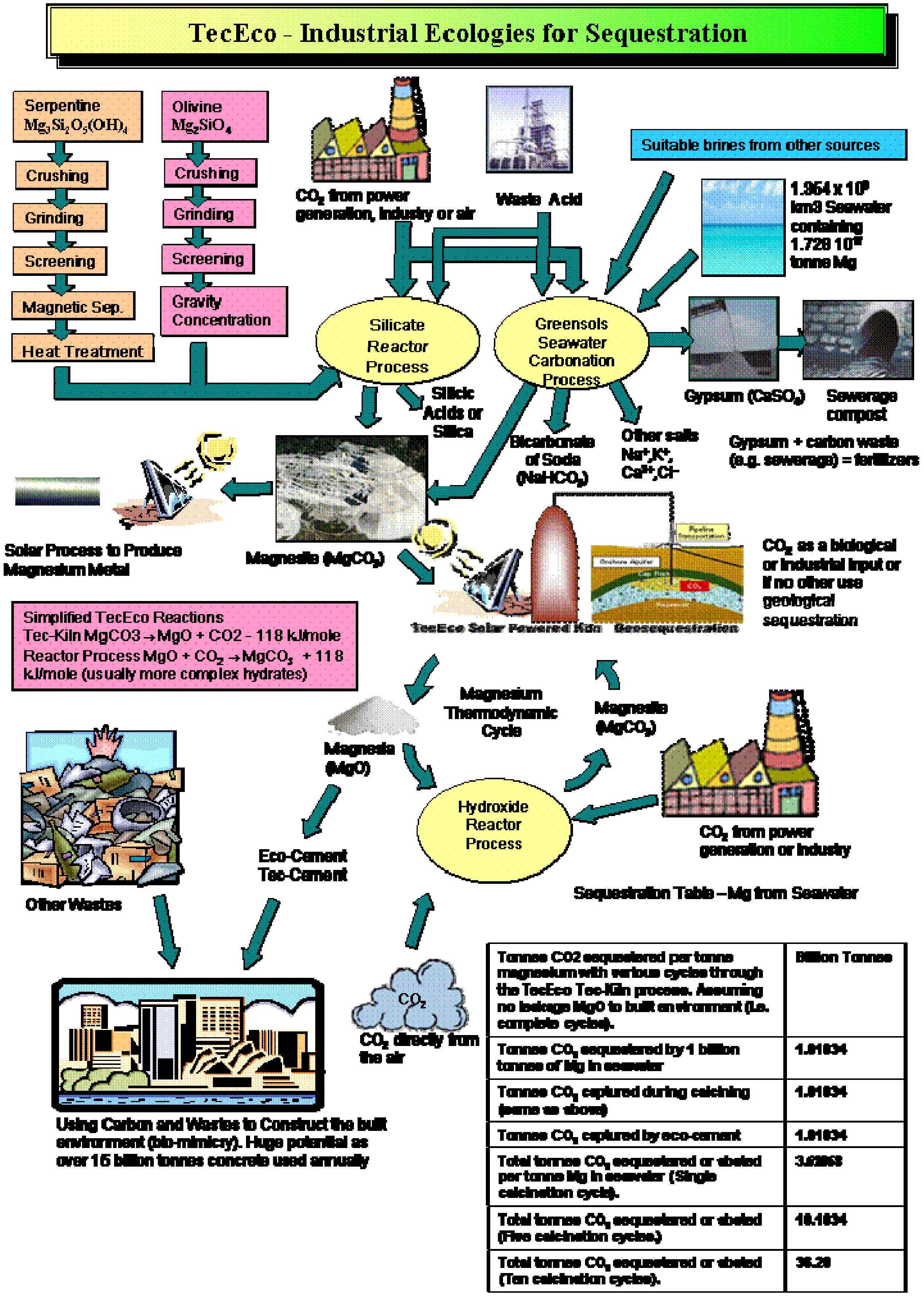


Figure 3 - CarbonSafe Process Vector Diagram for Seawater

Technologies are still evolving to use the CO_2 produced by the hydroxide carbon capture cycle and it could even be fed back into the Greensols process to make more magnesite. The CarbonSafe Alliance believe that as some 70% of all anthropogenic materials flows on the planet are to construct the built environment, structures are an obvious repository for carbon and this why we have invented Eco-Cement and materials using it.

The $MgCO_2$ and hydroxide/carbonate slurry process cycles mimic photosynthesis using the same central atom (magnesium). They can go around and around like a bicycle wheel as together, mass and energy are neither created nor destroyed, only lost outside the system through inefficiencies.

The efficiencies of the various sub-processes are fundamental to making the CarbonSafe process economic and minimizing the amount of energy required overall. An important area of research we are engaged in is to develop technologies for the efficient collection, concentration and transfer of heat energy and information is available at the TecEco web site (http://www.tececo.com).



Tonnes C02 sequestered per tonne magnesium with various cycles through the TecEco Tec-Kiln process. Assuming no leakage MgO to built environment (i.e. complete cycles).	Billion Tonnes
Tonnes CO_2 sequestered by 1 billion tonnes of Mg in seawater	1.81034
Tonnes CO_2 captured during calcining (same as above)	1.81034
Tonnes CO_2 captured by eco-cement	1.81034
Total tonnes CO_2 sequestered or abated per tonne Mg in seawater (Single calcination cycle).	3.62068
Total tonnes CO_2 sequestered or abated (Five calcination cycles)	10.1034
Total tonnes CO_2 sequestered or abated (Ten calcination cycles).	36.20

Figure 4 - The CarbonSafe Process

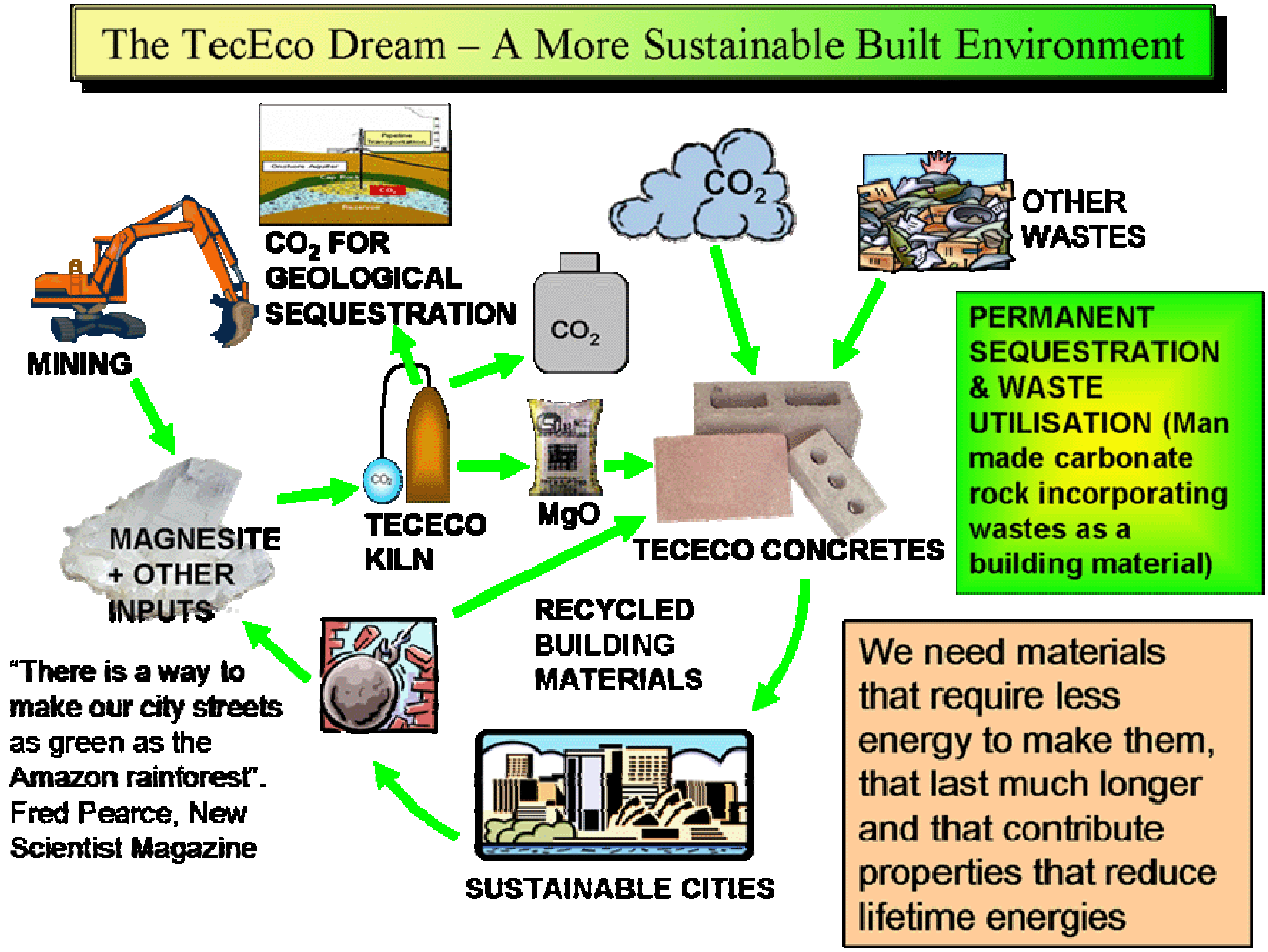


Figure 5 - Sustainable Cities

We call CarbonSafe a geo-photosynthetic process because it mimics the way that plants, algae and some bacteria capture and store carbon using photosynthesis. In 1796, Jean Senebier, a French pastor, showed that CO_2 was the "fixed" or "injured" air and that it was taken up by plants. Soon afterwards, Theodore de Saussure showed that the increase in mass of the plant as it grows could not be due only to uptake of CO_2, but also to the incorporation of water.

It followed that the process of photosynthesis achieves the following:

$CO_2 + H_2O$ + light energy ---> $(CH_2O)n + O_2$

Basing our industrial ecologies on CarbonSafe will result in sustainable cities that store carbon and are constantly recycled as in nature.

TecEco have developed an Excel model of the CarbonSafe process to work out the plant and process requirements to sequester enough CO_2 to avoid reaching a concentration of 450 parts per million in the atmosphere, considered by many as an upper limit to avoid the most dangerous effects of global warming and irreversible change.

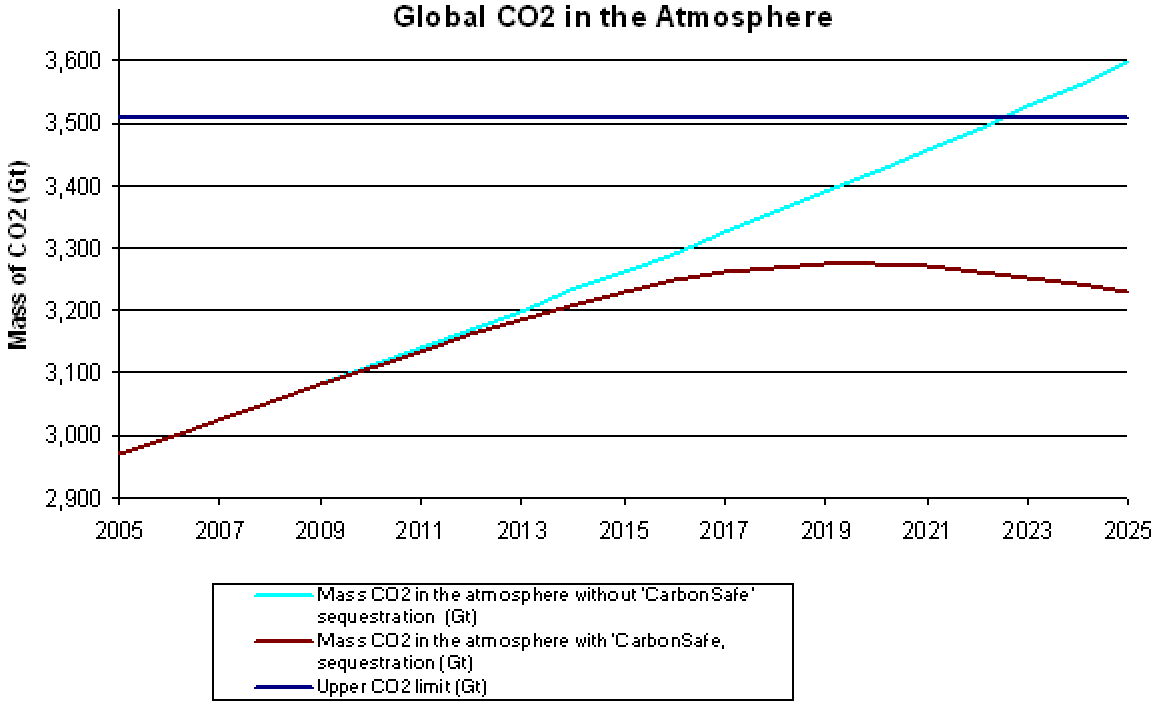


Figure 6 - The The CarbonSafe Alliance Model of the CarbonSafe Process

It relies on several assumptions, including a forecast for magnesia sales for use in concrete and the extent to which global abatement programs will be successful. Outputs include the number of plants of a given capacity that will be required as well as the costs and revenues involved in running the process. If you would like to review the model please go to the TecEco web site and look under tools (http://www.tececo.com/tools.php).

More information on Greensols, Eco-Cements and the TecEco Kiln, essential components of CarbonSafe, are included as appendices.

The Greensols Sub - Process

The Greensols process from Greensols Pty Ltd is an innovative method of separating water from dissolved salts using waste acid and carbon dioxide. Potable water and valuable salts are produced including bicarbonate of soda and magnesium carbonate which sequester significant CO_2.

The Greensols Process is our preferred option for producing the magnesium carbonate required for the CarbonSafe industrial ecology due to fact that it uses industrial CO_2 from power stations and waste acid as inputs and is potentially low cost. Potable water and a number of commodity salts are other outputs which can be sold to help fund the process.

The Greensols Technology modifies volumes of seawater, very slightly, to promote the inorganic precipitation of calcium carbonate or other carbonate mineral phases such as magnesium carbonate. The process permanently fixes CO_2 as mineralogically stable calcium carbonate or magnesium carbonate. There can be minimal change to the overall chemical composition of seawater with the discharged water being within the compositional range of normal coastal waters. Alternatively water with significantly less salt can be further purified to make drinking water. No nutrients are added.

The Greensols Technologies differ from sequestration projects involving vegetation as the sequestering agent, in that the removal of atmospheric CO_2 during the precipitation of the carbonate mineral is permanent. The extraction of CO_2 from the atmosphere and the production of calcium carbonate results from a one-way exchange between atmospheric carbon dioxide and seawater. Additionally, the leakage and stability problems currently associated with in-ground geo-sequestration technology are avoided, as are the nutrient enrichment problems associated with ocean nourishment.

The magnesium carbonate produced can remain as such, providing mineral sequestration. Alternatively it can be used as input for the manufacture of magnesium metal or passed to the $MgCO_2$ Cycle component of the CarbonSafe process which removes (and stores) the carbon dioxide, producing magnesium oxide.

The Hydroxide Carbon Capture Cycle Sub-Process

The Hydroxide Carbon Capture Cycle technology cannot be patented and several research groups are involved including in further developing it including the university of Cincinnati, Ohio (Keener 2001), Los Alamos National University (Butt, Lackner et al. 1996), the university of Barcelonia (Fernandez, Segarra et al. 1999) and Arizona State University (Bearat, McKelvy et al. 2002).

Ironically the process is well known as a way of making a healthy drink by the Arabs who sell us most of the oil causing the problem! (See Appendix 2)

The colder the water (as long as it is not frozen) the more CO_2 is will absorb. At say 4^oC the following reaction is encouraged

$Mg(OH)_2 + 2CO_2 \text{-->} Mg(HCO_3)_2$

At higher temperatures and with a lower partial pressure of CO_2 it can easily be reversed.

The Hydroxide Carbon Capture Cycle sub process is an essential part of CarbonSafe. Inputs include fresh magnesium oxide from the Tec-Kiln and low-concentration CO_2 from for example a power station. Outputs include high-concentration CO_2 and magnesium carbonate that requires rejuvenation.

Magnesium oxide from the kiln is dissolved in water to produce magnesium hydroxide slurry. Gas containing CO_2 is bubbled through the slurry, wherein carbonation occurs, creating magnesium carbonate hydrates in solution. The slurry is then heated to cause de-carbonation whereby the CO_2 previously absorbed is driven off and captured, resulting in the reformation of magnesium hydroxide that recycles through the process.

There is a limit to how many cycles can occur before contamination of the magnesium carbonate hydrate needs to be addressed. The rate of contamination by elements like, for example, iron will depend on a number of factors including what is in the flue gasses from for example a power station. It is hoped that processing through the Tec-Kiln will remove most of this form of contamination and at least enable the reprocessed magnesium oxide to be used as inputs to make The CarbonSafe Alliance cements. Further research needs to be undertaken prior to finalising the design of the process plant to establish the number of cycles that can be run prior to decontamination via the kiln.

The Tec-Kiln – Sub-Process

The Tec-Kiln will have to be used to produce magnesium oxide from magnesium carbonate, whether the source is the Greensols process or mining.

The Tec-Kiln was originally designed for low temperature (<750ºC) calcination of magnesium carbonate to produce material for use in Tececo Cements.

The Tec-Kiln is distinguished from existing kilns in that it grinds and calcines simultaneously, making use of the heat generated by grinding to assist with calcination. The low temperature requirements make it easy for the Tec-Kiln to operate using non-fossil-fuel energy, such as solar power, and run as a closed cycle in order to capture CO_2.

After several cycles the magnesium compounds in the Hydroxide Carbon Capture Cycle become contaminated by elements like iron, lessening the ability of the process to capture CO_2, and requiring re-calcination in the Tec-Kiln. The extent to which this will occur, and the solutions that can be employed, will be subjects for further research that will be undertaken prior to the establishment of a pilot plant.

It is likely that contaminated magnesium carbonate, once calcined, can be used in The CarbonSafe Alliance Cements and the feasibility of this will also be assessed during the project.

Eco-Cement

Eco-Cement is a new more environmentally sustainable type of cement which incorporates reactive magnesia[2] and wastes that is more environmentally sustainable. Eco-Cement used to make porous concretes absorbs CO_2 from the atmosphere to set and harden. It can also be recycled back to Eco-Cement. Wastes such as fly and bottom ash, slags etc. can also be included for their physical properties as well as chemical composition without problems such as delayed reactions. The CarbonSafe Alliance plan to make the magnesia[2] that is used in Eco-Cements using solar energy in a new kiln that combines heating and grinding and captures CO_2. Given this production scenario Eco-Cement concretes have the capacity to become a huge carbon sink.

As stated by Fred Pearce in the article on Eco-Cements published in the New Scientist magazine (Pearce 2002) “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.”

Making the built environment a repository for recyclable resources (referred to as waste) as well as a huge carbon sink is an alternative that is both politically and economically viable.

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[2] Reactive magnesia is also variously known as caustic calcined magnesia, caustic magnesia or CCM. The temperature of firing has a greater influence on reactivity than grind size as excess energy goes into lattice energy.

John Harrison got the idea of using carbon and wastes in building materials from his observations of nature. During earth's geological history, large tonnages of carbon were put away as limestone and coal by the activity of plants and animals. Shellfish build shells from it and trees turn it into their wood. These same plants and animals wasted nothing, the waste from one was the food or home of another. John concluded that the answer to the problems of greenhouse gas and waste was to use them both in building materials.

Eco-Cements are made by blending reactive magnesium oxide with conventional hydraulic cements like Portland cement. They are environmentally friendly because in porous concretes the magnesium oxide will first hydrate using mix water and then carbonate forming significant amounts of strength giving minerals in a low alkali matrix. Many different wastes can be used as aggregates and fillers without reaction problems. The reactive magnesium oxide used in Eco-Cements is currently made from magnesite (a carbonate compound of magnesium) found in abundance and that in the CarbonSafe industrial ecology will be produced from seawater.

When added to concrete magnesia[2] hydrates to magnesium hydroxide, but only in porous materials like bricks, blocks, pavers and porous pavements will it absorb CO_2 and carbonate. The greater proportion of the elongated minerals that form is water and carbon dioxide. These minerals bond aggregates such as sand and gravel and wastes such as saw dust, slags, bottom ash etc.

Eco-Cement can include more waste than other hydraulic cements like Portland cement because it is much less alkaline, reducing the incidence of delayed reactions that would reduce the strength of the concrete. Portland cement concretes on the other hand can't include large amounts of waste because the alkaline lime that forms causes delayed and disruptive reactions.

The more magnesium oxide in an Eco-Cement and the more porous it is, the more CO_2 that is absorbed. The rate of absorption of CO_2 varies with the degree of porosity. Carbonation occurs quickly at first and more slowly towards completion. A typical Eco-Cement concrete block would be expected to fully carbonate within a year. Eco-Cement also has the ability to be almost fully recycled back into cement, should the concrete structure become obsolete.

Appendix 2

The technology behind the Hydroxide Carbon Capture Cycle is simple and in part works as in the recipe below.

RECIPE FOR ENRICHING WATER WITH MAGNESIUM CARBONATE TO ACHIEVE 120 MG/L MG CONTENT:

From the ARAB HEALTHY WATER ASSOCIATION (http://www.mgwater.com/mgdrinks.shtml)

FOUR EASY STEPS FOR MAKING THE MAGNESIUM/BICARBONATE DRINKING WATER CALLED "WW", USING MAGNESIUM HYDROXIDE IN "MILK OF MAGNESIA", AND CARBON DIOXIDE IN "CARBONATED WATER"

The chemical formula reaction is $Mg(OH)_2 + 2CO_2 \text{-->} Mg(HCO_3)_2$

Step 1: CHILL COMPLETELY TO REFRIGERATOR TEMPERATURE A 1 LITER BOTTLE OF "FULLY CARBONATED" WATER. Carbonated waters such as "Canada Dry Seltzer" which consist of only water and carbon dioxide (CO_2) are suitable. "Club sodas" such as "Schweppes Club Soda" are also suitable; they are carbonated water with a small amount of added sodium.

Step 2: SHAKE WELL A BOTTLE OF PLAIN MILK OF MAGNESIA (MoM), THEN MEASURE OUT AS ACCURATELY AS POSSIBLE 3 TBS (45 ml) AND HAVE IT READY. The plastic measuring cup that comes with the MoM is accurate and ideal for the purpose. Use only plain MoM without flavorings, sweeteners, mineral oil, or other additives. The "active ingredient" should be only magnesium hydroxide (Mg(OH)2), 400 mg per teaspoon (5 ml), and the "inactive ingredient" should be only purified water. 41.7% by weight of magnesium hydroxide is magnesium (Mg), so 1 teaspoon of MoM has 167 mg of Mg, and 1 tablespoon (TBS) has 500 mg of Mg (1 TBS = 15 ml).

Step 3: REMOVE THE BOTTLE OF CARBONATED WATER FROM THE REFRIGERATOR WITHOUT AGITATING IT. REMOVE THE CAP SLOWLY AND CAREFULLY TO Page 1 of 3 Recipes for enriching water with magnesium 29/01/2006 http://www.mgwater.com/mgdrinks.shtml MINIMIZE THE LOSS OF CO2. SLOWLY ADD THE PREMEASURED MoM, THEN PROMPTLY REPLACE THE CAP. Next, shake the bottle vigorously for 15 to 30 seconds, making the liquid cloudy. After 1/2 hour or so the liquid will have cleared, and any un-dissolved Mg-hydroxide will have settled to the bottom of the bottle. Again shake the bottle vigorously for 15 to 30 seconds, making the liquid cloudy again. When the liquid again clears all of the Mg hydroxide in the MoM should have reacted with all of the CO_2 to become dissolved (ionized) magnesium and bicarbonate. However, if a small amount of un-dissolved Mg hydroxide still remains in the bottom of the bottle as a sediment it may be ignored. This 1 liter of concentrated magnesium bicarbonate water will have 1,500 mg of magnesium and 7,500 mg of bicarbonate. This concentrate must be diluted in order to be "WW".

Step 4: DILUTE THIS CONCENTRATE 11:1 TO MAKE DRINKABLE MAGNESIUM/BICARBONATE WATER (WW). To make 4 liters of WW measure and transfer 1/3 liter of the concentrate (333 ml) into a 4 liter container. Fill the container with 3 2/3 liters of plain, preferably purified water. Or, prepare a single glassful of WW by adding 11 ounces of water to 1 ounce of the concentrate. This drinkable water will have approximately 125 mg of Mg and 625 mg of bicarbonate per liter, at pH ~8.3. Other dilutions of the concentrate may of course be made, if so desired.

This patented formula (we don't think the patent would have a chance of standing up) is available to bottlers through the Arab Healthy Water Association.